



PRACTICALS

Indira Gandhi
National Open University
School of Sciences

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PLANT ECOLOGY AND TAXONOMY – INTRODUCTION

Laboratory course II **BBYCL-134** is the second course in Life sciences. It is based on the theory paper Plant Ecology and Taxonomy. In this laboratory course you will be asked to do some experiments related to Ecology and Taxonomy. These experiments will develop your practical skills. Your hands on experience by doing the small experiments will improve your observation capacity, analytical skills and assessment criteria.

Laboratory course is a very interesting and useful course. It needs to be completed in 7 days. A four credit course requires 15 hours of time by students. You have to essentially spend as many hours each day as mentioned in the laboratory session plan.

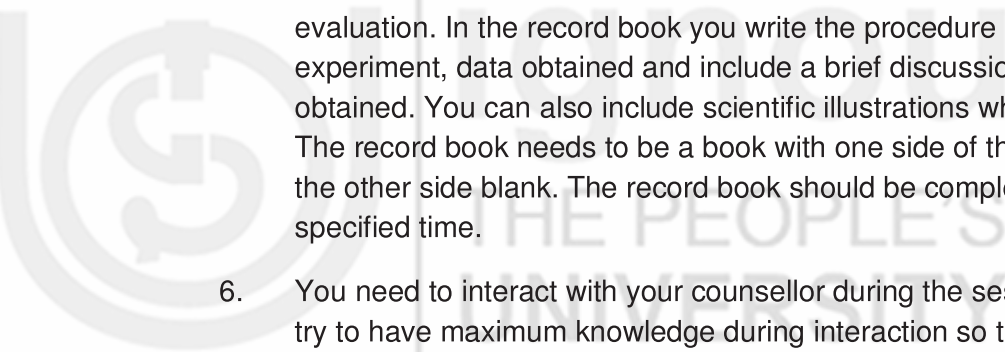
Nine experiments for the course will include practical assignments for both Plant Ecology and Taxonomy. The first seven experiments are of Ecology and 8, 9 are for Taxonomy. Ecology experiments are based on study of abiotic and biotic components of an ecosystem. You will learn about various instruments used in the measurement of abiotic variables such temperature, soil, wind speed, humidity and rainfall. Some experiments based on the study of composition and properties of abiotic factors such as soil. You will be doing some simple laboratory tests that will help you to detect presence of various ions in the soil. You will also be able to study some properties of soil and compare given soil samples based on their properties. Interactions between the biotic components of ecosystem will also be studied by means of epiphytes and parasites. Other practical exercises will include identification of various features peculiar to plants found in specific habitats (hydrophytes, xerophytes). The later experiments will be based on the study of community structure with emphasis to various parameters and attributes such as frequency, abundance and density of species. The studies will be based on some field data assignments, photographs and other relevant material.

The taxonomy experiments mainly include the identification of Dicot and Monocot plants based on their vegetative and floral characters. Each plant bears specialised features which are characteristic of the family. The plant and flower details are observed very carefully and based on the characters the plant is classified into a particular family. The second experiment includes collection of any wild plant which is carefully dried and herbarium is prepared. The laboratory experiments of taxonomy will strengthen your knowledge about identification and classification of plants.

The time duration of the practical course will be two weeks. The necessary guidance required for performing the experiments will be provided by the counsellors. The performance will be assessed and marked at the end of the course by an examination. The examination will be based on the experiments performed during the laboratory course. The assessment on guided experiments will be done for 70% and rest 30% will be for the assigned experiments.

Study Guide

1. Before starting the laboratory course you should be well aware of the experiments thoroughly by reading and have knowledge about the methodology.
2. Underline the important steps for each experiment in the lab manual.
3. Be cautious while handling the chemicals and instruments in the laboratory. Carry a dissection kit consisting of pair of scissors, needles, scalpel and forceps in the laboratory.
4. Carry an observation notebook with you and record all your observations, results, doubts and difficulties in carrying out various experiments. A detailed account of the observations and results are generally found with students having good practical skills.
5. Besides the observation notebook, a record book needs to be prepared which will be submitted to the counsellor at the time of examination for evaluation. In the record book you write the procedure of your experiment, data obtained and include a brief discussion of the results obtained. You can also include scientific illustrations wherever required. The record book needs to be a book with one side of the page ruled and the other side blank. The record book should be completed in the specified time.
6. You need to interact with your counsellor during the session. You should try to have maximum knowledge during interaction so that you can give your best performance during the laboratory session. The practical experience will prove useful and meaningful to you and make the subject more interesting for you.



Ecology and Taxonomy Practicals

Session Plan

Day	Session	Practicals	Hrs.	Total Hrs.
Day 1	Session I	Exercise 1 – Introduction	2	48
	Session II	Exercise 2 – Instruments to measure microclimatic variables Exercise 3 – Determination of pH, Rapid Field test for chloride, nitrate, sulphate, organic matter in soil	2 4	
Day 2	Session III	Exercise 4 – Determination of bulk density, porosity and rate of infiltration of water in soil from different habitats	4	
		Exercise 5 – Study of ecological adaptations in plants	4	
Day 3	Session IV	Exercise 6– Minimal quadrat study of herbaceous vegetation in the college campus by species area curve method	4	
		Exercise 7– Quantitative analysis of frequency of vegetation and comparison using Raunkiaer's frequency distribution law	4	
Day 4	Session V	Exercise 8 – Study of vegetative and floral characteristics of some Dicot and Monocot families	8	
Day 5	Session VI	Exercise 9 – Mounting of a properly dried and pressed specimen of any common wild plant with herbarium label	4	
		Revision of work done	4	
Day 6	Session VII	Revision	4	
		Practical examination and viva-voce	4	

Plant Ecology and Taxonomy, Practicals

Scheme of Practical Examination

Time: 4Hours		Maximum Marks: 30
Questions	Practicals	Marks
Ecology		
Q1	Instrument to measure microclimatic variables (spot)	5
Q2	Determination of pH, Rapid field test for chloride, nitrate, sulphate, organic matter in soil (exercise)	6
Q3	Determination of bulk density, porosity and rate of infiltration of water in soil from different habitats (exercise)	6
Q4	Study of morphological adaptations in plants (spot) Spot – photograph/slide/plant material/herbarium/specimen/museum specimen	5
Q5	Minimal quadrat study of herbaceous vegetation in the college campus by species area curve method (exercise)	6
Q6	Quantitative analysis of frequency of vegetation and comparison using Raunkiaer's frequency distribution law. (exercise)	6
Q7	Viva voce	2
Q8	Record book	2
Spots – Any five spots (exercise 1,4) as mentioned above (5 marks)		
Exercise – Any one exercise(2,3,5,6)as mentioned above (6 marks)		
Taxonomy		
Q1	To study the vegetative and floral characteristics of some Dicot and Monocot families. (exercise)	4+4 (Monocot +Dicot)
Q2	Herbarium submission	3
Q3	Viva voce	2
Q4	Record book	2
Viva voce (4 marks)		
Record book (4 marks)		

EXERCISE 1

Introduction to Plant Ecology and Taxonomy Laboratory

Structure

- 1.1 Introduction
- 1.2 Ecology and Taxonomy
 - Objectives

1.1 INTRODUCTION

In the previous units of your graduation study program you have been introduced to various forms of plants ranging from lower (non-vascular) to highly developed higher (vascular) plants. The plants live in different habitats and interact with different life forms present along with them at that place along with various physical factors. Plants interact with various factors such as soil and temperature. The study of interaction of living forms with their physical conditions is included in ecology. The plant forms have been classified and named according to their morphological features. The study of this branch of science has been referred as taxonomy.

1.2 ECOLOGY AND TAXONOMY

Ecology is the study of the interaction of living (biotic) and non-living (abiotic) components of the environment. Abiotic components mainly include soil, water and the environmental conditions in which an organism survives. Various types of interactions are observed within the living forms (biotic components) and these can be both positive and negative. The study of interaction between the living and non-living forms provides vital information about the structure of an ecosystem. The study of ecology is important in assessing the effect of changes in the ecosystem. Changes in abiotic conditions are known to produce a detrimental effect on the living components of the ecosystem. In today's world changes in the biotic associations need to be assessed very critically under different time frames and changing environmental conditions.

Taxonomy is the study of classification of organisms based upon their characteristic features. This branch of science deals with description, identification, classification and nomenclature of plants (taxonomic botany).

Each plant form bears some distinctive features and these characteristics help in identification of taxa. The pattern of variation of characters among species helps in identification, classification and categorization of species. The plant species is described using specific features or attributes. An unknown plant specimen is identified based on these characters or comparison with the known species. Nomenclature i.e., naming the species is another important aspect of taxonomy. The species are classified i.e., included in a group based on the characters. This is followed by assigning the species identified to a family.

To study practical aspects of taxonomy, various vegetative and reproductive features of the plants are examined.

Objectives

The main objectives of ecological studies include:

- ❖ study of various abiotic and biotic components,
- ❖ understanding of various interactions among biotic components,
- ❖ study of the concept of ecosystem, biome and biosphere,
- ❖ study of instruments and equipments used for measurement of variations in various abiotic components such as light, temperature, humidity, rainfall and soil,
- ❖ study of the plant diversity and identifying plants using taxonomic tools,
- ❖ identification of the characteristics specific to given plant family,
- ❖ to know the systemic position of a given plant species, and
- ❖ maintenance of records of plant species by making a herbarium.

Books and material for reference

Dirk R. Walters and David J. Keil, *Vascular Plant Taxonomy*, 4th Edition. Kendall/Hunt Publishing Company.

Heywood, V. H. 1993. *Flowering Plants of the World*. Oxford Univ. Press, New York.

Singh, P. 2007. *An Introduction to Biodiversity*. Ann Books India, New Delhi. (with special reference to Chapter 11 – Angiosperms, for knowing and understanding the morphological characters for describing plants)

Bhattacharyya, B. 2009. *Systematic Botany*. 2nd Ed. pp 1-576, Narosa Publ. House, New Delhi.

Gleason, H.A. and Cronquist, A. 1991. *Manual of Vascular Plants of North Eastern United States and Adjacent Canada*, 2nd edition. New York Bot. Gard., Bronx.

Simpson M.G. 2010. *Plant Systematics*, Second edition, Elsevier, Academic Press Publications.

EXERCISE 2

Study of Instruments Used to Measure Microclimatic Variables

Structure

- | | |
|--|---|
| 2.1 Introduction | 2.3 Anemometer |
| Objectives | 2.4 Psychrometer (wet- and dry-bulb hygrometer) |
| Study Guide/Prior Reading | 2.5 Rain gauge |
| 2.2 Soil thermometer (earth thermometer) | 2.6 Lux meter |

2.1 INTRODUCTION

The measurement of various abiotic factors such as light, temperature, humidity, rainfall, wind and soil conditions is an important aspect of ecology. These abiotic factors can be measured using instruments. Specific instruments have been designed to measure change in these factors. For example, soil thermometer is used to measure temperature of soil while wind speed and direction are measured by an anemometer. A hygrometer measures humidity, rain gauge measures the amount of rainfall and luxmeter is used to measure intensity of light.

Each instrument is described in detail below with emphasis on its functioning. All the instruments need to be studied carefully to understand their role in understanding the abiotic variables.

Objectives

After performing these exercises you should be able to:

- ❖ describe instruments used in the measurement of various abiotic factors,
- ❖ describe the working of soil thermometer,

- ❖ describe the working of anemometer,
- ❖ describe the working of Psychrometer,
- ❖ describe the working of rain guage, and
- ❖ describe the working of luxmeter.

Study Guide/Prior Reading

Kalra, Y.P. and Maynard, D.G. 1991. Methods Manual for Forest Soil and Plant analysis. Forestry Canada, Northwest Region, Northern Forestry Centre, Edmonton, Alberta. Information Report NOR-X-319E. 116 p.

2.2 SOIL THERMOMETER (EARTH THERMOMETER)

Method- Observe the photograph of the soil thermometer provided to you.

Description-It is an instrument that measures the temperature of the soil.

Structure – It is a glass thermometer containing mercury. A metal thermocouple terminal is attached to the dial that has the centigrade scale. The bulb of the thermometer is surrounded by paraffin wax. The bulb is inserted into the hole in the ground for measuring the temperature. The outer glass shield of the thermometer protects it. The steel tube is lowered in the soil to the desired depth for getting the measurement.

The thermometer is based on the principle of thermal expansion. The volume of the liquid expands as the soil gets heated. The soil temperature is measured at the soil depth of more than 1 foot.

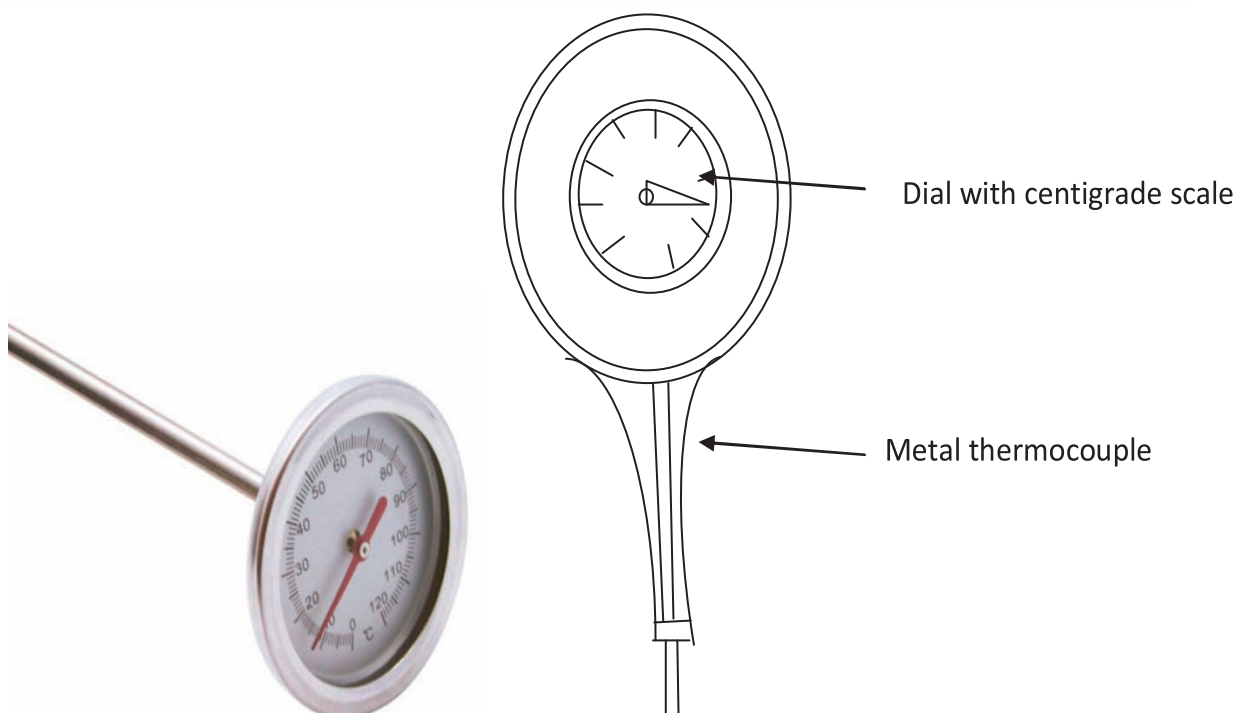


Fig. 2.1: Images of Soil Thermometer.

2.3 ANEMOMETER

Method – Observe the photograph of the anemometer provided to you.

Description – It is an instrument that measures the wind speed.

Structure – The term anemometer is derived from the Greek word ‘*anemos*’ which means wind. The instrument is commonly used in meteorology. The anemometer was first described by **Leon Battista Alberti** in 1450.

Anemometers are of different types. Cup anemometer is the most common type.

Cup anemometer (rotational anemometer)

It consists of four hemispherical cups mounted on horizontal arms. The arms are mounted on a vertical shaft. The cups are arranged symmetrically on the arms. The anemometer was developed by **John Patterson** in 1926. The air flows through the cups in horizontal direction and turn the shaft at a rate proportional to the wind speed. The wind speed can be calculated by counting the turns of the shaft over a set time interval. The speed of rotation of the anemometer is proportional to the wind speed.

Cup anemometer was modified by an Australian **Dr. Derek Weston** in 1991. The improved instrument could measure both wind speed and direction. The turbulence produced by the apparatus drags the torque (produced by the cups) in the opposite direction. The change in the movement of the arms influences the rotational speed.

Other types of anemometers include:

Vane anemometers (windmill or a propeller anemometer) – A propeller and a tail are present on the same axis. Accurate and precise wind speed and direction can be measured using this instrument.

Ultrasonic anemometers – Ultrasonic sound waves are used to measure wind velocity. The wind speed is based on the sonic pulses/sound waves. The main application of these anemometers includes weather stations, ship navigation, aviation and wind turbines.

Acoustic resonance anemometer – These anemometers use resonating acoustic (ultrasonic) waves for measurement of wind speed. Separate standing-wave patterns at ultrasonic frequencies are created using ultrasonic transducers. The wind passing through the cavity shifts the wave. The measurement of shift gives wind speed and direction. The instrument was designed by **Dr. Savvas Kapartis** in the year 2000.

Plate anemometers – These are modern anemometers. They consist of a flat plate suspended from the top. The wind deflects the plate.

Tube anemometers – They were invented by **William Henry Dines** in 1892. It consists of a glass U tube containing a liquid manometer (pressure gauge). One end of the tube is bent in a horizontal direction which faces the wind. The vertical end remains parallel to the wind flow. The wind blows into the mouth of a tube and increases pressure on the side of the manometer. The pressure difference between the open mouth (of straight tube) facing the wind and small holes in a vertical tube closed at the upper end give the measure of the wind speed.

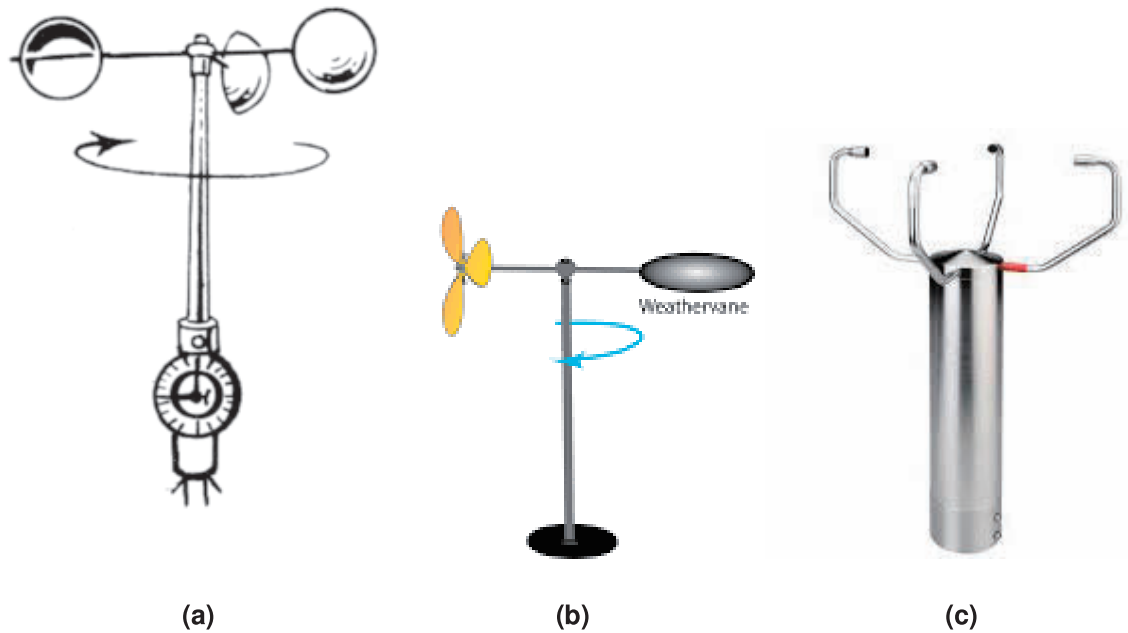


Fig. 2.2: Various types of anemometers; (a) Cup, (b) Windmill, (c) Ultrasonic..

2.4 PSYCHROMETER (WET AND DRY BULB HYGROMETER)

Method – Observe the photograph of the anemometer provided to you.

Description – It is an instrument that measures humidity and water vapor present in the atmosphere. The hygrometer was invented by an Italian **Leonardo da Vinci** in 1480.

Structure – The instrument consists of two thermometers, one having a dry bulb and the other having the wet bulb. Evaporation at the wet bulb lowers the temperature. The temperature measured by dry-bulb represents air temperature. Temperature of condensation (the dew point), or changes in electrical capacitance or resistance are used to measure difference in humidity. Relative humidity is computed from the ambient temperature as shown by the dry-bulb thermometer and the difference in temperatures between the wet-bulb and dry-bulb thermometers. The instrument was further modified by Swiss polymath **Johann Heinrich Lambert** (1755).

The hygrometers can be of different types. Some of these include:

Chilled mirror dew point hygrometer

This anemometer uses dew point for measurement of humidity. Dew point is the temperature at which moist air (or water vapor) saturates and cooling results in condensation of water.

Capacitive hygrometers

In this instrument, electronic sensors with the accuracy of $\pm 2\%$ RH are used. The sensors are effective in overcoming effects such as condensation and high temperature. The dielectric constant of a polymer or metal oxide measures humidity.

Resistive hygrometers – The change in electrical resistance of a material gives measure of humidity.

Thermal hygrometers – The change in thermal conductivity of air gives measure of humidity.

Gravimetric hygrometer – This hygrometer measures the mass of an air sample and gives accurate moisture content of the air.

Hygrometers prove useful in protection and maintenance of wooden musical instruments such as pianos, guitars, violins, and harps. They assist in controlling humidity control which can damage human skin, body and promote growth of mildew and dust mites.



Fig. 2.3: Wet and dry bulb hygrometer (Psychrometer).

2.5 RAIN GAUGE

Method – Observe the photograph of the rain gauge.

Description – It is an instrument that measures the amount of rainfall an area receives in a period of time. The hygrometer was invented by an Italian **Leonardo da Vinci** in 1480.

A rain gauge is an instrument used to measure the quantity of precipitation such as rain, snow, hail or sleet occurring in an area (meter square) in a certain amount of time (usually in mm-millimeter). One mm of precipitation is equivalent to one liter of rainfall per meter square. The rain gauge was introduced by **King Sejong**.

Structure – The instrument includes a cylindrical cup and a funnel system. Funnel collects rain and then empties into a cylinder, which is inside a larger container that collects excess rainwater. The gauge is set in open ground with

the funnel rim 30 cm above the ground surface. The rain water is collected in an enclosed bottle or cylinder.

Autographic gauge – In this type of gauge can be either tilting-siphon type or the tipping-bucket type. For a tilting-siphon rain gauge, the rainwater in a collector displaces so that marking pen attached to the float makes a continuous trace on the paper. In tipping-bucket rain gauge, two buckets rest on a pivot. One bucket receives rain water, empties the rainwater and allows the other bucket to collect water. The recording chart is mounted on a drum which is driven by clockwork. The drum rotates round a vertical axis. The autographic recorder gets triggered to register each 'tilt'. A continuous record of precipitation and rainfall intensity can be obtained using this instrument.

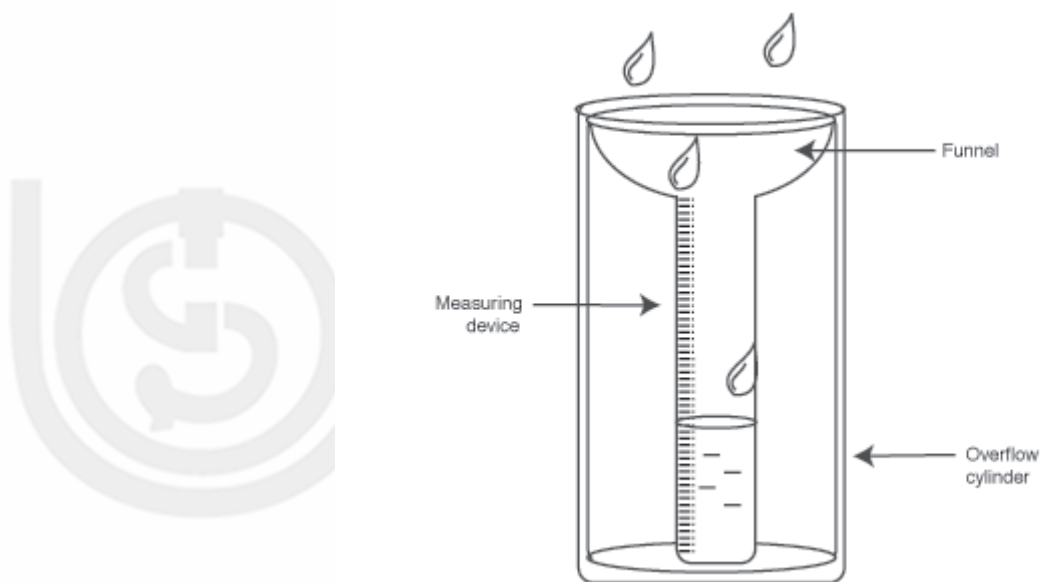


Fig. 2.4: Rain gauge.

2.6 LUX METER

Method – Observe the photograph of the Lux meter.

Description – A lux meter is an instrument that measures brightness of light or illuminance. Illuminance is a measure of the intensity of light falling on a surface. The lux is the unit of measurement of illuminance or brightness. Lux is derived from candela which is the standard unit for measurement of light. A candela is light equivalent to the brightness of one candle. One lux equals one lumen of light spread across a surface one square meter. Illuminance is inversely proportional to area. One lux is equal to one lumen per square meter: $1 \text{ lx} = 1 \text{ lm/m}^2$

Example – A flux of 1000 lumens, concentrated into an area of 1 square meter has an illuminance of 1000 lux. However, the same 1000 lumens, spread out over 10 square meters, would produce a dimmer illuminance of only 100 lux.

Structure – Lux meter measures luminous flux per unit area. It uses a photo cell to capture light. The meter converts light to an electrical current. The device calculates the lux value of the light captured with measurement of

current. The measurement of light varies with light intensity and distance. Lux meters are of different types.

Reflected Light Lux Meter – This measures light reflecting from the photography subject to the camera. It is positioned near or in the camera itself.

Incident Light Lux Meter – It is positioned near the photography subject. It measures the light intensity falling on the photography subject.

Lux meters provide a quantified measurement of the amount of light available. It compares the light intensity in different conditions. It is used in photography and video filming. Light measurement can help photographers to adjust shutter speed and depth of field to get the best picture quality. It allows adjustments in different light levels on screen.

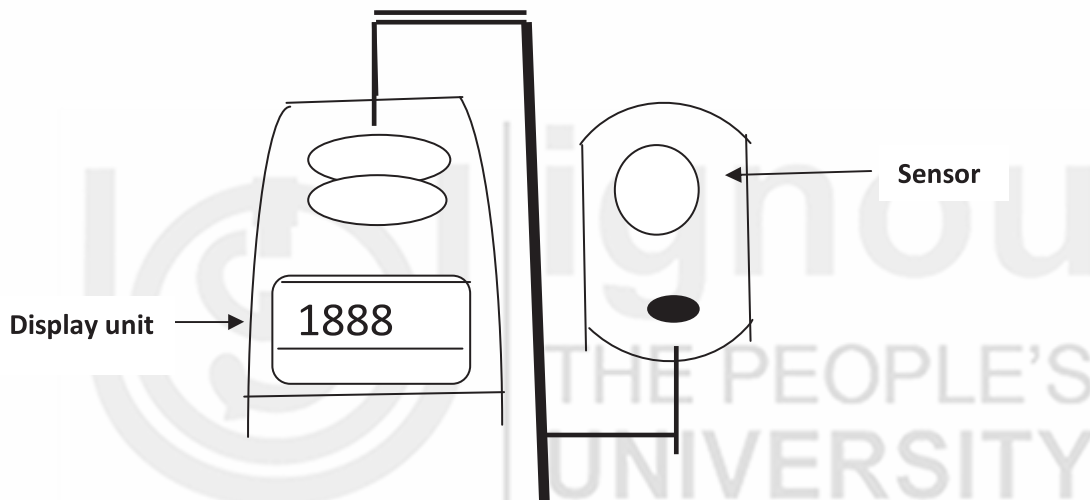


Fig. 2.5: Lux meter.

Suggested readings

- Recommended Chemical Soil Test Procedures for the North Central Region (2012) North Central Regional Research Publication No. 221 (Revised 2015).
- Soil Infiltration. Guide for educators (2014) <https://www.ncrs.usda.gov>
- Article source-<http://en.wikipedia.org/w/index.php?oldid=422418952>

Determination of pH, and Analysis of Two Soil Samples for Carbonates, Chlorides, Nitrates, Sulphates, Organic Matter and Base Deficiency by Rapid Field Tests

Structure

- | | |
|---|--|
| 3.1 Introduction | 3.5 Determination of nitrates in the given soil samples |
| Objectives | |
| Study Guide/Prior Reading | 3.6 Determination of sulphates in the given soil samples |
| 3.2 Determination of pH in the given soil samples | 3.7 Determination of organic matter in the given soil samples |
| 3.3 Determination of carbonates in the given soil samples | 3.8 Determination of base deficiency in the given soil samples |
| 3.4 Determination of chlorides in the given soil samples | |

3.1 INTRODUCTION

Soil is an important component of the ecosystem. A thorough understanding of the soil ecosystem is required to manage agroecosystems so that long term fertility and productive capacity of the soil is maintained. Many biological, chemical and physical factors determine soil quality. Measurement of some of these components determines the health of the soil. The change in the properties of the soil can be assessed qualitatively and quantitatively. The physical, chemical and micro-biological properties of the soil are evaluated to assess the change in the quality of soil.

Objectives

After performing this exercise you should be able to:

- ❖ measure the soil pH,
- ❖ analyse soil to demonstrate presence/absence of carbonates, chlorides, nitrates, sulphates, organic matter and base deficiency using simple tests, and
- ❖ record the chemical characteristics of soil.

3.2 SOIL pH

Soil pH is the most important property of the soil. It is related to plant nutrition. Soil pH is a measure of the hydrogen ion (H^+) activity in the soil solution. It is defined as the $-\log_{10}$ of the hydrogen ion concentration. Soil pH gives the concentration of hydrogen ions that can be easily exchanged. The pH exerts a strong effect on solubility and availability of nutrient elements. It influences nutrient uptake by plants. Soil pH between pH 6.0 and 6.5 indicates that most plant nutrients are in their most available state. Soil pH affects nutrient availability as the H^+ ions take up space on the negative charges along the soil surface displacing nutrients.

A pH less than 4 in soil indicates the presence of free acids obtained from the oxidation of sulfides. At pH less than 5.5, high concentrations of H^+ , aluminum and manganese in soil solution can reach toxic levels. A pH more than 5.5 suggests occurrence of ions such as aluminium and phosphorus. A pH of 7.8 to 8.2 indicates presence of calcium carbonate. Elements like nitrogen, potassium, calcium, magnesium and sulfur are more available within soil at pH 6.5 to 8 while boron, copper, iron, manganese, nickel and zinc are more readily available within soil pH 5 to 7.

Soil pH may also change due to alteration in carbon dioxide concentration, salt concentration, hydrolysis and solubility of soil constituents.

3.2.1 Measurement of Soil pH

pH of the soil solution can be measured using pH paper or pH meter.

3.2.2 Materials Required

1. 5 g soil from two different sites
2. pH meter with appropriate electrode(s) or pH paper
3. Pipettes
4. Distilled or de-ionized water
5. 0.01 or 1.0 M $CaCl_2$
6. Buffer solutions for calibrating the pH meter

3.2.3 Procedure

1. Take 5 g of the soil sample in a test tube.
2. Add 5 ml distilled or deionized water to the soil sample.
3. Stir vigorously for 5 seconds and let stand for 10 minutes.
4. The pH of the soil suspension can be measured by either using a pH paper or by using a calibrated pH meter.

When we use a standard strip of the pH paper, we compare the color reaction with the standard chart.

When we use a pH meter, we must ensure that the electrodes are properly dipped in the slurry. Carefully swirl the electrode and read the pH immediately.

Precaution- The electrode tips should be dipped in the slurry.

3.2.4 Observations and Results

Take the soil solution and record the observations of the pH values of the given soil samples. Note the observations in the Table.

S. No.	Soil A	Soil B

The soil pH indicates the type of soil. It indicates if the soil is acidic or alkaline. The pH ranges from 0 to 14. The pH 7.0 indicates neutral soil (levels of H^+ and OH^- are equal). A pH value below 7.0 indicates that soil is "acidic," and readings above 7.0 indicate "alkaline" soil conditions. Plants generally require a slightly acidic soil, i.e., within a pH range of 6.2 to 6.8. Soil pH is very important for nutrient availability to plants. At certain pH ranges sufficient amounts of these nutrients be transformed into these ionic forms. When the soil pH is outside the desirable range (6.2 to 6.8), the nutrients are bound in the soil and are not in a form useful to plants.

The soil contains various nutrient ions such as chlorides, sulphates, nitrates, and phosphates along with organic matter. All these constituents provide nutrition to plant roots and are essential for maintenance of plant growth.

The chemical properties of soil can be determined by **rapid spot tests**. [The rapid tests only determine presence or absence of different salts. They do not measure (= calculate) the amount.]

3.3 DETERMINATION OF CARBONATES

The presence of carbonates in the soil can be easily measured using Rapid spot test. This method measures the levels of various ions qualitatively i.e., it just indicates the presence of a particular ion.

3.3.1 Materials Required

Soil sample

White cavity tile

Hydrochloric acid

3.3.2 Procedure

1. A pinch of soil is taken on a white cavity tile.
2. The dilute hydrochloric acid (HCl) is added to it.
3. The acid reacts with carbonates present in the soil and carbon dioxide gas escapes in the atmosphere showing effervescence.
4. The degree of effervescence has been divided into categories 1-4 depending upon the intensity.

3.3.3 Observations and Results

Perform the test for the soil samples provided and record the observations.

S. No.	Soil A	Soil B

Compare the results obtained with that given in the reference table. It is noted that more the effervescence more is the level of carbonates present in the soil sample.

Soil type	Effervescence (CO ₂)	Category
Non-calcareous (less than 0.5%)	Less number of bubbles of CO ₂ formed	1
Slightly calcareous (0.5-2%)	Less number of bubbles of CO ₂ formed	2
Calcareous (5-10%)	More number of bubbles of CO ₂ formed	3
Very calcareous (more than 10%)	More number of bubbles of CO ₂ formed	4

3.4 DETERMINATION OF NITRATES

The presence of carbonates in the soil can be easily measured using Rapid spot test. This method measures the levels of various ions qualitatively i.e. it just indicates the presence of a particular ion.

3.4.1 Materials Required

Soil sample

White cavity tile

Diphenylamine

Concentrated sulphuric acid

3.4.2 Procedure

1. Take a pinch of soil in white cavity tile.
2. Add few drops of 0.02% diphenylamine in concentrated sulphuric acid (H_2SO_4).
3. The solution gives blue color which indicates presence of nitrates.
4. The depth of blue color is proportional to the quantity of nitrate present.
5. The nitrate content is expressed in scale of 1-4 depending upon the intensity of blue color.

Phenol disulfonic acid method (PDA)

The nitrate content can also be measured calorimetrically using this method (Harper, 1924).

3.4.3 Materials Required

1. Soil
2. Beakers (100ml)
3. Calcium sulfate
4. De-ionized water
5. CuSO_4
6. Ag_2SO_4
7. NH_4OH

3.4.4 Procedure

1. Weigh out 10 g of soil (dried and sieved) and transfer to a labelled 100-ml beaker. Add 0.1 g of calcium sulfate. Add 20 ml of de-ionized water. Mix the contents thoroughly with a glass rod. Shake for 1 min.
2. The extraction can also be done using 0.02 N CuSO_4 solution.
3. Ag_2SO_4 (0.007 N) is added to prevent chloride interference.
4. The samples are evaporated using hot a plate.
5. A neutral or slightly alkaline medium is maintained during sample evaporation. Temperature is controlled such that loss of residue is avoided.

6. The yellow color develops after adding 7 N NH_4OH .
7. The intensity of the color is measured by using a spectrophotometer at a wavelength of 415 nm.

3.4.5 Observations and Results

Perform the test for the soil samples provided and record the observations.

S. No.	Soil A	Soil B

The colorimetric methods provide a rapid and highly sensitive means to determine the presence of nitrate anion. Color formation appears quickly (<60 s) and results of test can be interpreted within no time. More intense the color more is the amount of nitrate present.

3.5 DETERMINATION OF CHLORIDES

It can be measured by colorimetric method.

3.5.1 Materials Required

1. Spatula
2. Spectrophotometer
3. Shaker
4. 50 mL Erlenmeyer flasks, filter funnels or tubes

3.5.2 Reagents

1. **Extracting Solution (0.01M)** – Weigh 4.72 g of $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$. Add to a 2 L volumetric flask. Adjust the volume with distilled water.
2. **Saturated Mercury (II) Thiocyanate [$\text{Hg}(\text{SCN})_2$] Solution (0.075%)** – Add approximately 0.75g $\text{Hg}(\text{SCN})_2$ to 1 l of distilled water and stir overnight. Filter through Whatman Filter Paper No. 42. The saturated solution can be stored for long period of time.
3. **Ferric Nitrate Solution** – Dissolve 20.2 g $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ (Ferric (III) nitrate non-hydrate) in approximately 500 ml of distilled water. Add concentrated nitric acid (HNO_3) until the solution is almost colorless (20 to 30 ml). Make the volume to 1 l with distilled water.
4. **Charcoal** washed in 0.01M $\text{Ca}(\text{NO}_3)_2$ and dried.
5. **Chloride Standard Stock Solution (1000 ppm)** – Dissolve 0.2103 g KCl in approximately 50 ml of extracting solution. Bring up to 100 ml. For preparing solution of 100 ppm (mg L^{-1}), 10 ml is take out from the stock solution (1000 ppm). The volume is made to 100 ml. Pipette out 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, and 10.0 ml from 100 ppm standard solution and make up the volume to 100 ml with extracting solution to get concentrations of 0.5, 1.0, 2.0, 4.0, 5.0, and 10.0 ppm.

3.5.3 Procedure

1. Add 10 g of soil into a 50 mL Erlenmeyer flask.
2. Add approximately 25 mg washed charcoal (dried).
3. Add 25 ml extracting solution.
4. Shake for 15 minutes and filter the contents using Whatman No. 42 filter paper.
5. Transfer a 10 ml aliquot to a 50 mL beaker.
6. Add 4 ml each of the thiocyanate and the ferric nitrate solutions. Shake to mix.
7. Allow 10 minutes for color development.
8. Read color intensity (optical density) OD at 460 nm.
8. Prepare a blank in a similar manner but without soil sample.
9. Prepare a standard curve by pipetting out 10 ml aliquot of each of the working standards. Plot the absorbance against concentration.
10. Determine chloride concentration using standard curve.

3.5.4 Observations and Results

More the optical density more is the amount of chloride present. The quantity of the chloride can be calculated using the standard curve prepared by using calcium chloride.

S. No.	Soil A	Soil B

3.6 DETERMINATION OF PHOSPHATES

The phosphate levels in the soil can be determined by the Ascorbic Acid or Fiske Subbarrow method.

3.6.1 Materials Required

1. **Extracting solution** – (0.5 M NaHCO_3 solution pH 8.5) Dissolve 420 g sodium bicarbonate in distilled water. Make volume to 10 l. Dissolve the salt by putting the flask on the magnetic stirrer. Adjust pH to 8.5 by adding 50% sodium hydroxide.
2. **Acid Molybdate Stock Solution** – Dissolve 60 g ammonium molybdate, $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$, in 200 ml of distilled water. Heat to about 60 °C until solution is clear. Allow the solution to cool. Add 1.455 g of antimony potassium tartrate in the solution. Slowly add 700 ml of concentrated sulfuric acid. Cool the solution. Dilute to make a final volume of 1l. This solution may be blue in color but becomes clear on dilution. Refrigerate and store in dark.

3. **Ascorbic Acid Stock Solution** – Dissolve 13.2 g of ascorbic acid in distilled water and dilute to a final volume of 100 ml. Refrigerate in dark.
4. 50 ml Erlenmeyer flasks
5. Rotating or reciprocating shaker
6. Funnels
7. Whatman Filter Paper No. 42 or No. 2
8. Funnel rack
9. Volumetric flasks

3.6.2 Procedure

1. Take 2 g of soil (ratio of soil-to-solution is 1:10) in a 50 mL Erlenmeyer flask.
2. Add 20 ml of extracting solution and shake at 200 rpm for 5 minutes at the room temperature.
3. Filter extracts through Whatman No. 42 filter paper. Refilter the contents if required.
4. Ascorbic Acid or Fiske Subbarow method can be used for color development.

Fiske-Subbarow Method

3.6.3 Reagents

1. **Acid Molybdate Stock Solution (P-B Solution)** – Dissolve 75.25 g of ammonium molybdate, $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$ in 500 ml of distilled water heated to 60 °C. Cool the solution and mix with 1500 ml HCl (37.5%). Dilute the solution to 2000 ml with distilled H_2O in a volumetric flask. Store in a glass-stoppered, brown bottle to which 100 g of boric acid (H_3BO_3) has been added.
2. **Dry Reducing Agent: Aminonaphthol-sulfonic acid (P-C Powder)** – Mix 5 g of 1-amino-2-naphthol-4 sulfonic acid with 10 g of sodium sulfite (Na_2SO_3) and 292.5 g of sodium pyrosulfite ($\text{Na}_2\text{S}_2\text{O}_5$). Grind the mixture to a fine powder. Store the solution in a brown bottle. The reagent can be kept for one year.
3. **Dilute Reducing Agent (P-C Solution)** – Dissolve 16 g of dry reducing agent in 100ml of distilled water heated to 60 °C. Cool and store in brown bottle. Make fresh every 3 weeks.
4. **Working Solution** – Add 25 ml of acid molybdate stock solution to a volumetric flask containing about 800 ml of distilled water. Mix thoroughly. Add 10 ml of ascorbic acid stock solution. Add distilled water to final volume of 1l. Prepare fresh.
5. **Stock Standard Phosphorus Solution (50 ppm)** – Dissolve 0.2197 g potassium dihydrogen phosphate (KH_2PO_4) in about 25 ml of distilled water. Dilute to a final volume of 1l with extracting solution.

6. **Working Standards** – Pipette calculated amount from 50 ppm stock standard phosphorus solution into volumetric flasks. Bring flasks to volume with extracting solution.

3.6.4 Procedure

1. Transfer a 5 ml aliquot of the extract to a test tube.
2. Add 0.25 ml acid molybdate solution (P-B solution). Shake to mix with filtrate.
3. Add 0.25 ml dilute-reducing agent (P-C solution). Allow color to develop 15 minutes.
4. Read optical density using colorimeter or spectrophotometer set at 660 nm within 45 minutes after adding reducing agent.
5. Prepare a standard curve by pipetting 5 ml aliquot of each working standard, developing color. Read the color intensity of the solutions. Determine concentration in soil extracts from intensity and the standard curve.

Ascorbic acid method

The method was given by Watanabe and Olsen (1965). This procedure is recommended for calcareous soils, particularly those containing more than 2% calcium carbonate. It can also be used for determination of phosphate in neutral and alkaline soils.

3.6.5 Reagents

Acid Molybdate Stock Solution

Reagent A

Dissolve 60 g of ammonium molybdate $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$, in 1250 ml of distilled water. Dissolve 1.455 g of antimony potassium tartrate in 500 ml of distilled water. Add both of these solutions to 5000 ml of 2.5 M H_2SO_4 (prepared by adding 148 ml of concentrated H_2SO_4 in one liter of water). Mix and dilute to 10,000 ml with distilled water. Store in a glass, pyrex bottle in a dark, cool place.

Reagent B

Dissolve 2.639 g of ascorbic acid in 500 ml of reagent A. This reagent must be freshly prepared.

3.6.6 Procedure

1. Transfer a 5 ml aliquot to a beaker or Erlenmeyer flask (50 mL or larger).
2. Add 15 ml of distilled water.
3. Add 5 ml of Reagent B and mix well.
4. Keep aside for 10 min for color development. Measure the optical density at 882 nm using colorimeter.

- Prepare a standard curve by pipetting a 5 ml aliquot of each of the working standards. Develop color and read intensity in the same manner as with the soil extracts. Plot intensity against concentration of the working standards.

3.6.7 Observations and Results

The intensity of the color is proportionate to the concentration of the element estimated. The color intensity is measured spectrophotometrically.

Precaution- Intensity of blue color can change slightly with every batch of molybdate reagent. The standard curve should be prepared after measurements for each day.

S. No.	Soil A	Soil B

3.7 DETERMINATION OF SULPHATES

Sulphates are determined by the turbidimetric method (Chesnin and Yien, 1951).

3.7.1 Materials Required

- 30-to 60-mesh $BaCl_2$ crystals
- 10% $BaCl_2$
- HCl

3.7.2 Procedure

Add few drops of acidified (treated with HCl) 10% $BaCl_2$ solution to 10 ml extract. The solution turns turbid. The presence of turbidity and/or white precipitate of $BaSO_4$ indicate presence of sulphates. The absorbance of the $BaSO_4$ suspension was measured within 30 min after precipitation with a colorimeter at 420 nm wavelength (Rossum and Villarruz, 1961).

3.7.3 Observations and Results

The more is the turbidity of the solution more the amount of phosphate present.

S. No.	Soil A	Soil B

3.8 DETERMINATION OF ORGANIC MATTER

Organic matter is the source of nutrients such as nitrogen released through microbial activity. It helps in soil aeration, filtration and moisture holding capacity. It is considered as an index of soil fertility.

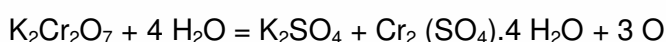
At first a simple qualitative test is performed. A small amount of soil is taken in a test tube. A few drops of hydrogen peroxide (H_2O_2) are added to the test tube containing the soil sample. Any organic matter present in the soil gets oxidized. This results in effervescence. A volume/intensity of the effervescence provides an idea of the presence of organic matter.

Organic matter of the soil can be estimated using Dichromate method (wet oxidation method) or loss on ignition method.

Wet oxidation method or Walkley-Black titrimetric wet oxidation method

3.8.1 Method

The method is based on the oxidation of carbon by oxygen liberated from potassium dichromate in the presence of sulphuric acid. The reaction is as follows:



3 atoms of oxygen are liberated from each molecule of potassium dichromate. Hence 1 ml of $\text{K}_2\text{Cr}_2\text{O}_7$ is equivalent to 3 mg of carbon. The conventional carbon to organic matter factor is 1.724.

3.8.2 Materials Required

Erlenmeyer flask

Sulphuric acid

Potassium dichromate

Phosphoric acid (concentrated)

o-phenanthroline- ferriin indicator

Ferrous sulphate heptahydrate -0.25 mol L⁻¹

In this method heat of dilution of conc. H_2SO_4 with 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ is the source of heat. Barium diphenylamine sulfonate (0.16% aqueous solution) is used as an indicator. "Ferriin" indicator (ortho-phenanthroline ferrous sulfate, 0.025 M solution) is used.

3.8.3 Procedure

1. Take 2 g of dried soil.
2. Add 10 ml of dichromate solution. Gently swirl.
3. Add 20 ml of sulfuric acid. Swirl gently to mix the contents. Swirl vigorously for 1 min.
4. Keep the flask aside for 30 min.
5. Add 200 ml of distilled water and 10 ml of concentrated phosphoric acid.
6. Add 3-4 drops of indicator and titrate with ferrous sulfate. As the endpoint approaches the color of the solution changes from green to deep green and blue. At the endpoint color changes from blue to red or maroon.

7. Blank is prepared using the same procedure.

Calculations-

$$\% \text{ Carbon} = \frac{V1 - V2}{W} \times 0.003 \times 100$$

V1 = volume of potassium dichromate

V2 = Volume of ferrous ammonium sulphate

W = weight of the soil

$$\text{Organic matter (\%)} = \% \text{ carbon} \times 1.724$$

Volumetric method (Walkley and Black, 1934)

3.8.4 Materials Required

1. Conical flask
2. Pipettes
3. Burette
4. Phosphoric acid (85%)
5. Sodium fluoride solution (2%)
6. Sulphuric acid (96 % containing 1.25% Ag_2SO_4)
7. **Standard 0.1667M $\text{K}_2\text{Cr}_2\text{O}_7$** - Dissolve 49.04 g of $\text{K}_2\text{Cr}_2\text{O}_7$ in water and dilute to 1 liter.
8. **Standard 0.5M FeSO_4 solution**- Dissolve 140 g Ferrous sulphate in 800 ml water, add 20 ml concentrated H_2SO_4 and make up the volume to 1 liter.
9. **Diphenylamine indicator**- Dissolve 0.5 g diphenylamine in 20 ml water and 100 ml concentrated H_2SO_4 .

3.8.5 Procedure

1. Weigh 1.0 g of the prepared soil sample and place it in a 500 ml conical flask.
2. Add 10 ml of 0.1667M $\text{K}_2\text{Cr}_2\text{O}_7$ solution and 20 ml concentrated H_2SO_4 .
3. Mix thoroughly and allow the reaction to complete for 30 minutes.
4. Dilute the reaction mixture with 200 ml water and 10 ml H_3PO_4 .
5. Add 10 ml of NaF solution and 2 ml of diphenylamine indicator.
6. Titrate the solution with standard 0.5M FeSO_4 solution to a brilliant green color.
7. A blank is prepared without sample.

Percent Organic matter = $Y \times 1.724$ (organic matter contains 58% organic carbon, hence $100/58=1.724$)

Note: Organic carbon to total organic matter conversion factor for surface soils vary from 1.724 to 2.0. A value of 1.724 is commonly used, although whenever possible the appropriate factor is determined experimentally for each type of soil.

3.8.6 Loss of Weight or Ignition Method (LOI) Materials Required

1. Sieve
2. Beaker
3. Oven
4. Muffle furnace

3.8.7 Procedure

1. Dry the ashing vessel (crucible) in oven at 105°C. Label the crucible and record the weight.
2. Weigh 5 to 10g of soil into crucible. Record the weight of the crucible.
3. Place the crucibles with soil into a drying oven set at 105°C for 4 hours. Cool in a dessicator. Record the weight of the crucible.
4. Place crucibles in muffle furnace set at 500°C. Ash overnight. Turn off the furnace. Place the crucibles in a dessicator for cooling. Record weight of the crucible.
5. The water lost from clay crystals is calculated using formula (%) = "loss on ignition" (%) - (0.05 x wt. of clay in the sample). Organic matter for organic soils can be determined by this method without any correction. It can also be calculated as

$$\text{Percent organic C} = \% \text{ OM} \times 0.58$$

3.8.8 Observations and Results

The organic matter is calculated using the formula given in the procedure.

S. No.	Soil A	Soil B

3.9 DETERMINATION OF BASE DEFICIENCY

It can be measured by colorimetric method (Datta et al., 1962)

3.9.1 Materials required

1. Spectrophotometer
2. Conical flask
3. Pipettes

4. Standard potassium dichromate solution (1N)
5. Concentrated sulphuric acid containing 1.25% Ag_2SO_4
6. Sucrose

3.9.2 Procedure

1. Take 1 g of soil in 100 ml conical flask.
2. Add 10 ml of 0.1667M $\text{K}_2\text{Cr}_2\text{O}_7$ and 20 ml of conc. H_2SO_4 containing 1.25 % Ag_2SO_4 .
3. Stir the reaction mixture and allow it to stand for 30 minutes.
4. The green color of solution (chromium sulphate) is read on a spectrophotometer at 660 nm.

Preparation of standard curve: Sucrose is used as a primary source of carbon. Take different quantities of sucrose (1 mg to 20 mg) in 100 ml flasks. Add 10 ml standard $\text{K}_2\text{Cr}_2\text{O}_7$ and 20 ml of concentrated H_2SO_4 in each flask. Swirl the flasks and leave for 30 minutes. A blank is also prepared in the similar way without adding sucrose. Green color develops. The color is read on spectrophotometer at 660 nm after adjusting the blank to zero. The reading so obtained is plotted against mg of sucrose as carbon source (carbon = wt. of sucrose \times 0.42 because carbon content of sucrose is 42%) or against mg C directly. The standard curve gives the estimate of organic carbon. The curve is shown directly against C content, which has been derived from mg sucrose used in preparing the standard curve.

Calculations

The carbon content of the sample is found out from the standard curve which shows the carbon content (mg of carbon v/s spectrophotometer readings as absorbance).

Percent C = $\text{mg C observed} \times 100/1000$ (observed reading is for 1 g soil, expressed as mg).

Percent OM = $\% \text{ C} \times 1.724$

3.9.3 Observations and Results

Organic matter is one of the major components of healthy and productive soils. The organic matter content of agricultural topsoil is usually in the range of 1–6%. On the basis of organic matter content, soils are characterized as mineral or organic. Mineral soils contain about 30 percent organic matter. Organic soils are naturally rich in organic matter and contain more than 30 percent organic matter. Organic matter releases nutrients in a form available to plants upon decomposition. Soil organic matter provides estimate for nitrogen, phosphorus and sulfur mineralized available for production of crop plants. Organic matter thus can serve as a reservoir of nutrients that can be released to the soil. A decline in organic matter content increases the susceptibility to soil erosion.

S. No.	Soil A	Soil B

Precautions

1. Care should be taken while handling the acids.
2. Weighing should be done accurately.
3. The methodology should be followed strictly as given.



EXERCISE 4

Comparison of Bulk Density, Porosity and Rate of Infiltration of Water in Soil of Three Habitats

Structure

- | | |
|---|---|
| 4.1 Introduction
Objectives
Study Guide/Prior Reading | 4.3 Measurement of Porosity of
Soil |
| 4.2 Measurement of Bulk Density
of Soil | 4.4 Measurement of Water
Infiltration Rate |

4.1 INTRODUCTION

Soil structure is influenced by its physical, chemical and biological characteristics. The structure and texture of soil affects the soil's ability to hold water. Soil physical properties are important because they determine the capacity of holding water and aeration. Soil physical characteristics are measured as changes in bulk density, soil moisture content, soil texture and water potential.

Soil physical properties form the foundation of several chemical and biological processes, which may be further governed by climate, landscape position, and land use.

Objectives

After performing these exercises you should be able to:

- ❖ measure the bulk density of different soil samples,
- ❖ measure the porosity of different soil samples, and
- ❖ measure the water infiltration rate of different soil samples.

Study Guide/Prior Reading

Blake, G.R. 1965. Bulk Density in Methods of Soil Analysis, Agronomy, No. 9, Part 11, C.A. Black, ed. pp. 374-390.

4.2 MEASUREMENT OF BULK DENSITY OF SOIL

Soil bulk density (apparent density) depicts the actual weight of the dry soil in a given volume. Dry bulk density (g/cm^3) is estimated as the ratio between dry mass (g) and wet sample volume (cm^3). It is usually expressed in terms of grams per cubic ($\text{Q/m}^3 > (\text{g/cm})$) or SI units of megagram per cubic meter. The dry bulk density of soil samples was determined by oven drying the samples at 60°C until constant weight. Density of an ordinary soil is approximately 2.65g/cc . It is measured by the simple method in which a cylindrical core of soil of known volume is cut and mass of the dried soil is measured.

Bulk density (BD) of a soil is ratio of the mass (M) of oven-dried soil to its bulk volume (BV) and includes the volume of the soil particles and the voids (pore spaces) between the particles. It increases with depth in the soil profile and normally occurs in the range of 1.0 to 1.7 g/cm .

4.2.1 Materials Required

1. Core sampler - hydraulic sampler
2. Sharp knife or spatula
3. Weighing balance (sensitivity 0.01 g)
4. Oven
5. Plastic bags
6. Weighing tins
7. Cellotape
8. Glass beads (260 pm)

4.2.2 Procedure

1. Prepare a smooth undisturbed vertical or horizontal soil surface. Insert sampler into the soil to fill the cylinder. Precaution should be taken so that soil remains undisturbed (not compressed).
2. The soil can be pushed out of the cylinder into a plastic bag. The bag should be closed and labelled.
3. If the soil is kept in the cylinder, place a metal disk on each end and carefully place in a plastic bag. The opening of the bag should be taped.
4. The soil filled cylinder is weighed. The weight of the wet soil along with tin and cylinder is recorded as $W1$. Record the weight of the tin as $W2$ and the weight of the cylinder as $W3$. These weights ($W2$ and $W3$) are taken before sampling.

5. The soil samples are dried in an oven at 105°C. For cores, 7.62 cm diameter. X 7.62 cm long, time of 72 h is used to dry the soil but for smaller soil samples less time is required. Record the weight of the oven dry sample, tin and cylinder as W4. The wet weight (W1) is used to calculate the moisture content at time of sampling.

Calculations

$$Db = W4 - W2 - W3$$

Vol. of cylinder and moisture content

$$QV = \frac{W1 - (W4 - W2)}{wt. \text{ of oven-dry soil.}} \times 100$$

The oven-dry weight of the sample is divided by the volume of the undisturbed sample at field moisture conditions. If the volume is very large, then a subsample is oven-dried and the oven-dried weight of the entire soil calculated.

4.2.3 Observations and Results

Record the observations for the each soil sample provided to you. Interpret the results on the basis of information provided to you.

Bulk density is an indicator of soil compaction. Higher is the number, more compacted is the soil. High bulk density indicates low soil porosity and soil compaction. Highly compact soil restricts root growth because of poor movement of air and water through the soil. Compaction results in shallow plant rooting which affects plant growth. Bulk densities greater than 1.6 g/cm³ restrict root growth. Sandy soils usually have higher bulk densities (1.3–1.7 g/cm³) while clays have bulk densities in the range of 1.1 – 1.6 g/cm³.

Table 4.1: Soil bulk density and root growth.

Soil Texture	Ideal bulk densities for plant growth (g/cm ³)
Sandy	< 1.60
Silty	< 1.40
Clayey	< 1.10

4.3 POROSITY

The porosity (pore space) of a soil provides the measure of open space present in the sample volume. It refers to the volume of soil voids that can be filled by water and/or air. It is inversely related to bulk density. Porosity is usually expressed as a percentage of the material's total volume.

4.3.1 Materials Required

1. 2 paper cups
2. Graduated cylinder

3. Beaker
4. Soil samples
5. Spoon/scrapper
6. Stopwatch or other timing device

4.3.2 Procedure

1. Pour 100 mL of water into cup and draw a line where the water comes up to. Write 100 mL in the total volume column on your data sheet. Pour out the water.
2. Fill the cup with the soil sample up to the marked line.
3. Using a graduated cylinder, slowly and carefully pour water into the cup until the water reaches the top of your sample. Record the volume of water remaining in the graduated cylinder on your data sheet.
4. Subtract the volume remaining from the total volume. This is the amount of water you added to your sample. The volume of water added to the sample on the data sheet gives the pore space.
5. To determine the porosity of the sample, divide the pore space volume by the total volume and multiply the result by 100.
6. Calculate porosity using the formula.

Calculation

$$\% \text{ pore space} = \text{pore space} / \text{total volume} \times 100$$

4.3.3 Observations and Results

Record the observations for the each soil sample provided to you.

Porosity refers to the volume of soil voids that can be filled by water and/or air. It is inversely related to bulk density. It has been found that loose, porous soils have lower bulk densities and greater porosities in comparison to tightly packed soils. Porosity varies depending on particle size. It is more in clayey and organic soils as compared to sandy soils. Loose, porous soils have lower bulk densities and greater porosities than tightly packed soils. Porosity varies depending on particle size and aggregation. It is greater in clayey and organic soils than in sandy soils. A large number of small particles in a volume of soil produce a large number of soil pores. Fewer large particles can occupy the same volume of soil so there are fewer pores and less porosity.

4.4 INFILTRATION RATE

The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 15 mm/h means that a water layer of 15 mm will take one hour to move into the soil. The infiltration rate varies depending on the initial moisture content.

4.4.1 Materials Required

1. Aluminum ring (3 to 6 inch in diameter)
2. Rubber weight
3. Block of wood or plastic insertion cap
4. Plastic wrap
5. Plastic bottle marked at 107 mL (3-inch ring) or 444 mL (6-inch ring) for 1 inch of water, or graduated cylinder
6. Distilled water or rainwater
7. Stopwatch or timer

4.4.2 Procedure

1. Clear all residues from the soil surface. Drive the ring into the soil to a depth of 3 inches using a rubber mallet and a plastic insertion cap or block of wood. The ring should be inserted downward evenly and vertically. Press soil inside the ring to eliminate gaps.
2. Cover the inside of the ring with plastic wrap, and drape it over the rim.
3. Pour 107 or 444 mL of distilled water or rainwater into the plastic lined ring. Gently pull plastic wrap away. Record the time it takes for the water to infiltrate the soil.
4. Repeat the step to determine steady state of infiltration rate.
5. Remove the ring with the soil intact.

These methods can be followed for three soil samples collected from three different habitats to have a comparison.

4.4.3 Observations and Results

Record the observations for the each soil sample provided to you.

Refer to the table and note the observations.

Soil type	infiltration rate (mm/h)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

The infiltration rate depends on soil texture (the size of the soil particles) and soil structure (the arrangement of the soil particles).

The infiltration rates for different soils as given by Tiedemann (1996) as follows

- low infiltration rate: < 15 mm / hour;
- medium infiltration rate: 15 to 50 mm / hour;
- high infiltration rate: > 50 mm / hour.

Water infiltrates rapidly in a dry soil.

Suggested readings

JoVE Science Education Database. *Environmental Science*. Soil Nutrient Analysis: Nitrogen, Phosphorus, and Potassium. JoVE, Cambridge, MA, (2018).



EXERCISE 5

Study of Ecological Adaptations in Plants

Structure

- | | |
|--------------------------------|--|
| 5.1 Introduction | 5.4 Features of Stem Parasite (<i>Cuscuta</i>), Root Parasite (<i>Orobanche</i>) (biotic interactions) |
| Objectives | |
| Study Guide/Prior Reading | |
| 5.2 Adaptations of Hydrophytes | 5.5 Features of Epiphytes, Insectivorous Plants (biotic interactions) |
| 5.3 Adaptations of Xerophytes | |

5.1 INTRODUCTION

Habitat is the type of natural environment in which a particular species of organism lives. Plants have adaptations to help them survive (live and grow) in different areas. Adaptations are special features that allow a plant or animal to live in a particular place or habitat. Plants have been classified into different types on the basis of their habitat. Mesophytes are land plants which grow at the normal land conditions with sufficient water in the soil to live. Hydrophytes are the plants that grow only in water. Xerophytes are plants which grow in desert areas with very low water availability and high temperatures. They can survive in drought conditions like the desert. Epiphytes are plants that grow on the surface of other plants. These plants are not parasites but survive on other big and tall-growing trees.

Any feature of an organism which enables it to exist under conditions of its habitat is called adaptation. Every organism possesses certain adaptive features which help in its survival or stabilization. Plants growing in dry habitats (xerophytes) and water bodies (hydrophytes) possess some specialized morphological and anatomical features that help them to adapt / survive in those conditions.

Objectives

After doing these exercises you should be able to:

- ❖ enlist the morphological adaptations in hydrophytes,

- ❖ enlist the morphological adaptations in xerophytes,
- ❖ describe the major features of epiphytes, and
- ❖ describe the major features of parasites.

5.2 ADAPTATIONS IN HYDROPHYTES

HYDROPHYTES

The plants that grow in water (freshwater or saline) either partially or completely are known as aquatic plants or hydrophytes. Hydrophytes are of three types.

Floating Hydrophytes

Plants that float on the surface of water are called floating hydrophytes. They may be free floating or rooted. These plants float freely on the surface of water and stay in contact with water and air. They are not rooted in the mud.

Examples- *Wolffia sp.*, *Trapa bispinosa*, *Eichhornia crassipes*, *Salvinia* and *Azolla*.

Submerged Hydrophytes

Plants which grow below the water surface are called submerged hydrophytes. They may be free-floating or rooted. Some plants are rooted in mud but their leaves and flowering shoots float on or above the surface of water. Example *Vallisneria*, *Hydrilla*, *Potamogeton*, *Najas* and *Ceratophyllum*.

Emergent (Amphibious) Hydrophytes

These plants are adapted to both aquatic and terrestrial modes of life. These plants grow in shallow water or on the muddy substratum. Roots and some parts of stems and leaves in these plants may be submerged in water or buried in mud but some foliage, branches and flowering shoots remain above the surface of water or spread over the land. The aerial parts show mesophytic or sometimes xerophytic features, while the submerged parts develop true hydrophytic characters. Examples- rice (*Oryza sativa*), *Marsilea*, *Sagittaria*, *Ranunculus aquatilis*, *Phragmites* etc. Amphibious plants that grow in saline marshy places are termed as halophytes. Amphibious plants in which shoots are completely exposed to air but the roots are buried in water lodged soil or mud are referred as marsh plants. The common examples are *Cyperus*, *Typha*, *Scirpus*, *Rumex*, etc.

5.2.1 Material and Methods

Observe carefully the plant species provided to you. Note down the morphological features.

Hydrophytic species- *Hydrilla*, *Eichhornia* (water hyacinth), *Wolffia*, *Lemna*.

5.2.2 Procedure

- Observe the plant samples carefully.
- Stem, leaf, and root are separated and the morphological adaptations are noted.
- The sections of the tissues such as stem, root and leaf are cut to study anatomical features.
- Transverse section of the tissues such as stem and root are taken, stained and mounted in glycerin. The prepared slide is observed under the microscope.

5.2.3 Observations and Results

The major adaptations in hydrophytes have been noted as changes in morphological and anatomical features.

Morphological features

1. Root systems in hydrophytes are poorly developed. They are either reduced or absent. Roots are absent in floating forms while submerged plants (*Hydrilla*) have less developed roots. The roots may be branched or unbranched. Root hairs are less developed or absent (*Lemna*). The plant body remains in direct contact with water, hence water gets directly absorbed by the plant surface.
2. The stem is long, slender, weak, spongy and flexible in submerged hydrophytes, while it is short, stoloniferous, thick and spongy in free floating plants.
3. The leaves of free-floating forms are smooth, shining and coated with wax. The leaves of submerged forms such as *Hydrilla* are thin, ribbon like. The plants sometimes show heterophylly i.e. two different types of leaves are present on the same plant. Example- *Potamogeton*, *Sagittaria*. The broad leaves are present on the upper surface while finely dissected narrow leaves are found submerged in water. The submerged leaves provide resistance against water currents while the leaves found on the upper surface of water regulate the hydrostatic pressure in the plant body.
4. In some floating plants, the petioles become swollen and spongy to provide buoyancy to plants. Examples- water hyacinth, *Trapa* etc.
5. Reproduction occurs mainly by vegetative methods such as fragmentation of shoots or buds.

Anatomical features

1. Parenchyma tissue occupies a large portion of the root and stem. The tissue helps in the exchange of gases. The parenchyma tissue found in the hydrophytes contains lots of air spaces, hence known as aerenchyma. Aerenchyma provides buoyancy and mechanical support to aquatic plants. Air chambers or spaces are filled with respiratory gases such as CO₂ and moisture.

2. Hypodermis is poorly developed. Thin walled cells are present in the region.
3. The vascular tissues are poorly developed. The vascular tissues are not required in these plants because the absorption of water and nutrients takes place through surface of plant.
4. Cuticle is absent or poorly developed.
5. Stomata are less in number or absent and exchange of gases takes place directly through cell walls. If present, they are confined only to the upper surface of the epidermis.
6. Chlorophyll is present in all the tissues.

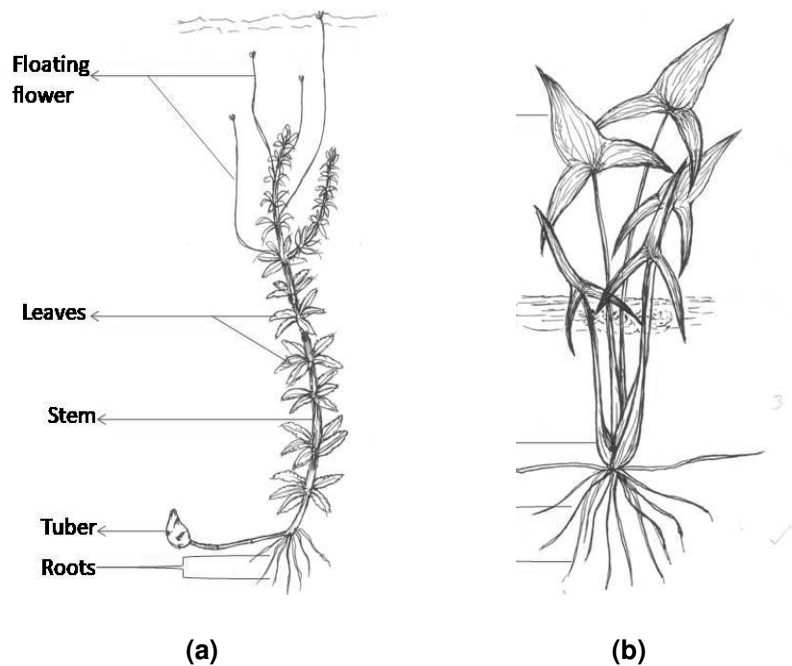


Fig. 5.1: (a) *Hydrilla*, (b) *Sagittaria* showing heterophylly.

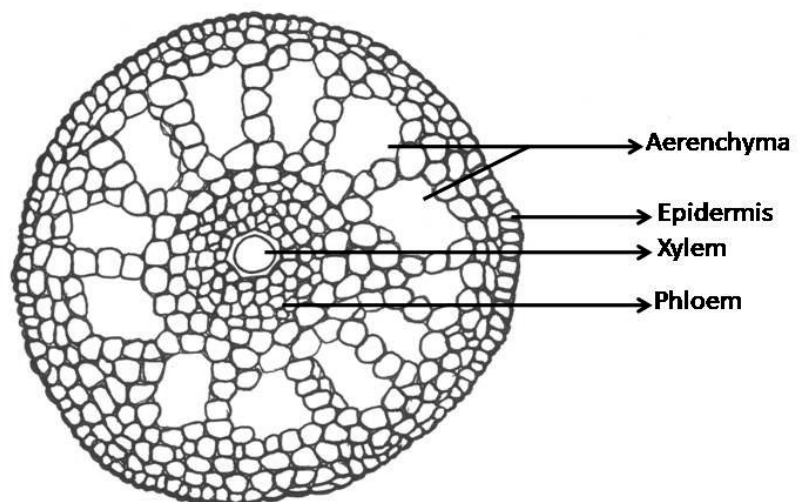


Fig. 5.2: Section of *Hydrilla* stem.

5.3 ADAPTATIONS IN XEROPHYTES

XEROPHYTES

Plants which grow in dry habitats or xeric conditions are called xerophytes. These plants are able to survive under conditions of high temperature and extreme dryness. Xerophytes are found in desert and semi-desert regions. These plants develop certain morphological and anatomical features that help in their survival in dry conditions. Plants show excessive transpiration. Ephemerals or “drought escapers/ evaders” complete their life cycle within a short period. Succulent plants possess fleshy organs which store water. The structural and physiological characteristics help in absorption of water, retaining water in tissues for long time and reduce transpiration to prevent water loss. Xerophytes are categorized into different groups according to their drought resisting power. These include:

1. Drought escaping plants

These xerophytes are short-lived. They survive critical dry periods in the form of seeds and fruits. The seeds possess hard and resistant seed-coats and pericarps. The seeds germinate at the advent of favorable conditions. The plants complete their life cycle within a few weeks time. The seeds become mature before the dry condition approaches. These are called ephemerals or drought evaders or drought escapers. Examples—members of families Zygophyllaceae, Boraginaceae, some grasses etc.

2. Drought enduring/ resistant plants

These are small sized plants which have capacity to endure or tolerate drought. These plants develop certain adaptive features which help them to resist extreme drought conditions. Some of these plants grow on rocky soils (lithophytes), deserts, sand and gravel (psammophytes) and waste lands (eremophytes). Some plants of xeric habitat have water storing organs. Example- *Agave*, *Bougainvillea*, *Portulaca*, *Lithops*, *Verbena*, *Lantana*.

Xerophytes can also be divided following groups

(1) Succulent and (2) Non-succulents xerophytes

Succulent xerophytes are those plants in which some organs become swollen and fleshy due to active accumulation of water in them. The plant body is composed of water storing tissues. Water stored in these tissues is used during extreme drought conditions.

5.3.1 Material and Methods

Observe carefully the plant species provided to you. Note down the morphological features.

Xerophytic species such as *Opuntia* will be provided to you.

5.3.2 Procedure

- Observe the plant samples carefully.

- Stem, leaf, and root are separated and the morphological adaptations are noted.
- The sections of the tissues such as stem, root and leaf are cut to study anatomical features.
- Transverse section of the tissues such as stem and root are taken, stained and mounted in glycerin. The prepared slide is observed under the microscope.

5.3.3 Observations and Results

Plants growing in the dry habitats develop certain morphological and structural changes in them.

Morphological adaptations

1. Xerophytes possess well developed root systems. The roots are profusely branched and grow very deep in the soil to get access of water. Root hairs are well developed and help in the absorption of water.
2. Stem is hard and woody and stunted in growth. Example - *Acacia*, *Zizyphus*. In some xerophytes, stems may be modified into thorns. Example- *Duranta*, *Ulex*, etc. In some plants such as *Asparagus* a number of axillary branches become modified into small needle-like green leaf like structures called cladodes. In succulent species such as *Euphorbia* stem become green. In succulents, main stem itself becomes bulbous and fleshy. Stem is covered with thick coating of wax and silica. Example- *Equisetum*. In some xerophytes stem are modified into leaf-like flattened, green and fleshy structures which are termed as phylloclades. Example- *Opuntia*, *Euphorbia splendens*.
3. The leaves are greatly reduced to scales. Leaf blades or pinnae are reduced. The pinnae are shed from the rachis and the green petiole swells and becomes flattened taking the shape of leaf. The photosynthesis is carried out by phylloclades or cladodes (modified stem). Example- *Casuarina*, *Ruscus*, *Asparagus*. Some xerophytes have needle-shaped leaves. Example- *Pinus*. In succulents, leaves are fleshy because of storage of water and latex. Some plants possess thick and leathery leaves. The waxy coating present on the upper surface of leaves reduces transpiration. Example- *Calotropis procera*.
4. In some plants, the petiole becomes flattened and is termed as phyllode. The phyllode stores excess amount of water and performs photosynthesis. Leaves in some extreme xerophytic grasses have capacity for rolling or folding. The leaves roll upwardly to prevent loss of water.
5. Hairs are present on the leaves and stems. Example- *Zizyphus*, *Nerium*, *Calotropis procera*.

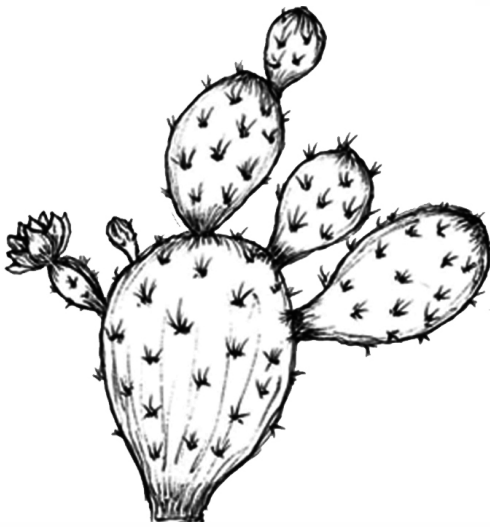


Fig. 5.3: *Opuntia* showing reduction of leaves into spines.

Anatomical adaptations

1. Epidermis possesses a well developed cuticle. The leaves show lignification and wax deposition on the upper surface. This prevents the loss of water from the surface of plant body. Multiple layered epidermis present on upper and lower surface of leaves. Example- Two or three layered epidermis in *Nerium* leaf.
2. Stomata are reduced in numbers and are mainly confined on the lower surfaces. The stomata are of sunken type i.e. they are present in the ridges and furrows or pits of mesophyll region. Subsidiary cells of sunken stoma are arranged in a way that outer chamber is connected by narrow opening or the stoma. Example- *Equisetum*. Walls of the guard cells and subsidiary cells are heavily cutinized and lignified.
3. Hypodermis consists of one or several layers of thick walled compactly grouped sclerenchyma cells. The cells are filled with tannin and mucilage. In leaves, mesophyll is compact and the intercellular spaces are greatly reduced. They may be spherical, rounded or cuboid in shape.
4. Palisade tissue develops in several layers. In succulent leaves, spongy parenchyma is present that stores water.
5. Shining smooth surface of cuticle reflects the rays of light and does not allow them to go deep into the plant tissues. Thus, it checks the heavy loss of water. Example *Nerium odorum*.
6. Some species of grasses show rolling up of leaves. This reduces the exposure of leaf surface to sun. The rolling of leaves occurs due to highly specialized motor cells. These cells become flaccid during dry periods. Some of the epidermal cells become enlarged and are called bulliform cells or motor cells or hinge cells. These are found usually on the upper surface of leaves.
7. Vascular tissues such as xylem and phloem are well developed.
8. Since the leaves are reduced, the photosynthetic activity is taken up by outer chlorenchymatous cortex.

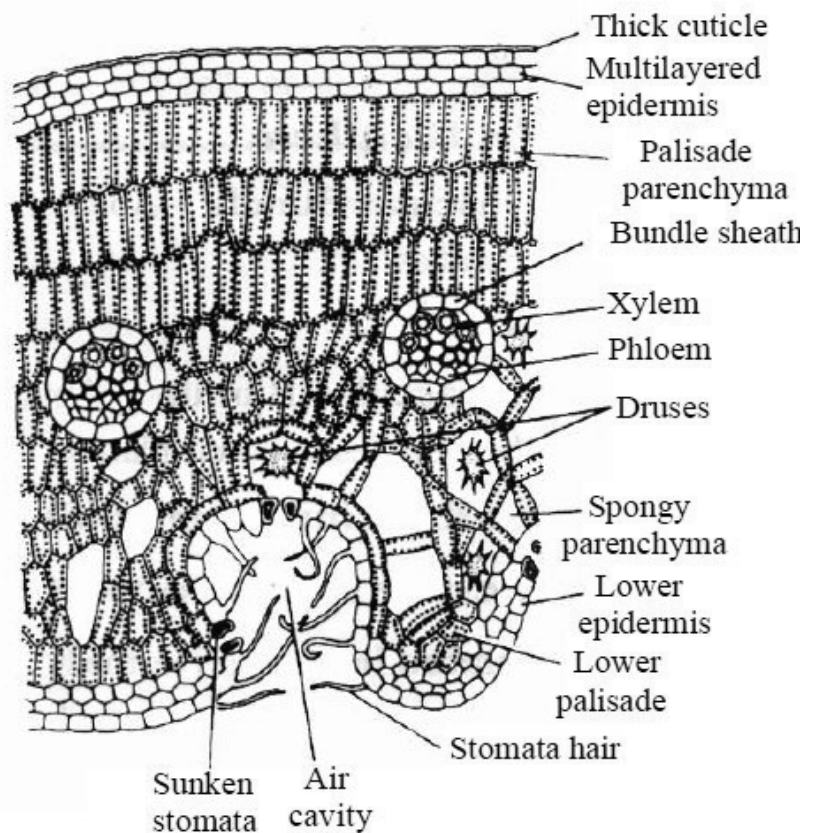


Fig. 5.4: Section of *Nerium* leaf showing sunken stomata.

5.4 FEATURES OF PARASITES

Parasites

Most plants are autotrophs and produce their food through photosynthesis. However, some plants lack chlorophyll and behave as parasites. A parasite is an organism that lives inside the host (other organism) or on a host. The parasite uses the host's resources to maintain itself. A parasitic plant attaches itself to another plant via haustorium. Haustoria are special suckers that invade the host plant and help in absorption of food such as sugars and minerals. Example- *Rafflesia arnoldii* is a parasitic plant that invades the underground roots of vines to take food. Many plants are totally dependent on their host for food. They are referred as total parasites.

Parasites infect an organism and can spread diseases. The parasites can be of two types- **endoparasites** i.e., which live inside the host body or cells and **ectoparasites** i.e., which live on the hosts.

Types of Parasitic Plants

Parasitic plants can be categorized into different types depending upon their attachment to the host, the degree of nutritional dependence upon the host and requirement of host for completion of life cycle. Parasites have been divided into two types depending upon their location in plants- stem and root parasites. Stem parasites occur in several families. These mainly include members of family Loranthaceae, Lauraceae. Giant dodder (*Cuscuta reflexa*). is the most common example of stem parasite. Root parasites occur in diverse taxonomic groups. Most of them belong to broomrape family, Orobanchaceae.

Parasitic plants may also be classified as hemiparasites or holoparasites. Hemiparasites contain chlorophyll when mature (hence are photosynthetic). They obtain water and dissolved nutrients by connecting to the host xylem via the haustorium when mature but complete their life cycle without hosts at maturity. Example- *Triphysaria* and *Odontites*. They are also referred as facultative parasites.

Holoparasites lack chlorophyll, are non-photosynthetic and totally depend upon the food contents of the host. They require a host to complete their life cycle. They are also referred as obligate parasites.

Besides these, some intermediate types are also found. They act as a link between the facultative and obligate parasites. These include species such as *Cuscuta* (dodder). The members of broomrape family (Orobanchaceae) have been considered as the best examples to study evolution of hemiparasites and holoparasites.

5.4.1 Material and Methods

Observe carefully the plant species provided to you. Note down the morphological features.

Plants include *Cuscuta* (stem parasite) and *Orobanche* (root parasite)

5.4.2 Procedure

- Observe the plant samples carefully.
- Study the morphology of stem, leaf, and root.
- Cut sections of the tissues such as stem, root and leaf are to study anatomical features.

5.4.3 Observations and Results

Stem parasite

In stem parasites, the vegetative portion consists of a stem and leaves. Holoparasites tend to have leaves reduced to scales, succulent stems and a primary haustorium.

Cuscuta

- *Cuscuta* (dodder) is stem parasite. The plant depends upon their hosts for carbohydrates. It belongs to the family Convolvulaceae (morning glory).
- Plant is leafless with branching stems. The plant tissues lack chlorophyll and hence plant cannot perform photosynthesis. It grows on other plants and uses their nutrients for its growth thereby causing weakening of the host plant.
- The stems are slender, thin and pink or brown in color. The stem attaches firmly to the host plants. The root gets removed and the mature plant lives without any attachment to the ground.

- The leaves are reduced to minute scales.
- The stems coil around the host producing suckers called **haustoria**. These are root like organs that penetrate the tissue of a host plant and help in absorption of food. Hence haustorium is the structure that acts as an interface from where nutrients, solutes, and carbohydrates are exchanged between host and parasite.
- The flowers are tiny, yellow or white bell-like and present in clusters.
- *Cuscuta* completely depends on the host plant to complete their life cycle, hence is considered as an obligate holoparasite.
- The prehaustorial cells produce adhesive substances such as pectins and polysaccharides. *Cuscuta* induces the host plant to produce sticky substances such as arabinogalactan proteins. These proteins promote adhesion. The glycoproteins secreted by the host plant localize to the cell-wall and induce adhesion along with components such as pectins.

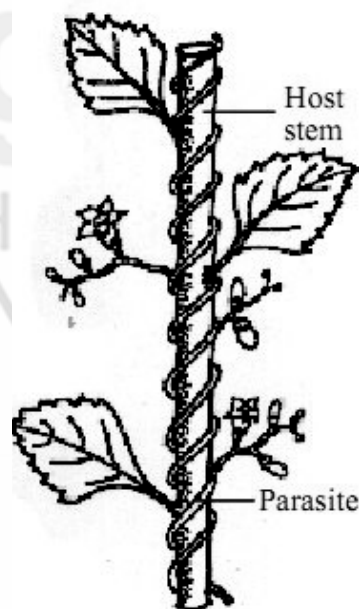


Fig.5.5: *Cuscuta*.

Root parasites

Complete Root Parasite – *Orobanche* (Broom rape)

- The plant belongs to family –Orobanchaceae (the broomrape family). *Orobanche* spp. are total root parasites affecting tobacco, brinjal, tomato, cauliflower, turnip and many other Solanaceous (eggplant, tomato, tobacco, potato), Cruciferous plants. The majority of species grow only on one or two host plants.
- *Orobanche* includes unbranched parasitic herbs. The plants lack chlorophyll. The plants are variable in color, ranging from yellowish-brown and reddish-violet to purple, blue, and orange.
- The plant consists of a stout, fleshy stem 15 to 50 cm long. This stem is yellow or brownish red in color and is covered by small thin and brown scaly leaves.

- The flowers are white and tubular, seeds are small and black in color. The flowers are born in spike. Fruits are one-celled capsules and many seeded.
- The plants live directly on their host by attaching strong haustoria to their roots. The haustoria penetrate the root tissues of the host and absorb nutrients.
- The seeds require about a week time to germinate. A substance produced by the roots of mature host plants encourages broomrape seed germination. Seeds are minute, long-lived (can survive in the soil for 13 yr).
- It gradually forms a nodule on the host root. As the nodule increases in size, small prominences emerge on its surface which develops into roots. They surround the nodule closely, and penetrate the host roots at other places.

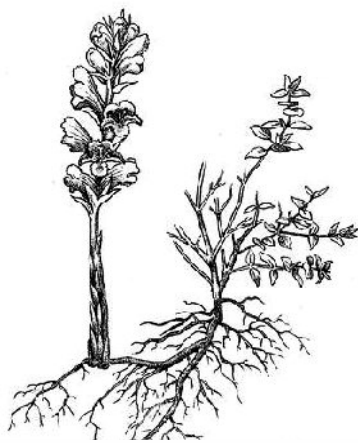


Fig. 5.6: Image showing *Orobanche*.

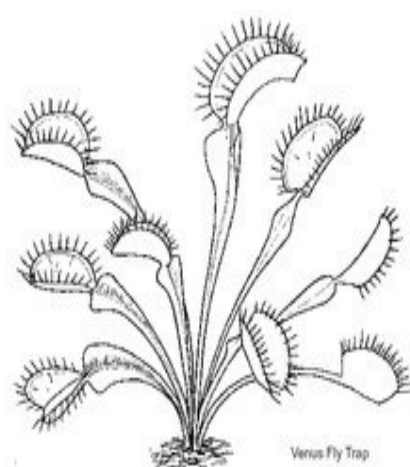
5.5 CARNIVOROUS PLANTS (INSECTIVOROUS PLANTS)

The plants that are capable of capturing and digesting insects and other animals are referred as carnivorous or insectivorous plants. They use pitfalls and traps for catching the prey. Leaf acts as a trap. It is generally hollow filled with liquid to passively collect and digest prey. The traps can be active or passive and this depends upon on the sticky mucilage. The mucilage may be present on the leaf surface or on gland-tipped hairs. The dense glandular hairs present on the leaf surface act as traps and help in absorption of nutrients from insects. Pitfall traps are found in pitcher plants. Venus flytrap (*Dionaea muscipula*) uses rapid leaf movements to capture insects. Bladder traps are found in bladderwort plants (*Utricularia*). They actively suck in small organisms by creating a partial vacuum. Lobster-pot traps are found predominantly in corkscrew plants (*Genlisea*), employ downward-pointing hairs to force prey deeper into the trap.

Carnivorous plants digest their prey through a process of chemical breakdown similar to digestion in animals using enzymes or bacteria. The end products are nitrogenous compounds and salts which are absorbed by the plants.

Most of the carnivorous plants belong to the family Lentibulariaceae. The family includes bladderworts (*Utricularia* species), butterworts (*Pinguicula*, species), and corkscrew plants (*Genlisea* sp.). The family Droseraceae mainly includes sundews (*Drosera*). Pitcher plants (*Nepenthes*) constitute the genus of the family Nepenthaceae. The different trapping mechanisms found in these plants include

1. Adhesive trap-The leaves have specialized short stalked glands that secrete sticky mucilage that traps small creatures. The adhesive trap leaves with tentacles. The tentacles provide a longer grasp of the prey. The thinner mucilaginous tentacles have been found in *Drosera*.
2. Pitfall traps are leaves modified into pit-like structures. The the base of the whorl of leaves seal to form a cup to catch water. Prey slip down the leaves into the pool at the base and drown. The traps may have nectaries, bright colors, or a flower-like scent to attract prey. The traps have hairs to direct prey to the trap opening or cause the prey to fall into the trap. The lip of the trap is usually slippery and the inside of the trap waxy. The leaves adjust the pH of the water and release digestive enzymes.
3. The most dramatic trap is the snap trap. Suction traps move too fast to see the action. A prey moves into the trap, brushes against the trigger hairs, and prey gets trapped. The trap will then slowly seal and digest the prey. The trap reopens after prey has been completely eaten up. These are found in *Dionaea muscipula* and *Aldrovanda vesiculosa*.
4. In *Utricularia inflata*, suction trap leaves.



Venus fly trap
(*Dionaea muscipula*)



Pitcher plant
(*Nepenthes*)

Fig. 5.7: (a) *Dionaea*; (b) *Nepenthes*

5.5.1 Material and Methods

Observe carefully the plant species provided to you. Note down the morphological features.

Photographs of the plants *Nepenthes*, *Dionaea* and *Drosera*

5.5.2 Procedure

- Observe carefully the plant samples.
- The plant parts such as stem, leaves and root are separated. The peculiar features are noted.

5.5.3 Observations and Results

Nepenthes

- It is also called tropical pitcher plant or monkey cup.
- These are perennial herbaceous plants.
- The plant possesses unusual leaf that develops a tendril at its tip. The tip of the tendril develops an amazing pitcher. The pitcher leaves function as passive pitfall traps. The pitcher swells and droops due to its weight.
- As the plant matures, leaf suddenly begins to inflate with air. Once inflated it begins to fill with liquid. The pitcher has a lid present on the top. When the leaf is fully grown, the lid opens and the trap is ready. They attract insects with the odor of nectar. Once inside the leaf, wax on the interior surface does not let the insect get grip on the walls of the pitcher. Eventually it falls, struggles to escape and this motion stimulates digestive glands to release a digestive acid.
- The nectar is secreted from the underside of the trap's lid. The prey slips from the mouth of the pitcher into a pool of liquid at the bottom. At the base of pitcher are present sticky hairs.

5.6 EPIPHYTES

Epiphytes are the plants that grows upon another plant or object and get physical support from them. Epiphytes are not attached through roots to soil. They get support from other plants. Most epiphytes are found in moist tropical areas. They are mainly angiospermous flowering plants. Common examples include species of orchids, members of the pineapple family (Bromeliaceae), mosses, ferns, and liverworts. They are found in tropical and temperate regions.

Epiphytes obtain water from rain. The specialized leaves found in some species absorb moisture. Minerals are obtained from rain, nutrients are generally absorbed from the debris present on the supporting plants. The seed dispersal occurs by wind. The seeds are feathery or small dust like.

5.6.1 Material and Methods

Observe carefully the plant species provided to you. Note down the morphological features.

Photographs of the plants moss, orchid

5.6.2 Procedure

- Observe carefully the plant samples.
- The peculiar features of the plants are noted.
- The sections of stem, root and leaf are cut and anatomical features are noted carefully.

5.6.3 Observations and Results

- The plant grows upon another plant for physical support.
- The root system is well developed. The roots may be normal, clinging or aerial. Normal roots absorb water, minerals, and organic nutrients from decaying barks of supporting plants. Clinging roots fix the epiphytes on the surface of the supporting object. They absorb nutrients from the humus and dust that are accumulated on the surface of bark. Aerial roots are green, spongy and hang downwardly in the atmosphere. They absorb moisture from the air. These roots are photosynthetic because of the presence of chlorophyll. Aerial roots absorb moisture from the humid air, allowing them to develop on other plants without harming their hosts. Example -orchid (*Dendrobium*).
 - Stem is generally succulent in vascular plants.
 - The leaves are less in number. Some orchids develop only a single leaf in a growing season. Leaves are mostly fleshy and leathery. The roots branch and produce number of delicate rootlets. Spoon-like leaves in rosettes have been reported in members of family Bromeliaceae. These leaves store rain water which is absorbed by the epidermal hairs present on the surface of the leaves.
- The fruits and seeds are usually dispersed by wind insects and birds.

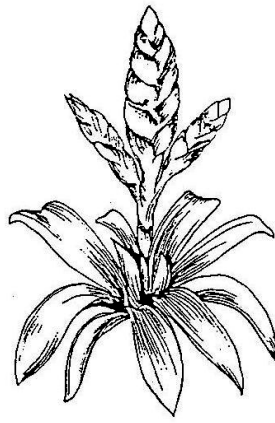
Anatomical features

Important anatomical features of epiphytes include

- Epidermis consists of thick cuticle and sunken stomata. These greatly reduce the loss of water from the plants.
- In succulent epiphytes, thin-walled parenchymatous tissue presents in the velamen that stores water.
- Aerial hanging roots possess a characteristic greenish white thin-walled massive tissue called velamen. The velamen is hygroscopic tissue that rapidly absorbs moisture from the atmosphere. It has been found in epiphytes belonging to the families Araceae and Orchidaceae. Velamen has been considered as a modification of multilayered epidermis. The cells are empty (i.e., dead) and cell walls show spiral or reticulate thickenings. Inner to the velamen, is present a layer called exodermis. The cells of exodermis are of two types- one having lignified and thick walled cells and another having thin walled cells or passage cells. The walls are permeable to water. The velamen is formed by dead compactly arranged cells with suberized walls. The velamen absorbs and retains moisture till that is absorbed by passage cells of exodermis.



(a)



(b)

Fig. 5.8: (a) *Tillandsia*; (b) Bromeliad.

Suggested readings

Williams, Stephen E. (1980) How Venus' Flytraps Catch Spiders and Ants. *Carniv. Pl. Newslett.* 9(3):65, 75-78 part 1

Katagiri, Yoshiaki (1984) The Leaf Blade Movement of *Drosera prolifera*. *Carniv. Pl. Newslett.* 13(2):52-53

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Volkova, Polina A. and Shipunov, Alexey B. (2009) The natural behavior of *Drosera*: Sundews do not catch insects on purpose. *Carniv. Pl. Newslett.* 38, 114-120.

Determination of Minimal Quadrat Size for the Study of Herbaceous Vegetation in the College Campus by Species Area Curve Method

Structure

6.1	Introduction	6.2	Requirements
	Objectives	6.3	Procedure
	Study Guide/Prior Reading	6.4	Observations and Results

6.1 INTRODUCTION

Plant species are not evenly distributed in an area. They may be present in high numbers at some places and less in number at other places. The distribution of species in an area is referred to as frequency. The plant frequency can easily be measured using quadrat method. A quadrat is a sampling unit (it could be in the form of a frame) that marks specific area of the community. The quadrat is a sample plot or unit for a detailed analysis of vegetation. It is a plot of specific size used to study a population or a community. Quadrats are used to assess vegetation, measure parameters such as plant density, frequency and biomass. It is difficult to find frequency of plant species for large populations or extensive habitats. Frequency varies according to size and shape of the quadrats used. Quadrats may be square, rectangular or circular in shape. In case of rectangular quadrat, ratio of breadth and length is generally 1: 2 or 1: 4 or 1: 8. Phytosociological analysis can be carried out using quadrat method.

Community analysis is carried by measuring quadrats [10m X 10m (100sqm) size] randomly to study tree species and shrub species present in a given area. A single quadrat cannot sample a community adequately, hence repeated quadrat samples are taken. The herbaceous species was studied by

laying 50 quadrats of 1m X 1m (1 m²) size randomly in each study site. For herbaceous vegetation quadrat size of 1m² is used. The size of the quadrat depends on the layer or type of vegetation being sampled.

Vegetation	Dimensions	Area(m ²)
Mosses	10 x 10cm	0.01
Herbaceous	31.6 x 31.6cm	0.1
Forest floor herb	1x 1m	1
Shrub	3.16 x 3.16 m	10
Forest/tree	10 x 10m	100

The concept of quadrat or sample-plot method was given by **Clements** (1898). In the study of forest community quadrats of one-fifth acre are established to include maximum number of trees. In study of shrubs and grass covers usually small size quadrats are used. For grassland and low herbaceous community, the quadrats of one square meter size or 50 cm x 50 cm size or even 20 cm x 20 cm size are used.

The total basal area is measured at breast height (1.5m) and calculated using the formula πr^2 . In case of herbaceous vegetation it is measured on the ground level by using calipers.

Types of Quadrats

Quadrats are named according to the use.

(i) List quadrats

When the organisms encountered in the sample plot are listed by their names, the quadrat is called list quadrat. It includes all the species botanically identified or otherwise. This quadrat gives floristic analysis of the community. This is used for studying the frequency of different species.

(ii) Count quadrat or list-count quadrat

In this type of quadrat, name and the number of individuals of each species present in an area are recorded. This type of quadrat is used for forest survey.

(iii) Cover quadrat

This quadrat records the ground area covered or shaded by vegetation.

(iv) Chart quadrat

Quadrats are mapped to scales to show the location of individuals of species. Individual plants are recorded on miniature quadrat on a graph paper. This is carried out with the help of instrument called pantograph. This measures long range vegetational changes.

Objective

After performing this practical exercise you will be able to:

- ❖ understand the use of quadrat in analysis of vegetation,
- ❖ describe the use of quadrat in determining the frequency, abundance and density of a species present in a given area, and
- ❖ determine the cover area for a species.

6.2 REQUIREMENTS

Measuring scale, nails, thread, hammer.

6.3 PROCEDURE

1. Visit any green area and lay down a series of horizontal and vertical grid lines in the area.
2. In each grid count the number of species present. Also note the total number of plant belonging to each species.
3. This can be repeated in plots of different sizes. Number of species are recorded for each plot.
4. The optimum quadrat size taken for the study of vegetation is 50 cm x 50 cm. The size is ascertained from the species-area curve analysis. The different parameters measured during the sampling include:
 - Counts—number of individuals of a species
 - Cover—the area (%) of the quadrat occupied by a plant species
 - Density—number of individuals of a species per unit area.
 - Frequency—number of quadrats in which the species is present
 - The occurrence and numerical strength of each species in each quadrat gives assessment of frequency and density.
5. **Frequency** : The number of quadrats in which occurrence of a species is observed in relation to the total number of quadrats sampled gives the **frequency**. It indicates the number of times a plant species is present within a given number of sample quadrats. This term refers to the degree of dispersion of individual species in an area. The study area is randomly sampled at several places and the name of the species is recorded. It can be calculated using the formula

Frequency (%) = (Number of sampling units in which the species occurs)/(Total number of sampling units employed for the study) X100

6. **Density** : The numerical strength of a species in present in definite unit space is called its density. It refers to the number of individuals of a

particular species per unit area. The number of individuals of a species in all quadrats, expressed as the fraction of number of total quadrats sampled gives the density of that species. Variation in distribution is caused by several factors like soil conditions, vegetative propagation, quantity and dispersal of seeds, grazing or other biotic activities and predation by insects or diseases.

Density of a species per unit area = Total number of individuals of a species in all the sample plots/Total No. of sample plots studied

7. **Abundance** : Abundance refers actually to density of population in those quadrats in which a given species occurs. To determine abundance, the sampling is done by quadrat or other methods at random at many places. In grasslands abundance can be recorded by uprooting the plants. It is the study of the number of individuals of different species in the community per unit area. The number of individuals of each species was summed up for all the quadrats divided by the total number of quadrats in which the species occurred. It is calculated using the formula

Abundance of a species = Total number of individuals of the species in all quadrats /Total number of quadrats in which the species occurred

8. **Cover** : The cover implies the area covered or occupied by the leaves, stems and flowers, as viewed from the top. The coverage is studied at the canopy level and the basal region. In forest, each layer of vegetation is considered separately for measuring the coverage. Basal cover is the basal area covered by crowns or stems penetrating the soil. Basal area in grasslands refers to the coverage of ground one inch above the ground surface by stems and leaves. It is also called herbage cover. The coverage can be measured by quadrat method, transect method and point method of sampling.

A table provided by **Daubenmire** given various cover classes for categorization of species.

Cover class	Range of coverage (%)
1	0-5
2	5-25
3	25-50
4	50-75
5	75-95
6	95-100

6.4 OBSERVATIONS AND RESULTS

The number of plants of each species present in each grid and the quadrat is counted. Similarly note down the observations for at least 10 such quadrats.

The data obtained is used for calculating the frequency, density abundance of the vegetation using the formulae provided.

The numbers of species found in the plots of different sizes are plotted on vertical axis (Y axis) against sample plot sizes plotted on the horizontal axis (X axis). A graph is drawn with size of the quadrat on X axis and number of species on the Y axis. A sigmoid curve will be obtained. This is called species-area curve. The point at which the curve starts flattening up is the minimum size of the quadrat required sampling that field.

Number of quadrat	Number of species
1	---
2	----
3	----
4	----
5	----

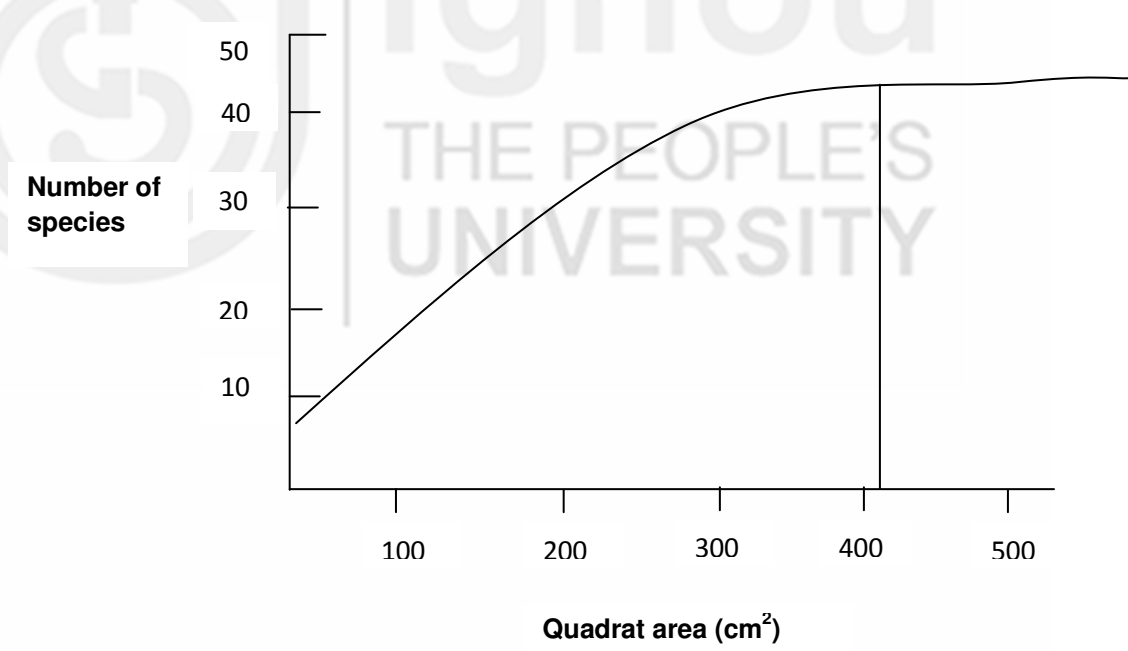


Table 6.1: Measurement of plant frequency in a given size quadrat.

Name of the species	Quadrats					Number of quadrats in which species occur	Total number of quadrats studied	Frequency (%)
	1	2	3	4	5			

Table 6.2: Measurement of plant density in a given size quadrat.

Name of the species	Quadrats					Number of species in all the quadrats	Total number of quadrats studied	Density
	1	2	3	4	5			

Table 6.3: Measurement of Plant abundance in a given size quadrat.

Name of the species	Quadrats					Total number of individuals of the species in all quadrats	Number of quadrats in which species occur	Abundance
	1	2	3	4	5			

Precautions

The quadrat should be of such small size so that it can cover maximum number of species.

Suggested readings

Baxter J. (2014) Vegetation Sampling Using the Quadrat Method. In: Methods in EEC (BIO221B) Dept. of Biological Sciences.

Quantitative Analysis of Herbaceous Vegetation for Frequency and Comparison with Raunkiaer's Frequency Distribution Law

Structure

7.1 Introduction	7.2 Requirements
Objectives	7.3 Procedure
Study Guide/Prior Reading	7.4 Observations and Results

7.1 INTRODUCTION

Frequency can be defined as the degree of uniformity of the occurrence of individuals of a species within a plant community. It indicates the number of times a plant species is present within a given number of sample quadrats. In a community, the individuals of all the species are not evenly distributed. The individuals of some species are widely spaced while those of some other species are found in clumps. The distribution patterns of individuals of different species indicate their reproductive capacity as well as their adaptability to the environment.

Frequency can be calculated using the formula

$$\% \text{ Frequency} = (\text{Number of sampling units or quadrats in which the species occurs}) / (\text{Total number of sampling units or quadrats employed for the study}) * 100$$

Suppose, species 'A' occurred in 4 quadrats out of total ten quadrats studied, the frequency of species A will be

$$4/10 \times 100 = 40\%$$

Raunkiaer's Frequency Distribution Law

Danish botanist **Christen C. Raunkiaer** in his study on plant communities gave '**Occupancy frequency distribution (OFD)**'. Raunkiaer recognized five frequency classes of plant species in the community on the basis of their frequency percentages. He divided the species into five classes A, B, C, D, E. Raunkiaer (1934) suggested that the number of species in frequency class A is greater than that of class B; B is greater than in class C, class C is greater, or equal or lesser than class D; and D is lesser than class E. i.e. $A > B > C = D < E$. This is also known as Raunkiaer's 'frequency law'. From the above law it is apparent that the species with low frequency value are higher in number than the species with higher frequency value in most natural communities. A reverse J shaped curve is obtained as Raunkiaer's Frequency distribution diagram.

The frequency class distribution is given on the basis of occurrence of species.

The classes are:

Class A 1-20% frequency

Class B 21-40% frequency

Class C 41-60% frequency

Class D 61-80% frequency

Class E 81-100% frequency

If the individuals of a species are evenly distributed over the area they may occur in the sample plots and thus the frequency of species will be 100%. Poorly dispersed species will occur only in a few quadrats and their frequency will be low. This indicates that higher the frequency value of a species in the area the greater will be the uniformity in the spread. Some species abundantly spread all over the area have a chance of occurring in all the sampling quadrats and therefore, its frequency will be 100. The plants with high frequency are wide in distribution.

The dispersion of species in relation to that of all the species is termed as relative frequency of a species. The relative cover, relative density and relative frequency determine the proportional representation of each species relative to the entire plant community.

Relative cover is the proportional cover of an individual species as a percentage of total plant cover. It is expressed as a percentage, ranging from 0–100%.

Relative frequency, relative density and relative dominance, was also drawn to compare the overall phytosociological importance of the species.

Relative density is the proportion of density of a species to that of stand as a whole. It is the study of numerical strength of a species in relation to the total number of individuals of all the species. The degree of dispersion of individual species in an area in relation to the number of all the species occurred.

Dominance of a species is determined by the value of the basal cover. It is the coverage value of a species with respect to the sum of coverage of the rest of the species in the area.

These parameters can be calculated by the formulas

Relative frequency (RF)= Frequency of the species/Sum of the frequencies for all species in stand x 100

Relative density (RD) = Total no. of individuals of a species/Total no. of individuals of all species x 100

Relative dominance (RDQ)= Total basal area of a species/total basal area of all species X 100

An 'Importance Value' (IV) for each species is derived from the combined contribution of the relative cover, relative density and relative frequency of each species in the community. Importance gives the measure of overall influence of a plant species in the community. This is because it combines relative cover, density and frequency, importance values range from 0–300. The relative value of these vegetational parameters (density, frequency and dominance) was calculated to compute Importance Value Index (IVI) for each species.

Objectives

After doing this practical exercise you will be able to

- ❖ describe the use of quadrat in determining the frequency, abundance and density of a species present in a given area,
- ❖ describe the Raunkiers Frequency Distribution Law, and
- ❖ categorize the species given in a specific area into different classes according to their frequency.

7.2 REQUIREMENTS

Measuring scale, nails, thread, hammer.

7.3 PROCEDURE

1. Visit any green area and lay down a series of horizontal and vertical grid lines in the area.
2. In each grid count the number of species present. Also note the total number of plant belonging to each species.
3. The number of quadrats in which occurrence of a species is observed in relation to the total number of quadrats sampled.

7.4 OBSERVATIONS AND RESULTS

The data obtained is put in the table and the frequency of the species is determined using the given formula.

Name of the species	Quadrats					Number of quadrats in which species occur	Total number of quadrats studied	Frequency (%)
	1	2	3	4	5			

Frequency indicates the number of times a plant species is present within a given number of sample quadrats. More frequent is the occurrence of the species, more is the frequency.

Precautions

The quadrat should be of such small size so that it can cover maximum number of species.

Suggested readings

Baxter J. (2014) Vegetation Sampling Using the Quadrat Method. In: Methods in EEC (BIO221B) Dept. of Biological Sciences.

To Study the Vegetative and Floral Characters of Some Dicot and Monocot Families

Structure

8.1 Introduction	8.3 Material Required
Objectives	8.4 Method
8.2 Study Guide	8.5 Observations

8.1 INTRODUCTION

Identification is central to the study of plant taxonomy and systematics. The initial step is to identify and classify the angiosperms till the family level. This is because a family is considered to be the smallest of the major classification categories and represents a more natural unit than any of the higher categories. To do so, a systematic description of the plant specimens and to assign them to their families forms the basis of any taxonomic investigation. A practical study of plants enables us to study the diagnostic morphological features, classify and identify their families using the identification key. In this exercise we will be describing five families Solanaceae, Brassicaceae, Asteraceae, Lamiaceae and Liliaceae of which four Solanaceae, Brassicaceae, Asteraceae, Lamiaceae are dicot families and Liliaceae is a monocot family.

Objectives

After doing this exercise you should be able to:

- ❖ describe the vegetative and floral characters of Solanaceae, Brassicaceae, Asteraceae, Lamiaceae and Liliaceae;
- ❖ draw the floral diagram and write floral formula of the families you have studied;
- ❖ differentiate between flowers of dicot and monocot plants; and
- ❖ to identify the members of families Solanaceae, Brassicaceae, Asteraceae, Lamiaceae and Liliaceae.

8.2 STUDY GUIDE

Flowering plants are classified on the basis of their vegetative and floral structures. As you know that the reproductive characters are more conservative (change less quickly than others in evolution), the study of a flower becomes an important aspect for identification of a plant and its classification into a family. You have to observe flower carefully to study features such as presence of bracts, pedicel, perianth and understand the number and arrangement of sepals and petals, stamens and gynoecia. Generally the flowers are well differentiated in calyx and corolla but in some plants the flowers are not well differentiated into sepal and petal, are presented as perianth. The perianth consists of tepal or tepals. As flower is the important part for identifying a family. You will also study how to write floral formula and draw floral diagram. The description of floral characters needs to be illustrated and presented in the form of a floral formula and a floral diagram. For this you must be familiar with the technical vocabulary. A glossary of semi technical terms has been provided to you at the end of this section. Here, we are going to study some selected families of dicots and monocots. One or two representative species from each family have been described in detail.

8.3 MATERIAL REQUIRED

In addition to general Biology Kit and Laboratory Kit provided you will require:

a) Plants

Family	Plant
Solanaceae	<i>Solanum nigrum</i> , <i>Withania somnifera</i>
Brassicaceae	<i>Brassica campestris</i> , <i>Iberis amara</i>
Asteraceae	<i>Sonchus oleraceus</i> , <i>Tridax procumbens</i>
Lamiaceae	<i>Salvia officinalis</i> , <i>Ocimum sanctum</i>
Liliaceae	<i>Asphodelus tenuifolius</i> , <i>Allium cepa</i>

b) Other Requirements

Hand Lens

File Book

Two Dissecting needles with sharp, pointed tips

A pair of fine forceps

Dissecting microscope

A sharp razor blade

Slides

Coverslips

8.4 METHOD

Description of flora is based on the study of several plants occurring in the region. The characters of each plant are studied in detail. We begin with the habit of the plant and the morphology of different structures. The morphological data includes – firsthand information about the type of the plant (tree, shrub, climber or herb), the size of the plant, the habit of the plant (prostrate, erect, etc.), leaf shape and its arrangement, type of inflorescence, the structure of the flower and type of fruits. The structural details include information about aestivation (arrangement) of petals and sepals and the type of placentation.

You have to record and draw all the vegetative and floral structures of the families you are studying, in your note book and get it checked by the teacher concerned. Draw the entire flower; make l. s. of flowers, draw a floral diagram, and construct floral formula of each plant that you are studying. Each and every diagram gives vital information about the plant.

i) Drawings

You should draw whole flower is in such a way that diagram depict as many structural details as possible (Fig. 8.1). The structure of flower is drawn after cutting the flower into two halves along a longitudinal plane. This is done with a sharp razor blade, starting at the pedicel, dividing through the centre of the abaxial side of the flower. Then lay the flower on the table or on the slide under a dissection microscope (if flower is small) and make a sketch of it. After drawing the half flower, you could observe details of the attachment of various parts to the receptacle (Fig. 8.1) Make a transverse section of the ovary with the help of a sharp razor blade to determine the type of placentation and to find out the number of ovules. Place the sections on a clean glass slide, mount in glycerine/water and observe by placing a cover slip under a dissection microscope.

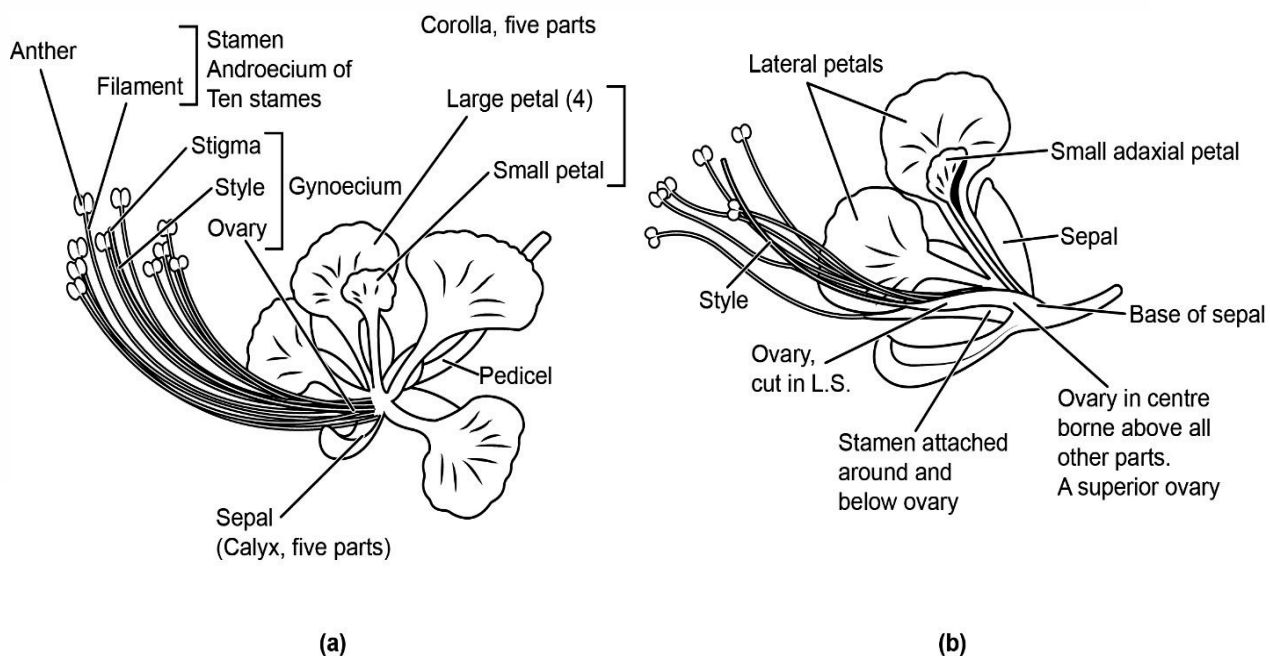


Fig. 8.1 a, b: Drawings of complete and half flower showing attachment of parts to the receptacle and internal structure of ovary.

ii) The Floral Diagram

The floral diagram is drawn to show the numbers and relationships of the different parts of the flower in a very formal way.

The various symbols used are shown in Table 8.1. These include a symbol for the axis of the inflorescence (drawn away from you) to which the flower is attached and for the bract (drawn nearer to you) which subtends the flower. Between these two are sketched four whorls of floral parts, viz., **calyx**, **corolla**, **androecium** and **gynoecium**, represented as four concentric circles. If there is more than one whorl of petals and stamens there will be more circles. When some of the floral parts are spirally arranged, a spiral is superimposed on the appropriate circle. The symbols for each part (Table 8.1) are then added (Fig. 8.2) depicting such characters as aestivation of calyx and corolla, then direction in which stamens open (introrse or extrorse), adnation or connation of stamens and the number and position of loculi as well as the placentation in the T. S. of the ovary. When the floral diagram is complete (Fig. 8.2), you can read most of the characteristics of the flower.

Table 8.1: Symbols used in floral diagrams.











Floral parts, etc.	Symbol
Floral axis	
Subtending bract	
Sepal	
Petal	
Perianth parts (when all petaloid)	as for petals
Aestivation	Overlapping of edges in diagram
Connation of petals, sepals edges joined by loop or line	
Stamens	
introrse	
extrorse	
Connation of stamens	
anther filaments (stamina tube)	
Adanation of stamens (e.g. epipetalous)	
Carpel gynoecium	Draw t. s. showing placentation



Fig. 8.2: Construction of a floral diagram, using symbols shown in Table (*Caesalpinia pulcharrima*).

iii) The Floral Formula

Floral formula is another way of representing of the structure of flower. The first symbol in the formula shows whether flower is actinomorphic or zygomorphic and whether it contains both stamens and pistil or only stamens or pistil. Calyx is represented by **K** and corolla by **C** and numbers of sepals or petals are added. If the sepals or the petals are united then a bracket encloses the number. For perianth symbol **P** is used. The stamens are depicted as **A** and adnation of parts is indicated by adding a single bracket, above the letters representing the part involved. Gynoecium is represented by symbol **G** and after adding the number of carpels, a line is drawn under the number if ovary is superior and over the number if ovary is inferior.

Table 8.2: Symbols used floral formula.

Floral part or characteristic	Symbol	Example
Symmetry		
Actinomorphic	\oplus	
Zygomorphic	$\%$	
Sex of flower		
Staminate (Male)	σ	
Pistillate (Female)	ρ	
Hermaphrodite	$\sigma\rho$	
Calyx	K	K_5 – sepals free $K_{(5)}$ – sepals fused
Corolla	C	C_5 – petals free $C_{(5)}$ – petals fused
Perianth parts (if all the same)	P	P_5 – 5 perianth parts, free $P_{(5)}$ – 5 perianth parts, fused
Androecium	A	$A_{(5)}$ – stamens fused
Indefinite number		A^∞ = indefinite number
Gynoecium		G
Ovary superior		\underline{G}_3 – 3 carpels, free
Ovary inferior	\overline{G}	\overline{G}_3 – 3 carpels, inferior
Connation	Brackets	$K(5)$ = 5 connate sepals
Adnation	Horizontal bracket	$\widehat{C}_5 A_5$ = 5 epipetalous stamens

The description given here is an attempt to summarise the characteristic features of families and genera. The families described here have been selected to illustrate typical variations in the dicot and monocot pattern and to give a reasonable cross-section of some important families. Under each family general description and characters are given with a brief description of some common example/s.

Study of the following families has been done as description, V.S. flower, section of ovary, floral diagram/s, floral formula/e and systematic position is assigned according to Bentham & Hooker's system of classification.

8.5 OBSERVATIONS

(A) Study of Vegetative and Floral Characters of the Family Solanaceae.

SOLANACEAE – NIGHTSHADE FAMILY

General characters

The family consists of 91–102 genera and about 2925 species. Some 18 genera and 88 species are found in India.

The family consists of herbs, shrubs and trees,

Leaves – simple, pinnate usually spiral or exstipulate,

Inflorescence – usually cymose; sometimes solitary flowers,

Flower– generally bracteate, pedicillate, usually actinomorphic (rarely zygomorphic), bisexual, hypogynous and pentamerous,

Perianth– biseriate, tubular, hypanthium absent,

Calyx – symsepalous (=gamosepalous), generally valvate aestivation persistent, 5 calyx lobes,

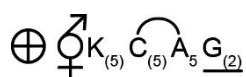
Corolla – sympetalous, variously shaped, funnel shaped (infundibulum), bell shaped (complanate) or rotate; convolute, imbricate or valvate lobes, valvate aestivation, Scale or hair-like outgrowths may arise from the inside of corolla tube,

Androecium – Stamens 5, antipetalous (opposite the petals), and epipetalous (attached to the petals), anthers ditheous, longitudinal in dehiscence,

Gynoecium – bicarpellary syncarpous, superior ovary, ovary obliquely placed, 2 locules, axile placentation, and anatropous ovules. A hypogynous nectariferous disc is present at the base of the ovary,

Fruit – berry, drupe, or capsule.

Floral formula



Common Indian forms are *Solanum*, *Nicotiana*, *Cestrum*, *Capsicum*, *Petunia*, *Datura*, *Hyoscyamus* and *Lycopersicum*.

Solanum nigrum

Kingdom : Plantae

Class : Dicotyledonae

Sub-Class : Gamopetalae

Series : Bicarpellatae

Order : Polemoniales

Family : Solanaceae

Genus : *Solanum*

Species : *S. nigrum*

Habit – annual herb,

Root – tap, branched,

Stem – erect, branched, herbaceous, cylindrical, solid, glabrous

Leaf – simple, alternate, cauline, petiolate, exstipulate, ovate, dentate, acute, reticulate venation,

Inflorescence – extra-axillary helicoid cyme,

Flower – pedicillate, ebracteate, hermaphrodite, actinomorphic, complete, pentamerous, hypogynous,

Calyx – 5 sepals, gamosepalous, oblong, acute, green, hairy, valvate or imbricate aestivation,

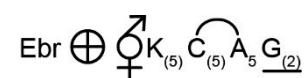
Corolla – 5 petals, gamopetalous, oblong, acute, twisted or valvate aestivation,

Androecium – 5 stamens, polyandrous, epipetalous, short filaments equal in length, anthers oblong, basifixed, introrse, yellow,

Gynoecium – 2 carpels (bicarpellary), syncarpous, superior ovary, globose, bilocular, axile placentation, stigma one, bilobed

Fruit – berry with persistent calyx.

Floral formula –





(a) Whole plant



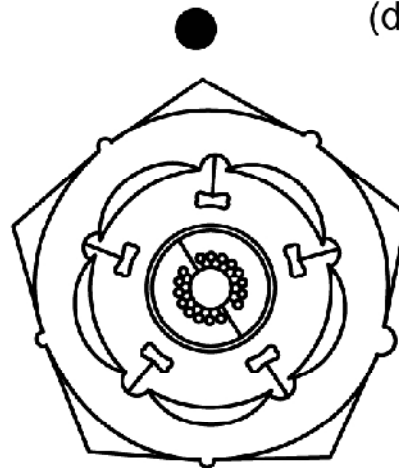
(b) L.S of flower



(c) Stamens



(d) Carpel



(e) Floral diagram

Fig. 8.3: *Solanum nigrum* (a) Branch with inflorescence; (b) L.S. of flower; (c) Stamens; (d) Carpel; (e) Floral diagram.

i) *Withania somnifera*

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Gamopetalae
Series	:	Bicarpellatae
Order	:	Polemoniales
Family	:	Solanaceae
Genus	:	<i>Withania</i>
Species	:	<i>W.somnifera</i>

Habit – a perennial herb,

Root – tap root, branched,

Stem – erect, aerial, herbaceous with basal part woody, branched, cylindrical, solid, hairy green,

Leaf – cauline, exstipulate, petiolate, alternate, simple, ovate, entire, acute, glabrous, unicostate reticulate,

Inflorescence – cymose, axillary umbellate cyme,

Flower – ebracteate, sub-sessile, actinomorphic, regular, hermaphrodite, pentamerous, hypogynous, complete, cyclic,

Calyx – 5 sepals, gamosepalous, campanulate, pentafid valvate, persistent, green, hairy, inferior,

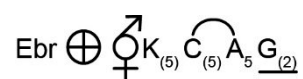
Corolla – 5 petals, gamopetalous, valvate, campanulate, greenish–yellow, inferior,

Androecium – 5 stamens, polyandrous, epipetalous, antipetalous (alternipetalous) ditheous, basifixed, introrse,

Gynoecium – 2 carpels (bicarpellary), syncarpous, ovary superior, bilocular, many ovules in each locule, axile placentation, obliquely placed ovary, placenta swollen, style long, stigma bifid and capitate,

Fruit – Berry enveloped by persistent calyx.

Floral formula –



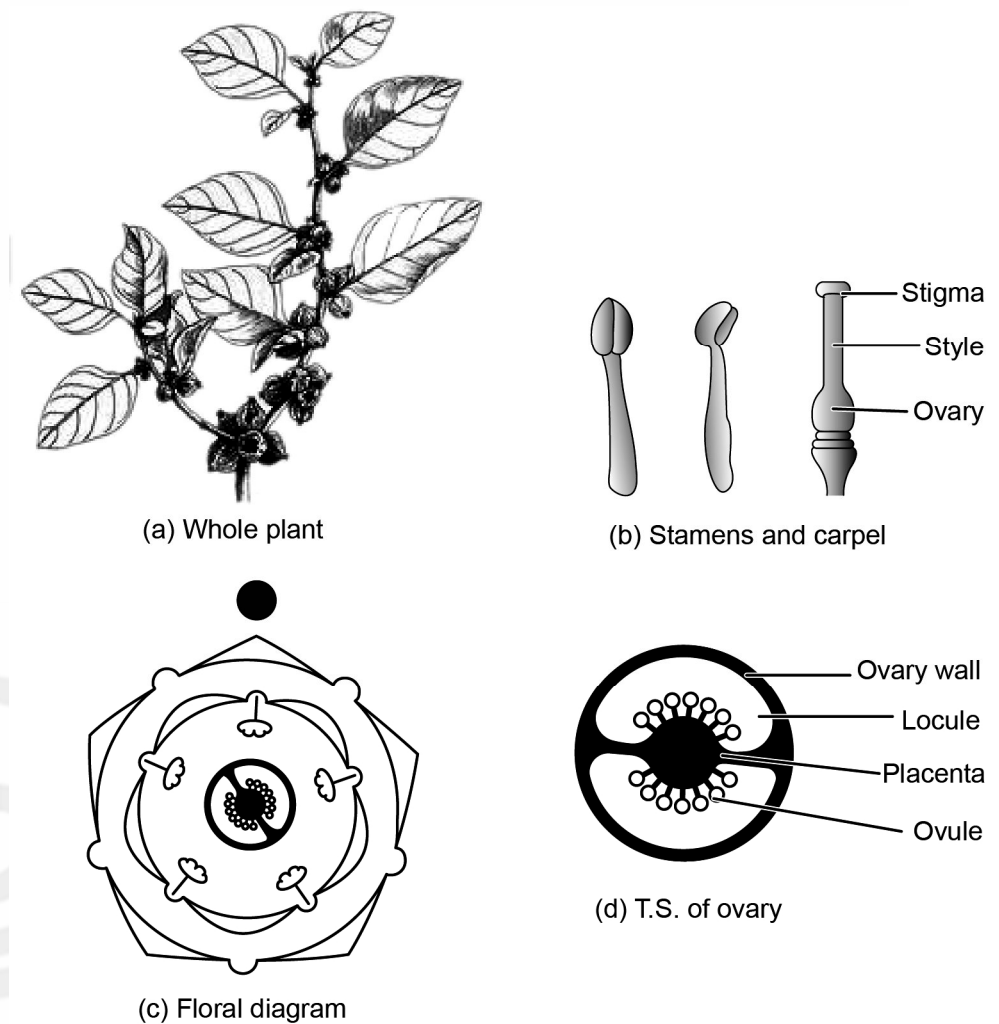


Fig. 8.4: *Withania somnifera* (a) Branch with inflorescence; (b) Stamens and Carpel; (c) Floral diagram; (d) T.S. of ovary.

Classification and Identification

Class. Dicotyledonae

1. Cotyledons two
2. Venation reticulate
3. Flowers pentamerous

Sub-Class. Gamopetalae

1. Petals fused

Series. Bicarpellatae

1. Carpels two
2. Ovary usually superior

Order. Polemoniales

1. Alternate, exstipulate leaves
2. Flowers actinomorphic

Family. Solanaceae

1. Flowers solitary terminal or cymosely umbelled
2. Septum is oblique and the placentae are highly swollen
3. Fruit– berry or capsule

(B) Study of vegetative and floral characters of the family Brassicaceae**BRASSICACEAE (MUSTARD FAMILY)****General characters**

This family consists of 321–338 genera, 3400–3700 species. In India, the family is represented by 51 genera and 138 species. Plants contain a watery, pungent juice.

Habit – herbs,

Leaves – simple, often lobed or divided, spiral, exstipulate, with branched or unbranched hairs,

Inflorescence – indeterminate raceme, rarely solitary, axillary flowers,

Flower – bisexual, complete, mostly actinomorphic, pedicillate, ebracteate, tetramerous and hypogynous. The receptacle is elongated to form gynophore, perianth is dichlamydeous and cruciate,

Calyx – 4, free caudaceous sepals, arranged in two whorls of 2 each (2+2), the outer large, saccate, inner two narrower,

Corolla – 4, free distinct petals, arranged in a whorl. Imbricate aestivation, show a distinct **cruciform arrangement** (long claws spread out in the form of the Greek symbol **cross**) Valvate aestivation,

Androecium – usually consists of 6 stamens, biseriate, tetradynamous, 2+4 outer two shorter, antisepalous, inner 4 longer, anthers dithecous, basifixed, introrse with longitudinal dehiscence, disc is often present at the base of the stamens which has four basal nectarines,

Gynoecium – Bicarpillary, syncarpous with superior ovary, with two parietal placentae, a false septum (**replum**) extends from the parietal placenta dividing the ovary into two locules, placentation axile – parietal, each carpel has two ovules, style simple or absent, stigma two–lobbed or discoid,

Fruit – capsule called siliqua.

Floral Formula –

$$\text{Ebr } \oplus \text{ } \overline{\text{K}}_{2+2} \text{ C}_4 \text{ A}_{2+4} \underline{\text{G}}_{(2)}$$

The common Indian genera are *Brassica*, *Raphanus*, *Nasturtium*, *Iberis*, *Coronopus*, *Draba* and *Lepidium*.

i) *Brassica campestris*

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Polypetalae
Series	:	Thalamiflorae
Order	:	Parietales
Family	:	Brassicaceae
Genus	:	<i>Brassica</i>
Species	:	<i>B. campestris</i>

Habit – annual cultivated winter herb,

Root – taproot, branched,

Stem – erect, herbaceous, cylindrical, slightly hairy, branched, solid, smooth, green,

Leaf – cauline, simple, alternate, exstipulate, petiolate, glabrous, upper leaves entire, lower leaves lyrate, unicostate, reticulate venation,

Inflorescence – Racemose, Corymbose raceme,

Flower – pedicellate, ebracteate, actinomorphic, hermaphrodite, hypogynous, complete, tetramerous, cruciform, cyclic, bright yellow,

Calyx – sepals 4, polysepalous, arranged in whorls of two each, 2 outer antero-posterior, sepals on inner whorl are lateral and longer, imbricate aestivation,

Corolla – four petals, polypetalous, each petal consists of a limb and claw, cruciform arrangement, imbricate aestivation,

Androecium – stamens six, polyandrous, arranged in two whorls, two outer short stamens, four inner long stamens (tetradynamous), anthers ditheous, basifixed, introrse,

Gynoecium – two carpels (bicarpellary), syncarpous, ovary superior, unilocular, divided into two chambers by a false septum (replum) parietal placentation, style short, stigma bilobed,

Fruit – a narrow, pod-like Siliqua.

Floral formula – $\oplus \frac{\text{♂}}{\text{♀}} K_{2+2} C_4 A_{2+4} \underline{G_{(2)}}$

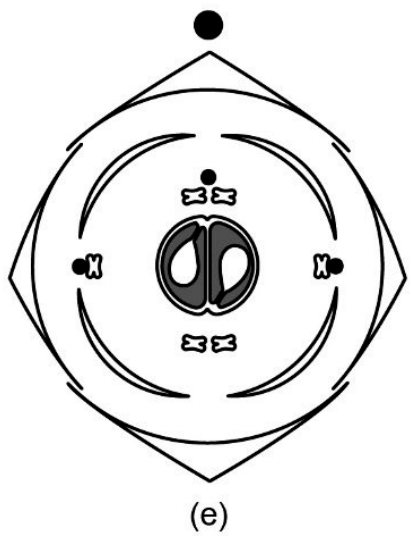
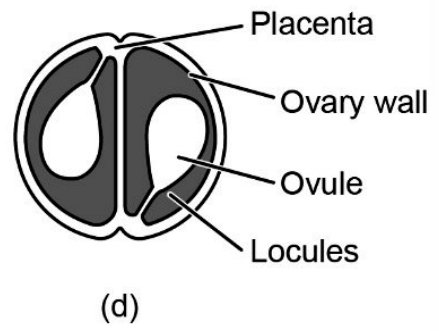
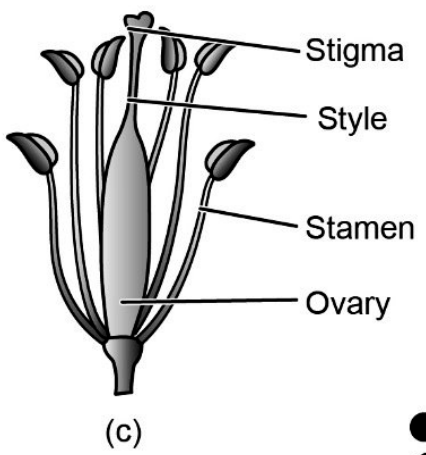
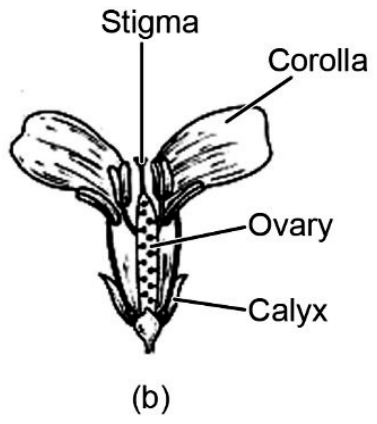


Fig. 8.5: *Brassica campestris* (a) Branch with inflorescence; (b) L.S. of flower; (c) Stamens and carpel; (d) T.S. of ovary; (e) Floral diagram.

i) ***Iberis amara***

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Polypetalae
Series	:	Thalamiflorae
Order	:	Parietales
Family	:	Brassicaceae
Genus	:	<i>Iberis</i>
Speices	:	<i>I. amara</i>

Habit – annual herb,

Root – taproot, branched,

Stem – erect, herbaceous, aerial, branched, green, solid, rough surface,

Leaf – cauline, simple, alternate, sessile, glabrous, exstipulate, unicostate reticulate venation,

Inflorescence – Racemose, corymb,

Flower – pedicellate, ebracteate, complete, bisexual, zygomorphic, hypogynous, tetramerous, cyclic, white,

Calyx – four sepals, polysepalous, arranged in whorls of two each, imbricate aestivation

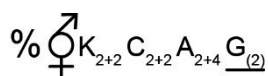
Corolla – four petals, polypetalous, two outer petals large, two inner petals small, each petal consists of a limb and claw, **cruciform**, valvate, white,

Androecium – stamens six, free (polyandrous), arranged in two whorls, two outer short stamens, four inner long stamens (tetradynamous), anthers ditheous, basifixed, introrse,

Gynoecium – two carpels (bicarpellary), syncarpous, ovary superior, unilocular when young but becomes bilocular at maturity due to the formation of false septum – replum; parietal placentation, style long, stigma capitate,

Fruit – Siliqua.

Floral formula –



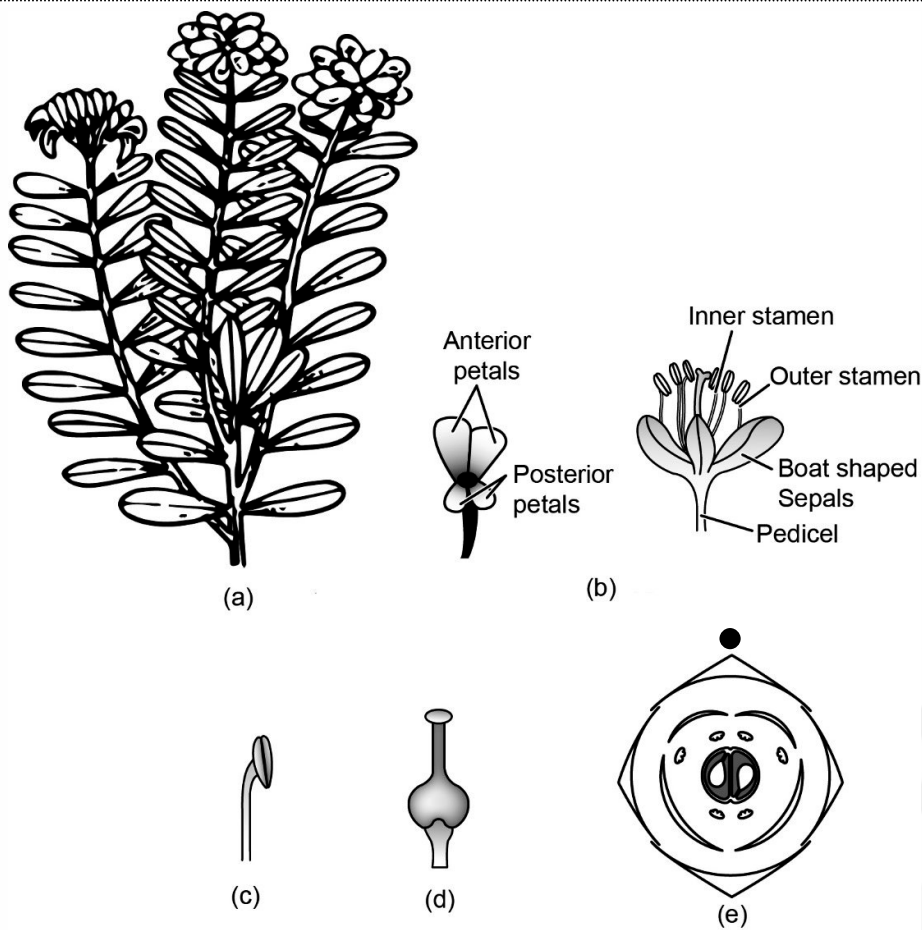


Fig. 8.6: *Iberis amara* (a) Branch with inflorescence; (b) L.S. of flower; (c) Stamen ; (d) Carpel; (e) Floral diagram.

Classification and Identification

Class. Dicotyledonae

1. Cotyledons two
2. Venations reticulate.
3. Flowers pentamerous.

Sub-Class. Polypetalae

1. Petals free.

Series. Thalamiflorae

1. Flowers hypogynous and ovary superior.

Order. Parietales

1. Carpels united to form unilocular ovary with parietal placentation.

Family. Cruciferae

1. Herbs with alternate exstipulate leaves.
2. Corolla cruciform.
3. Stamens tetradynamous.
4. Ovary bicarpellary, syncarpous, unilocular but becomes bilocular due to the development of a false septum; fruit siliqua.

(C) Study of vegetative and floral characters of the family Asteraceae**ASTERACEAE/COMPOSITAE (SUNFLOWER FAMILY)****General characters**

Asteraceae is a large family comprising around 1530 genera and about 23,850 species of which 138 genera and 708 species are represented in India.

The family consists of herbs, shrubs and trees. Lactiferous or resin ducts are present in some taxa.

Inflorescence – Inflorescence is elaborate called head or capitulum. The highly reduced individual flower is called floret. Each head consists of a flat or conical receptacle that bears one or more type of flowers. Head can be homogamous or heterogamous. Each capitulum has numerous florets on a common receptacle and is surrounded by involucre of bracts. The central florets having tubular corolla are called as disc florets. They form the central disc of the capitulum. The outer ring of flowers surrounding the disc florets is called ray florets. They are usually sterile or pistillate. They form a circle around the margin of the head. In homogamous head, both the florets are same in structure i.e. all are bisexual, either regular (tubular) or ligulate. In heterogamous type, there is a distinction between the florets. The central disc florets are bisexual while the peripheral ray florets are ligulate and pistillate. Head can either be **discoid** i.e. having bisexual disc flowers, **disciform** i.e. having pistillate or sterile bisexual or staminate disc flowers, **radiate** i.e. having central disc flowers and peripheral ray flowers or **ligulate** i.e. having bilabiate ray flowers.

Flower – Bracteate, sessile, epigynous bisexual or unisexual, pentamerous, besides ray and disc florets, neutral florets are also present,

Calyx – Usually represented by scale or hairs (pappus) having 2–infinite awns, bristles or scales,

Corolla – sympetalous, having 5 lobes with 3–5 teeth at the end can be bilabiate, corolla zygomorphic with a short tube, or actinomorphic with short or elongated tube, ligulate,

Androecium – Stamens –5, whorled, epipetalous, alternipetalous, syngenesious, fuse to form a tube, anthers basifixed, longitudinal or introrse,

Gynoecium – bicarpillary, syncarpous, with inferior ovary, 2 carpels, one locule, basal placentation. Style solitary, branched, stigma two, basal placentation, ovule anatropous, unitegmic,

Fruit – Cypsella.

Floral formula –

Ray florets: $Br \frac{\%}{\text{♀}} K_0 \text{ or } P C_{(5)} A_0 \overline{G}_{(2)}$

Disc florets: $Br \frac{\%}{\text{♂}} \text{ or } \oplus \frac{\text{♂}}{\text{♀}} K_0 \text{ or } P C_{(5)} A_{(3)} \overline{G}_{(2)}$

Neutral florets: $\frac{\%}{\text{♂}} \text{ or } \oplus K_0 C_{(5)} A_0 G_0$

Some common members of Asteraceae in India are: Sunflower (*Helianthus annuus*), Marigold (*Tagetes erecta*), Lettuce (*Lactuca sativa*), Safflower (*Carthamus tinctorius*), Carrot grass (*Parthenium hysterophorus*), *Vernonia arborea*, *Xanthium*, *Crysanthemum* and *Dahlia*.

i) ***Sonchus oleraceus***

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Gamopetalae
Series	:	Inferae
Order	:	Asterales
Family	:	Asteraceae
Genus	:	<i>Sonchus</i>
Species	:	<i>S. oleraceus</i>

Habit – annual and sometimes biennial herb,

Root – taproot, upright with many branches,

Stem – simple or branched, glabrous, cylindrical, green, milky,

Leaf – cauline, alternate, simple, lower leaves petiolate, middle and upper leaves elliptic, oblanceolate, or lanceolate, entire soft, glabrous, acutely prostrate, coarsely spinulose dentate margin, apex acute,

Inflorescence – capitulum, involucre of bracts at the base of inflorescence; homogamous with rayflorets only,

Flower – bracteate, sessile, ligulate, zygomorphic, complete, pentamerous, epigynous, cyclic,

Calyx – reduced to pappus (persistent),

Corolla – petals 5, gamopetalous, ligulate, strap-shaped, valvate, yellow,

Androecium – stamens 5, epipetalous, syngeneious, ditheous, basifixed, introrse,

Gynoecium – bicarpellary, syncarpous, ovary inferior, unilocular, placentation basal, singleovule style long, single, stigma bifid,

Fruit – Cypsella.

Floral formula–



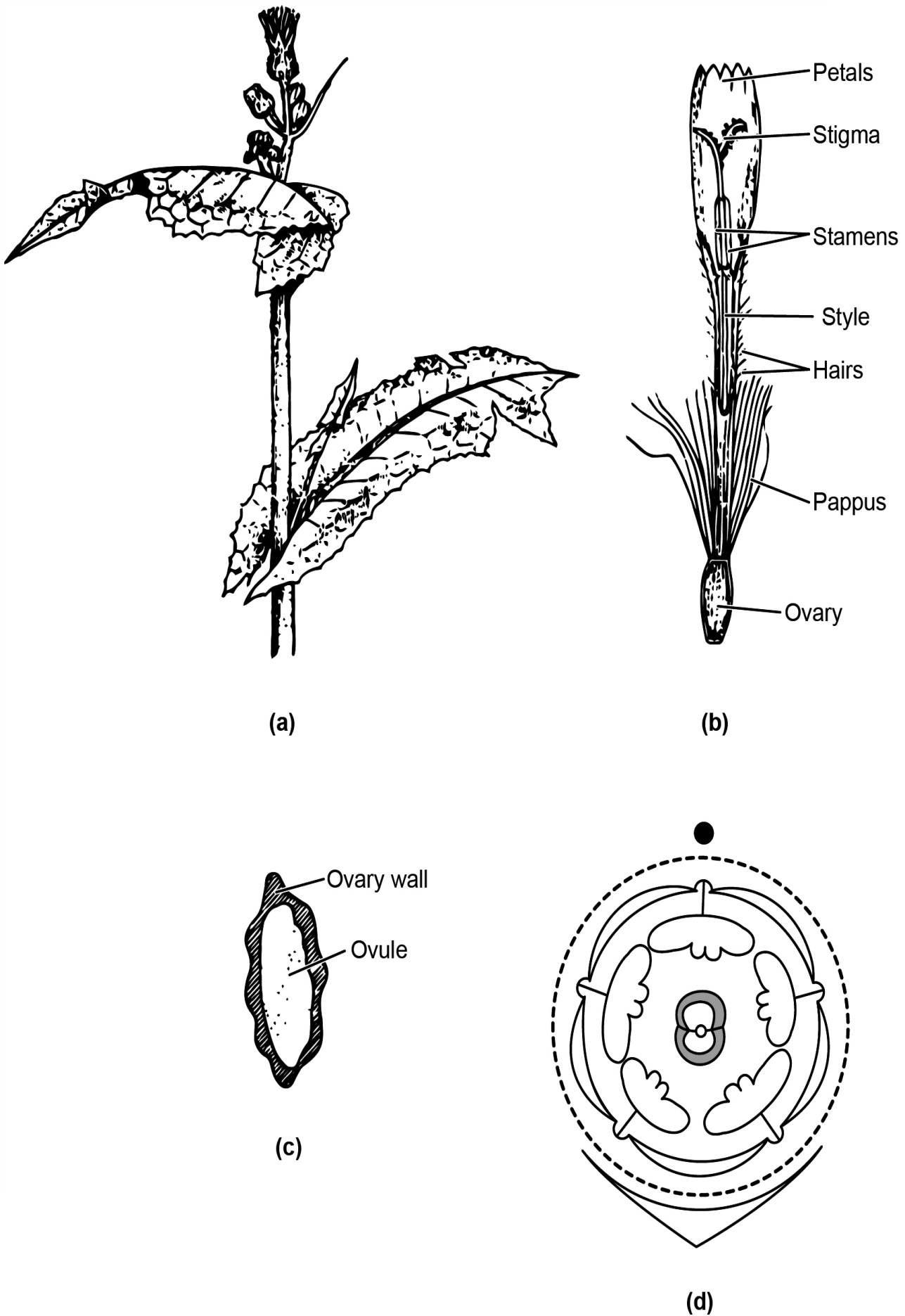


Fig. 8.7: *So nchus*: (a) Branch with inflorescence; (b) Disc floret; (c) L.S of ovary; (d) Floral diagram.

ii) *Tridax procumbens*

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Gamopetalae
Series	:	Inferae
Order	:	Asterales
Family	:	Asteraceae
Genus	:	<i>Tridax</i>
Species	:	<i>T.procumbens</i>

Habit – a perennial herb, found growing as weed in waste land,

Root – tap root, hairy,

Stem – herbaceous, weak, cylindrical, decumbent, branched, hairy,

Leaf – pedicillate, exstipulate, simple, opposite, margins dentate (toothed or lobed) showing reticulate venation,

Inflorescence – solitary capitulum on long peduncle, head and receptacle surrounded by green involucre, heterogamous, the tubular disc-florets occupy the centre and the ligulate ray florets found at the margins. Biseriate bracts forming a campanulate involucre,

Flower – central deep yellow disc florets, marginal/peripheral light yellow ray florets,

Disc florets – bracteolate, bracteoles thin and persistent, yellow, complete, bisexual, pentamerous, actinomorphic,

Calyx – reduced into numerous hairy outgrowths called **pappus**; arranged on top of ovary,

Corolla – petals 5, gamopetalous, regular, tubular, ligulate or bilabiate, valvate aestivation, deep yellow,

Androecium – absent in ray florets; in disc florets – Stamens 5, epipetalous, syngenesious, filaments free, alternate with petals. Anthers dithecal, basifixed, introrse and dehiscent longitudinally,

Gynoecium – bicarpellary, syncarpous, ovary inferior, unilocular with a single ovule, basal placentation. Style simple, long, passing through anther tube, bifid hairy stigma,

Ray florets – bracteolate, bracteoles membranous, tubular, sessile, incomplete, pistillate, zygomorphic, epigynous,

Calyx – represented by hairy pappus,

Corolla – trifid, gamopetalous, ligulate,

Androecium – absent,

Gynoecium – bicarpillary, syncarpous, inferior ovary, unilocular with single basal ovule, stigma bifid,

Fruit – cypsela with persistent pappus.

Floral Formula –

Disc florets: $\oplus \overset{\text{♂}}{\text{♀}} K_0 \text{ (pappus)} \overset{\text{C}}{\text{A}}_{(5)} \overline{\text{G}}_{(2)}$

Ray florets: $\% \overset{\text{♀}}{\text{♀}} K_0 \text{ (pappus)} \text{C}_{(3)} \text{A}_0 \overline{\text{G}}_{(2)}$

Classification and Identification

Class. *Dicotyledonae*

1. Cotyledons two
2. Venation reticulate.
3. Flowers pentamerous.

Sub-Class. *Gamopetalae*

1. Petals fused.

Series. *Inferae*

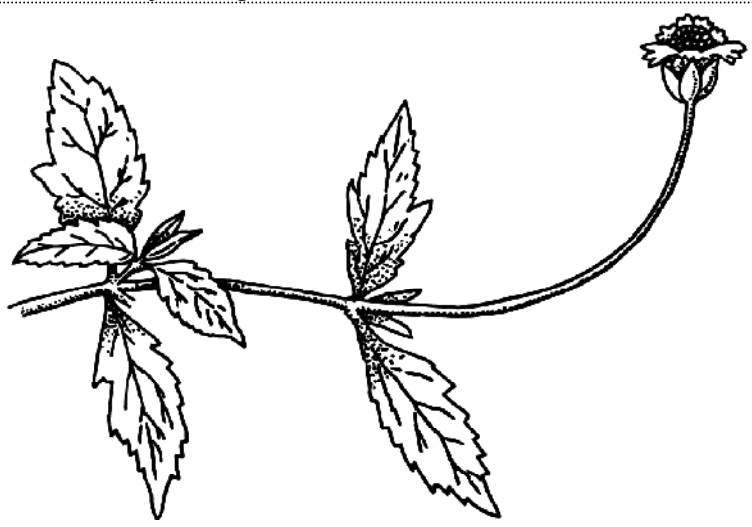
1. Ovary inferior.
2. Stamens usually as many as corolla lobes.

Order. *Asterales*

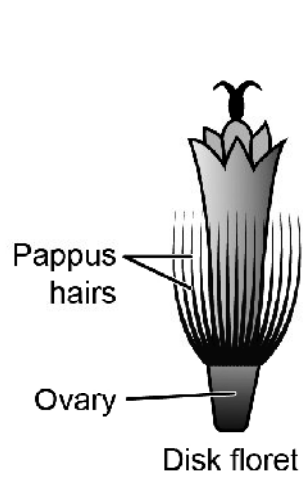
1. Stamens epipetalous.
2. Ovary unilocular with one ovule.

Family. *Compositae*

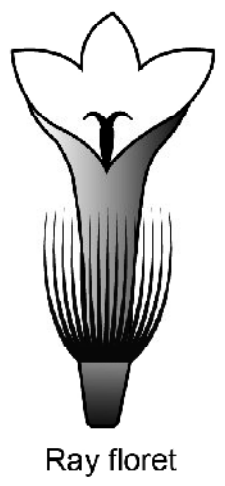
1. Leaves generally alternate.
2. Inflorescence capitulum.
3. Calyx reduced to hairy pappus.
4. Stamens epipetalous and syngenesious.



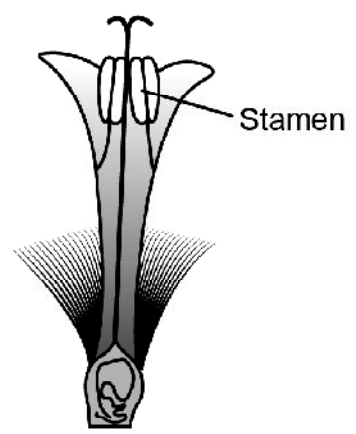
(a) Flowering stem



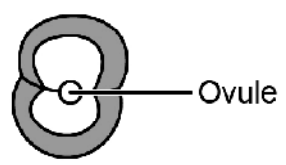
Disk floret



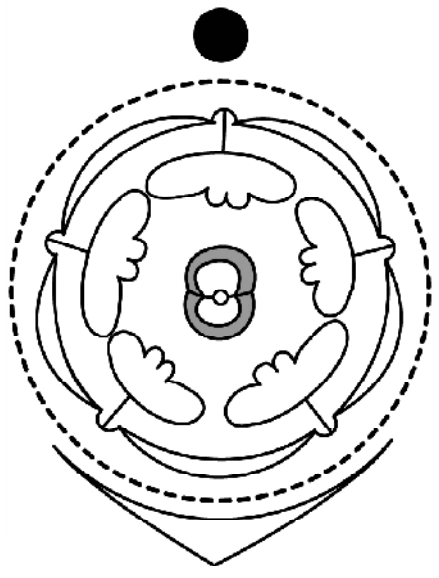
Ray floret



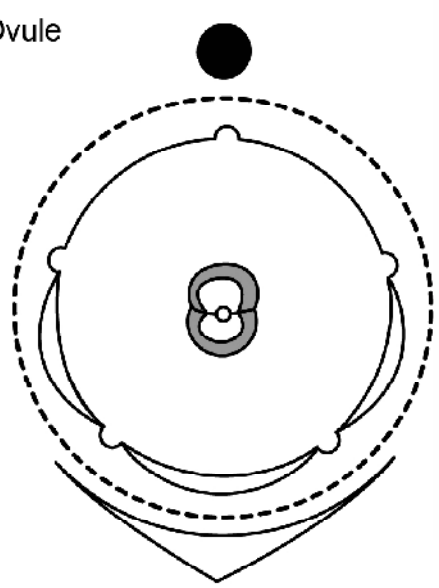
(c) L.S. of disk floret



(d) T.S. of ovary



(e) Floral diagram of disc floret



(f) Floral diagram of ray floret

Fig. 8.8: *Tridax* (a) Branch with inflorescence; (b) Disc and ray floret; (c) L.S. of disc floret; (d) T.S. of ovary; (e) Floral diagram of disc floret; (f) Floral diagram of ray floret.

(D) Study of vegetative and floral characters of the family Lamiaceae**LAMIACEAE/LABIATAE (MINT FAMILY)****General characters**

The family comprises about 264 genera and 6990 species all over the world. Some 64 genera and 350 species occur in India.

Habit – It consists of aromatic herbs and shrubs. Short stalked glandular trichomes producing ethereal essential oils are present on all parts of the plant. These produce the characteristic aroma,

Root – Tap and branched root,

Stem – aerial, herbaceous, rarely woody, quadrangular, hairy, branched, sometimes underground suckers,

Leaves – simple, opposite, rarely whorled, exstipulate, hairy, with aromatic smell,

Inflorescence – Commonly verticillaster consisting of a pair of condensed dichasial cymes at each node, solitary or axillary flowers,

Flowers – Pedicillate or sessile, bracteate, complete mostly zygomorphic, hermaphrodite, pentamerous, hypogynous,

Calyx – 5 sepals, gamosepalous, bilabiate with 1/4 or 2/3 arrangement of sepals, valvate or imbricate aestivation,

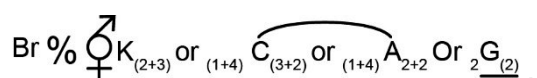
Corolla – 4 to 5 corolla lobes. Corolla has a tubular base which widens towards the mouth. Petals 5, gamopetalous. Five lobes are unequal and mostly bilabiate. Valvate or imbricate aestivation,

Androecium – Stamens 4, didynamous (2+2), posterior 2 stamens reduced as staminodes, epipetalous, longitudinal dehiscence, anthers ditheous and introrse,

Gynoecium – Bicarpillary, syncarpous, superior, situated on hypogynous honey secreting disc; usually bilocular but becomes tetralocular by the formation of false septum, one ovule in each locule, style– gynobasic (arising from the base of the ovary), stigma bilobed,

Fruit – schizocarpic/carcerulus.

Floral formula:



Common Indian members of Lamiaceae include *Oscimum*, *Salvia*, *Mentha*, *Coleus* and *Nepta*.

i) *Salvia officinalis*

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Gamopetalae
Series	:	Bicarpillatae
Order	:	Lamiales
Family	:	Lamiaceae
Genus	:	<i>Salvia</i>
Species	:	<i>S.officinalis</i>

Habit – an annual herb with strong aromatic smell,

Root – Tap, branched,

Stem – herbaceous, erect, aerial, branched, quadrangular (4 sided), solid, green,

Leaves – cauline or ramal, simple, opposite, exstipulate, ovate, serrate, acute, aromatic smell, reticulate venation,

Inflorescence – Verticillaster, 6 flowered whorls,

Flowers – pedicellate, bracteate, hermaphrodite, zygomorphic, complete, hypogynous, pentamerous, cyclic,

Calyx – 5 sepals, gamosepalous, bilabiate, 2 lobes in one whorl and 3 in the other, imbricate aestivation, inferior,

Corolla – 5 petals, gamopetalous, corolla tube short, bilabiate (4/1), upper lip of 4 petals and lower of 1 petal; imbricate aestivation, inferior, white or purple,

Androecium – Stamens fertile 2, (sometimes didynamous with 2 stamens absent or present as staminodes), polyandrous, epipetalous, short filament connected to a long connective, versatile, anthers stamen bears half fertile anther lobe at the posterior end and a small flat sterile anther lobe at the anterior, introrse,

Gynoecium – bicarpellary, syncarpous pistil, ovary superior, bilocular ovary in early stages but tetralocular at later stages, axile placentation, one ovule in each locule, style gynobasic i.e., arises from the base of the ovary, stigma bifid,

Fruit – carcerulus.

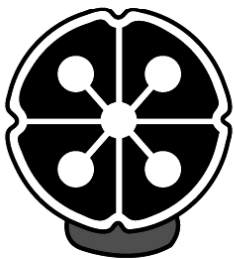
Floral formula – $\text{Br } \% \begin{array}{c} \text{♂} \\ \text{♀} \end{array} \overset{\curvearrowright}{\text{K}}_{(3+2)} \text{C}_{(2/3)} \text{A}_2 \underline{\text{G}}_{(2)}$



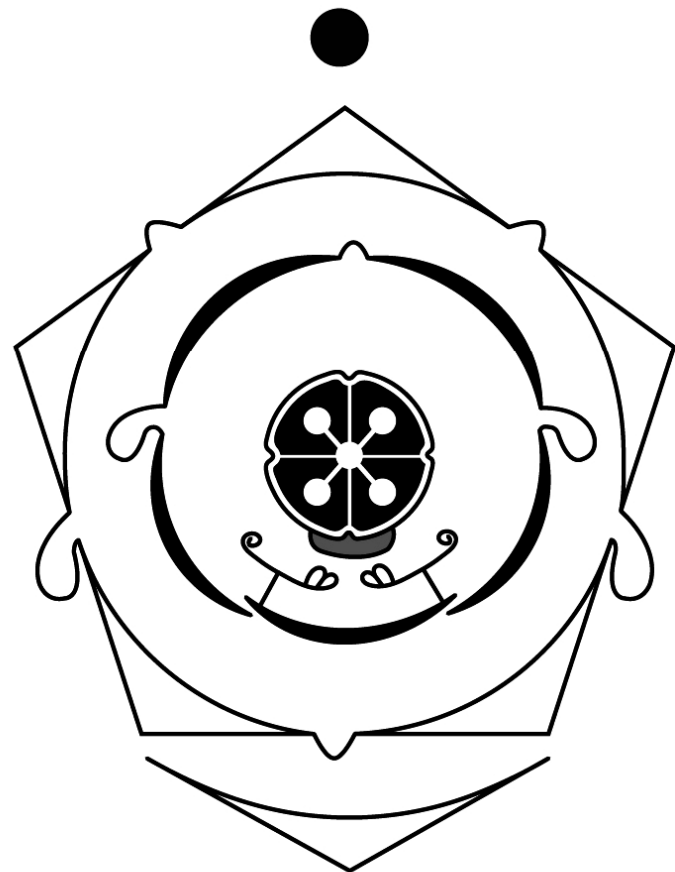
(a) Plant



(b) L.S. of flower to show ovary



(c) T.S. of ovary



(d) Floral diagram

Fig. 8.9: *Salvia*(a) Branch with inflorescence; (b) Gynobasic style; (c) T.S of ovary; (d) Floral diagram.

ii) *Ocimum tenuiflorum*

Kingdom	:	Plantae
Class	:	Dicotyledonae
Sub-Class	:	Gamopetalae
Series	:	Bicarpillatae
Order	:	Lamiales
Family	:	Lamiaceae
Genus	:	<i>Ocimum</i>
Species	:	<i>O.tenuiflorum</i>

Habit – a perennial herb with aromatic smell,

Stem – erect, aerial, branched, quadrangular (4 sided), woody, solid, green,

Leaves – cauline or ramal, simple, opposite, sometimes whorled or exstipulate, ovate, serrate, acute, aromatic smell, reticulate venation,

Inflorescence– Verticillaster, 6–10 flower whorls,

Flowers – pedicellate, bracteate, hermaphrodite, zygomorphic, complete, hypogynous, pentamerous, cyclic,

Calyx – 5 sepals, gamosepalous, bilabiate, posterior or upper lip broad, lower or anterior tip with four small sepals, petaloid (purple), anterior lip with small lobes, posterior lip broad, imbricate aestivation, inferior,

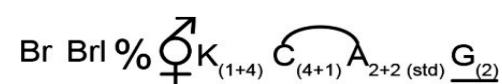
Corolla – 5 petals, gamopetalous, bilabiate, upper lip 4 lobed, lower lip large, imbricate aestivation, inferior, white or purple,

Androecium – Stamens 4, polyandrous, didynamous, epipetalous, fifth (posterior) stamen completely suppressed, anthers bicelled, introrse, dorsifixed,

Gynoecium – bicarpellary, syncarpous with superior ovary, ovary bilocular in early stages but tetralocular in later stages, axile placentation, single ovule in each locule, style gynobasic i.e., arises from the base of the ovary, stigma bifid,

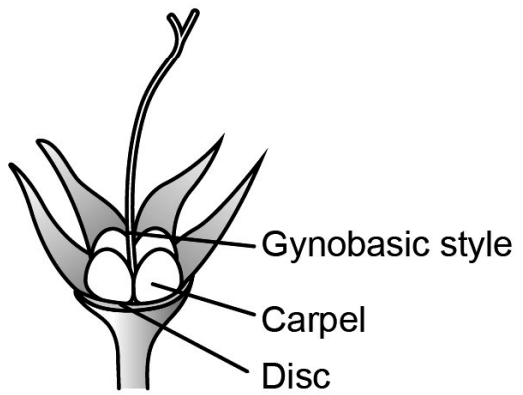
Fruit – Carcerulus.

Floral formula –

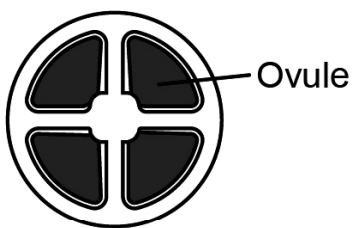




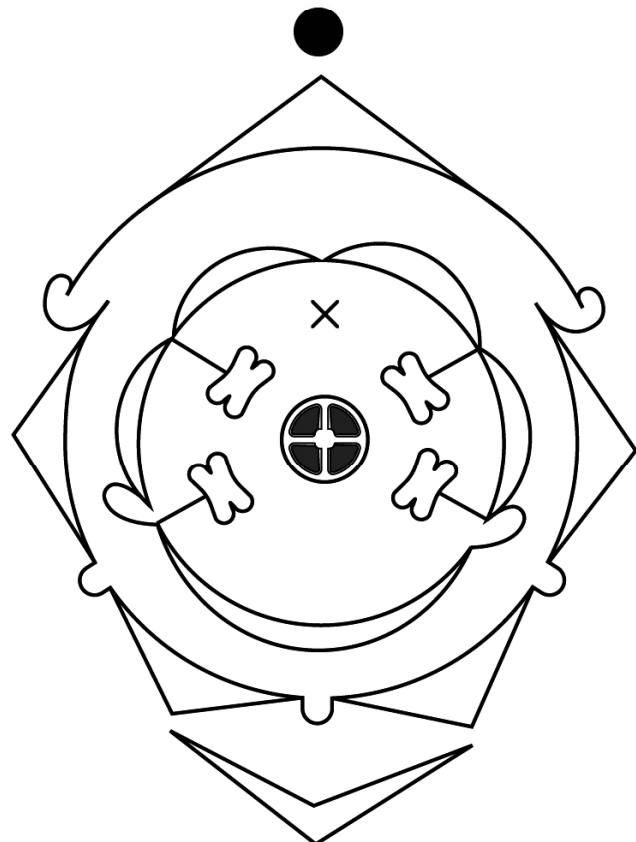
(a) Plant



(b) L.S. of flower to show ovary



(c) T.S of ovary showing ovules



(d) Floral diagram

Fig. 8.10: *Ocimum* (a) Branch with inflorescence; (b) Flower showing ovary and gynobasic style c) T.S of ovary showing ovules; (d) Floral diagram.

Lamiaceae**Classification and identification.****Class. Dicotyledonae**

1. Cotyledons two
2. Venation reticulate.
3. Flowers pentamerous.

Sub-Class. Gamopetalae

1. Petals fused.

Series. Bicarpellatae

1. Carpels two.
2. Ovary usually superior.

Order. Lamiales

1. Flowers zygomorphic.
2. Corolla bilipped.
3. Stamens 4, didynamous or 2.
4. Ovary 2 – 4 locular.
5. Fruit drupe or schizocarpic.

Family. Labiatae

1. Stem quadrangular
2. Decussate or whorled exstipulate leaves.
3. Inflorescence verticillaster.
4. Gynoecium generally bilocular with 2 ovules in each locule, sometimes tetralocular with one ovule in each locule.
5. Style gynobasic.
6. Fruit carcerulus.

(E) Study of vegetative and floral characters of the family Liliaceae.**LILIACEAE (LILY FAMILY)****General characters**

Family Liliaceae comprises some 250 genera and 2500 species of which 35 genera with about 190 species grow in India.

Habit – perennial herbs,

Root – fibrous, adventitious, sometimes tuberous,

Stem – bulbous or rhizomatous, phylloclade or cladode,

Leaves – basal or cauline, alternate or whorled, sheathing, simple exstipulate/stipulate,

Inflorescence – terminal raceme or umbel; sometimes solitary,

Flowers – actinomorphic or zygomorphic, pedicellate, bisexual, complete, bracteates,

Perianth – 6 tepals, biseriata (in two whorls of 3 each), free or united, homochlamydeous or dichlamydeous, tepals often larger and showy,

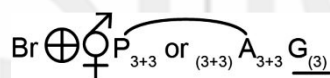
Androecium – 6 stamens, into whorls of 3+3, distinct and free, anthers ditheous, usually basified, introrse or extrorse, longitudinal or terminal pore,

Gynoecium – tricarpillary, syncarpous with superior ovary, style solitary, simple, trilocular,

Stigma – trilobed, placentation axile,

Fruit – Capsule or berry.

Floral Formula –



Common examples of Liliaceae members are: *Allium*, *Lilium*, *Tulipa*, *Gloriosa*, *Yucca*, *Dracaena*, *Smilax*, *Asparagus* and *Ruscus*.

i) ***Asphodelus tenuifolius* (H. Piazzi)**

Kingdom	:	Plantae
Class	:	Monocotyledonae
Series	:	Coronarieae
Order	:	Liliales
Family	:	Liliaceae
Genus	:	<i>Asphodelus</i>
Species	:	<i>A. tenuifolius</i>

Habit – annual herb,

Root – adventitious, fibrous,

Stem – small bulb (compressed stem),

Leaf – radical, slender, erect, fistular, glabrous, pointed, sessile, parallel venation,

Inflorescence – racemose, raceme,

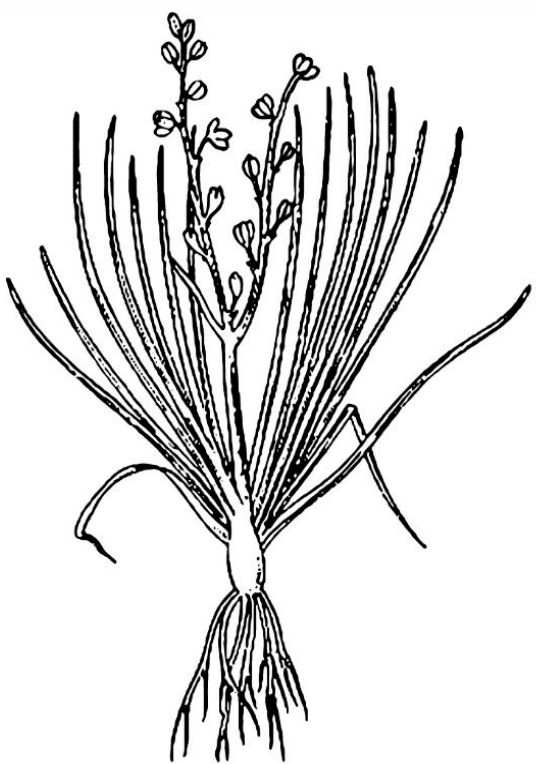
Flower – bracteate, pedicellate, complete, actinomorphic, bisexual, regular, hypogynous, trimerous, small,

Perianth – six tepals (in two whorls of three each), polytepalous, valvate, white, free or united at the base, imbricate aestivation,

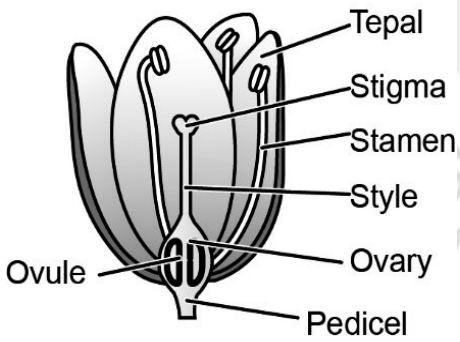
Androecium – stamens six (in two whorls of three each), epiphyllous, polyandrous, filaments broad at the base of the ovary, anthers dithecous, basifixed or versatile, introrse, brown,

Gynoecium – tricarpellary, syncarpous, ovary superior, trilobular, each locule with two ovules, placentation axile, style short, stigma three lobed, yellow,

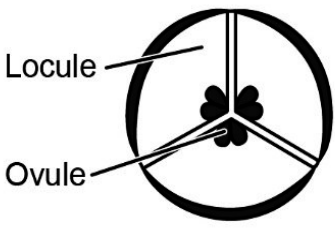
Fruit – Small loculicidal capsule.



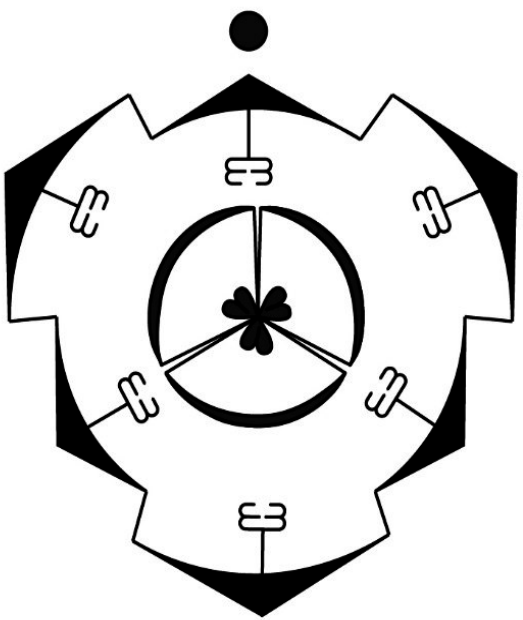
(a)



(b)



(c)



(d)

Fig. 8.11: *Asphodelus* (a) Branch with inflorescence; (b) L.S. of flower; (c) T.S. of ovary; (d) Floral diagram.

ii) *Allium cepa* (H. Piaz)

Kingdom	:	Plantae
Class	:	Monocotyledonae
Series	:	Coronarieae
Order	:	Liliales
Family	:	Liliaceae
Genus	:	<i>Allium</i>
Species	:	<i>A. cepa</i>

Habit – an annual cultivated herb,

Root – adventitious fibrous,

Stem – underground tunicated bulb, reduced to a conical disc like structure,

Leaves – radical, cylindrical, long, exstipulate, sessile, fleshy, sheathing leaf base, hollow,

Inflorescence – Many monochasial cymes grouped together. These appear like a terminal umbel on a leafless scape, each cyme is enclosed by 2 or 3 membranous bracts arranged in an umbellate manner,

Flower – pedicillate, bracteate, actinomorphic, complete, hermaphrodite, trimerous, white,

Perianth – 6 tepals, arranged in 2 whorls of 3 each; gamophyllous, united at the base, white imbricate aestivation,

Androecium – stamens 6, arranged in two whorls of 3 each, polyandrous, epiphyllous, anthers large, ditheous, dorsifixed, introrse,

Gynoecium – tricarpillary, syncarpous, ovary superior, trilocular, axile placentation, 2 ovules per locule, style short, stigma 3-lobed,

Fruit – a loculicidal capsule.

Floral formula –



Point of attachment of inflorescence

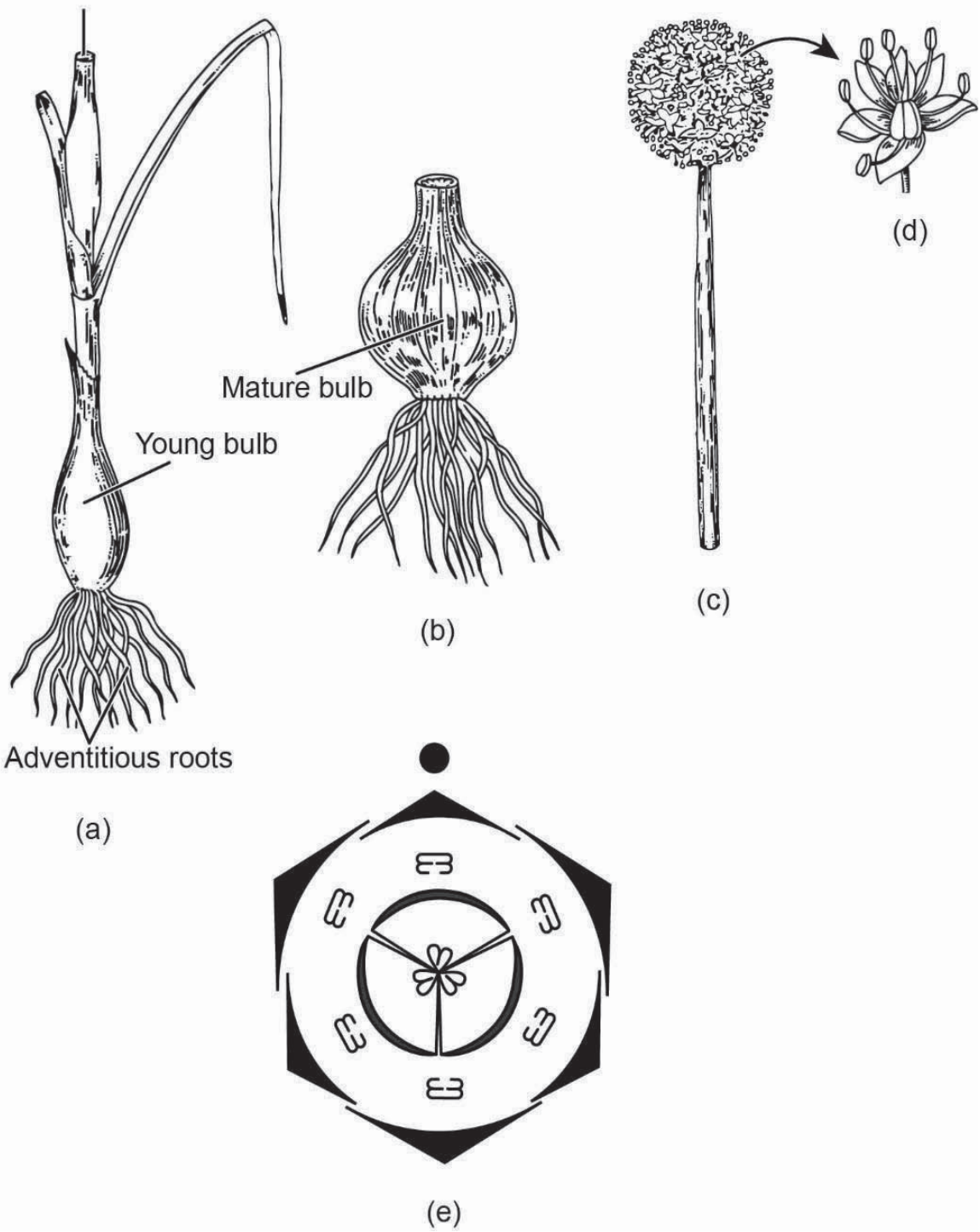


Fig. 8.12: *Allium cepa* (a) Plant with bulb; (b) Mature bulb; (c) Inflorescence; (d) Mature flower; (e) Floral diagram.

Classification and Identification

Class. Monocotyledonae

1. Cotyledon one
2. Venation parallel.
3. Flowers trimerous.

Series. Coronarieae

1. Inner perianth petaloid
2. Ovary superior.

Order. Liliales

1. Tepals present.
2. Presence of coloured perianth (petaloid).
3. Ovary superior.
4. Nectaries present at the base of the tepals or stamen filaments.

Family. Liliaceae

1. Inflorescence usually scapiferous racemose type.
2. Perianth in two whorls and petaloid.
3. Stamens also in two whorls and epiptepalous.
4. Gynoecium 2–5 locular and placentation axile.

GLOSSARY TO STUDY A PLANT

Adventitious root	: roots arising from other organs such as stem.
Aestivation	: arrangement of sepals and petals in the bud.
Albuminous	: endospermous.
Axile Placentation	: placenta placed along the column in a compound ovary.
Axillary	: on the side of a structure or at the nodes of the axis.
Basal	: at or near the bottom of the structure.
Basifixed	: anther attached at its base or to the apex of the filament.
Berry	: a fleshy fruit with succulent schizocarp.
Bifid	: two lobed.
Bilabiate	: two lipped with upper and lower segments.
Bipinnate	: a compound leaf with two axes.
Bisexual	: flower having both carpel and stamens.
Bract	: a modified or reduced leaf found associated with reproductive structures.
Bracteole	: a small or secondary bract borne on the side of the pedicel.

Campanulate	: bell shaped.
Capitulum	: head.
Carpel	: unit of gynoecium and represents a modified sporophyll of a flower.
Cauline	: positioned along the length of the stem.
Circinate	: leaves coiled on themselves from the apex towards the base.
Complete	: flower having all the four whorls i.e. sepals, petals, androecium, gynoecium.
Convolute	: perianth parts of a single overlapping at one margin, being overlapped at the other.
Contiguous	: parts touching each other but not fused.
Corm	: enlarged solid underground stem.
Corolla	: innermost whorl of modified leaves.
Cyathium	: an inflorescence bearing small, unisexual flowers and subtended involucre.
Cyme	: determinate inflorescence.
Cypsela	: an achene derived from inferior ovary.
Decussate	: opposite leaves or other structures at right angles to the preceding pair.
Dentate	: sharp coarse teeth that point outward at right angles to margin outline.
Determinate	: a shoot that terminates its growth after certain period.
Diadelphous	: with two group of stamens.
Dichlamydeous	: perianth composed of distinct outer calyx and inner corolla.
Dichogamy	: difference in timing of maturation of male and female floral parts.
Didymous	: stamens in two equal pairs.
Didynamous	: stamens in two unequal pairs.
Dioecious	: male and female flowers on separate plants.
Dorsifixed	: anther attached dorsally and medially to the apex of the filament.
Drupe	: a fleshy fruit with hard, stony endocarp.
Ebracteate	: lacking bracts.
Epicalyx	: a series of bracts subtending the calyx.

Epigynous	: sepals, petals and stamens attached at apex of the ovary.
Epipetalous	: stamens adnate to petals or corolla.
Episepalous	: stamens adnate to sepals or calyx.
Fibrous root	: adventitious, moderate branching roots like a mat.
Free	: parts are not fused, separate.
Fusiform	: spindle shaped– narrow ellipsoid with attenuate ends.
Gamopetalous	: petals fused.
Gamosepalous	: sepals fused.
Glabrous	: smooth, without hair.
Herbaceous	: soft or slightly succulent.
Hermaphrodite	: a plant with bisexual flowers.
Hypanthium	: a cup like enlargement of the receptacle of flower, loosely surrounding the gynoecium or united with it.
Hypogeous	: with cotyledons remaining in ground during germination.
Hypogynous	: with sepals, petals and stamens attached at the base of the superior ovary.
Imbricate	: leaves or other structure overlapping.
Imparipinnate	: pinnately compound leaf with a terminal leaflet.
Imperfect	: flower unisexual.
Incomplete	: lacking one or more of the whorls or floral parts.
Inferior ovary	: with sepals, petals, stamens and hypanthium attached at the apex of the ovary.
Inflorescence	: an aggregate of more than one flower.
Introrse	: dehiscing inward i.e. toward the center of the flower.
Involucre	: bracts arranged spirally in one or more whorls around the cluster of flower.
Lanceolate	: shaped like a lance head; of a narrow oval shape tapering to a point at each end.
Legume	: a dry dehiscent fruit derived from carpel.
Ligule	: a small appendage on the upper side of the leaf.
Locule	: an ovary cavity bounded by ovary walls and septa.
Longitudinal dehiscence	: dehiscing along the suture parallel to the long axis of the thecae.

Marginal	: placenta along the margin of the ovary.
Monoecious	: having unisexual flowers, either staminate or pistillate or bisexual but always on the same plant.
Multiseriate	: perianth composed of three distinct whorls.
Ob lanceolate	: lanceolate with the more pointed end at the base.
Oblique	: asymmetrical base.
Oblong	: margins straight, parallel.
Obtuse	: apical margins straight.
Ovate	: egg shaped with broader end at the base.
Ovule	: an immature seed.
Palmatifid	: lobed or divided.
Panicle	: an indeterminate inflorescence.
Pappus	: the sepals in Asteraceae modified as awns, scales or bristles.
Parietal placentation	: placenta on the innerwall.
Perfect	: bisexual flower with stamen and pistil.
Perfoliate	: a leaf blade that is sessile, base completely surrounding the stem.
Perianth	: petals and sepals are of similar appearance.
Perigynous	: hypanthium present, attached at the base of the ovary.
Petiole	: a leaf stalk.
Pinnately compound	: a compound leaf with leaflets arranged oppositely or alternately.
Pinnatifid	: lobed or divided nearly to the midrib but not separated into distinct leaflets.
Pistil	: the part of gynoecium composed of ovary, styles and stigma.
Pistillate	: unisexual flowers with carpels.
Placenta	: an ovule bearing tissue of the ovary.
Polygamous	: a plant with bisexual and unisexual flowers.
Polypetalous	: petals free.
Raceme	: an indeterminate inflorescence consisting of single axis with pedicellate flowers.
Radial	: asymmetric, regular, actinomorphic.

Receptacle	: the tissue or region of a flower to which other floral parts are attached.
Reticulate venation	: venation in which veins appear to join back and appear like mesh or net.
Ruminate	: unevenly textured, coarsely wrinkled.
Sepal	: segment of calyx which is green and protective in function.
Serrate	: saw toothed, sharp teeth and ascending.
Sessile	: without a petiole.
Siliqua	: a dry, dehiscent 2-carpeled fruit.
Simple leaf	: leaf which is not divided into leaflets.
Spinose	: margins with teeth bearing sharp, stiff, spine like processes.
Stamen	: male reproductive organ.
Staminate	: flowers unisexual, bearing stamens only.
Staminode	: a sterile stamen producing no functional stamen.
Stipule	: leaf like structures present at the base of petiole.
Style	: a stalk like structure of the pistil between stigma and ovary.
Superior ovary	: ovary with sepals, petals, stamens and hypanthium attached at the base of the ovary.
Syncarp	: an aggregate fruit, typically of berries.
Syncarpous	: with carpels connate, pistil and ovary are compound (fused).
Syngenesious	: anthers connate and filaments distinct.
Taproot	: a well developed primary root.
Tepal	: a unit of perianth in which parts (petals and sepals) appear undifferentiated.
Tetradynamous	: with stamens in two groups four long and two short.
Umbel	: a determinate or indeterminate, flat topped or convex.
Unicarpellary	: gynoecium composed of one carpel.
Unifoliate	: a leaf bearing a single leaflet.
Uniseriate	: with single whorl of parts.
Unisexual	: flowers having either carpels or stamens.
Valvate	: sepals and petals closely arranged in a circle but do

Exercise 8	To Study of Vegetative and Floral Characters of Some Dicot and Monocot Families
aestivation	not overlap.
Venation	: pattern of arrangement of veins and vein branching on leaf.
Versatile	: anther moving freely with the point of attachment with filament.
Verticillaster	: a dichasial cyme which occurs in the leaf axil in the form of a whorl of flowers at each node.
Verticillate	: having three or more leaves per node.
Whorled	: three or more leaves or other structure per node.



Mounting of A Properly Dried and Pressed Specimen of any Common Wild Plant With Herbarium Label

Structure

9.1 Introduction	9.4 Method
Objectives	Collection of Specimens
9.2 Study Guide	Carrying the Specimens
9.3 Material Required	Examining the Plant
	Drying
	9.5 Observations
	9.6 Precautions

9.1 INTRODUCTION

In the previous exercises you have studied about plants belonging to dicots and monocot families. You have also learnt about describing a plant species with various vegetative and floral characters. In this unit you will study about collecting a plant specimen and making a herbarium specimen of that plant so that it can be preserved for long time to study.

Herbarium is a standard method of preserving plants for future study and reference. It is an important part of any botanical study. It provides complete information about plant species existing in an area. It also provides details (important characteristics) of the plant at a glance. The characteristic features of the plant help in the identification of the family to which it belongs to.

Objectives

After doing this exercise you should be able to:

- ❖ know various equipment, which are required for plant collection;
- ❖ get acquainted with pressing material to be used;

- ❖ collect plant parts which are to be pressed;
- ❖ dry, mount and label of plant specimens; and
- ❖ store the herbarium sheets in proper place.

9.2 STUDY GUIDE

For doing satisfactory work you must read the following units before coming to the laboratory.

The UGC (CBCS) course - core Botany-, Paper II – Plant Ecology and Taxonomy (BBYCT-133), Unit-12 Herbaria and Botanical Gardens, Section 12.3 Herbarium.

9.3 MATERIAL REQUIRED

In addition to general Biology Kit and Laboratory Kit provided you will require :

- a) **Wild plants belonging to dicot or monocot family**
- b) **Other Requirements**
 - i) a gardener's knife
 - ii) a plant press or vasculum
 - iii) blotting papers to dry plants
 - iv) trowel to dig and uproot the plants
 - v) collecting and mounting sheet
 - vi) gum tape, labels, waterproof ink and pen
 - vii) other equipment used in collection are collecting pick, secateur, vasculum, hatchet, spade, etc.

9.4 METHOD

Herbarium sample consist of a pressed dried plant sample that is permanently stuck to a sheet of paper along with the required information.

Preparation of herbarium involves two steps

- 1) Collection of specimen
- 2) Carrying the Specimen
- 3) Examining the Plant
- 4) Drying
- 5) Preservation of specimen

In this section you will study about preserving plants for a herbarium because as a student you should how to make and maintain a herbarium. Some plants are also grown in a botanical garden or specially maintained in green house for this purpose. Before doing this exercise you should study Unit 12 of this course.

9.4.1 Collection of Specimens

- 1) You should remember one important thing about making plant collection – **Do not pick plants haphazardly**. Choose only those plants whose flowers are large and whose organs are easily seen.
- 2) If possible collect complete plants with flowers and fruits (sometimes they are necessary for recognising species of some families such as Cruciferae, Umbelliferae, Asteraceae).
- 3) The underground parts (root, bulbs, and rhizomes) are often interesting. Try to collect them. If the plant is large take just a branch with leaves, flower and fruits.

9.4.2 Carrying the Specimens

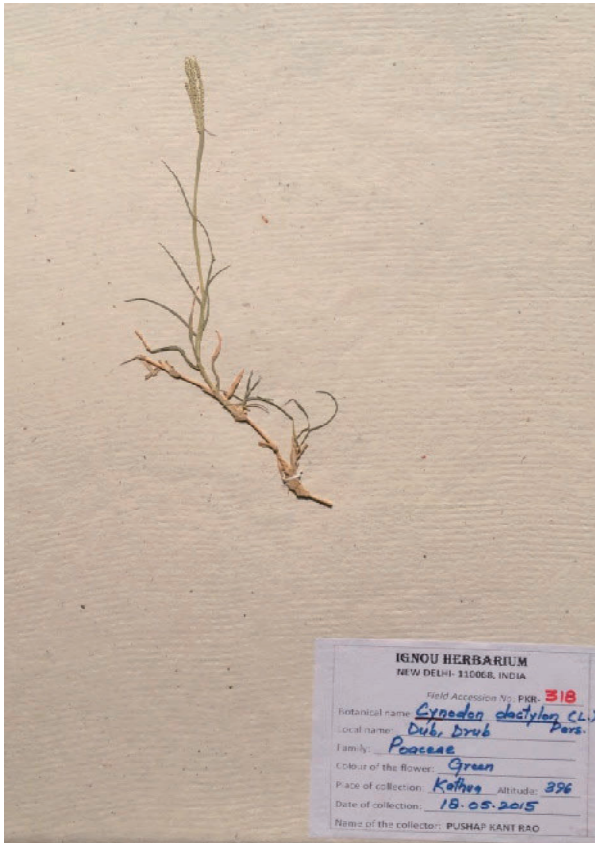
1. Carry each plant specimen in separate bag or container.
2. Place the plant flat between newspapers and place in a cardboard folder and fastened in a strap or keep the plant in the vasculum. as you have already read in unit 12 of this course.
3. Attach a label to each plant stating details of its habitat, date, name of place, name of collector, flower colour and any other interesting feature.

9.4.3 Examining the Plant

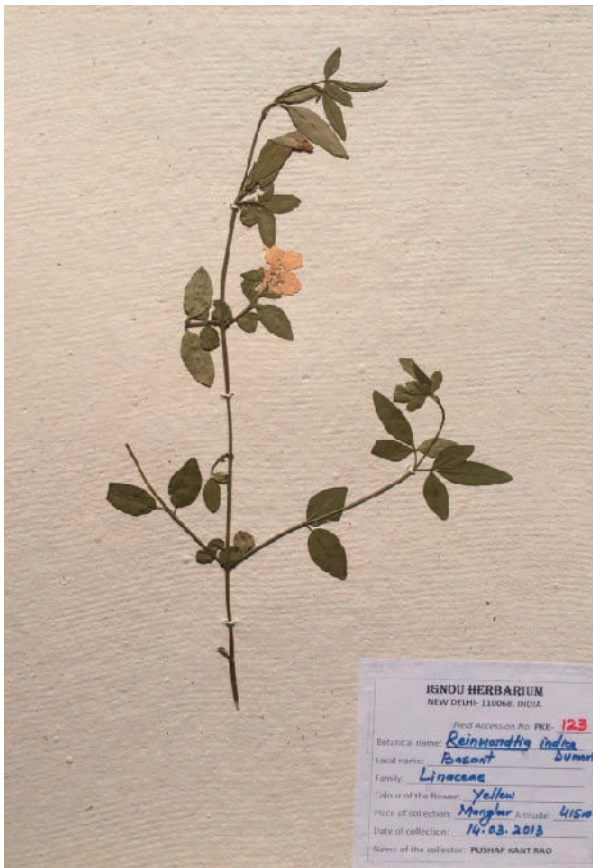
- 1) Identify the name of the plant with the help of your counsellor and in due course of time you will be able to name the plant by yourself.
- 2) You can also keep a plant with some labelling with it and it could be identified with the help of different Floras.
- 3) Make a few sketches to point out the characteristics which helped you in identification of the plant.

9.4.4 Drying

- 1) Spread each plant carefully in between blotting paper or newspaper.
- 2) Then place the plant in the plant press with its label.
- 3) After a few days (the next day, if the plants are very moist) check that the plants are properly laid out and change the paper.
- 4) Check the specimens and if they are properly dried, place them in your herbarium.
- 5) Place the plant on a herbarium sheet (a fairly large piece of special paper or on any fairly thick paper), fix the dried plants in their natural position with some cellotape.
- 6) If the plant is too big, break the stem cleanly or arrange fragments of the leafy stem, the floral stem and the fruits.



(a) *Cynodon dactylon*



(b) *Reinwardtia indica*

Fig. 9.1: Mounted Specimens.

- 7) Rewrite the label which will be placed in the bottom right hand corner of the page as given below. Copy out the notes you have already made on it. (It is not necessary that you should identify the family and name of a plant). The name and family of the plant can be identified with the help of the counsellor at your study centre.
- i) *Heading*: Country, state or province name, name of the institution.
 - ii) *Scientific name* of the specimen followed by the author's name and the name of the family.
 - iii) *Locality*: Specific locality should be mentioned, so that if another person wants to collect the same specimen, he should be able to reach the exact site without much difficulty.
 - iv) *Habitat*: Vegetation type, moisture content of soil and atmosphere, soil type, elevation, direction of slope, etc. should also be mentioned.
 - v) *Date of collection* should include the exact month and year to indicate when the specimen was collected.
 - vi) *Name of collector*.
 - vii) *Collection number*: The literature on plant systematics identifies and refers to the specimen by the collector's name and collection number. Hence, the collection number is a must for any collector.
- 8) You can arrange the herbaria according to their habitats (aquatic, from dunes, from mountain rocks) or according to their uses (edible, medicinal, ornamental, fodder plants; harmful plants, poisonous plants etc.).

Activity 1 : Collect two plants of your choice and prepare herbarium sheets. Submit these to your counselor when you come for the lab session. You will be evaluated on this work.

9.5 OBSERVATIONS

When the specimen is completely dried and you have completed the mounting of the specimen then it is ready for study various vegetative and reproductive characters of the plant and record in your note book.

9.6 PRECAUTIONS

- 1) You should always collect specimen which is in flowering and fruiting stage.
- 2) Herbs are collected complete their underground parts.
- 3) At least five specimens of plants, preferably in different stages of flowering and fruiting should be collected.
- 4) The sample should be dried properly
- 5) While studying the specimen, the sheet should never be turned upside down.
- 6) The herbarium samples should be protected from insects and mites.

ACKNOWLEDGEMENT OF FIGURES

EXERCISE 2: STUDY OF INSTRUMENTS USED TO MEASURE MICROCLIMATIC VARIABLES

Fig. 2.1: Source <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fstatic-01.daraz.com>

Fig. 2.2: (a) Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fkids.kiddle.co%2Fimages%2Fthumb%2F1%2F1d%2FAnomometer>

(b) Source: [https://www.google.co.in/imgres?imgurl=http%3A%2F%2F3.bp.blogspot.com%](https://www.google.co.in/imgres?imgurl=http%3A%2F%2F3.bp.blogspot.com%2F)

(c) Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fwww.biral.com>

Fig. 2.3: Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fwww.picclickimg.com>

Fig. 2.4: Source: [https://www.google.co.in/imgres?imgurl=https%3A%2F%2F2.bp.blogspot.com%](https://www.google.co.in/imgres?imgurl=https%3A%2F%2F2.bp.blogspot.com%2F)

EXERCISE 4: COMPARISON OF BULK DENSITY, POROSITY AND RATE OF INFILTRATION OF WATER IN SOIL OF THREE HABITATS

Fig. 4.4: Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Flh4.googleusercontent.com>

EXERCISE 5: STUDY OF ECOLOGICAL ADAPTATIONS IN PLANTS

Fig. 5.5: Source: <https://www.google.co.in/imgres?imgurl=http%3A%2F%2Fsecure.tutorsglobe.com>

Fig. 5.6: Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fthumbs.dreamstime.com>

Fig. 5.7: (a) Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fi.pinimg.com>

(b) Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fc8.alamy.com>

Fig. 5.8: (a) Source: <https://www.google.co.in/imgres?imgurl=https%3A%2F%2Fwww.gardendesign.com>

(b) Source: [https://www.google.co.in/imgres?imgurl=http%3A%2F%2Fwww.bromeliad.org.au%](https://www.google.co.in/imgres?imgurl=http%3A%2F%2Fwww.bromeliad.org.au%2F)

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