NAVSARI AGRICULTURAL UNIVERSITY

As per the Fifth Dean Committee Recommendations for the
B. Sc. (Hons.) Agri. Course Curriculum

ICAR

Practical Manual

Ag. Chem. 1.1 (2 + 1)

Fundamentals of Soil Science

First Semester B.Sc. (Hons.) Agriculture

PREPARED BY

Prof. H. P. Dholariya
Assistant Professor

Dr. Navneet Kumar
Associate Professor

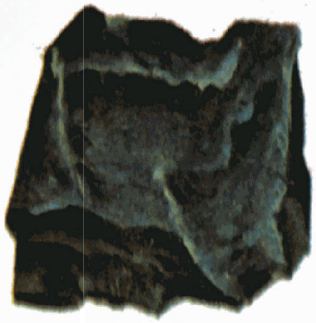
College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

IGNEOUS ROCKS

GRANITE

DIORITE

FELSITE



BASALT

OBSIDIAN

SEDIMENTARY ROCKS

CONGLOMERATE

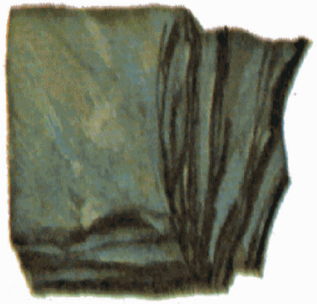
SANDSTONE

SHALE

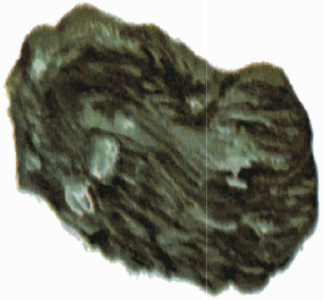
LIMESTONE

DOLOMITE

METAMORPHIC ROCKS



SLATE



SCHIST

SERPENTINE

QUARTZITE

MARBLE

As per the Fifth Dean Committee Recommendations for the
B. Sc. (Hons.) Agri. Course Curriculum

NAVSARI AGRICULTURAL UNIVERSITY

ICAR

Practical Manual

Ag. Chem. 1.1 (2 + 1)

Fundamentals of Soil Science

First Semester B.Sc. (Hons.) Agriculture

PREPARED BY

Prof. H. P. Dholariya
Assistant Professor

Dr. Navneet Kumar
Associate Professor

College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

Publisher
Principal
College of Agriculture,
Navsari Agricultural University,
Waghai-394 730 (Gujarat)
Phone No. 02631 – 246688
Fax No. 02631 - 246622

Edition : First: January, 2019

Copies: 300

Department of Soil Science & Agricultural Chemistry,
College of Agriculture,
Navsari Agricultural University,
Waghai (Dangs) – 394730.

University Publication No.:.....2018-19

Dr. Z. P. Patel
Dean & Principal
M. 9624363999

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

Phone No. : 02631 - 246688
Fax No. : 02631 - 246622
Email : zprin@nau.in, caw@nau.in

FOREWORD

The course entitled **"Fundamentals of Soil Science"** is offered as a mandatory course in the curriculum of First Semester B.Sc. (Hons.) Agriculture through the Department of Agricultural Chemistry and Soil Science, under College of Agriculture, Navsari Agricultural University, Waghai (Dangs), Gujarat.

In this Practical Manual information is provided on Soil Profile and Soil Genesis. It is hoped that an understanding of soil Properties will be enhanced through soil profile.

An attempt is being made in this manual to compile the available up-to-date information on the subject in the most easily understandable manner and to make the information user-friendly. Board of studies of Soil Science and Agricultural Chemistry, Navsari Agricultural University, has already decided to prepare practical manual of various courses. So, keeping in view the requirement as per ICAR and necessity of students, the manual has been published.

I am sure that this manual will clear the basic concepts of Soil genesis and management of soil properties and it will be a useful ready reference material for all the students of first semester B.Sc. (Hons.) Agriculture. I shall feel more than satisfied, if this manual would serve the purpose of students in pursuit of their academic goals. I convey my hearty congratulations to Prof. H. P. Dholariya and Dr. Navneet kumar for their commendable efforts in bringing out this practical manual.

January, 2019

(Z. P. Patel)

Reg. No. : _____ **Batch No.: _____**

Roll No. : _____ **Uni Seat No.: _____**

CERTIFICATE

This is to certify that the practical work has been satisfactory carried out by Shri/Kumari _____, in the course No. **Ag Chem. 1.1**, Course Title **"Fundamentals of Soil Science"** (2+1) of First semester B.Sc. (Agri.) in the laboratory of Department of Agricultural Chemistry and Soil Science during the academic year _____.

He/She has certified_____ practical exercise out of _____ in the subject of **"Fundamentals of Soil Science".**

External Examiner **Course teacher**

Place :

Date :

INDEX

: Syllabus :

Course no. : Ag. Chem. 1.1
Title : Fundamentals of Soil Science
Credit hours : (2+1) = 3

Theory:

Soil as a natural body, Pedological and edaphological concepts of soil; Soil genesis: soil forming rocks and minerals; weathering, processes and factors of soil formation; Soil Profile, components of soil; Soil physical properties: soil texture- Methods of particle size analysis, structure, density and porosity, soil colour, consistence and plasticity; Elementary knowledge of soil taxonomy classification and soils of India; Soil water retention, movement and availability; soil air, composition; source, amount and flow of heat in soil; soil temperature and plant growth; Soil reaction-pH, soil acidity and alkalinity, buffering, effect of pH on nutrient availability; soil colloids - inorganic and organic; silicate clays: constitution and properties; sources of charge ion exchange, cation exchange capacity, base saturation; soil organic matter: composition, properties and its influence on soil properties; humic substances - nature and properties; soil organisms: macro and micro organisms, their beneficial and harmful effects.

Practical

Study of soil sampling tools, collection of representative soil sample, its processing and storage. Study of soil profile in field. Study of soil forming rocks and minerals. Determination of particle density and bulk density of soil and computation of porosity, Determination of soil moisture content and maximum water holding capacity and computation of moisture constants. Determination of soil texture by feel and international pipette method. Studies of capillary rise phenomenon of water in soil column and water movement in soil. Study of soil map. Determination of soil colour. Demonstration of heat transfer in soil. Determination of soil pH and electrical conductivity. Determination of cation exchange capacity of soil. Estimation of organic matter content of soil.

1. COLLECTION AND PROCESSING OF SOIL FOR ANALYSIS

Introduction

Soil sampling is perhaps the most vital step for any soil analysis. As a very small fraction of the huge soil mass is used for analysis, it becomes extremely important to get a truly representative soil sample of the field. A wrong sample is not only wasting of time and money but also leads to the erroneous conclusions and recommendations, which will prove costly to the farmers.

Objectives of soil sampling

1. To evaluate soil fertility status for making fertilizer recommendations.
2. To predict the probable crop response to applied nutrients.
3. To classify soil into different types of soil groups, fertility groups for preparing soil maps and soil fertility maps.
4. To identify the types and degree of soil related problems like salinity, alkalinity and acidity etc. and to suggest appropriate reclamation / amelioration measures.
5. To find out suitability for growing crops and orchard.
6. To find out suitability for irrigation.
7. To study the soil genesis.

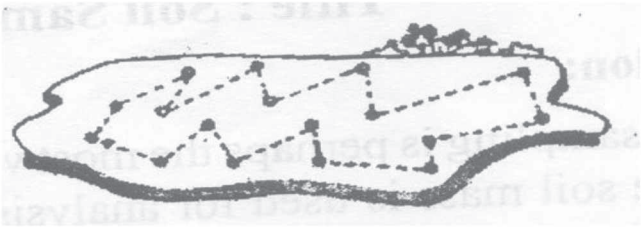
For collecting a representative soil sample, following points must be taken into considerations

1. The sample must truly represent the field it belongs to.
2. A field can be treated as a single sampling unit and it is appreciably uniform. Generally, an area not exceeding 0.5 ha is taken as one sampling unit.
3. Variations in slope, colour, texture, crop growth and management practices are the important factors that should be taken into account for sampling. Separate samples are required from areas differing in these characteristics.

1. Sample each field separately

When area within a field differ in crop growth in the appearance of soil in elevation or are known to have been cropped or manured differently, devide the field accordingly and sample each area separately.

2. Take a composite sample

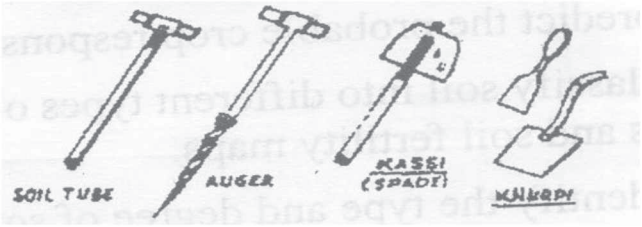


Take a composite sample from each area, scrape away surface little then draw a sample from surface to plough depth (or 0-15 cm) in 15 to 20 spots. Collect these in a clean cloth bag. If you use a khurpi or a kassi, first dig a 'V' shaped hole and take one thin slice (2 to 2.5 cm).

3. Sample between lines in planted crops

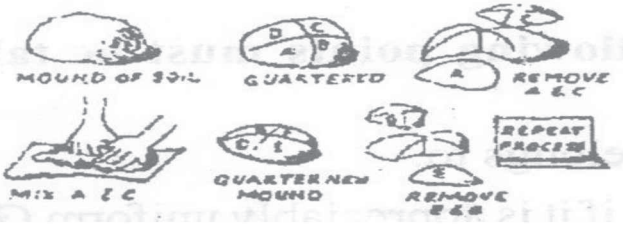
When crops have been planted in rows, sample in between lines do not sample unusual area avoid recently fertilized area, old bunds, marshy spots, near trees or compost piles or other non representative locations.

4. Use proper sample tools



Use proper sampling tools. Sample can be taken quit satisfactorily with a soil tube, an auger, a kassi or a kurpi. Soil tube and auger are more suited for drawing samples from lower depths.

5. Mix sample thoroughly



Mix the sample well by stirring with hands on a clean piece or cloth, paper or polythene sheet, Discard all but 0.5kg of soil by the process of quartering ensures a representative final sample dry In shade and fill in cloth or polythene bag

6. Packing and marking

Place a durable label inside and a tag outside. The bag giving details of the location, depth of sampling number the soil sample bags. Tie the bag properly for sending to soil testing laboratory

Fig. Various steps involved in collection of representative soil sample and their handling.

Sampling from recently fertilized plots, bunds, channels, marshy tracts and areas near trees, wells, compost piles or other non-representative locations must be carefully avoided.

4. An area of about 2-3 meters along sides of the field should not be sampled in large fields.
5. Larger areas may be divided into appropriate number of smaller homogenous units for better representation.

Depth of sampling

The penetration of plant roots is an important consideration in deciding the depth of sampling; therefore following factors may be kept in mind

1. For cereals, vegetables and other seasonal crops, the samples should be drawn from 0-15 cm i.e. plough layer.
2. For deep rooted crops or longer duration crops like sugarcane, cotton or under dry farming condition, draw samples from different depths depending on individual requirement.
3. For plantation crops or fruits trees, prepare composite sample from soil collected at depth of 0-30, 30-60 and 60-100 cm from 4 to 5 pits dug in about 0.5 ha field at the time of planting.
4. For saline- alkali soils, salt crust if visible on the soil surface or suspected, should be sampled separately and record the depth of sampling. Generally, the sample should be drawn upto 15 cm depth from surface for testing of salinity and alkalinity / acidity.
5. In case composite samples are drawn below 15 cm as for certain flowering plants like roses, the depth from which soil samples have been drawn should be indicated.

Sampling tools

Sample can be drawn with the help of (i) soil tube (tube auger), (ii)screw type auger, (iii) post hole auger, (iv) kassi or phawda (spade) and (v) khurpi

For sampling of soft and moist soil, a tube auger, spade or khurpi is satisfactory. A screw type auger is more convenient on hard or dry soil while the post hole auger is useful for sampling excessively wet .area like rice fields. If a spade or khurpi is used, a "v" shapped cut maybe first made up to the plough layer and a uniformly 2 cm thick slice is taken from one clean side. Tube auger attached to a long extension rod is convenient for sampling from lower depths.

Information Sheet

Sr. No.	Indentification mark	Depth of sampling	No. of spots sampling	Area of the field	Upland or low land	Irrigated (yes/no)	Previous crop raised	When manure/ fertilizer applied
1.								
2.								
Tick mark (√) the additional tests required (S, Zn, Cu, Fe, Mn, B, Mo)					Recommendation Sought for (crop name)			

Soil sampling procedure

1. For making composite sample, collect small portions of soil up to the desired depth (0-15 cm or more) by means of suitable sampling tools from 15 to 25 well distributed spots, moving in a zig-zag manner from each individual sampling site after scrapping off the surface litter, if any, without removing soil.
2. From field having standing crops in rows, draw samples in between rows.
3. Mix the soil collected from various spots covering the entire area thoroughly by hand on a clean piece of cloth or polythene sheet.
4. Reduce bulk to about 500 g by quartering process in which the entire soil mass is spread, divided into four quarters, two opposite ones are discarded and the remaining two are remixed. Repeat this process until about 500 g of soil is left.

Precautions in collection and storage of samples

Special care in collection and handling the soil samples is required for preventing contaminations. Following precautions should be taken to minimize the error:

1. Avoid contact of the sample with chemicals, fertilizers or manures.
2. Use stainless steel augers instead of rusted iron khurpi or kassi for sampling for micronutrient analysis.
3. Do not use bags or boxes previously used for storing fertilizers, salt or any chemicals.
4. Store soil samples preferably in clean cloth or polythene bags.
5. Use glass, porcelain or polythene jar for long duration storage.

Labeling of samples

Label the samples for identification. A label of thick paper with identification mark and other details should be put inside the sample bag and another label carrying same details tied/pasted outside the sample bag written with lead pencil or a permanent ink marker.

Information sheet

In addition to the location, field number, name of cultivator and identification marks, relevant information about slope, drainage, irrigation, previous cropping history, fertilizer, manure used etc. must be recorded and sent along with the soil samples. This is a specific requirement of soil testing service and must be insisted upon.

Registration of samples in the laboratory

As soon as the samples arrive at the laboratory these are to be serially registered giving the date, identification mark and other relevant particulars furnished in the information sheet. .

Processing of the samples for analysis

1. Air dry the soil samples in shade.
2. For aggregate size distribution, dry the samples slowly and when sufficient friable, pass it gently through 8 mm sieve and air dry.
3. Crush the soil clods lightly and grind with the help of wooden pestle and mortar.
4. Pass the entire quantity through 2 mm stainless steel sieve.
5. If the gravel content is substantial, record as per cent of the sample (w/w).
6. For certain type of analysis (e.g. organic carbon), grind the soil further so as to pass it through 0.2 to 0.5 mm sieves.
7. Remix the entire quantity of sieved soil thoroughly before analysis.

*****

2. STUDY OF SOIL PROFILE AND ITS CHARACTERISTICS

Soil Profile

For a complete appraisal of soil, which can be considered to be a three dimensional unit, the surface features and characteristics as well as characteristics in depth need to be studied. Such a study can be made of the soil formed in depth, as can be seen in a soil profile. The vertical section of soil from surface down to hard rock from which the soil is formed is called soil profile. Each soil profile has a sequence of different layers is called horizon. A soil horizon can be defined as layer of soil approximately parallel to the soil surface with characteristics produced by soil forming processes.

Designations for horizons and layers

Capital letter symbols are used in designating soil horizons include A, 3, C and R. They indicate dominant kinds of departures from the parent material. The sub-divisions are indicated by placing an arabic number after the capital letter. Thus, symbols A1, A2, A3, B1, B2 are obtained. The layers in the profile are grouped as under:

1. The "O" group is a organic horizon which is formed above mineral soil. This results from litter derived from plant and animal residue.

2. The "A" group (zone of eluviation) is mineral horizon which lies at or near the surface. This is characterized as a zone of maximum leaching.

3. The "B" group (zone of illuviation) occur immediately below the "A" horizon in which maximum accumulation of material such as Fe and Al oxide and the silicate clay occur. These may have washed down from upper horizon or they may have formed in B horizon.

4. The "A" and "B" horizon together are called "solum". This portion of profile is developed by soil forming processes and is distinguished from the parent material.

5. The "C" horizon is the unconsolidated materials underlying the solum. It is less weather than solum and consequently has not been subject to horizon differentiation.

6. The "R" layer the parent rock laying below the parent material is termed as bed rock or R horizon.

7. **Regolith:** Solum plus parent material (A + B + C) is referred to as regolith.

Characteristics of different horizons

1. 'O' Horizon

The "0" group is an organic horizons which is found above the mineral soil. It formed of the plant and animal residues. It is separated in two divisions:

O1: In this horizon, plant and animal residues can be recognized by the necked eyes.

O2: It is also organic horizon in which original plant and animal forms can not be recognized by necked eyes.

2. A_1 horizon

It is a topmost mineral horizon. Organic matter is fully decomposed and mixed with mineral matter to give colour darker than lower one.

3. A_2 Horizon

It is a horizon of maximum eluviation of clay, Fe and Al oxides and O.M. Quartz and other resistant minerals are more. It is lighter in colour than the horizons above or below it.

4. A_3 Horizon

It is a transitional layer between A and B horizon with properties more nearly like those of A. Some time it is absent.

5. B_1 Horizon

It is also a transitional layer between A and B horizon with properties more like B than A. Some time it is absent.

6. B_2 Horizon

It is a zone of maximum accumulation of clays and Fe and Al oxides. Colour is darker than that of A2. Maximum development of blocky or prismatic structure or both. It is also known as illuvial horizon.

7. B_3 Horizon

It is a transitional horizon between B and C with properties more like B2 horizon.

8. 'C' Horizon

It is a horizon below A and B relatively less affected by the soil forming processes. It is outside the zone of major biological activity.

9. 'R' Horizon

It is underlying consolidated bed rocks.

Lowercase letter symbols to designates subordinate distinctions within master horizons

Letter	Distinction
a	Organic matter, highly decomposed
g	Gleying (mottling)
h	Illuvial accumulation of organic matter
i	Organic matter slightly decomposed
k	Accumulation of carbonates
n	Accumulation of sodium
o	Accumulation of Fe and Al oxides
p	Ploughing or other disturbance
q	Accumulation of silica
r	Weathered or soft bed rock
s	Illuvial accumulation of organic matter and Fe and Al oxides
t	Accumulation of silicate clays
w	Distinctive colour or structure
x	Fragipan (high bulk density, brittle)
y	Accumulation of gypsum
z	Accumulation of soluble salts

PROFORMA 'H'

I. Site characteristics data be collected for each soil profile

Profile No.			Soil type
Date of collection			Collected by
State	District	Tehsil	Village (town. city)
Relief	Elevation	Land form	Parent material
Drainage	Slope	Groundwater. depth and fluctuation. If any	
Erosion	Stoniness	Geology	Salinity and alkalinity
Climate	Present land use	Natural vegetation	

II. Profile characteristics

Horizon	Depth	Colour (Matrix)		Texture	Stucture (grade form & size)	Consistency	Roots	Clay films	pH & Co_3	Other Feaures (sticknsides, craks, fragments etc.)
		Dry	Moist							

Description of soil profile in the field

To describe a soil profile in the field, a vertical cut in situ is made (profile is dug in the field). Then horizons are demarketed and its characteristics are noted in standard Performa given in the exercise. A model description is given below:

ERU SERIES

Typifying pedon

Eru clay-cultivated. (Munsell colour notations are for dry soils unless otherwise noted).

AP	0-25 cms	Dark grayish brown (10 YR 4/2): very dark grayish brown (10 YR 3/2) moist; coarse columnar breaks into medium angular blocky peds, dry hard, moist firm. Wet sticky and plastic; fine roots many: very few fine (1-2 mm) lime nodules and gravels; clear and smooth boundary; pH 8.1.
A11	25-75 cms	Dark brown (10 YR 3/3); clay; very dark grayish brown (10 YR 3/2) moist; coarse angular blocky; slickenside pressure faces tending to intersect; dry very hard, moist firm, wet sticky and plastic; few fine lime nodules (1-2 mm), and gravels. Diffuse 'boundary; pH 8.3
A12	75-140 cms	Very dark grayish brown (10 YR 312) clay; coarse prismatic breaks into peds with slickenside pressure faces; very few fine lime nodules (1-2 mm) and gravels: dry very hard, moist very firm, wet sticky and plastic; diffuse boundary; pH = 8.3.
Cl	140-180 cms +	Very dark brown (10 YR 2/2); clay; massive very few fine lime nodules (1-2 mm) and gravels; dry hard. Moist firm, wet sticky and plastic; pH = 8.0.

JALALPUR SERIES

Typifying pedon: Jalalpur clay-cultivated (colour notations are for dry soils unless otherwise noted).

Ap	0-25 cms	Very dark grayish brown (10 YR 3/2) clay; coarse columnar blocky breaks into medium sub angular blocky peds; fine porous; few to many lime concretions (5-10 mm giving strong effervescence with dilute HCl; dry hard, moist firm, wet sticky; fine roots plentiful; clear and smooth boundary; pH = 7.9.
B_1	25-105 cms	Dark brown (!O YR 3/3) day; medium moderate sub angular blocky, wedge shaped peds with shining faces; lime concretions (5-10 mm) many, giving violent effervescence; with dilute HCl; few ferruginous concretions; dry very hard, moist firm, wet sticky and plastic; clear and smooth boundary; pH = 7.9.
B_2	105-131 cms	Dark yellowish brown (10 YR ¾ D & M) clay; medium moderate angular blocky; wedge shaped peds with shiny faces; Lime concretions (5-10 mm) plentiful along lower half of the peds giving violent effervescences; dry very hard, moist firm, wet sticky and plastic; many fine dark ferruginous concretions; clear and smooth boundary; pH = 7.9.
Cl	131-140 cms	Yellowish brown (l0 YR 5/4) silty clay loam; dark yellowish brown (10 YR 4/4 moist) Massive; lime concretions (5-10 mm) abundant; fine ferruginous concretions and gravels many; violent effervescences with dil. HCl; dry hard, moist firm, wet sticky; pH = 9.2.

another.

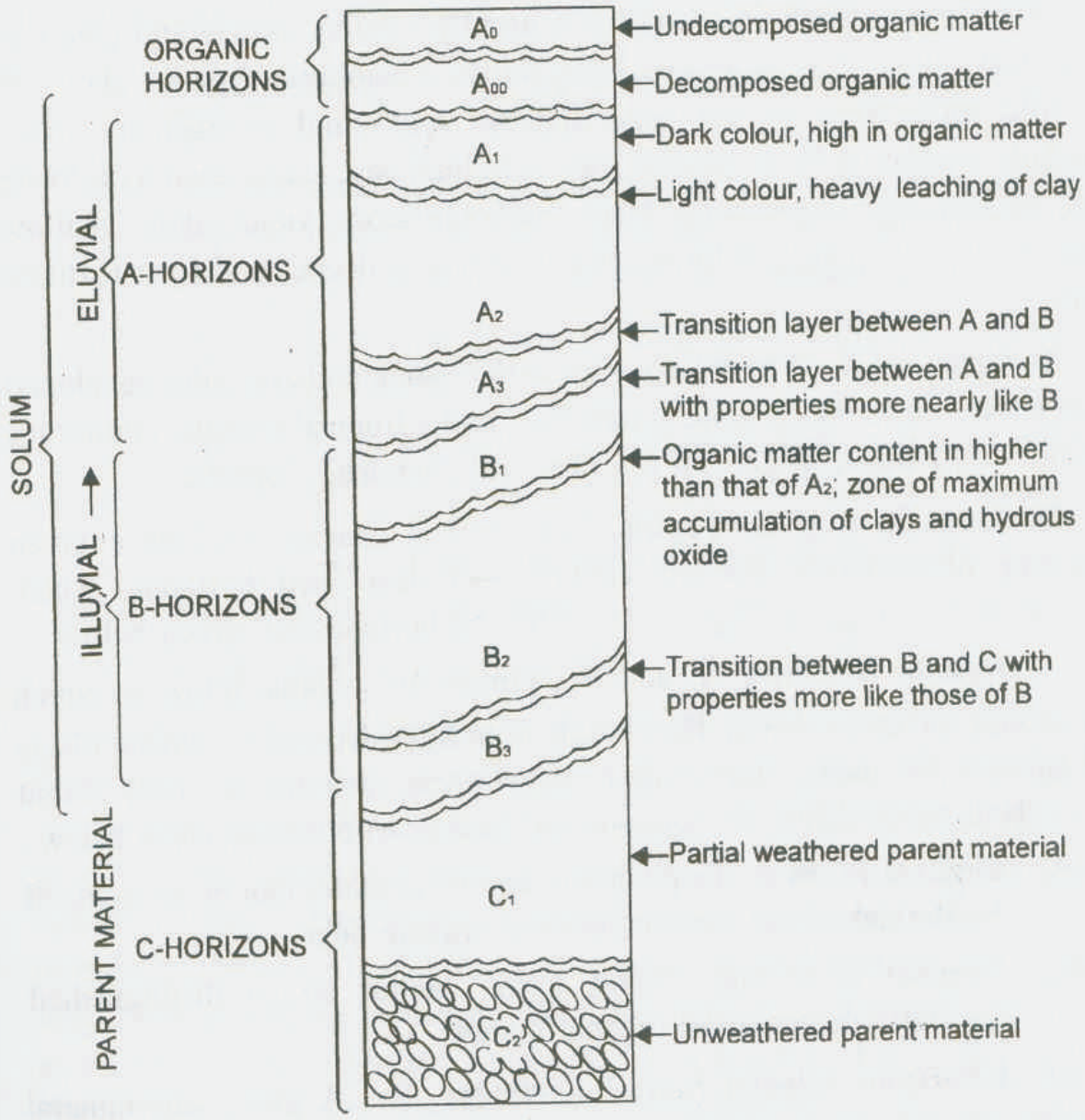


Fig. 20.1. A well-developed imaginary soil profile.

A well developed imaginary soil profile

*****

3. STUDY OF SOIL FORMING ROCKS

Rock is a consolidated mass of one or more minerals. It is a mixture of minerals and therefore their physical and chemical composition vary with the characteristics of minerals present in them.

Classification

Rocks are divided into three natural groups based on mode of origin of formation.

(i) Igneous (ii) Sedimentary and (iii) Metamorphic.

Igneous rocks are the oldest rocks, formed from the molten magma. Sedimentary rocks are formed from weathered igneous rocks. Both igneous and sedimentary rocks can be modified in to metamorphic rocks. All the three are weathered into soil parent materials.

1. Igneous rocks

The igneous rocks are formed by solidification of molten magma. These rocks are the primary rocks and make up about 95 % of the earth's solid' crust and on an average approximately 88 % of the mass of these rocks consists of feldspar, free quartz and amphibole Igneous rocks are further classified on the basis of (i) the depth of formation and (ii) the percentage of silica content.

(I) Classification on the basis of depth of formation

a. Plutonic

These rocks are formed when the magma solidified at greater depth about 2 to 3 miles deep under the surface of the earth. These are crystalline rocks as the size of crystals is bigger. e.g. granite, syenite, gabbro, norite etc.

b. Intrusive or dike

These rocks are formed when the magma solidified at moderate depth The crystals are smaller in size. e.g. dolerite, pegmatite etc.

c. Extrusive or volcanic or effusive

These rocks are formed when the solidification of magma takes place on the surface of the earth as a result of volcanic activity. e.g. Rhyolite, pumis, basalt, trap etc.

(II) Classification of Igneous rocks on the basis of percentage silica content

a. Acidic

SiO_2 content is more than 65 % e.g. granite, pegmatite, rhyolite

b. Intermediate

SiO_2 content is between 55 to 65 % e.g. syenite, diorite, andesite.

c. Basic

SiO_2 content is between 44 % and 55 -%. e.g. basalt, gabbro, dolerite etc.

d. ultrabasic

SiO_2 content is less than 44 % e.g. peridotite, picrite.

The characteristics of some important rocks are given in the table.

2. Sedimentary rocks

The weathering products of igneous and metamorphic rocks when transported by water or glaciers form new deposits, which in time become cemented and solidified into new form of rocks called the sedimentary rock. The water plays an important role in the formation of these rocks so they are also known as **aqueous rocks**. The different layers are formed by sediment deposition, which are cemented together with silica, lime, iron oxide etc. so they are also known as **stratified rocks**.

Classification

The classification of sedimentary rocks is based on the mode and mechanism of accumulation, consolidation and grain size.

(i) Transported mechanically and deposited

These rocks are formed due to accumulation of residues left during the operation of process of weathering and transportation or transported mechanically through water and then cemented to form rock. Depending upon their grain size, they are further grouped as:

a. Rudaceous

If the individual grains forming rocks are of the size of boulders and pebbles called Rudaceous. e.g. Grit and shingle are loose fragmented rocks of varying size and shapes. Grit is composed of sharp and angular sand. Single is composed of large rounded pebbles generally mixed with sand. Breccias are coarse-grained rocks, composed of angular fragments cemented in a matrix of fine sand.

b. Arenaceous

The rocks which have individual grain of sand size are classified in these group. e.g. Sand stone is, sand cemented by any cement like silica, lime, iron oxide, organic matters and clay. e.g. siliceous sand stone, calcareous sand stone, ferruginous sand stone, carbonaceous sand stone, argillaceous sand stone.

c. Argillaceous

The individual grains are of clay size the formation of these racks. They are also loose and consolidated. Various clays are loose sediments. Kaolin is China clay formed from the decomposition of feldspar. Pipe clay is iron free clay while fire clay is clay free from lime and alkalies. Shales are compacted clay rocks. They are porous, soft and of variegated colour white, red, yellow etc. Laterite rocks are composed of clay mixed with hydroxides of iron and aluminum.

(ii) Transported in solution and precipitated

a. Chemical precipitates

These rocks are formed due to precipitation and consequent accumulation of the soluble constituents traveling with the surface run-off. The precipitation may take place under suitable chemical environment or due to microbial activity. Calcareous rocks consist chiefly of calcium carbonate and are usually called lime stones. Quite a large variety of lime stones occur are of widely differing in purity, texture, hardness and colour. Rock salt and gypsum are precipitated due to drying up of inland lakes and seas.

b. Organic precipitates

These are the products of accumulation of organic matter and are preserved under suitable conditions. Coal, peat, lignite are the carbonaceous (carbon containing) sediments whereas the silicious (silica containing) rocks are composed of SiO_2 derived from plants and animals like diatoms etc.

3. Metamorphic rocks

The metamorphic rocks are formed from igneous and sedimentary rocks through the action of heat, pressure and chemically active liquids and gases. Metamorphism may result in changes mainly physical, chemical or both.

a. Thermometamorphic rocks

Very hot molten magma present beneath the earth crust, when moves from its place, comes in contact with other rocks. Due to enormous temperature of highly heated lava, the composition of rock which comes in contact is completely changed. Many times new rocks are formed.

e.g. Lime stone ⟶ Marble and calcite (Recrystalized)

Sand stone ⟶ Quartzite

b. Dynamqmetamorphicrocks

The weight of overlying rocks and their movement produces a great pressure and heat. Therefore, folding of rocks takes place. Because of pressure, the crystals of rocks become flat and stratas are formed. Many times new rocks are formed. This is called **dynamometamorphic rocks**. When the layers can not be separated, the rocks are called gneiss. eg. Granite gneiss, diorite gneiss etc. When the folias arc thinner (quite flat) and can easily be separated, the rocks are called **schist**. e.g. quartz schist, chlorite schist, talc schist, mica schist etc. Many a time the effect of high pressure is such that the original form of rock is completely changed, the folias are thin and in parallel flakes. e.g. shale to slate.

c. Hydrometamorphic rocks

The water is the most abundance of all the liquids. Circulating hot water may lead to variation in mineral-solution and redeposit them in the inter space of rocks as in quartzite or it may dissolve and recrystalize the minerals of rock.

e.g. Feldspar + Water ⟶ Muscovite mica + K - silicate + SiO_2

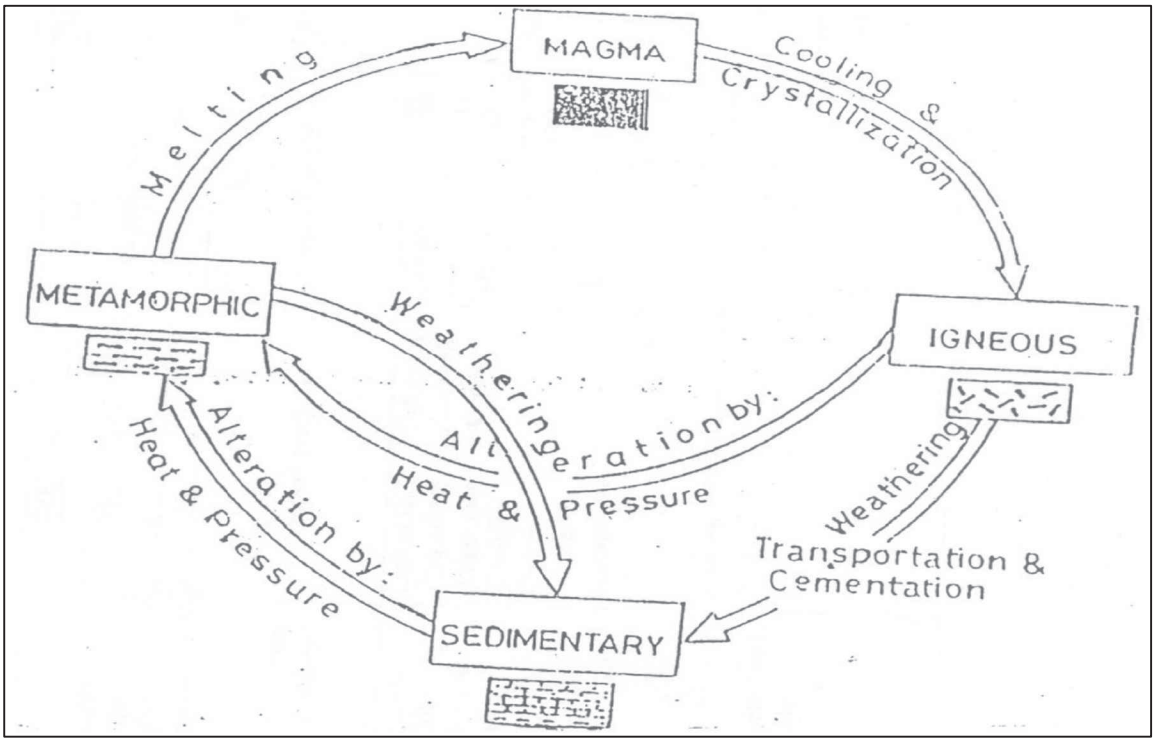


Fig.: A schematic diagram of rock cycle. The cycle, if uninterrupted, will continue from magma, through igneous rocks, sediments, sedimentary rocks, metamorphic rocks, and again to magma. It may be interrupted at various stages along its coarse to follow the altered path shown by arrows through the middle of the diagram.

CLASSIFICATION OF ROCKS

IGNEOUS		SEDIMENTARY						METAMORPHIC
On the basis of depth of formation	**On the basis of silica content**	**Transported mechanically and deposited**		**Transported in solution and precipitated**				
a. Plutonic (2-3 mile deep) -Granite -Syenite -Gabbro	a. Acidic (SiO_2>65%) -Granite -Rhyolite -Norite	Arenaceous or sandy	Argillaceous or clayey	Chemical precipitates		Organic precipitates		a. Thermometamorphic (non-foliated) e.g. Limestone to Marble-Sandstone to Quartzite
b. Instrusive or Dyke (moderate depth) –Dolorite - Pegmatite	intermédiate ($SiO_2$55-65%) -Syenite -Diorite	(i) Loose - Shingle - Grit	(i) Loose -Chinaclay -Pipeclay -Fire clay	Loss of CO_2 - Calcareous -Lime stone -Chalk -Dolomite -Stalactitie - Stalagmites	Evaporation -Rock salt -Gypsum	Siliceous-Diatomaceous	Carbona-ceous -Peat -Lignite -Coal	b. Dynamomctamorphic (foliated) -Bended folia-gneiss e.g. Granite gneiss Diorite gneiss - Thinner folia-schist e.g. Quartz schist Chlorite schist -Parallel folia-flakes Shale to Slate
d. Extrusive or volcanic (on the surface) -Rhyolite -Basalt -Trap -Pumis	c. Basic ($SiO_2$44-55%) -Basalt -Gabbro -Dolorite	(ii)Consolidated -Rudaceous -Conglomerate -Breccia -Sandstone -Stalac	(ii)Consolidated -Shales -Laterite					C. Hydrometamorphic Recrystalization of minerals in rock Feldspar--- Muscovite mica
	d. Ultrabasic (SiO_2<44%)- Peridotite- Picrite							

IMPORTANCE OF ROCKS: THEIR CHARACTRISTC AND MINEROLOGICAL COMPOSITION

Sr. No.	Name of Rocks	General Appearance	Mineralogical composition	Classification	Locality	Remarks
IGNEOUS ROCKS						
1	Granite	Light coloured, mixture of pink and white or black and white with shining medium granied hard rocks	Orthoclase feldspar, quartz and mica with or without hornblende	Igneous plutonic, acid rock	A.P., Belgam, -Khanpur, Vanakbori, -Dantiwada, Panchmahal, Sabarkantha.	High silica content. sp.gr. - 2.64g.cc
2	Syenite	Light coloured pale grey to pink, medium grained hard rocks	Little or absence of quartz, orthoclase feldspar, hornblende, sometimes little plagioclase feldspar.	Igneous plutonic sub acidic rock	--do--	Intermediate silica sp. gr. is 2.80.
3	Diorite	Greenish black, medium grained hard rocks	Plagioclase feldspar, hornblende, biotite and auite.	Igneous plutonic sub basic rocks	Dacan trap Junagadh.	, Sp. gr. is 2.80.
4	Basalt	Dark coloured very compact and fine grained rocks with micro crystalline structure	Plagioclase feldspar, Augite, Magnetite.	Igneous volcanic basic rocks	Trap area of South Gujarat and Saurashtra.	Av. sp. gr. is3.0, high content of basic ions and smooth surface
5.	Trap (Amygdaloidal)	Medium coloured fine grained compact rocks with cavities filled with zeolite.	Plagioclase feldspar, Augite and magnetite	Igneous volcanic basic rocks	Trap area, Dhari, Amreli,Rajkot, Gondal, Morbi, Botad.	-
6.	Trap (vesicular)	Medium coloured rock with greenish spots, grained with long vesicles.	Plagioclase feldspar, fine Augite and mgnetite.	Igneous volcanic basic rocks	--do--	-
7.	Trap (concretionary)	Medium coloured, fine grained, concretionary soft rock.	Plagioclase feldspar Augite, Magnetite	Igneous volcanic basic rocks	Trap area, Dhari, Amreli,Rajkot, Gondal, Morbi, Botad.	Irregular rounded mass
8.	Trap (Buff or red)	Buff coloured, fine grained, fairly compact rock, with unfilled cavities.	Plagioclase feldspar, Hornblende,Magnetite	Igneous volcanic basic rocks	Trap area Dhari, Amreli, Rajkot,Gondal, Morbi, Botad, Rajula etc.	-

SEDIMENTARY OR AQUEOUS ROCKS

8.	Shingle	Light red coloured loose mass composed of large rounded pebbles.	Mainly quartz	Loose, arenace ous sediment- tary rock	Gokak	Layers are compressed.
9.	Grit	Composed of sharp & angular sand with grey colour.	Mainly quartz	Loose, arenac-eous, sediment-tary rocks	Gokak	Layer can not be distinguished
10.	Conglomerate	Variously coloured consists of large rounded pebbles with elastic texture. present	Mainly quartz but pebble of other minerals are also	Consolidated arenaceous sedimentary rock	Gokak and Panchmahal	Hardly any layers are seen.
*	Breccia	Variously coloured coarse-grainedl rock composed of angular fragments fixed in the matrix of fine sand.	Mainly Quartz with other minerals	Consolidated arenaceous sedimentary	Gokak side near Varoli in Bombay	Layer can not be seen
11.	Sand stone (white)	Dirty white colour) granular mass made up of consolidated sand. Not so hard &compact.	Mainly quartz	--do--	Gokak, Morbi, Himatnagar, Bharuch, Panchmahal. Surendranagar districts	Rough to feel no layers
12.	Sandstone (Badami)	Slightly reddish colour, granular & rough to feel, medium hard rock	Mainly quartz	--do--	Gokak side near Varoli in Bombay	No Layers
13.	Sand Stone with Layers	Slightly red or red and layers grey coloured layers fine grain medium hard layered rock	Mainly quartz	--do--	Gokak and Belgam	Distinct layers
*	Sand stone black	Grey black some times with metallic iron luster. L coarse grained medium hard rock	Quartz with hydrated oxide of iron and aluminum as cementing material	--do--	Gokak	Very few layer to be seen
14.	Laterite	Brown red with yellow spots, vesicular medium hard rock, rough to feel hills	Mixture of hydrated oxids of iron and alumina	Consolidated argillaceous loose sedimentary	Belgam, Ratnagiri, Dharwar, Thana, Satara &Dang	It becomes hard when opened.

15.	Shale(White),	White coloured soft rock easily crumbling in hand extremely fine grained with definite layers	Mainly clay	Consolidated argillaceous Sedimentary rocks,	Dharwar	-
16.	Shale (Red) or (Pink)	Scarlet red coloured fine grain porous soft rocks with definite layers	Mainly clay	--do--	--do--	-
17.	Shale (Yellow)	Porous light yellow coloured soft rocks with layers	Mainly clay	--do--	--do--	-
18.	Lime stone, (Shahabad)	Light yellowish green colour with layer quite visible quick effervescence with acid	Mainly $CaCO_3$	Consolidated calcareous, Sedimentary rocks	Shahabad and Nizamudin	Layers are quite distinct
19.	Lime stone (Cuddapah)	Black colour with layers gives effervescence with acid	--do--	--do--	Madras near kaladgi in Bombay	Distinguished from black marble by layer
20.	Lime stone (Porbandar)	White granular mass with rough surface and gives effervescence with acid.	--do--	--do--	Saurashtra and Baroda	No layers
*	Lime stone (Sindh)	Dirty white granular porous, some times cellular fairly soft	--do--	--do--	Punjaband Sindh .	-
*	Limestone (Bagalkot)	Red coloured hard, gives effervescence with acid	--do--	--do--	Bagalkot	No layer
21.	Coal	Black shining colour with layers	Carbon	carbonaceous sedimentary rock	Kutch and some part of Saurashtra, Raniganj, Bengal	-
METAMORPHIC ROCKS						
22.	Quartzite	Fine granular mass rather rough to feel dull whitish grey colour without layer	Entirely quartz	Hydro metamorphic rocks	Gokak and Kandala	-
*	Hematite quartzite	Alternate layer of hematite and quartzite, yellowish brown coloured hard rock	Hematite and quartz	--do--	Gokak and Bagalkok	-

23.	Granite gneiss	White and pink colour with layers arranged in a parallel manner but are compact	Quartz, orthoclase feldspar hornblende and mica	Dynamo metamorphic rock (foliated)	Gokak, Khanpur, Mysore, Baroda, Sabarkantha, Banaskantha	Layers are not distinct, can not be separated
24.	Granite Schist	Light coloured & white or pink with layers	--do--	--do--	--do--	Layers can be easily separated
25.	Mica schist	Various colour like light green, pink, white or black, shining foliated soft rocks	Mica and few crystals of quartz	--do--	Gokak,Mysore, Nellore, Panchmahal	--do--
*	Quartz mica schist	Light coloured rocks with mica forming thin layer	Quartz is abundant mica is also an imp. constituent	--do--	Gokak	-
26.	Chlorite schist.	Green coloured foliated rocks	Mainly chlorite with quartz, feldspar, mica	--do--	Khambhat and granite area	--do--
*	Hornblende schist	Dark green coloured fairly soft rocks with elongated crystals	Mainly hornblende	--do--	Gokak	-
*	Talc schist	Greenish white mass soft and soapy to feel layers are seen	Chiefly talc	--do--	Near Mewad and Ajmer in Rajasthan	Very soft rocks
27.	Slate	Grey to black colour compacted and uniform texture, foliated structure	Mainly clays (formed from shale)	--do--	Kaladgi, Champaner (Baroda)	--do--
28.	Marble(white)	White shining and crystalline appearance readily gives effer-vescence with acid, Hard rock	$CaCO_3$ (Recrystalize)	Thermo metamorphic rocks	Jabalpur,Ambaji (Palanpur), Jesalmer, Indore	No layer
29.	Marble(green)	Green coloured shining & crystalline appearance, readily gives effervescence with acid, hard rock	--do--	--do--	--do--	--do--

ROCKS FOUND IN GUJARAT

	Rocks	Locality
1.	Granite	Kadana, Pavagadh, Sabarkantha
2.	Clay rock	Tadkeswar
3.	Mica schist	Panchmahals
4.	Quartzite	Kadana
5.	Quartz mica schist	Kadana, Amreli
6.	Dolerite	Amreli
7.	Lime stone (white)	Baroda
8.	Lime stone	Tadkeswar, Chorvad, Porbandar, Amreli, Morbi, Jamnagar, Limbadi, Banaskantha, Sabarkantha.
9.	Granite gneiss	Baroda
10.	Marble (Black & White)	Ambaji, Palanpur, Idar, Rajpipla.
11.	Gneiss	Sabarkantha, Banaskantha.
12.	Dolomite	Ambaji
13.	Sand stone	Morbi, Himatnagar, Bharuch, Panchmahals.

*****

4. STUDY OF SOIL FORMING MINERALS

The minerals are the naturally occurring inorganic, homogeneous substances having definite chemical composition, physical properties and specific geometric forms (crystal) such as quartz, orthoclase etc.) From agricultural stand point, soil minerals are important because they provide.

(i) plant nutrients (ii) space for water and (iii) physical supports to plants.

Characteristics of minerals

The minerals have definite chemical composition. Mostly they exist as salt or oxides. Besides having definite chemical composition, the minerals have more or less definite physical properties viz. colour, luster, transparency, crystallinity, streak, hardness, cleavag e and specific gravity by means of which they can often be identified right in the field and laboratory.

Physical characteristics

1. Colour

Each mineral has got its characteristic colour, which give some indication for its classification. But in nature, colour of mineral is greatly variable and is dependant on its chemical composition. e.g.

1. Colourless	Quartz
2. White to pale	Feldspar, dolomite, gypsum muscovite mica, kaolin
3. Yellow	Iron pyrite, sulphur
4. Greenish	Olivine, serpentine
5. Reddish brown	Garnet
6. Black	Biotite mica, haematite, magnetite, graphite, augite

2. Luster

It is reflection of light from the surface of the mineral. There are several types of mineral lusters. viz.

(i) Metallic	:	The luster of metals e.g. copper pyrite, iron pyrite, graphite
(ii) Vitreous	:	The luster of glass e.g. rock crystal, rock salt
(iii) Resineous	:	The luster of yellow resin e.g. peach stone

(iv) Pearly : The luster of pearl
e.g. Mica

(v) Silky : The luster of silk
e.g. asbestos

(vi) Adamantine : The luster of diamonds
e.g. Diamond

(vii) Waxy : The luster of wax
e.g. Flints (greasy like oil)

3. Structure

The structure refers to the typical shape or forms of crystal fragment or mineral aggregate. There are 6 basic systems of crystalline forms.

(i) Monometric or cubical: The three axes are of equal length and at right angles to one another as in cube. egogalena, halite, garnet.

(ii) Dimetric or tetragonal: Two axes ate equal and one unequal. All these axes are at right angles to one another. e.g. zircon.

(iii) Trimetric or orthorhombic: There are 3 axes, all at right angles but of different lengths. e.g. sulphur, olivine.

(iv) Monoclinic: There are 3 unequal axes, two of which are not at right angles, while the third makes a right angle with the plane of other two. e.g. orthoclase, gypsum,

mica, horn-blende.

(v) Triclinic: This has 3 unequal axes but none form right angle with any other pyramide like. e.g. plagioclase.

(vi) Hexagonal: This has 3 equal axes at 120° arranged in one plane and one more forth axis of a different length at right angle to the other three. e.g. quartz, calcite.

The arrangement of crystals gives rise to several kinds of structures:

1. Granular 2. Lameller (like plates) 3. Columnar
4. Reticulated 5. Stelleted and 6. Drusy

4. Transparency

It is the degree of the penetration of light through a mineral. viz.

Transparent – e.g. Mica

Translucent – e.g. Quartz

Opaque - e.g. pyrite

5. Streak

It is the colour of finely divided powder obtained when the mineral is rubbed on a piece of unglazed porcelain plate. If the mineral is harder than the porcelain plate the streak can be obtained by scratching the surface of the specimen with a piece of corundum. Some times the colour of the streak differ from the colour of the mineral. e.g.

Minéral	**Colour**	**Streak**
Heamatite	Reddish black	Red
Magnetite	Black	Black
Limonite	Black	Yellowish
Iron pyritie	Brass yellow	Greenish black
Apatite	Pink to yellow	White

6. Hardness

Hardness of mineral is defined as the resistance offered to scratching or abrasion. The hardness of mineral is determined by scratching the smooth surface of one mineral with the edge of another. The diamond is the hardest as it can scratch all the substance in this universe. Hardness is referred to by number from one to ten. Mho has arranged the minerals in order of increasing hardness which is known as **Mho's scale of hardness**. This is as under:

Mineral	Relative hardness
Talc	1 - softest
Gypsum	2
Calcite	3
Fluorite	4
Apatite	5
Feldspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10- hardest

With the use of this scale, hardness of other mineral can be determined. e.g. If a given mineral scratch gypsum but not to calcite, its hardness is between 2 and 3. As a rough and ready method the following scale is useful.

Finger nail - 2.5, Copper - 3.0, Glass - 5.5 and Iron (sharpknife) - 6.5

7. Cleavage

It is the property of certain minerals to split along planes to one or more faces when they are struck with a hard object. e.g.

Cubical Cleavage	:	Cleavage in three direction at right angle. e.g. galena.
Rhombohedral	:	In three direction but not in right angle – rhombic e.g. calcite.
Basal	:	In one direction e.g. Mica.
Fracture	:	Irregular e.g. glass and quartz.

8. Specific gravity

It is the ratio the weight of mineral and weight of an equal volume of water. It is more or less constant and hence the substance can be easily recognized from its sp. gr. e.g. gypsum 2.3, quartz 2.65 and hematite 5.3. If specific gravity is more than 2.85 is called heavy Minerals and less than 2.85 light minerals.

Classification of minerals

The minerals are classified by two ways on the basis of their (i) origin and (ii) chemical composition.

(I) On the basis of origin

On the basis of origin and mode of formation, the minerals can be classified as (1) Primary minerals and (2) Secondary minerals.

I. Primary minerals

When a mineral arises trom the cooling and solidification ofa molten megma, it is called primary minerals. e.g. given in table

2. Secondary minerals

When a mineral arises through the metamorphism or weathering of primary or other pre - existing minerals, it is called secondary minerals. e.g. given in table.

(II) On the basis of chemical composition

The minerals have definite chemical composition and they are found in compound form in the rocks except few are found in elemental form. According to their chemical composition, minerals are divided into eight groups as under:

(1) Silicate	(2) Elements	(3) Oxides	(4) Sulphates
(5) Carbonates	(6) Sulphjdes	(7) Phosphates	(8) Halides

Classification of minerals

According to origin and mode of formation

I. PRIMARY

Orthoclase Feldspar	-$KAlSi_3O_8$
Albite Feldspar	-$NaAlSi_3O_8$
Anorthite Feldspar	-$CaAl_2\ Si_3O_8$
Quartz	-SiO_2
Hornblende	-$Ca_2Al_2Mg_2Fe_3Si_6O_{22}\ (OH)_2$
Muscovite mica	-$KH_2Al_3\ (SiO_4)_3$
Biotite mica	-$KH_2(Mg,\ Fe)_3\ Al\ (SiO_4)_3$
Augite	-$Ca_2\ (Al,\ Fe)_4\ (Mg,\ Fe)_4\ Si_6O_{24}$

II. SECONDARY

Calcite	-$CaCO_3$
Magnesite	-$MgCO_3$
Dolomite	-$CaMg\ (CO_3)_2$.
Sederite	-$FeCO_3$
Gypsum	-$CaSO_4\ 2H_2O$
Apatite	- $Ca_5\ (Fe,\ Cl,\ OH)\ (PO_4)_3$
Limonite	- $FeO(OH)nH_2O$ or $Fe_2O_3.3H_2O$
Hematite	- Fe_2O_3
Gibbsite	- $Al_2O_3.3H_2O$
Clay minerals:	
Kaolinite	- $Al_2\ (OH)_4\ Si_2O_5$
Montmorillonite	- $Al_2\ (OH)_2\ Si_4O_{10}$
Hydrous mica	- $KAl_2\ (OH)_2\ (Al.\ Si)_3\ O_{10}$

According to chemical composition

I. SILICATE

Muscovite, Biotite

Feldspar, Olivine

Epidote:$Ca_3(AlFe)_3OH(SiO_4)_3$

Zeolite-$CaAlSi_7O_4.7H_2O$

Amphibole

2. ELEMENTS

Graphite-(C)

Diamond-(C)

Sulphur-(S)

3. Oxides

Quartz- SiO_2

Hematite-Fe_2O_3

Goethite- $FeO(OH)$-Fe_2O, H_20

Limonite-$Fe_2O_3.3H_20$

Magnetite-Fe_3O_4

Pyrolusite-MnO_2

Rutile- TiO_2

4. SULPHATES

Gypsum-$CaSO_4.2H_2O$

Baryte- $BaSO_4$

Anhydrite-$CaSO_4$

5. CARBONATES

Calcite-$CaCO_3$

Magnesite-$MgCO_3$

Dolomite-$CaMg(CO_3)_2$

6. SULPHIDE

Copper pyrite - CuS_2

Iron pyrite - FeS_2

Galena - PbS

7. PHOSPHATES

Apatite

$Ca_5(Fe,Cl.\ OH)(PO_4)_3$

8. HALIDES

Fluorite-CaF_2(Fluorspar)

Rock salt- NaCl (Halite)

Chemical composition and physical characteristics of important minerals

Sr. No.	Mineral	Chemical composition	Colour	Streak	Luster	Opacity	Hardness	Sp. gr.
I. Elemets								
1.	Graphite	C	Steel grey	Dark shining	Metallic	Opaque	1	2.2
2.	Sulphur	S	Yellow	Yellow or white	Resineous	Translucent	1-2	2.07
II. Oxides								
3.	Rock crystal (Quartz)	SiO_2	Various	White	Vitreous	Transparent	7	2.6-2.7
4.	Amethyst	SiO_2	Purple	White	Vitreous	Translucent	7	2.65
*	Rutile	TiO_2	Brown	Pale brown	Adamantine	Transparent	6-6.5	4.25
5.	Milkquartz	SiO_2	Milk white	White	Vitreous	Translucent	7	2.65
6.	Chalcedony	SiO_2	Variously coloured	White	Resineous	Opaque	7	2.6
*	Brucite	$Mg(OH)_2$	Greenish white	White	Pearly to vitreous	Translucent	2.5	2.39
7.	Carnelian	SiO_2	Yellow red	White	Resinous waxy	Translucent	7	2.6
*	Gibbsite	$Al(OH)_3$	Greenish grey	White	Pearly to vitreous	Transparent	2.5	2.39
8.	Agate	SiO_2	Variegated colours	White	Resineous waxy	Translucent	7	2.6
*	Goethite	$FO_3.H_2O$ or FeO (OH)	Blackish brown yellow	Brownish	Adamantine	Transparent	5.5-5	3.3-4.3
9.	Flint	SiO_2	Smoky brown bluish	White	Resineous waxy	Translucent	7	2.6
10.	Jaspar	SiO_2	Dull red, brown yellow	White	Dull (earthy)	Opaque	7	3.6

11.	Opal	SiO_2	All coloured white, yellow, brown, grey etc.	White	Sub vitreous	Translucent	5.5-6.5	1.9-2.3
12.	Haematite	Fe_2O_3	Steel grey	Rcd	Earthy to metallic	Opaque	5-6.5	4.9-5.2
*	Iimenite	$FeTiO_3$	Black	Black	Metallic	Opaque	5-6	4.72
13.	Limonite	$2(Fe_2O_3).3H_2O$ $FeO(OH)_2nH_2O$	Yellowish	Brownish	Earthy	Opaque	5-5.5	3.6-4.0
14.	Magnetite	Fe_3O_4	Black	Black	Dull metallic	Opaque	5.5-6.5	4.9-5.2
*	Pyrolusite	MnO_2	Dark grey to black	Black	Metallic	Opaque	6-6.5	5.06
15.	Corundum	Al_2O_3	Red, brown, black	White	Vitreous	Opaque	9	4
III. Silicates								
16.	Plagioclase feldspar	$Na(AlSi_3O_8)+Ca(Al_2Si_2O_8)$	White greenish & reddish	White	Pearly	Translucent	6-6.5	2.6-2.76
*	Albite	$NaAl\ Si_3O_8$	Greyish white	White	Sub vitreous	Translucent	6	2.6-2.76
*	Anorthite.	$CaAl_2Si_3O_8$	Greyish white	White	Sub vitreous	Translucent	6	2.6-2.76
*	Oligoclase	$Na_2CaAl_2Si_6O_{17}$	Greyish white	White	Sub vitreous	Translucent	6	2.6-2.76

17.	Orthoclase Feldspar	$KAlSi_3O_8$	Colourless to pinkish white	White	Vitreous to pearly	Translucent	6	2.56
*	Microcline	$KalSi_3O_8$	Creamy to pinkish white	White	Vitreous to pearly	Translucent	6	2.56
18.	Zeolite	Ca.K.Na.Al. silicates	White	White	Vitreous to pearly	Translucent	6	2.8
*	Stilbite	$CaAl_2Si_7O_{18}7H_2O$	Creamy to pinkish white	White	Vitreous to pearly	Opaque	4	2.1-2.2
*	Kaolinite	$Al_4Si_4O_{10}(OH)_8$	Whitish grey	White	Pearly	Opaque	1	2.6
*	Montmorillonite	$Al_2Si_4O_{10}(OH)_2xH_2O$	Greyish yellow	White	Dull	Opaque	2-2.5	2.6
*	Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$	Yellowish white	White	Pearly	Opaque	1-1.5	2.84
*	Serpentine	$Mg_6Si_4O_{10}(OH)_8$	Greenish yellow to greyish brown	White	Waxy to silky	Opaque	4-6	2.5-2.6
19.	Muscovitemica	$KAl_2(AlSi_3O_{10})(OH)_2$	Colourless to white	White	Pearly to vitreous	Translucent	2.5	2.8-2.31
20.	Biotitemica	$K(Mg,Fe,Mn)_3(AlSi_3O_{10})(0H)_2$	Brown to dark green	Grey	Vitreous to pearly	Translucent	2.5-3.0	2.8-3.4
*	Galuconite	$K(Fe,Mg,Al)_2(Si_4O_{1O})(OH)_2$	Green to brown	Greenish grey	Earthy	Opaque	2-3	2.5-2.8
*	Apophyllite	$KCa_4(Si_4O_{lO})_2F.8H_2O$	Pinkish white	White	Pearly to vitreous	Translucent	5	2.35
*	Chorite	$Mg_{1O}Al_2(Si_6Al_2)O_{22}(OH)_{16}$	Brownish green	Greenish white	Earthy to pearly	Translucent	1.5-2.5	2.6-3.3

21.	Hornblende	$NaCa(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$	Dark green to brown or black	Greyish	Vitreous	Opaque	5.5-6.0	3.0-3.4
*	Augite	$Ca(Mg, Fe, Al)(Al, Si)_2O_3$	Dark green	Whitish grey	Vitreous	Opaque	6	3.2-3.5
*	Enstatite	$MgSiO_3$	Light green	White	Vitreous	Opaque	6	3.2-3.9
*	Epidote	$Ca_2(Al, Fe)_3Si_3O_{12}(OH)$	Brownish	Greyish white	Vitreous	Opaque	7	3.3-3.6
22.	Talc	$Mg_3Si_4O_{10}(OH)_2$	Greyish white	White	Pearly	Translucent	1	2.82
*	Vermiculite	$Mg_3Si_4O_{16}(OH)_2xH_2O$	Yellow	White	Pearly	Opaque	1.5	2.4
23.	Actinolite	$Ca_2(Mg,Fe)_5Si_3O_{22}(OH)_2$	Green	Greenish white	Vitreous	Opaque	5.5	3.35
24.	Olivine	$MgFeSiO_4$	Olive green to dark green	Whitish grey	Vitreous	Opaque	6.5	3.2-4.3
*	Zircon	$ZrSiO_4$	Various colour	white	Vitreous	Opaque	7.5	-
25.	Tourmaline	$Na(Mg,Fe)_3Al_6(BO_3)_3(Si_6O_{18})(OH)_4$	Blackish brown to dark blue	White	Vitreous	Opaque	7.5	3.0-3.2
IV. Carbonates								
26.	Calcite	$CaCO_3$	Colourless to white	White	Vitreous	Translucent	3	2.71
*	Magnesite	$MgCO_3$	Brownish	Brown	Dull meallic	Opaque	5.5	-
*	Dolomite	$CaCO_3\ MgCO_3$	White	White	Vitreous to pearly	Translucent	3.5-4.0	2.85

V. Sulphates								
*	Anhydrite	$CaSO_4$	White	Greyish white	Vitreous	Translucent to Translucent	3.5	2.96
*	Baryte	$BaSO_4$	White	White	Vitreous	Translucent	3-3.5	4.48
*	Gypsum	$CaSO_4.2H_2O$	Colourless or white	White	Vitreous to pearly	Translucent to Translucent	2	2.32
VI. Sulphide								
27.	Iron pyrite	FeS_2	Brass yllow	Greenish black	Metallic	Opaque	6-6.5	5.01
*	Copper pyrite	CUS_2	Brass yellow	Greenish black	Vitreous	Opaque	3.4	3.1
28.	Galena	Pbs	Grey	Grey black	Metallic	Opaque	4-5	3.2
VII. Phosphates								
*	Apatite	$Ca_3(P0_4)_2(F,Cl,OH)$	Pink to yellow	White	Vitreous	Transparent to Opaque	5	3.1-3.2
VIII. Halides								
29.	Fluorite(Fluorspar)	CaF_2	Violet blue	Colourless	Vitreous	Opaque	4.0	3.1
30.	Halite(rocksalt)	NaCl	Bluish white	Colourless	Vitreous	Opaque	2.5	2.1

INFORMATION ON SOME IMPORTANT MINERAL FOUND IN GUJARAT

Sr. No.	Name	Rank of Gujarat All India basis	Occurrence in Gujarat	Uses
1.	Boxite	Second	(Kutch), Jamnagar, Junagadh, Amreli, Bhavnagar districts	Aluminum industries
2.	Calcite	Second	Bhavnagar, Jamnagar, Junagadh, Surendranagar, Rajkot, Amreli districts	Manufacturing for powder optical industries. Mattlegical operation and pottery work for shlning in chalk.
3.	Chalk	First	Bhavnagar, Junagadh districts	-
4.	Fire clay	Second	Surendranagar, Rajkot, Tadkeswar	Pottery bricks
5.	Silica sans	Second	Surendranagar district	Glass ware industries
6.	Moulting sans	Third	Bhavnagar,Junagadh	Costing process in foundry industries
7.	Gypsum	Fourth	Jamnagar, Junagadh, Bharuch, Porbandar	Cement industries, Plaster of paris, Ammonium sulphate, H_2SO_4,Paint, Power industries
8.	Horspar	Fifth	Junagadh,	Copper & lead.
9.	Okar	Sixth	Jamnagar, Surendranagar, Bhavnagar	Ceramic, Cement industries.
10.	Limestone	Seventh	Amreli, Bhavnagar, Junagadh, Rajkot, Jamnagr, Surendranagar, Kutch	Cement, Slate pen, Chemical washing powder
11.	Feldspar	-	Junagadh	-
12.	Agate	-	Tadkeshwar	-
13.	Conglomarate	-	Panchmahal, Dhari, Rajula, Amreli, Rajkot, Gondal, Morbi	-
14.	Biotite mica	-	Baroda	-
15.	Coal (Lignite)	-	Kutch & some part of Saurashtra	-
16.	China clay	-	Mehsana, Sabarkhatha, Bharuch, Junagadh	-
17.	Asbestose	-	Sabarkatha,	-

Observations and Calculations

(A) Particle density (Dp)

1. Weight of empty pycnometer (R.D.bottle)=W_1= _____ g.
2. Weight of empty pycnometer + Water = W_2 = _____ g.
3. Weight of R.D. bottle + soil + Water =W_3 = _____ g.
4. Weight of soil taken = 10 g.

Calculation

Weight of water displaced by soil i.e. volume of

Soil solids= $(W_2 + 10) - W_3$ =

$$\text{Particle density (Mg M}^{-3}) = \frac{10}{(W_2 + 10) - W_3} = \_\_\_\_\_$$

(B) Bulk density (Db)

Observations

1. Weight of empty bottle =W_1= _____ g.
2. Weight of bottle+ soil =W_2= _____ g.
3. Volume of soil or volume of water needed to fill the bottle =V= ____ml.

Calculation

Weight of soil = $W_2 - W_1$ = _____ g.

Volume of soil = V = _____ml.

$$\text{Bulk density (MgM}^{-3}) = \frac{(W_2 - W_1)}{V} = \_\_\_\_\_$$

=_____

(C) Porosity of soil

Observations

1. Bulk density of a soil = (Db) = _____ Mgm^{-3}
2. Particle density of a soil = (Dp) = _____ Mgm^{-3}

$$\text{Per cent pore space} = 100 - \left(\frac{Db}{Dp} \times 100\right)$$

=_____%

5. DETERMINATION OF DENSITIES OF SOIL

(A) Measurement of particle density (Dp) of soil

The Particle density of a soil is referred to the mass of a unit volume of soil particles (Soil solids). It determined by measuring the mass and volume of soil solids.

Principle

When a known mass of dry soil is immersed in water and air is expelled out, the amount of displaced water equals to the volume of soil particles.

Equipments

1. Pycnometer (R.D. bottle) and 2. Balance.

Procedure

1. Weigh empty pycnometer.
2. Fill the dry pycnometer with water completely.
3. Wipe outer side of the pycnometer with apiece of filter paper and weigh it.
4. Pour out water and dry it from outside with a piece of filter paper.
5. Put 10 g of oven-dry soil into the pycnometer.
6. Fill the pycnometer up to top with water using the pipette and wash with a jet of water any particles sticking to the inner side of the neck.
7. Expel the entrapped air by gently boiling the contents.
8. Allow the contents to cool to room temperature and fill the pycnometer to the brim/ mark with boiled and cooled water.
9. Fix the stopper well.
10. Clean the outer side of the pycnometer with a filter paper and weigh it.

B. Measurement of bulk density (Db) of soil

(Laboratory method for disturbed soil)

Bulk density is defined as the ratio of mass of oven dry soil to its bulk volume and is expressed as g cm^{-3} or Mgm^{-3}. The bulk volume is the volume of soil particles plus pore space.

Relationship between porosity and densities of soil:

$$\% \text{ solid space} = \frac{\text{Bulk density}}{\text{Particle densit}} \times 100$$

Since, % pore space + % solid space = 100

Or % pore space = 100 -% solid space

$$\text{or} \quad \% \text{ pore space} = 100 - \frac{\text{Bulk density}}{\text{Particle density}} \times 100$$

$$\% \text{ pore space} = 100 \left[1 - \frac{\text{Bulk density}}{\text{Particle density}} \right]$$

(D) Weight of a hectare soil

Wt. of a hectare soil (t/ha) up to 15cm depth = Db x 1000x 10000x Depth (m)

=_____

=_____kg/ha

=_____t/ha

Principle

The mass of the oven-dry soil which fills the container of a known volume is determined by weighing. The volume of the packed soil will be equal to the capacity of the container. Bulk density is then calculated as the ratio of mass of soil to its volume.

Equipments and materials

1. Plastic bottle of 100 ml capacity 2. Balance.

Procedure

1. Weigh an empty large weighing bottle of about 50 ml capacity or specific gravity bottle without stopper.
2. Fill the bottle with soil up to the brim and tap it 15-20 times by letting it fall gently on the table from a height of approximately 2.5 cm each time. (This tapping is assumed to produce the same. state of packing as occurring naturally in the field. However, this assumption is not strictly correct.)
3. Empty the bottle and find its volume by filling it completely with water from a burette.

(C) Measurement of porosity of soil

Porosity of a soil sample is its that volume which is occupied by air and water or porosity of a soil is the fraction of soil volume not occupied by soil particles.

Procedure

1. Determine the soil bulk density (Db) and particle density (Dp)
2. Calculate the total porosity.

(D) Calculate the wt of a hectare soil

Result 1. Use bulk density of soil

Sample	Dp Mg m^{-1}	Db Mg m^{-1}	% porosity	Wt. of soil (t ha^{-1})
Soil				

*****

Observations (for soil):

1. Wt. of empty watch glass (A) =_____
2. Wt. of watch glass + moist soil sample (B) =_____
3. Wt. of sample (B-A) =_____
4. Wt. of watch glass + oven dry sample (C) =_____
5. Moisture content in sample (B-C) =_____

Calculations:

$$\text{Percentage moisture in soil} \quad \frac{(B-C)}{(B-A)} \times 100$$

= _____

Observations (for plant):

1. Wt. of empty watch glass (A) =_____
2. Wt. of watch glass + plant sample (B) =_____
3. Wt. of sample (B-A) =_____
4. Wt. of watch glass + oven dry sample (C) =_____
5. Moisture content in plant sample (B-C) =_____

Calculations:

$$\text{Per cent moisture in plant} = \frac{B - C}{B - A} \times 100$$

=

6. DETERMINATION OF MOISTURE CONTENT FROM SOIL AND PLANT

Water is essential for all forms of life. It plays a very significant role in soil-plant growth relationship. In plant growth, water not only forms a major part of the plant itself, but it is also essential for the process of photosynthesis, acts as a solvent and nutrient carrier and maintains the turgidity of the plant. In fact, the soil water is a great regulator of physical, chemical and biological activities in the soil. Determine moisture in the air-dry sample and use the value so determined for expressing all subsequent calculations on an oven dry basis. This is necessary as the moisture in the bulk sample may very considerably with changes in atmospheric humidity. Water in a soil is measured by (i) Gravimetric method (ii) Neutron Scattering (iii) Gamma rays attenuation and (iv) Soil moisture tension. Gravimetric method is the simplest one so it is described here:

Principle

Weighed soil sample is place in an oven at 105°C and it is dried to constant weight. The weight difference is considered to be water present in soil sample. An error can result from the oxidation of organic matter.

Apparatus

1. Watch glass 2. Balance 3. Oven 4. Desiccator

Procedure

1. Weigh the watch glass to the nearest 0.1 g.
2. Weigh accurately 5 g of soil / 1 g plant sample and put it immediately on the watch glass and cover it to prevent loss of moisture by evaporation.
3. Place the watch glass in oven at 105°C (in case of soil) and 70 °C (in case of plant) for 24 hrs.
4. Allow the sample to cool for some time in oven. Then close the watch glass and put it in desiccator for further cooling. After the completion of this step, weigh the closed can with the oven dry soil or plant sample.
5. Calculate the moisture percentage in soil and plant sample.
6.

Result

Sample	**Soil**	**Plant**
% Moisture		

Observations and Calculations

Observations

1. Weight of empty brass cup = W_1 = _____ g.
2. Weight of brass cup + soil =W_2 = _____ g.
3. Weight of brass cup + Soil + water = W_3 = _____ g.
4. Weight of water absorbed by filter paper =W_4 = 0.5 g.

Calculation

1. Weight of oven-dry soil =$W_2 - W_1$ = _____ g.
2. Weight of actual water absorbed by soil = $(W_3-W_2) - W_4$ = _____ g.
3. Maximum water holding capacity of soil (%)

$$\text{MWHC (\%)} = \frac{\text{Moisture held by soil}}{\text{Weight of dry soil}} \times 100$$

$$= \frac{(W_3-W_2) - W_4}{W_2 - W_1} \times 100$$

= _____

= _____%

7. DETERMINATION OF MAXIMUM WATER HOLDING CAPACITY (MWHC) OF SOIL

Maximum water holding capacity is the amount of moisture absorbed (i.e. macro and micro pore space is completely filled with water) per unit weight of dry soil, when placed in water under saturated condition. It is expressed in terms of percentage. It is also called as maximum water retentive capacity of soil. The moisture retains is governed by inherent characteristics of soil such as

1) Texture
2) Type and amount of clay minerals
3) Particle size distribution
4) Organic matter content
5) Capillary and non-capillary porosity.

The maximum water holding capacity is of great value in practical agriculture since it provides a simple means of determining soil moisture content required for good plant growth.

Principle

When a thin layer of soil is allowed to absorb water from a free water surface total pore space gets completely filled with water gradually. The amount of water thus retained in the soil helps in calculating maximum water holding capacity of the soil.

Apparatus/Materials

1. Brass cup with cap.
2. Filter paper
3. Balance.
4. Weigh box
5. Petri dish
6. Spatula

Procedure

1. Weigh an empty brass cup with cap and filter paper.
2. Fill up the dry soil in brass cup with gentle taping after removing the cap.
3. Tap the brass cup and level the soil with a help of spatula.
4. Remove the outer soil with the help of brush and place the cap on brass cup.
5. Weigh the brass cup with soil and cap.
6. Place the brass cup in a petri dish containing water (See that the brass cup should be submerged in water up to 1/4th depth).

Calculation

Relationship between moisture constants

(1)

Hygroscopic coefficient (H.C.)	= (MWHC -21) x 0.234	= _____
Wilting coefficient (W. C.)	= H. C. / 0.68	=_____
Moisture equivalent (M. E.)	= H. C. / 0.37	= _____
Available water	= M. E. – W. C.	= _____

(2)

Wilting coefficient (W. C.)	= (MWHC -21) / 2.9	= _____
Hygroscopic coefficient (H.C.)	= W. C. x 0.68	= _____
Moisture equivalent (M. E.)	= W. C. x 1.84	= _____
Available water	= M. E. – W. C.	= _____

(3)

Moisture equivalent (M. E.)	= (MWHC -21) x 0.635	= _____
Hygroscopic coefficient (H.C.)	= M. E. / 2.71	= _____
Wilting coefficient (W. C.)	= M. E. / 1.84	= _____
Available water	= M. E. – W. C.	= _____

7. Allow the brass clip with soil in water for one and half hour or till the soil becomes completely saturated with water i.e. soil surface becomes shining.
8. After complete saturation, take up the brass cup, wipe off the outer surface of cup with blotting paper and weigh it.
9. Substract the moisture absorbed by the filter paper to correct the results and calculates the maximum water holding capacity of the given soil.

N.B.: Moisture equivalent indicates field capacity of medium and fine textured soils.

Results:

Soil moisture	**%**
Maximum water holding capacity	
Hygroscopic coefficient	
Moisture equivalent	
Wilting coefficient	
Available water to plant from soil	

*****

Observations and Calculations:

1. Diameter of the permeameter = d = _____ cm.

2. Cross sectional area of the permeameter = A = _____ cm^2

3. Depth of water above the soil = h = _____ cm.

4. Length of soil column = L = _____ cm.

5. Time for which percolate collected = t = _____ min.

6. Volume of percolate' collected = Q =_____ cm^3.

7. Total head at the inflow = Hi = h+L

8. Total head of the outflow = Ho = O.

9. Hydraulic head difference = ▲H = Hi - Ho = h + L= ____

10. Hydraulic gradient = (h + L) / L = _____

Hydraulic conductivity, Ks (cm/min) = (Q / At) x (L / (L+H))

8. DETERMINATION OF HYDRAULIC CONDUCTIVITY OF SOIL

The saturated hydraulic conductivity of soil refers to the readiness with which a saturated soil transmits water through its body and Is expessed as length per unit time. It depends upon several soil factors and properties of the field. The soil factors affecting the hydraulic conductivity are: (i) pore geometry (ii) minerological composition of the soil (iii) stratification, (iv) preserce of entrapped air in the soil pores (v) the microbial activity in the soil and (vi) viscosity and density of fluid. If saturated hydraulic conductivity is adjusted to account for viscosity and density of the fluid, we obtain the so called intrinsic permeability which depends upon the soil properties only. The saturated hydraulic conductivity (Ks) is related to the intrinsic permeability (k') as follows:

$$\mathbf{Ks} = \frac{k' dg}{n}$$

Where d is density (Mg m^{-3}) and n is the ($Kgm^{-1} S^{-1}$) of the fluid and g is the acceleration due to gravity (ms^{-2}).The solid liquid interaction, if any can influence Ks through its effect on the nature of the pores and the overall porosity. The hydraulic con-ductivity of soil may vary from 0.001 cmhr-1 in fine clays to over 25 cmhr-' in coarse sand and gravel.

Method of determination (Laboratory Method)

Constant head method:

Principle:

If a constant water head is maintained on one end of a saturated column of soil of length L, the volume of water (Q) percolating through the other and per unit cross - sec-tional area (A) of the soil column per unit time (t) will he directly proportional to the hydraulic gradient ▲H/L) across the Length of the soil column:

$Q/ At = - Ks (▲H/L)$

According to Darcy's law the proportionality constant Ks, in the above equation is the hydraulic conductivity of the soil. The symbol ▲H in Eq.(1) stands for the difference.

In total head between inflow and outflow ends of a column where total head (H) is the sum of the hydraulic head (h) and gravitational head (z) at a given point of measurement in the soil column, Thus

$H_{top} = h_{top} + Z_{top}$

$H_{bot} = h_{bot} + Z_{bot}$

$▲H = H_{top} - H_{bot} = (h_{top} + Z_{top}) - (h_{bot} + Z_{bot})$

Apparatus:

1. Brass permeameters of about 7 cm inside diameter and 10 cm length with the perforated bottoms. The diamensions of permeameters can vary but smaller the diameter more is the eror due to the wall effect.
2. A wooden or iron stand for supporting the permeameter.
3. A water reservoir with mariotte arrangement for maintaining a constant water head on the soil surface
4. A stop watch
5. Graduated cylinders
6. Measuring rods
7. Glass rod

Procedure:

1. Place a filter disc on the screen of the permeameter.
2. Take 200 g of air dry soil passed through 2mm sieve.
3. Dump or put entire sample in one lot into the permeameter.
4. Pack the sample by tapping the permeameter 15-20 times on a wooden block through a height of 2.5 cm.
5. Place a filter paper disc on the soil surface in the permeameter.
6. Saturate the soil by placing the permeameter in a tray filled with water so that the water level is slightly above the bottom of the samples.
7. Further saturate the samples by raising the water level in the tray to the soil surface level in the permeameter.
8. Place the permeameter On the stand and start the siphon to maintain a constant head of 2 - 3 cm of water on the top of the soil by siphon tubes and Mariotte arrangement as shown in the figure (Do not allow the water to flow over the top of the permeameter).
9. Keep at least four replications.
10. When a steady flow is obtained, start collecting the percolate in a graduated cylinder or a beaker.

11. Measure the volume of percolate collected in a known time.
12. Record a few consecutive readings till the flux is constant.
13. Measure the exact water head on the soil surface with the help of a meter rule and then discontinue the experiment.
14. Measure the length of soil column with the glass rod.
    (For this push the rod into the soil vertically and note down the length of rod marked with soil.)
15. Note down the temperature of the water used in the experiment.

Precaution:

Avoid overflow of water by adjusting lower end of the air tube in the Mariotte-arrangement.

*****

Observations and calculations

For coarse sand

1. Weight of dish = W_1 = _____ g.
2. Weight of dish + dry coarse sand = W_2 = _____ g.
3. Weight of coarse sand = W_2-W_1 = _____ g.

$$\text{Percentage of coarse sand on air dry basis} = \frac{W_2 - W_1}{20} \times 100$$

Table: The time of Sedimentation for the clay and silt Fractions (Depth of sedimentation = 10cm)

Temp. ^0C	Clay Decantation		Silt Decantation		Temp. ^0C	Clay Decantation		Silt Decantation	
	Hr.	Min.	Min.	Sec.		Hr.	Min.	Min.	Sec.
8	11	0	6	40	21	7	50	4	40
9	10	40	6	30	22	7	40	4	30
10	10	25	6	30	23	7	25	4	30
11	10	10	6	10	24	7	15	4	20
12	9	50	6	0	25	7	15	4	15
13	9	35	5	50	26	6	55	4	10
14	9	20	5	40	27	6	45	4	5
15	9	5	5	30	28	6	40	4	0
16	8	50	5	20	29	6	30	3	55
17	8	35	5	10	30	6	20	3	50
18	8	25	5	0	31	6	15	3	45
19	8	10	5	0	32	6	5	3	40
20	8	0	4	48	33	5	55	3	35

9. DETERMINATION OF TEXTURE OF SOIL

The process of determining the amount of individual soil separates below 2 mm in diameter (i.e. sand, silt and clay) is called mechanical analysis or particle size analysis.

Two methods viz. International Pipette method and Hydrometer methods are used commonly for determining the particle size analysis of the soil.

Both' these methods are based on the principle of sedimentation known as **Stoke's law**.

Stokes (1851) stated that the velocity of a falling particle in a liquid medium is proportional to the radius square of particle and not to its surface.

Mathematically it is expressed as

$$V = \frac{2}{9} \times \frac{g\, r^2\, (ds - dw)}{\eta}$$

Where, V = velocity of settling particle (cm/sec)

g = acceleration due to gravity (981 cm/sec^2)

ds = density of soil particle (2.65 g/cc)

ŋ = coefficient of viscosity (0.0015 at 4^{0}C)

dw = density of water (1.0g/cc); r = radius of spherical particle (cm)

The Stokes' law is valid under following conditions/assumptions

1. Particles must be spherical and rigid,
2. Particles must be large in comparison with the molecules of the liquid, so that medium can be considered homogenous (In other words particles have no Brownian movement).
3. Particles fall without any hindrance.
4. Particles must be of uniform density.
5. The suspension must be still. Any movement of suspension will alter the velocity of fall.

For silt + clay

1. Weight of dish = W_1 = _____ g.
2. Weight of dish + silt + clay (in 25ml suspension) = W_2 = _____ g.
3. Weight of silt+ clay (in 25ml suspension) = (W_2-W_1)=_____ g.

$$\text{Percentage of silt + clay in the soil} = \frac{(W_2-W_1) \times 1000 \times 100}{25 \times 20}$$

= _____

= _____

(25 is the suspension taken and 20 is the weight of soil sample taken)

For clay

1. Weight of dish =W_1 = _____ g.
2. Weight of dish + clay (in 25ml suspension) = W_2 = _____ g.
3. Weight of clay = (W_2-W_1) = _____ g.

$$\text{Percentage of clay in the soil} = \frac{(W_2-W_1) \times 1000 \times 100}{25 \times 20}$$

= _____

= _____

International pipette method

The pipette method is a standard method for particle size analysis of soils because of its accuracy but it is time consuming hence it can not be employed where large number of samples have to be analyzed.

The following soil fractions can be determined by this method

Size fraction	Diameter of particle (mm)
Coarse sand	2.0 -- 0.2
Fine sand	0.2 --0.02
Silt	0.02 --0.002
Clay	Below 0.002

Equipments

One litre cylinder, balance and weight box, hot water bath, cover glass, filtration apparatus, 70 mesh sieve, dish, oven, wash bottle, thermometer, 25 ml pipette, rubber pastle, sedimentation cylinder, one litre beaker, burner and shakin g machine

Reagents Hydrogen peroxide (H_2O_2 - 6%), HCl (2N), NaOH (l N)
Phenolphthalein (1%) $AgNO_3$ solution

Procedure

Pretreatment and dispersion of soil

Pretreatment of soil is done as and when required to obtain and maintain maximum dispersion during the process of mechanical analysis. Usually, treatment with H_2O_2 and acid is done for most of the soil samples. The organic matter present in soil is oxidized by H_20_2. After this treatment, soil is treated with dilute HCI to dissolve CO_3 and to remove all exchangeable metal ions. Sometimes, for the removal of cementing material like oxides of iron and alumina, soil is treated with sodium dithionite citrate.

For fine sand:

1. Weight of dish $= W_1 =$ _____ g.
2. Weight of dish + fine sand $= W_2 =$ _____ g.
3. Weight of fine sand $= W_2 - W_1 =$ _____ g.

$$\text{Percentage of fine sand} = \frac{(W_2 - W_1) \times 100}{20}$$

$$= \text{_____}$$

$$= \text{_____}$$

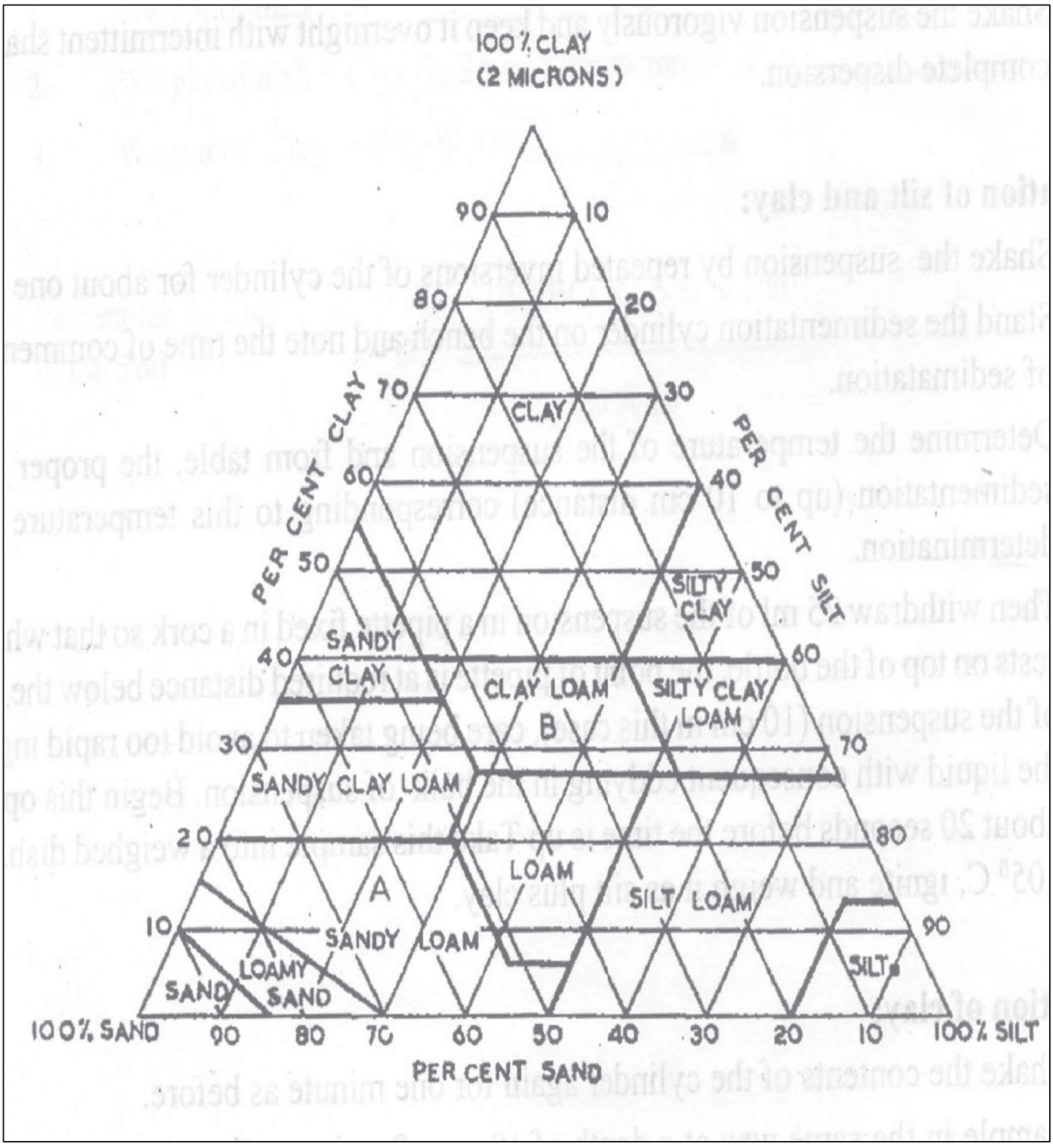
1. Treatment with hydrogen peroxide (for the removal of organic matter)

1. Take 20g air dry soil (2 mm) to a 500 ml beaker.
2. Add 60 ml 6 percent H_2O_2 to destroy organic matter
3. Mix well and allow the reaction to proceed in the cold, preferably overnight placing the cover glass on the beaker.
4. Place it on a hot water bath for about 30 minutes.
5. Stir the content frequently (to avoid frothing). If frothing continues add extra 20-40 ml H_2O_2 and heat it until most of the organic matter is oxidized.

2. Treatment with acid and filtration

1. When the contents of the beaker are cold, clean the sides with a rubber pastle.
2. Add 25 ml 2N HCl and shake to destroy $CaCO_3$ present in soil. If the soil contain more than 2 per cent of $CaCO_3$ ' add an extra 2.5 ml of 2N acid for each per cent present or add extra 2N acid slowly until the pH falls between 3.5 to 4.0 which can be tested by blue litmus paper.
3. Dilute to approximately *250* ml and thoroughly rub the soil with a rubber pastle. Allow the acid and soil to react for one hour, rubbing well at intervals.
4. Now filter through a Buchner funnel using 11 cm Whatman No.50 hardened filter paper.
5. Wash the soil with four successive portions, each of 100 ml distilled water continue the leaching with water until on testing a few drops of filtrate, it is nearly neutral to litmus or it is free from chlorides($AgNO_3$ test).
6. In case soil contains more than 2-3 per cent gypsum then after the peroxide treatment of such soil as described above, transfer the soil and water to a shaking cylinder dilute it to about 650 ml and add 115 ml 2N HCl. If the soil contains more than 10 per cent $CaCO_3$, add an extra 2.5 ml HCl for each per cent present. After allowing any CO_2 evolved to escape, close the cylinder and shake for 8-16 hours in the shaking machine to dissolve all the gypsum present. After shaking, filter through a Buchner funnel and wash the soil with water as be fore, until the filtrate is nearly neutral to litmus or free from chloride.

Soil textural diagram



7. Remove soil adhering to the Buchner funnel filter paper by using a rubber tipped finger as a policeman. Place the sample in an oven dried treated sample as the base weight for calculating percentages of the various fractions.

3. Removal of iron oxide

If iron oxide is to be removed, do not follow last step i.e. oven drying of soil sample.

1. Add 180 ml of citrate bicarbonate' buffer, having 160 ml of 0.3 M Na-citrate solution(88.4 g/l)to the sample, stir and add 3.5 ml of sodium hydrosulfite also known as dithionite ($Na_2S_2O_4$) gradually, as some samples may froth.
2. Put the beaker in a water bath, at 80°C and stir intermittently for 20 minutes.
3. Remove the beaker from the water bath and filter the suspension in Buchner funnel with Whatman No-50 filter paper. If a brownish colour remains, repeat the above steps. If samples are completely gleyed (gray), proceed the following step.
4. Wash 5 times with a jet of water and filter the suspension through Buchner funnel.
5. Determine oven dry weight described in forgoing paragraph.

Separation of coarse sand

After pretreatment spread out the filter paper along with soil on a large clock glass. Place a 70 mesh sieve in the mouth of a sedimentation cylinder. Pour suspension on to the sieve and with a stream of water from the wash bottle, wash as much material as possible through the sieve, until no more clay, silt and fine sand remain on the sieve and the cylinder about one-half full. Transfer the coarse material thus left on the sieve to a weighed dish. Dry it at 105°C and weigh it. Calculate the percentage of coarse sand.

Dispersion

1. Add 10 ml 1 N NaOH in the cylinder.
2. Make the volun1e of the suspension in the sedimentation cylinder up to
   100 ml rendering it alkaline to phenolphthalein.
3. Shake the suspension vigorously and keep it overnight with intermittent shaking for complete dispersion.

Separation of silt and clay

1. Shake the suspension by repeated inversions of the cylinder for about one minute.
2. Stand the sedimentation cylinder on the bench and note the time of commencement of sedimentation.
3. Determine the temperature of the suspension and from table, the proper time of sedimentation (up to 10 cm distance) corresponding to this temperature for silt determination.
4. Then withdraw 25 ml of the suspension in a pipette fixed in a cork so that when cork rests on top of the bottle, the point of pipette is at required distance below the surface of the suspension (10 cm in this case), care being taken to avoid too rapid ingress of the liquid with consequent eddying in the bulk of suspension. Begin this operation about 20 seconds before the time is up Take this sample into a weighed dish. Dry at 105°C, ignite and weigh it as silt plus clay.

Separation of clay

1. Shake the contents of the cylinder again for one minute as before.
2. Sample in the same way at a depth of 10 cm after the settling time taken from the clay in the table.
3. Dry it at 105^0C, ignite and weigh it.

Separation of fine sand

1. Pour away the bulk of the supernatant liquid.
2. Transfer the sediment to a 400 ml beaker.
3. Add water to a height of 10 cm above the base.
4. Stir well and allow to stand for the requisite period taken from the silt column in the Table against the observed temperature.
5. Pour away the turbid suspension.
6. Fill the beaker again to the mark with water and repeat this process until the liquid is no longer turbid at the end of the required period.
7. Collect the residue, which is fine sand, dry it at 105°C and weigh.

   Calculate the percentage of the sand.

Textural triangle and its use

A procedure for using the textural triangle (Fig. 2.1) to determine the textural class of a soil which contains 55 per cent clay 32 per cent silt and 13 per cent sand is as follows:

1. Take the per cent clay (55) on the left side or clay side and draw a line parallel to the bottom or sand side of the triangle. .
2. Take the per cent silt (32) on the right side or silt side and draw a line parallel to the left side or clay side of the triangle.
3. The area in which intersection of two lines occurs gives the textural class or texture of the soil in this case, it is clay.
4. As a check, check the per cent sand (13) and draw a line parallel to the right side of the triangle.
5. If all the three lines intersect at the same point the class name has been determined correctly.

Result

Sample	Textural class
Soil	

*****

Observations

Soil depth (cm.)	Soil temperature	
	Morning (8.00 am)	Afternoon (3.00 pm)
Surface		
5		
10		
15		
20		
30		

According to Fourier's Law, the heat flux is proportional to the temperature gradient

$$q_h = -k \frac{dT}{dz}$$

q_h = heat flux by conduction (W m^{-2})

N = thermal conductivity (W m^{-1} K^{-1})

T = temperature (K or ^{0}C)

z = position (m)

Example : Calculate the soil heat flux (W m^{-2}) for the soil having soil thermal conductivity 1.1 W m^{-1} K^{-1} using measured temperatures of 5 cm and 10 cm depth.

10. MEASUREMENT OF SOIL TEMPERATURE AND CALCULATION OF SOIL HEAT FLUX

Soil temperature is influencesrate of seed germination, seedling emergence and growth, root development, and most microbial processes. Plants and microorganisms survive in certain range of temperatures. Too low and too high temperature are lethal to microorganisms. The microclimate for a seed, plant, or microorganism can be impacted by different soil management practices. Ridging or ploughing a soil increases the soil surface area and can expose the soil to more radiation, resulting in warmer temperatures. Mulches and other crop residues insulate the soil, keepingsoil surfaces cooler during hot weather and warmer during cold periods. Understanding how soil and land characteristics influence soil temperature enables us to make better decisions in growing crops, planting trees, or managing compost.

There are different kinds of instruments used to measure soil temperature. Somerequire manual readings whereas soil temperature sensors can be connected to a data logger.

Apparatus

Screw auger and soil thermometer

Procedure

1. Make holesof different depth in soil with the help of screw auger.
2. Insert the thermometers designed for different depths in an oblique position and fill the holes with soil. Pour some water so that soil is set properly adjacent to bulb of the thermometers.
3. After about a day record the soil temperatures.
4. Note down the temperature in this way during the day at specific intervals.

*****

ANALYTICAL CHEMISTRY: Basic concepts, techniqu es and calculation

Basic concepts such as law of mass action (driving force of chemical reaction is proportional to active masses of reactions), dissociation constant of water (increase rapidly with temperature and use to calculate concentration of H+ and OH- ions in solutions in which water is present), pH scale (-log10 H+) is advantageous to express the ionic concentration without negative exponents in very dilute solutions (<1M or 1N), buffer solutions (resists the change in pH generally useful where steady pH is required), solubility product constant (use to dissolve the precipitate or to enhance the precipitation or for separation of different ionic species in the solution), potentiometry and conductometry (cases in which ordinary methods fails to give useful results, these two methods are important because of abrupt change in physicochemical properties at end point is reached or passed eg. Titration of weak acid v/s weak base, and indicator's behavior (for colour change at least 2 pH unit changes is required) are used in analytical chemistry.

Volumetric methods involves (1) acid-base (salt & water are formed), (2) precipitation, argentometric (titrant forms ppt with analyte), complexometric (titrant forms complex with analyte), redox (involves loss/gain of electron) and iodimetric (I2 used to titrate reducing agent) and iodometric (I' reduce strong oxidizing agent) reactions.

In above mentioned methods, primary and secondary standards are used. Primary standard substance must be (1) in pure form (2) react in one way (3) non-hygroscopic (4) and must have high m.wt. and high dissociation constant.

Special precautions necessary for preserving solutions are (1) bottle must be kept tightly stoppard to prevent evaporation of solvent which would cause an increase in solute concentration (2) shake the solution before withdrawal (3) sodium hydroxide should be protected from atmospheric gases and bottle should be coated inside with wax and (5) AgNO3 should be protected from light.

Units

1) **Equivalent weight**

(i) Eq. wt. of acid = M. wt. / basicity

(ii) Eq. wt. of base = M. wt. / acidity

2) **Normality: No. of g. eq. / litre**

(i) N of con. Acid = $\frac{10 \times \text{sp. Gr. X \% purity}}{\text{Eq. wt.}}$

(ii) Vol. of Conc. acid req. to prepare = $\frac{\text{g. eq. wt. x desired N x desired vol. (ml)}}{\text{sp. gr. X \% purity x 10}}$

desired vol. and desired normality

3) **Molarity = g. M. wt / litre**

g/l = M x M. wt.

4) **Percent:** It is a gram of solute in 100g (w/w) or ml of solute in 100ml solvent (v/v) or weight of solute in 100ml solvent (w/v).

5) **m.e.:** eq. wt. is expressed in milligram.

m.e.= Volume (ml) x N

mg = Volume(ml) x N x eq,wt,

= m.e. x eq. wt.

6) **ppm:** Parts of unit weight present in one million unit weight or volume.

i.e. 1000 x 1000 = 106

ppm or mg/l or mg/kg or g/ton or mg% x10 = m.e./l x eq.wt.

=m.e./100g x 10 x eq.wt

= % x 10000

7) **kg/ha** = lbs x 2.24

8) **kg/ha** = lbs/acre x 1.12

9) **kg/ha** = ppm x 2.24

10) $N_1V_1 = N_2V_2$ (used for calculation of N & V)

11) P_2O_5 = P x 2.29

12) K_2O = K x 1.19

COMMON TECHNIQUES

The main techniques employed in quantitative inorganic analysis are based upon (a) the quantitative performance of suitable chemical reactions and either measuring the amount of reagent needed to complete the reaction, or ascertaining the amount of reaction product obtained; (b) appropriate electrical measurements (e.g. potentiometry); (c) the measurement of certain optical properties (e.g. absorption spectra); or (d), in some cases, a combination of optical or electrical measurements and quantitative chemical reaction (e.g. amperometric titration).

The quantitative execution of chemical reactions is the basis of the traditional or 'classical' methods of chemical analysis: gravimetry, titrimetry and volumetry. In gravimetric analysis the substance being determined is converted into an insoluble precipitate which is collected and weighed.

In titrimetric analysis, the substance to be determined is allowed to react with an appropriate reagent added as a standard solution, and the volume of solution needed for complete reaction is determined. The common types of reaction which find use in titrimetry are (a) neutralization (acid-base) reactions; (b) complex-forming reactions; (c) precipitation reactions; (d) oxidation-reduction reactions.

Electrical methods of analysis involve the measurement of current, voltage or resistance in relation to the concentration of a certain species in solution. Techniques which can be inclu ded under this general heading are (i) voltammetry (measurement of current at a micro-electrode at a specified voltage); (ii) coulometry (measurement of current and time needed to complete an electrochemical reaction or to generate sufficient material to react completely with a specified reagent); (iii) potentiometry (measurement of the potential of an electrode in equilibrium with an ion to be determined;(iv) conductimetry (measurement of the electrical conductivity of a solution).

Optical methods of analysis are dependent either upon (i) the absorption of radiant energy and the measurement of the amount of energy of a particular wavelength absorbed by the sample, or (ii) the emission of radiant energy and measurement of the amount of energy of a particular wavelength emitted.

Atomic absorption spectroscopy involves vaporizing the specimen, often by spraying a solution of the sample into a flame, and then studying the absorption of radiation from an electric lamp producing the spectrum of the element to be determined,

Emission method involves flame photometry, in which a solution of the sample is injected into a flame and light emitted is investigated.

Observations:

(A) Soil EC

Electrical conductivity of 0.01 M KCl = _____dSm^{-1}

Electrical conductivity of 1 : 2.5 soil water suspension = _____ dSm^{-1}

Electrical conductivity of 1 : 5 soil water suspension = _____ dSm^{-1}

Based on the soil EC values, the soils may be classified as follows:

$EC_{2.5}$ (dSm^{-1})	
< 0.8	Normal
0.8-1.6	Critical for salt sensitive crops
1.6-2.5	Critical for salt tolerant crops
> 2.5	Injurious to most crops

(B) Soil pH

pH of standard solution 1. _____

2. _____

3. _____

pH of 1:2.5 soil water suspension = _____

pH of 1:5 soil water suspension = _____

Based on the pH values, the soils may be classified as follows

pH (1:2.5)	
Acidic < 6.5	requires liming for reclamation
Normal 6.5- 7.5	Optimum for most crops
Alkaline 7.5 – 8.5	requires application of org. manures
Alkali > 8.5	requires gypsum for amelioration

11. DETERMINATION OF EC AND pH OF SOIL

The electrical conductivity of soil is measured from (i) saturation extract or (ii) 1:2 soil: water ratio or (iii) 1 : 2.5 soil : water ratio by weight. The soil reaction of pH is meant to express the acidity of alkalinity of the soil. The pH is very important property of the soil as it determines the capacity for the growth of the plants, availability of nutrients, physical conditions of the soil and the microbial activity.

Principles

ELECTRICAL CONDUCTIVITY (EC)

Total soluble salts are estimated from electrical conductivity (EC) of aqueous soil extracts. EC is a measure of the ability of a salt solution to carry electric current by the migration of ions under the influence of an electric field. Like metallic conductor, solutions also obey Ohm's law. The unit of conductivity is dSm^{-1} or mmhos cm^{-1} which is the reciprocal of resistance in Ohm's cm^{-1}.

pH

pH meter works on the principle as mentioned in Nernst equation. It consists of two electrodes. 1) Glass electrode or Indicator electrode and 2) Calomel electrode or Reference electrode. When the both electrodes are dipped in aqueous solution under test, the potential is developed in the solution. That potential difference between both the glass electrode and the calomel electrode is measured by pH meter.

Equipment/Apparatus

(1) EC meter with cell, (2) pH meter with electrodes, (3) Balance, (4) 100 ml Beaker and (5) Glass rod.

Reagents

1. Standard 0.01 M KCl solution: Dissolve 0.7456 g potassium chloride (KCl) in distilled water and dilute to one litre. At 25°C it gives electrical conductivity 1.413 mmhos cm^{-1} (dSm^{-1}). The instrument is to be calibrated with this solution.

2. Buffer solutions: pH 4.0, 7.0 and 9.2.

Procedure

For EC

1. Weigh 20 and 10 g soil in two different 100 ml beakers.
2. Add 50 ml of distilled water in each beaker and stir intermittently with a glass rod.
3. Allow the soil suspension in the beaker to settle for about half hour.

4. Calibrate the instrument using standard KCl (1.41 dSm^{-1}) solution.
5. Rinse and immerse the cell in soil suspension and measure EC of given sample.

For pH

6. Place a known standard buffer solution in a beaker and immerse the electrodes.
7. See that the electrodes do not touch the wall of the beaker.
8. With the help of the knob, put the instrument the needle at the known pH of the buffer solution and adjust.
9. The buffer is then removed and the electrodes are carefully washed with distilled water.
10. Stir intermittently with glass rod and immerse the electrodes in a beaker containing the soil – water suspension and measure the pH.
11. Remove the electrodes from the soil – water suspension, clean them with distilled water and then dip into a beaker containing distilled water.
12. Classify the soil for EC and pH and give your comments.

Result

Sample	EC dSm^{-1}	pH (1:2.5)
1: 2.5 Soil : water		
1: 5 Soil : water		

Inference

*****

OBSERVATION:

1. Weight of the soil sample taken = W1 = _____ g
2. Sample titration value = T = _____ ml
3. Blank titration value = B = _____ ml
4. Normality of the acid used = N = _____

CALCULATION:

CEC of the soil

$$\text{CEC (me/100 g soil)} = \frac{(B - T) \times N \times 100}{W1}$$

12. DETERMINATION OF CATION EXCHASNGE CAPACITY (CEC) OF SOIL

Cation exchange in soils is a reversible chemical reaction. The cation held on the surface of soil mineral and within the crystal framework of some mineral species plus those are a part of certain organic compounds can by reversibly replaced by those of salt solutions and acids. The CEC (usually expressed as me/100 g of soil) is defined as the sum of the exchangeable cations of a soil. Some exchangeable ions are more easily replaced then others and completeness of replacement of some cations will depend upon the method, it is especially important to specify the method used when reporting figures for CEC of the soils.

In the method most commonly used a suitable quantity of the soil is leached with neutral normal Ammonium acetate solution to displace the exchangeable cations by NH_4 ions. The excess of ammonium acetate (NH_4OAC) being washed with achlcohol. The NH_4^+ adsorbed by the soil is than determine by distillation with MgO.

The use of netural N-NH_4OAC has the following three advantages.

1. It is highly buffer, as a result while saturating the soil. Complex with NH_4^+, the last part of the solution leached through the soil emerges with the same pH as the solution added .
2. NH_4^+ can be easily determined.
3. NH_4^+ is more effective in the displacement of the cations from the soils used.

Apparatus:

1. Erlenmeyer flask 500ml.
2. Beaker 500ml
3. Distillation apparatus
4. Hot plate
5. Porcelain dish
6. Burette 50ml
7. Funnel
8. Filter paper No.44
9. Electronic balance

REAGENTS:

1. **Neutral N NH_4OAC**

   Dilute 114 ml of glacial aecetic acid (99.5%) with distilled water to a volume of approximately 1 liter. Add 138 ml of conc.NH_4OH and add water a volume of about 1980 ml. Check the pH of the resulting solution, add NH_4OH as needed to attain pH 7.0, and dilute the solution to a volume of 2 liter with water OR 154 gr of NH_4OAC to 2 liter of water.

2. **Methyl or Ethyl alcohol (60%):**

   Dilute 250 ml of alcohol to 1000 ml using distilled water.

3. **NH_4Cl crystal**
4. **MgO**
5. **0.1 N H_2SO_4: Dilute 3ml of 36 N acid into 1000ml H_2O**
6. **0.1 N$AgNO_3$ solution:Dissolve 17 gr $AgNO_3$ in water and make it 1000 ml.**
7. **Mixed indicator:**

   Bromocresol green (0.5%) and methyl red (0.1%) mixed indicator is prepared by dissolving (0.5 gr)of bromocresol green and 0.1 gr methyl red in 100 ml of 95% ethanol and adjusting the solution to the bluish purple mid color at pH 4.5 with dilute NaOH or HCl .This indicator is pink at pH 4.2 and bluish green at the pH rises to pH 4.9 and above.

8. **2% boric acid solution :**

   weigh 2 g of boric acid in 100ml of distilled water.

PROCEDURE:

1. Weigh 5 gm soil in Erlenmeyer flask.
2. Add 100 ml of NH_4OAC solution and shake it for 30 min. and keep it over night.
3. Filter the content into 1000 ml beaker using Whatman No. 44 filter paper. Transfer the soil completely on the filter paper.
4. Continue to leach the soil with NH_4OAC solution, using 20-25 ml solution at a time using in all 100 ml (6-7 washing are required) keep the filtrate for the determination of total and individual exchangeable bases.

5. To the soil on the filter paper add a little amount of NH_4Cl crystal and leach with alcohol-continue washing (8-10 washing)f the residual till the filter runs free of chloride (Test it with $AgNO_3$).
6. Transfer the residue and filter paper to a 600 ml distillation flask. Add 3-5 gm of MgO and 200-300 ml of distill water.
7. Connect the flask to the distillation apparatus place a 250ml beaker containing of 25 ml 2% boric acid solution alongwith 2 drops of mixed indicator under the condenser of the distillation apparatus to received Ammonia.
8. Start distillation by heating the distillation flask. Continue heating till no ammonia is evolved through the end of the condenser, test it with litmus paper.
9. Back titrate the contents of the beaker with 0.1 H_2SO_4 Solution.

*****

Observations

1. Weight of soil (W) = _____ g.
2. Normality of $K_2Cr_2O_7$ used (N) = _____ .
3. Volume of $K_2Cr_2O_7$ added in soil sample =_____ ml.
4. Volume of 0.5 N $Fe(NH_4)_2 (SO_4)_2. 6H_2O$ used for blank (B) =_____ ml.
5. Volume of 0.5 N $Fe(NH_4)_2 (SO_4)_2. 6H_2O$ used for soil sample (S) =_____ ml.

Reactions

(A) $2K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2\ K_2SO_4 + 2\ Cr_2(SO_4)_3 + 8\ H_2O + 6(O)$

$3C + 6(O) \longrightarrow 3\ CO_2$

$2K_2Cr_2O_7 + 8H_2SO_4 + 3C = 2\ K_2SO_4 + 2\ Cr_2(SO_4)_3 + 8\ H_2O + 3\ CO_2$

(B) $2\ Fe(NH_4)_2 (SO_4)_2. 6H_2O \longrightarrow 2FeSO_4 + 2(NH_4)_2SO_4 + 12H_2O$

$2FeSO_4 + H_2SO_4 + O \longrightarrow Fe_2(SO_4)_3 + H_2O$

$2\ Fe(NH_4)_2 (SO_4)_2. 6H_2O + H_2SO_4 + O = 2(NH_4)_2SO_4 + Fe_2(SO_4)_3 + 13H_2O$

(C) $2C_6H_5NHC_6H_5 \xrightarrow[-H_2O]{+O} 2(C_6H_5NHC_6H_4) \xrightarrow[-H_2O]{+O} C_6H_5N\text{-}C_6H_4C_6H_4N\text{-}C_6H_5$

Diphenylamine — (Colourless) Diphenylbenzidine — (Violet) Diphenylbenzidine

Calculations

% Organic Carbon $= \dfrac{(B - S) \times 0.003 \times 100}{2 \times W}$

% Organic matter = % O.C. x 1.724

% Nitrogen = % O.C. x 0.0862

13. ESTIMATION OF ORGANIC CARBON CONTENT IN SOIL

Principle

A suitable quantity of the soil is digested with chromic and sulphuric acids, making use of the heat of dilution of sulphuric acid. The excess of chromic acid left over unreduced by the organic matter of the soil is determined by a titration with standard ferrous sulphate or ferrous ammonium solution using diphenylamine as an internal indicator.

Apparatus

(1) 500 ml beaker (2) Pipette (3) Burette (4) Analytical balance (5) Glass rod.

Reagents

1. **1 N Potassium dichromate ($K_2Cr_2O_7$) solution:** Dissolve 49.04 g pure crystals of potassium dichromate in water and dilute to 1 litre.
2. **0.5 N Ferrous ammonium sulphate solution:** Dissolve 785 g of Ferrous ammonium sulphate ($Fe(NH_4SO_4)_2$ $6H_2O$) in 4 litres of distilled water containing 100 ml conc. H_2SO_4. **OR** 139 g of $FeSO_4$ $7H_2O$ can also be used and that of dissolved in distilled water and add 15 ml conc.H_2SO_4 and dilute to 1 litre.
3. **Ortho-Phosphoric acid (95%)**
4. **Diphenylamine indicator:** Dissolve 0.5 g diphenylamine in a mixture of 100 ml conc. H_2SO_4 and 20 ml water.
5. **Sulphuric acid:** Not less than 96%.

Procedure

1. Weigh 1.0 g soil sample in a 500 ml beaker.
2. Add 10 ml 1N $K_2Cr_2O_7$ by means of a pipette and 20 ml concentrated H_2SO_4 by measuring cylinder.
3. Mix thoroughly and allow the reaction to proceed for 30 minutes on asbestos sheet.
4. Dilute the reaction mixture with 200 ml of water and 10 ml H_3PO_4 by measuring cylinder and add 7-8 drops of diphenylamine indicator.
5. Titrate the solution with std. 0.5 N $Fe(NH_4)_2(SO_4)_2$ to a brilliant green colour.
6. A blank without soil should be run simultaneously.
7. Calculate the organic carbon content of a given soil sample.

On the basis of organic carbon content, soil be classified as follows:

Low < 0.5%

Medium 0.5-0.75%

High > 0.75%

Results

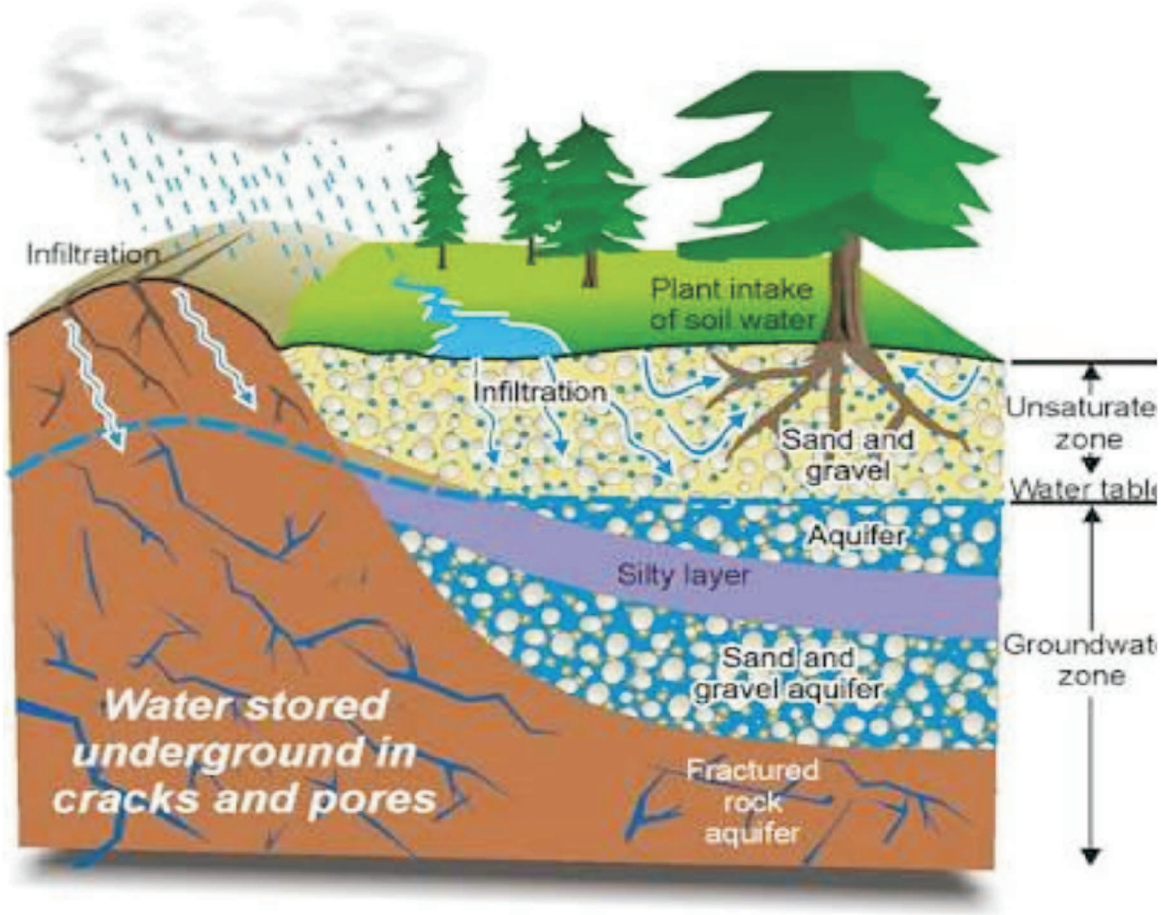
Sample	% O.C.	% O.M.	% N
Soil			

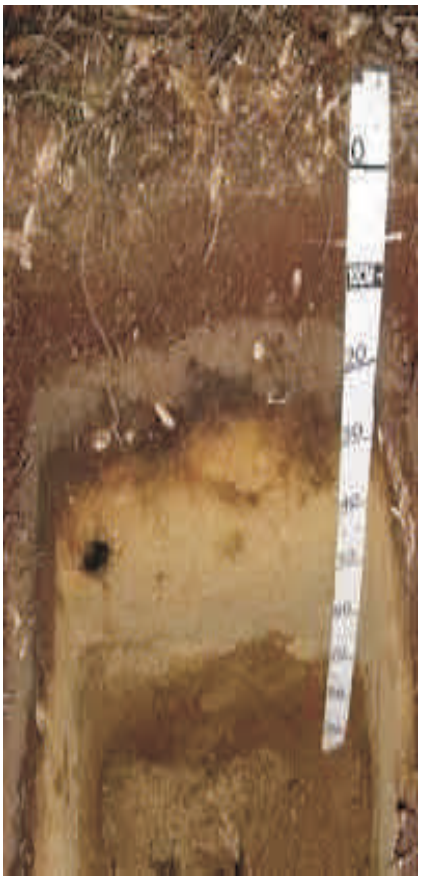
Inference

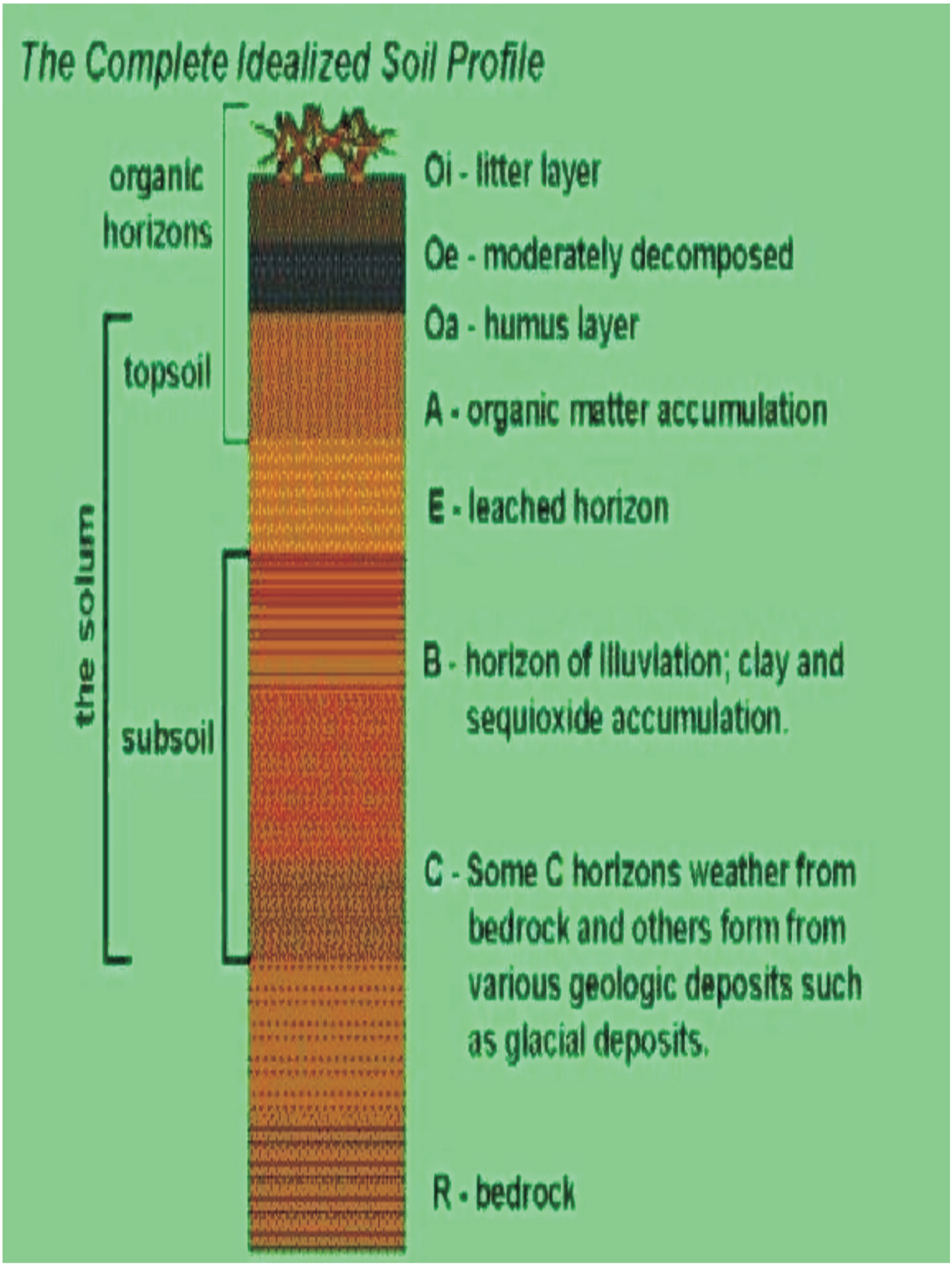
*****

NOTES

NOTES


Infiltration
Plant intake of soil water
Infiltration
Sand and gravel
Unsaturate zone
Water table
Aquifer
Silty layer
Groundwat zone
Sand and gravel aquifer
Water stored underground in cracks and pores
Fractured rock aquifer




The Complete Idealized Soil Profile
organic horizons
topsoil
subsoil
the solum
Oi - litter layer
Oe - moderately decomposed
Oa - humus layer
A - organic matter accumulation
E - leached horizon
B - horizon of illuviation; clay and sequioxide accumulation.
C - Some C horizons weather from bedrock and others form from various geologic deposits such as glacial deposits.
R - bedrock

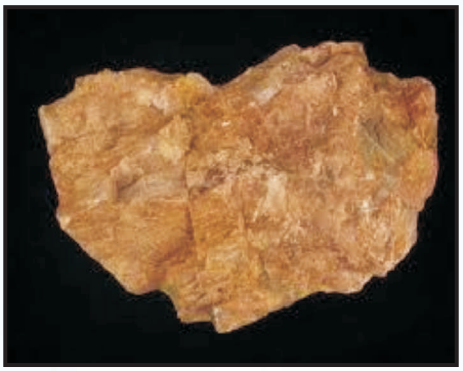
Minerals

Kaolinite

Gibbsite

Sulphur

Graphite



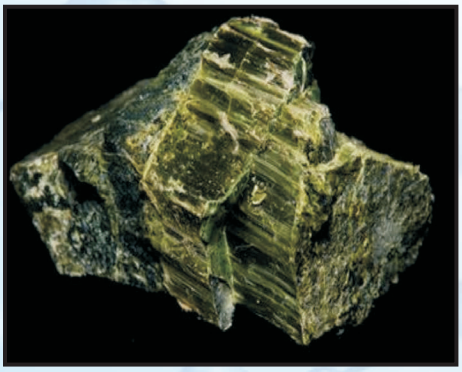
Feldspar

Chalk

Serpentine

Gypsum

Calcite



Asbestose

Coal

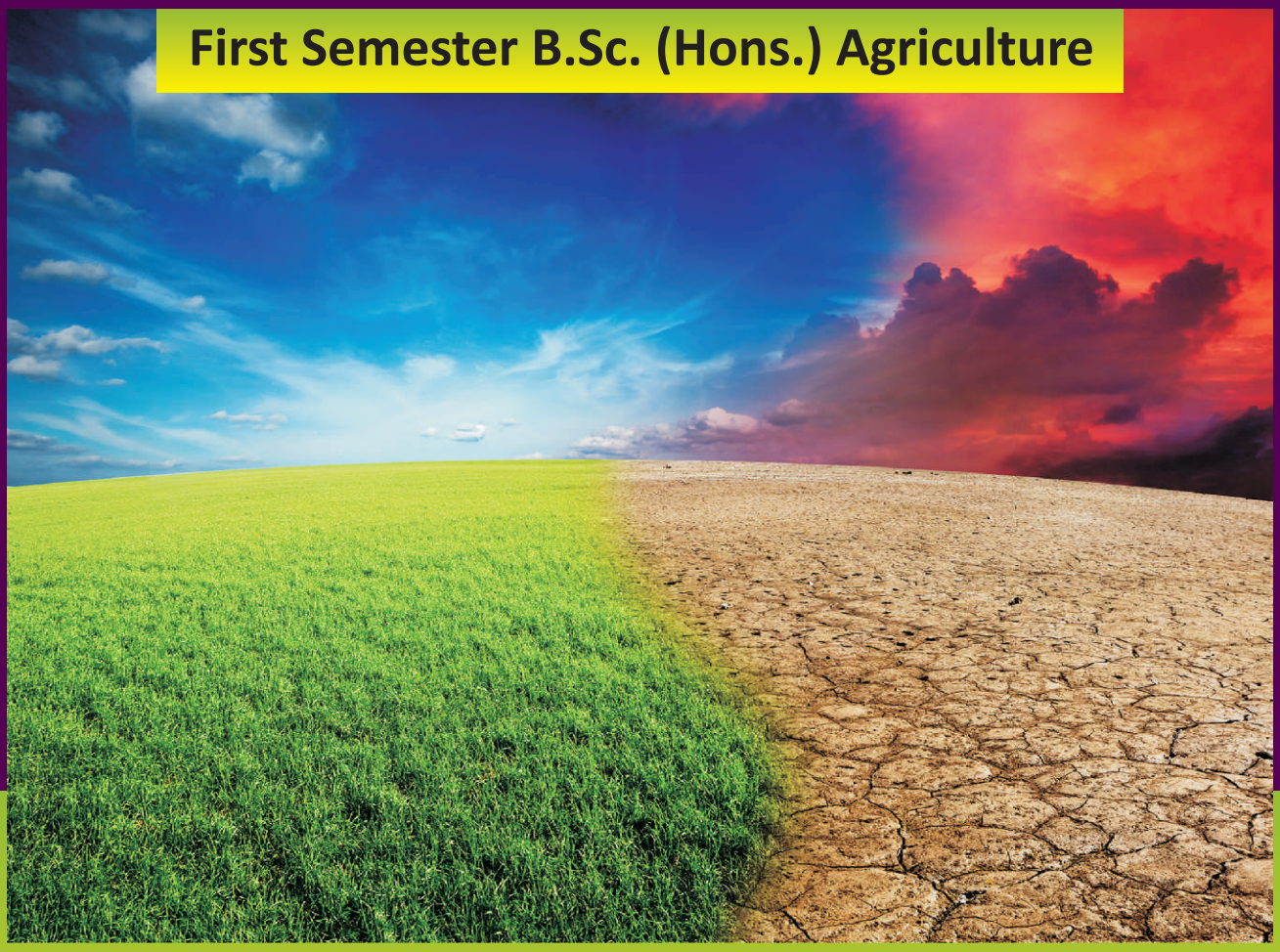
Boxite

Practical Manual

Ag. Met. 1.1 (1 + 1)

INTRODUCTORY AGRO METEOROLOGY AND CLIMATE CHANGE

First Semester B.Sc. (Hons.) Agriculture



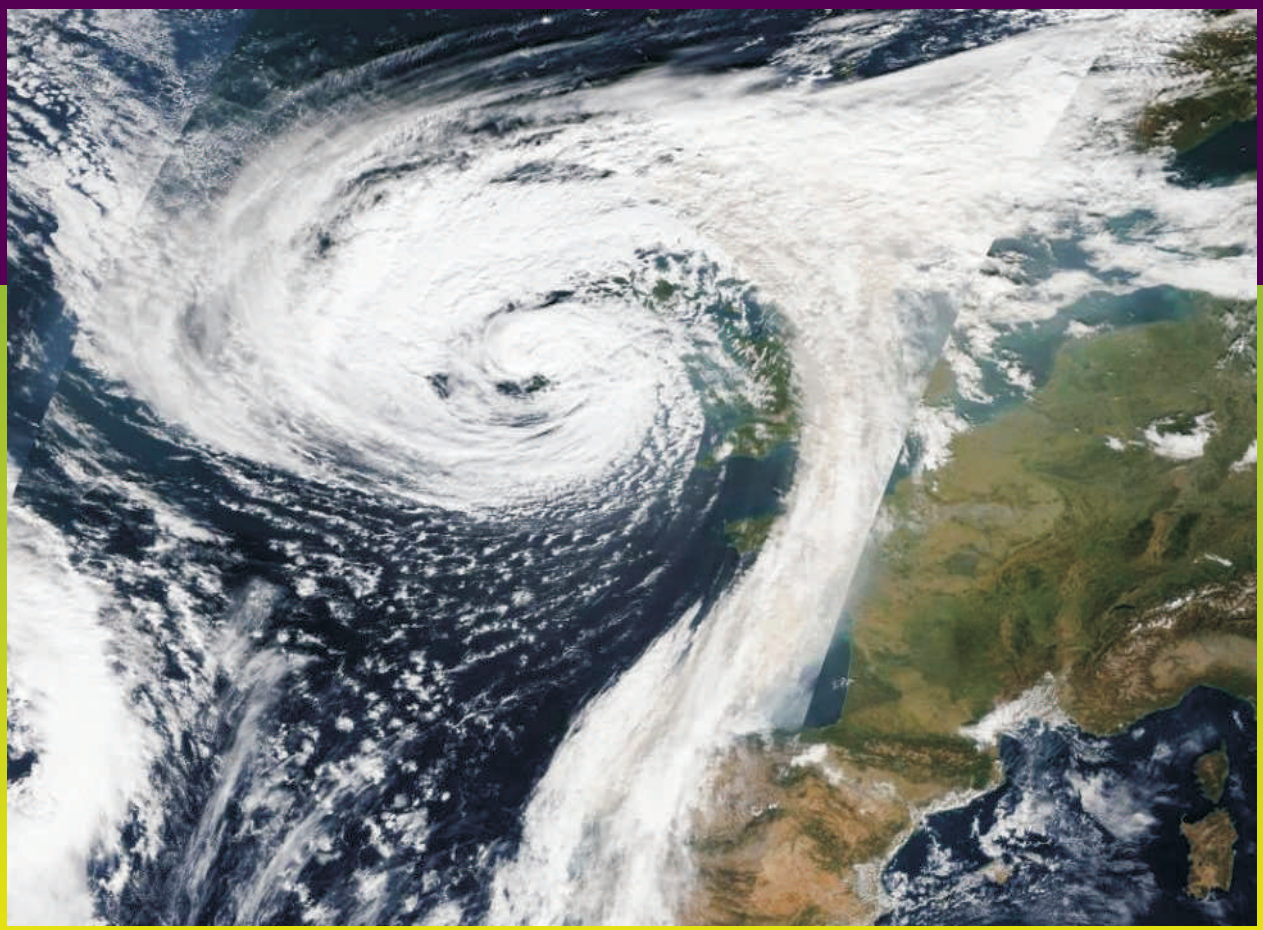
:: Prepared and Complied by ::

Dr. R. R. Pisal Dr. A. P. Patel Dr. V. M. Patel

Prof. S. S. Sonawane Prof. H. P. Dholariya

NAVSARI AGRICULTURAL UNIVERSITY

College of Agriculture
Navsari Agricultural University
Waghai - 394730



Practical Manual

Ag. Met. 1.1 (1 + 1)

INTRODUCTORY AGRO METEOROLOGY AND CLIMATE CHANGE

First Semester B.Sc. (Hons.) Agriculture

NAVSARI AGRICULTURAL UNIVERSITY

:: Prepared and Complied by ::

Dr. R. R. Pisal Dr. A. P. Patel Dr. V. M. Patel

Prof. S. S. Sonawane Prof. H. P. Dholariya

Name of Student : _____

Uni. Seat No.: _____ **Registration No. :** _____

College of Agriculture
Navsari Agricultural University
Waghai - 394730

March, 2020

Publication year:
March-2020

Copies:
300

Publisher:
College of Agriculture
Navsari Agricultural University
Waghai (Dangs)- 394 730 Gujarat
Phone: 02631- 246688
Fax:02631-246622

Printed at:
Asian Printery
Near Talati hall, Raipur Darwaja, Raipur, Ahmedabad
Phone: 079-22148826, Email:asianprintery@yahoo.com

Dr. J. J. Pastagia
Principal

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

NAVSARI AGRICULTURAL UNIVERSITY

Phone No. 02631 - 246688
Fax No. 02631 - 246622
caw@nau.in

:: FOREWORD ::

A new course on Introductory Agro Meteorology and Climate Change has been designed in agricultural universities at undergraduate as per syllabus laid out by the 5th Deans Committee recommendations of ICAR. The 36th academic council meeting of NAU, held on 25th April 2017, with item note 36.05. and approved 5th Dean recommendation from the year 2017-18 along with the detail distribution of courses.

Agriculture and weather are the essential components of the crop production. Crop production depends upon the prevailing weather conditions at different stages of crop growth. Precise measurements of weather elements are required to understand the proper interpretation in relation to crop growth and development. The practical exercises of this manual are according to new syllabus of agrometerology course running in the UG programme. An attempt is being made in this manual to compile the available up-to-date information on the subject in the most easily understandable manner and to make the information user-friendly.

I am sure that this manual will clear the basic concepts of agricultural meteorology and it will be a useful ready reference material for all the students of first semester B.Sc. (Hons.) Agriculture. I shall feel more than satisfied, if this manual would serve the purpose of students in pursuit of their academic goals. I convey my hearty congratulations to Dr. R. R. Pisal, Dr. A. P. Patel, Dr. V. M. Patel, Prof. S. S. Sonawane and Prof. H. P. Dholariya for their commendable efforts in bringing out this practical manual.

March 07, 2020

(J. J. Pastagia)

:: INDEX ::

EXERCISE : 1

STUDY OF METEOROLOGICAL OBSERVATORIES, SITE SELECTION AND LAYOUT

Introduction:

We know that quality and quantity of any crop production mainly depend on weather. Weather has a direct and indirect effect on crop production. For investigating pr ecisely and quantitatively the relationships between crop and weather, the detailed development observations of the crop and the regular observations of the weather are essential. Recording of weather phenomena is essential as relation between the climate of a region and the kind of plant is obvious. **Meteorological observatory** is a place where all the necessary instruments are exposed for measuring weather phenomenon.

Types or classes of meteorological observatories:

Four types of weather station s are recognized depending on the number of weather elements measured, the frequency of measurement, status of the observer and location. These four types of weather stations are as follows.

1. Synoptic stations: These are stations managed by full-time observer who maintain continuous weather watch and make hourly instrumental observations of the weather elements on which information is required for the compilation of the synoptic charts or weather maps used in weather forecasting.
2. Agricultural stations: These are stations managed by part-time observer making at least twice daily instrumental observations of the major weather elements. Evaporation, grass minimum and soil temperatures and solar radiation are also usually measured in view of their obvious importance in agriculture.
3. Climatological Stations: These are stations managed by part-time observers making only once or twice daily instrumental observations of temperature, humidity, rainfall and wind.
4. Rainfall stations: These are stations managed by part-time observers who take daily reading of rainfall only.

The surface observatories are letter coded into six classes.

(a) **Class A :** Observatories : These are provided with eye reading instruments and self-recording instruments. The observations are recorded every a fter hour round the clock.

(b) **Class B :** Observatories : Most of these are furnished with eye-reading instruments and self recording instruments. Regular observations are made at least twice a day.

(c) **Class C :** Observatories : These have the same instruments or equipment that of described in Class B Observatories but observations are recorded only once a day.

(d) **Class D, Class E and Class F** Observatories: These have less number of instruments or equipments or are non- instrumental.

Selection of site for Agrometeorological Observatory:

Agrometeorological observatory is a place where all meteorological as well as biological observations are recorded simultaneously.

- ❖ The site of the observatory should be located at the center of the agricultural research farm and the size of the plot may be of 60 X 40 m with its longer side running north-south direction.
- ❖ The site should be enclosed with barbed wire fencing and should be easily accessible during rains.
- ❖ Water logging should be avoided.
- ❖ The site should be well exposed i.e. away from high buildings, trees, main channels and drains etc.

Location of instruments: Generally every agro meteorological observatory is provided with given below instruments.

1. Sunshine recorder 2. Anemometer 3. Wind vane 4. Stevenson screen 5. Double size Stevenson screen 6. Ordinary rain gauge 7. Self-recording rain gauge 8. Soil thermometer 9. Grass minimum thermometer 10. U.S.W.B. Class 'A' Pan 11. M.C.P. (micro climatic pole) 12. Dew gauge. 13. Soil moisture plot

All these instruments are fixed in observatory in a given sequence (see lay out).

Calculation of LMT: -

The local mean time corresponding to Indian Standard Time varies from place to place depending upon longitude of a place. L.M.T. at a place is the mean time determined with refer ence to the sun. When sun rises at any place it is said to be 7° clock locally.

LMT = IST + 4 (L1- L2)

L1 = Longitude of Allahabad

L2= Longitude of the station

I.S.T.: The Indian Standard Time is the L.M.T. of longitude 82 ½° East. It is five and half -hours ahead of Greenwich Mean Time.

G.M.T.: The Greenwich Mean Time is the Local Mean Time of Greenwich. **Greenwich Mean Time** (**GMT**) was established in 1884 at the International Meridian Conference, when it was decided to place the Prime Meridian at Greenwich, England. Greenwich Mean Time (GMT) is also known as Zulu Time

Where is Greenwich, England?

- Longitude 0° 0' 0"
- Latitude 51° 28' 38"N (North of the Equator)

The longitude of SKNagar and Allahabad is 72^0 19' E and 82^0 30' E respectively. Difference between longitude is 10^0 0', SKNagar is situated in west of Allahabad so we have to add time in an IST (4 minutes for each longitude) and that is 40 minutes. Now as per this calculation we have to record observations at 0740 and 1440 IST at SKNagar Center.

Time of observations: In Agricultural meteorological observatory the observations are to be taken and recorded at 0700 hrs and 1400 hrs LMT (i.e. 0740 and 1440 hrs LMT of SKNagar location) except Pan evaporation & raingauge observations are to be taken at 0830 IST.

Location	Latitude N	Longitude E	Altitude (m)
SKNagar	24^0 19’	72^0 19’	154.5
Anand	22^0 35’	72^0 58’	45.0
Surat	20^0 00’	72^0 52’	11.3
Navasari	20^0 57’	72^0 54’	10.0
Rajkot	22^0 18’	70^0 47’	138.0
Junagadh	21^0 30’	70^0 30’	61.0
Jamnagar	22^0 27’	70^0 02’	20.0
Amreli	21° 18'	71° 12'	130.0
Bhavnagar	21° 46'	72° 08'	30.0
Porbandar	21° 38'	69° 36'	7.0
Surendranagar	22° 43'	71° 38'	74.0

Ex.: Calculate observation time at 0700 and 1400 LMT of above locations (Any three).

*****

EXERCISE : 2

MEASUREMENT OF BRIGHT SUNSHINE HOURS, TOTA L SHORTWAVE AND LONGWAVE RADIATION ESTIMATION

INTRODUCTION:

The energy that travels in the form of electromagnetic waves through space is called as radiant energy. This energy received from the sun is called as solar radiation or insolation. The sun emits almost a constant amount of solar radiation (1.94 cal/ cm^2/ min) continuously. It is called solar constant.

Solar radiation is one of the most important factors in photosynthesis and transpiration of crops. B ut since its measurement involves advanced and costly instruments, indirect estimation of the same from sunshine hour's data is useful. Hence, the measurement of bright sunshine hour is important.

Objective: To acquaint the students with principal, constriction and working of various solar radiation measuring instruments.

(A) Sunshine recorder

Parts of Sunshine recorder:

1. Campbell-Stokes sunshine recorder
2. Sunshine cards
3. Sunshine plastic scale

Procedure:

1. Select the appropriate card as per the season.
2. Insert the card in the appropriate groove of the recorder after sunset.
3. Remove the burnt card in the evening after sunset and mark the date of observation on the reverse of the card.
4. Tabulate the duration of sunshine recorded during each hour of the day.
5. Calculate the bright sunshine duration using the special plastic scale.
6. Estimate the total amount of clouds in the sky in Oktas.

Measurement of Sunshine:

The sunshine is measured by means of Campbell-Stokes sunshine recorder. This consist of a glass sphere of 10 cm diameter, mounted concentrically in a section of spherical bowl, the diameter of which is such that the sunrays are focused sharply on a card held in the grooves cut into the bowl. Three overlapping pairs of grooves are provided in the bowl to take cards suitable for different seasons o f the year. **Long curved** cards are used in summer, **short curved** cards in winter and **straight** cards in equinoxes. The time indicated by a correctly adjusted sunshine recorder is the true solar time or **local apparent time**.

Sunshine cards:

Three types of cards namely, the short curved card (13th October to 28th February), the long curved card (13th April to 31st August) and straight card for other seasons (during equinoxes) are used in grooves. These cards are subdivided into hourly intervals. While inserting the new cards its 12 hour line should be adjusted to coincide with noon line on the bowl. As the sun moves across the sky, its focused image burns a trace on the card so that by measuring the trace for the whole day the duration of sunshine during the day can be accurately recorded.

Sunshine scale:

A **sunshine scale** measures the burn hour. It is made of celluloid. A special plastic scale is provided in which the subdivisions of the hour are marked. There are 10 parts in scale each part consists of 0.1 hour (6 minutes). The parallel sunshine scale is used for straight card and trapezoidal scale is used for long and short curved cards.

The duration of sunshine can be obtained correct to 0.1 of an hour. The hours marked in the sunshine card refer to local mean time (LMT) of the station. The sunshine is measured in the units of bright sunshine hours per day.

Installation:

The sunshine recorder is installed on a masonry pillar of 5′ (1.52 m) or 10′ (3.04 m). There should not be any obstruction having an elevation of 3° above the horizon.

Precautions:

1. Avoid excessive vigour in polishing the glass sphere. Avoid cleaning the glass bowl with any cloth.
2. Remove any deposits of dew, frost, snow or bird droppings immediately.
3. If the trace us not parallel to the central line of the card, carry out leveling and other adjustments of the recorder.
4. Use appropriate cards for the season.

(B) Radiation instruments:

1. **Pyrheliometer**: To measure direct solar beam on a plane surface at normal incidence.
2. **Pyranometer**: The instrument used to measure total incoming radiation (total short wave radiation) is called pyranometer. Principle of working is temperature differential s between two surfaces (black & white) is directly proportional to difference in solar radiation incident upon them.
3. **Albedometer**: It is used to measure reflectivity of short wave radiation is called albedometer. (Principle: as same as pyranometer).
4. **Net radiometer**: Net radiometer is measure net radiation. It has two pyranometers, the sensors of which are exposed to earth and sky. The sensor exposed to sky measures the incoming radiation and the other facing towards earth's surface measures outgoing radiation. The sensor is shielded with plastic domes, which are transparent to both short and long wave radiation.
5. **Quantum sensor**: It measures the photo synthetically active radiation (visible radiation). This instrument is most useful because it measures portion of solar radiation, which is essential for photosynthesis.

6. **Spectro-radiometer**: This instruments measures solar radiation in narrow wave bands. This has been developed by ISRO in the wave band width between 400 and 1010 nano micron.
7. **Luxmeter**: For measurement of intensity of radiation.

Units of measurement: solar radiation is expressed as watt per square metre. In meteorology, it is measure in cal/ cm^2 / m and another unit is Langley / min

1 watt = 1 jule / s 1 cal/ cm^2/ min = 697.93 watt/ m^2

Precautions:

a) Pyranometers should be kept horizontal while in use.
b) Observation should be repeated to check for accuracy.
c) Any shading on sensors should be avoided.
d) While tacking observation, plastic dome should be in fully inflated state.
e) The instrument is usually held 50- 100 cm above the surface over which observation is to be recorded.
f) Plastic dome should be clean and free from wrinkles and deposits of foreign matter.

Shortwave and long wave radiation estimation

Objectives:

1. To compute global radiation
2. To compute net short wave radiation, net outgoing radiation and net radiation

Introduction:

Global radiation is defined as the total of direct and indirect radiations (diffused, scattered radiation). The amount of radiation at the top of the atmosphere (Ra) is dependent on latitude and the time of year (Table Value). Radiation while passing through atmosphere is scattered and absorbed by the atmosphere constituents and clouds. Hence, the amount of radiation reaching to earth surface is identified as solar radiation or global radiation (Ra). This is largely dependent on cloud cover. This radiation when falls on soil, crop or water surface are reflected back and lost to the atmosphere. This reflection depends on the nature of surface .

Estimation by Angestrom's formula:

$$Rs = Ra (0.25 + 0.50 \ n/N)$$

Where, n = actual sunshine hours measured by sunshine recorder

N = Maximum possible sunshine hours for a given station and latitude for a given month (Table value)

Ra = Radiation at the top of the atmosphere in mm (Table value)

Estimation of net short wave radiation:

$$Rns = (1 - \propto) Rs$$

Calculate this value for crop surface ($\propto$ = 0.25) and for water ($\propto$ = 0.05)

Estimation of net long wave radiation and total net radiation:

Data required: (i) Latitude (ii) Altitude (iii) Mean Air temperature
(iv) Mean Relative Humidity (v) Sunshine hours

Tables required:

(1) Ra = Extra terrestrial radiation

(2) N = Maximum sunshine hours for different months and latitudes

Determination of net long wave radiation (Rn1):

Rn1 is a function of temperature (T), vapour pressure (ed) and percent sunshine hours ratio n/N, values of the f (T), f (ed) and f (n/N) are available from the tables.

R/n = RL↑ - RL↓

According to Stefan-Boltzmann law the intensity of radiation emitted by a radiating body is equal to the fourth power of the 'T' of that body

$Rln = \varepsilon s \sigma T_s^4 - \varepsilon a \sigma T_a^4$

Where, ε = Emissivity of soil (s) and air (a) Ts & Ta = Mean soil and air temperature

Assume that As = Ta

$\sigma T_s^4 - \sigma T_s^4 (a + b \sqrt{ed})$

$\sigma Ta (1 - a - b \sqrt{e})$

This is applicable for clear sky conditions

$= T_a^4 (1 - a - b \sqrt{e}) (e + m\ n/N)$

where, e = 0.01 , m = 0.9, a =0.44, b = 0.092

n = actual bright sunshine , N= maximum possible sunshine hours

Net radiation :

Rn = Rns – Rn1

$= Rs (1-\propto) (A + B\ n/N) - \sigma T_a^4 (1 - a - b \sqrt{ed}) (l + m\ n/N)$

$= Ra (1-0.25) (0.18+0.55\ n/N) - \sigma T_a^4 (1 - a - b \sqrt{ed}) (l + m\ n/N)$

The net radiation is the algebraic sum of net short radiation (Rns) and net long wave radiation (Rnl). The net long wave radiation always represents a loss and it is a negetive term.

Rn = Rns –Rnl

This give a net radiation for a given place and for a given month in terms of depth (mm) of evaporable water (1 mm of water = 58 cal of heat energy)

Example:

Calculate net radiation of a crop surface ($\propto$ =0.25) of a station having latitude 21.30' N, altitude 61 m with the following data for the month of Februray

Mean temperature = 30^0 C

Mean RH = 50%

Sunshine = 9.5 hrs

*****

EXERCISE : 3

MEASUREMENT OF MAXIMUM , MINIMUM TEMPERATURES AND SOIL TEMPERATURE

Introduction:

Air temperature plays a vital role in crop growth and development. Crop water use increases with the increase in temperature. There are three cardinal temperatures (viz. maximum, minimum, and optimum temperature ranges) for germination, flowering and other crop developmental processes. The range of temperatures present also determines final grain yields during the crop-growing season and hence, the observations of air temperatures at different hours of the day as well as maximum and minimum values for the day are important.

Aim : To measure the maximum, minimum and the prevailing air and soil temperature.

Description of the instruments:

Stevenson Screen (Single size):

- It is a wooden box in which (1) Dry bulb (2) Wet bulb (3) Maximum thermometer and (4) Minimum thermometer are exposed.
- It provides all the essential conditions for the exposure of the thermometers i.e.
  (1) Free access of air to the bulb of the thermometers
  (2) Protects the thermometers from the direct exposure to sunrays and raindrops.

It is a double louvered wooden box, with a dimension being 2'X 2.5' X 3.0' with double roof. The upper one projecting 2" beyond the sides of the screen and slopping from front to back. The front of the screen is hinged as a door and can be opened downwards. The Stevenson screen is to be erected on four iron posts with the door opening to the north. The bottom of the screen should be kept 120cm. above the ground level.

Maximum Thermometer:

- It is a mercury in glass type of thermometer ranging from –35°C to +55°C, having a mercury constriction which does not allow mercury to come down when the prevailing temperature falls, unless mechanical jerk is given.
- It records the **highest temperature** reached since last observation.
- The thermometer is to be set at 0700hrs. LMT by giving jerks.

Minimum thermometer:

- It indicates the **lowest temperature** reached during last 24 hrs.
- It is an alcohol / spirit in glass type thermometer ranging from –40°C to +50°C, having a light narrow index.
- Reading is taken from the end of index, which is away from the bulb.
  It is set at 1400 hrs. LMT by tilting the thermometer with the bulb upwards.

Dry bulb Thermometer:

- It is an instantaneous instrument, which gives the current temperature of the air. It is mercury in glass type thermometer.
- It is just like an ordinary mercury thermometer ranging from -35°C to 55°C, used for calculating the relative humidity, dew point temperature and vapour pressure.
- The least count of the thermometer is 0.5°C but reading is recorded up to 0.1°C.

Wet bulb Thermometer:

- It is same as the dry bulb thermometer except that the bulb of this thermometer acts as an evaporating surface.
- The bulb is enclosed with muslin, which is connected with a thread dipped in distilled water container.
- The water flow is maintained through the thread and keeps the bulb of the thermometer wet.
- This temperature is used for calculating dew point temperature, relative humidity and vapour pressure.

Maximum and Minimum thermometers are kept inside the screen horizontally where as dry bulb and wet bulb are hanged vertically.

Double Size Stevenson Screen:

Its construction is similar to that of single size Stevenson Screen except that it is double in length. In this screen self-recording instruments like Thermograph, Hygrograph or Thermo hygrograph, Evaporigraph Barograph etc are kept.

Thermograph:

It is an instrument used for recording continuously the temperature of air. Common type of thermograph is Bourdon tube, which has a flattened, curved metal tube filled with liquid, sealed and fastened rigidly at one end. With change of temperature, there is unequal expansion or contraction of the liquid and the metal, producing a change of curvature in the tube thus moving the free end. This movement is communicated to a pen, which is caused to moving up and down on a drum that is being rotated by a clockwork arrangement within it. In this manner a continuous record of temperature is traced on the graph sheet surrounding the rotating drum.

Thermo hygrograph: It is an instrument used for recording continuously temperature and relative humidity both on a single graph paper.

Soil thermometer:

Soil thermometers are used for recording the variation of soil temperature with time and depth in the layers which are affected by diurnal variation and with which crops are primarily concerned. Diurnal range of soil temperature is the highest at the surface and this range decreases rapidly with depth and becoming practically negligible at a depth of 1 ft. These thermometers are held by the iron stands in inclined position making 60° angle with soil surface. Soil thermometers commonly used are of

three depths 5, 10 and 20 cm. Thermometers should face south direction. These are placed 45 cm apart in a plot of size 120x180 cm.

Grass Minimum Thermometer (The Terrestrial Radiation Thermometer):

This instrument is used to measure the actual minimum temperature experienced by the plant near ground surface. The grass minimum temperature is lower than the air temperature at screen height. The readings of the thermometer indicate **the possibility of occurrence of ground frosts**. A ground frost is likely to have occurred when the instrument records $0^{O}C$ (32°F) or below it.

Its construction and working is similar to that of minimum thermometer. The thermometer is exposed 1" above ground surface on its support over the grass plot in the evening and its reading is noted before sunrise in the next morning. After reading the instrument in the morning, it should be removed to the observatory room or some shady place (indoors) to avoid direct exposure to solar radiation.

Hour of Observation:

- Reading of grass minimum thermometer is taken before sunrise.
- Temperature observations viz. dry bulb, wet bulb, maximum, minimum and soil are recorded at 0700 and 1400 hours LMT.
- After sunset sunshine card is changed and grass minimum thermometer is exposed.
- Air temperatures reported is always measured inside a thermometer shelter.

*****

EXERCISE : 4

MEASUREMENT OF WIND SPEED AND WIND DIRECTION AND PREPARATION OF WIND ROSE

AIM:

To measure the wind direction and wind speed at the time of observation.

Name of instrument:

1. Cup counter anemometer
2. Wind vane

Procedure:

1. Watch the wind vane for few minutes and identify the direction.
2. Read the direction to which the arrowhead points, nearest to the sixteen prints of the compass.
3. Note the initial and final reading of the anemometer after 3 minutes. Subtract the initial reading and multiply by 20 to get the instantaneous wind speed at the time of observations in kilometre per hour (kmph).
4. Subtract the anemometer reading at 7:00 hrs. LMT of the observation date and divide the difference by 24 to get the main daily wind speed for the observation dates.

WIND VANE:

The common instrument to determine wind direction is wind vane. This instrument indicates the direction from which wind blows. It is a balanced lever that turns freely about a vertical axis. One end off the lever exposes a broad surface to the wind, while the other end of which is in the form of an arrow head points to the direction from which the wind blows. This narrow end is the form of an arrow head. Under this movable system, there are eight fixed rigid bars that are set to the eight cardinal directions i.e. North, North-East, South-East, South, South-West, West and North-West.

Installation: It is installed over a wooden plank, is fixed on a wooden post. The height between the pointer and ground level is exactly 10 feet (3.05m). The north indicator should be se to true north and not to the magnetic north. The axis of the wind vane should be exactly vertical

Units: there are two ways of expressing wind direction

By sides: In sixteen point of a compass as

N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW.

By degrees (from north, measured in clockwise as 360, 20, 50, 70, 90, 110, 140, 160, 180, 200, 230, 250, 270, 290, 320, 340,)

CUP COUNTER ANEMOMETER:

Wind speed is measured by cup counter anemometer. This instrument consists of three or four hemispherical cups fixed at the end of metal arms from a central point. The cup wheel is pivoted at the centre to a vertical spindle passing through a brass tube attached to the anemometer box. The cups a re set in motion due to the pressure difference occurring between two faces of the cup. The vertical spindle (about which the cups rotate) is connected to a mechanical counter through a gear system from which the number of rotations made by the cups can be counted. The counter is directly calibrated in kilometre.

Installation:

In an agro-meteorological observatory, wind instruments are installed at an open site. It is installed on pillars or wooden posts so that the height of the centre of anemometer cup or the arrow head should be 10′ (3.05 m) above the ground. The minimum exposure criterion for the wind instruments is that any obstruction should be away by at least 10 times the height of the obstruction.

Units of measurement: The wind speed is directly measured in terms of km/ hr. However, the wind speed in synoptic charts is given in knots.

The conversion of different units:

1 knot = 1 Nutical mile = 1.15 mile/ h = 1.85 km/ h = 0.51 m / s.
1 mph = 0.8684 knot = 1.609 kmph = 0.447 m/s.
1m/s = 1.94 knots = 3.6 kmph = 2.24 mph.

Maintenance:

1. The screw cap of the wind vane should be lubricated by clock oil every fortnight.
2. Anemometer should be lubricated every week.
3. Every six monthly the bearing should be washed and lubricated thoroughly.

Precursors:

1. Make sure that the wind vane moves freely before taking the readings.
2. During light winds, when wind vane does not respond readily, give a light turn to the wind vane by hand and allow it to take up the direction of wind.
3. Reading should be taken nearest to sixteen point of a compass for wind vane.
4. Record the anemometer reading carefully.

Observations & calculation of wind speed:

Instantaneous wind speed: Note down two readings from anemometer at an interval of three minutes. Multiply the difference by 20 to get wind speed at the time of observation in km/h.

Mean daily wind speed: Subtract the Anemometer reading at 0700 LMT of the previous day from that at 0700LMT of the observation day and divide the difference by 24 to get the mean daily wind speed for the observation day.

Barograph: It is used for recording continuously the atmospheric pressure. It consists of several metallic chambers, one on top of other. The combined motion of these is communicated to a lever, terminating in a pen. The pen writes a record of the pressure upon a graph paper wound around a drum while the drum is being rotated by clock within it.

Exercise: Take the reading of wind vane and Cup counter Anemometer. Calculate a wind speed at the time of observation and mean daily wind speed.

*****

EXERCISE : 5

DETERMINATION OF VAPOUR PRESSURE, RELATIVE HUMIDITY AND DEW POINT TEMPARATURE

Introduction:

The humidity in the atmosphere is of great physical as well as biological importance. It influences the internal water potential of plants and the rate at which plants transpire into the atmosphere. H umid conditions affect the growth and development of many pathogens especially the fungal organisms.

Objectives:

1. To measure dry bulb and wet temperature and calculation of RH, VP and Dew Point temperature.
2. To familiarize with hygrometric table.

What is Psychrometer?

The instrument which contains both dry bulb and wet bulb thermometers for the measurement of dry bulb and wet bulb temperatures is called psychrometer. The depression of wet bulb gives an idea abou t the relative humidity of the air at particular time.

What are the different measures of humidity parameters?

The atmospheric humidity is measured in various units. The important measures of humidity are; vapour pressure, relative humidity, dew point temperature etc.

- **Vapour pressure:** Air contains different gases and water vapour also behaves as a gas. The pressure of air is the sum of the partial pressures of its component gases. The partial pressure due to presence of water vapour in air is called vapour pressure. The vapour pressure is expressed in c.g.s. Units of pressure viz. milli bars or milli meters of mercury (mm of Hg). The M.K.S unit of pressure is Pascal. The pressure exerted by the water vapour under saturated conditions is called as the saturation vapour pressure (S.V.P.). The saturation vapour pressure depends on the temperature of the air. It increases nearly exponentially with the air temperature. The pressure exerted by water vapour actually present in the air is called as actual vapour pressure of the air or simply, the vapour pressure of air.
- **Saturation deficit:** It is the difference between saturated vapour pressure and the actual vapour pressure present in the atmosphere.
- **Relative humidity:** The ratio of actual vapour pressure to saturation vapour at the prevailing air temperature is called as relative humidity. It is normally expressed in percentage.
- **Dew point temperature:** Dew point temperature is the temperature at which air would become saturated if it is cooled at constant pressure without addition or removal of water vapour. Thus, the actual vapour pressure is equal to the saturation vapour pressure at the dew point temperature. If the dew point temperature is close to the air temperature it means that the air is nearly saturated.

Description of Dry bulb and Wet bulb thermometers:

Dry bulb Thermometer:

- It is an instantaneous instrument, which gives the current temperature of the air. It is mercury in glass type thermometer.
- It is just like an ordinary mercury thermometer ranging from -35°C to 55°C, used for calculating the relative humidity, dew point temperature and vapour pressure.
- The least count of the thermometer is 0.5°C but reading is recorded up to 0.1°C.

Wet bulb Thermometer:

- It is same as the dry bulb thermometer except that the bulb of this thermometer acts as an evaporating surface.
- The bulb is enclosed with muslin, which is connected with a thread dipped in distilled water container.
- The water flow is maintained through the thread and keeps the bulb of the thermometer wet.
- This temperature is used for calculating dew point temperature, relative humidity and vapour pressure.

As the temperature falls the alcohol contracts and end of alcohol column in stem moves towards the bulb dragging the index along with it by the surface tension of the liquid. If subsequently the temperature increases, the alcohol flows freely past the index without displacing it. Thus the position of the end of the index farthest from the bulb indicates the lowest temperature reached since the thermometer was last set.

Dry bulb and Wet bulb thermometers are kept vertically inside the Stevenson screen.

Relative humidity:

- When the air is saturated no evaporation takes place and therefore there is no difference between the temperature in the wet and dry bulb thermometers. The R.H. is therefore said to be 100%.
- On the other hand, when the air is not saturated evaporation takes place in the wet bulb thermometer. As this takes up heat energy from the mercury contained in the wet bulb consequently the temperature goes down. The greater the evaporation, the lower will be the temperature and hence the greater the difference between the temperature of the wet and the dry bulb thermometer.
- The R.H. is obtained by calculation or by using ready- made tables like Hygrometric and SVP tables from which one can find the relative humidity and dew point temperature corresponding to wet and the dry bulb temperatures.

Hygrograph:

It is an instrument used for recording continuously the relative humidity of the air. Huma n hair has a property when it is free from fat that its length varies with the relative humidity but it varies ve ry little with other elements. The length of human hair increases with increase in humidity and decreases with its decrease, increase in length being ½-2 ½ % of original length.

Micro-climatic Pole (M.C.P):

It is a wooden pole of 12'height fixed at the center of observatory at which micrometeorological observations like temperature and humidity are taken with the help of either a whirling or Assamann Psychrometer at 1', 2', 4', 8' and 12' height. In case of Assamann Psychrometer extra reading at ground surface is also recorded. The pole is painted white and height of 1', 2', 4', 8' and 12' from ground surface are marked on it. The side of the pole places a wooden ladder 8 feet height.

Artificial ventilated psychrometers:

(A) Whirling Psychrometer:

This instrument is used to measure the temperature and relative humidity of the air both in open as well as inside crops at various heights.

In this Psychrometer whirling or rotating the thermometer provides the aspiration, which is mounted side by side on a suitable wooden frame with a movable handle. To obtain desirable air speed of about 5 meters/sec the psychrometer should be given about 4 revolutions per second. Avoid direct sunlight falling on the instrument while taking observation.

(B) Assamann Psychrometer:

This instrument is designed for accurately measuring the temperature and relative humidity of the air, both in the open as well as inside crops.

In this psychrometer the aspiration is provided by means of a clockwork fan, by which air is drawn at a speed higher than 10 feet per second. Each bulb is protected from external radiation by two highly polished coaxial tubes so that instruments can be held even in strong sunshine without risk of solar radiation affecting the readings.

By the reading of dry bulb and wet bulb thermometer of whirling or Assamann psychrometer, vapour pressure and relative humidity is computed.

Hour of Observation: Observation of dry bulb and wet bulb thermometers are recorded at 0700 and 1400 hours LMT.

ESTIMATION OF RH AND VP

Relative humidity (RH)

$$\textbf{RH} = \frac{e_a}{e_s} \times 100$$

Where, e_a = AVP at dry bulb temperature or SVP at dew point temperature, mmHg

e_s = SVP at dry bulb temperature, mmHg

SVP at dew point temperature = e_a = E' – AP (Td- Tw)

Where, E' = SVP at wet bulb temperature in mmHg

A= Psychrometric constant (0.0008)

P= Atmospheric pressure (1013 mb or 760 mmHg)

AP = 0.6 mmHg or 0.8 mb

Vapour pressure (VP)

$$e_a = e_w - 0.0006\ P\ (T_d - T_w)\ (1+0.00115\ T_w)$$

Where, e_a = Actual Vapour pressure (mb)

e_w =Saturation vapour pressure at wet bulb temperature

P =Atmospheric pressure (mb),1013 mb

T_d = Dry bulb temperature (°C)

T_w = Wet bulb temperature (°C)

$$e_a = e_w = \frac{0.480\,(T_d - T_w)}{610 - T_W} \text{ x } P$$

Solved example for given data :

Date	Time (hrs)	Temperature (°C)		Atmospheric pressure (mb)	SVP (e_s)	SVP* (e_w)
		(T_d)	(T_w)		(mm)	
24/01/03	0738	14.0	12.4	999.4	12.0	10.8
	1438	18.4	16.4	992.7	15.9	14.0

* SVP values to be obtained from Hygrometric table

(i) Convert SVP into mb units to make the pressure value balanced, i.e. taking 1 mm = 1.333 mb

At 0738 hours e_s = 1.333 x 12 = 16.00 mb

e_w = 1.333 x 10.8 = 14.4 mb

Calculation of VP at 0738 hrs

$$e_a = 14.4 - \frac{0.480\,(14.0 - 12.4)}{610 - 12.4} \text{ x } 999.4$$

= 14.4 – 1.28 = 13.12 mb

$$\text{RH (\%)} = \frac{e_a}{e_s} \text{ x } 100 = \frac{13.12}{16.0} \text{ x } 100 = 82\ \%$$

Dew point temperature

It is defined as the temperature at which air becomes saturated when it is cooled at constant pressure without removal or addition of moisture.

It can be seen from hygrometric tables directly.

Calculation of dew point temperature and dew point depression

Ex.-1 : Calculate dew point temperature, if air temperature and relative humidity (RH) are 15.0 ^{0}C and 58 % respectively.

Tdp = T - (100-RH)/5

Where Tdp= Dew point temperature (^{0}C)

T= Air temperature(^{0}C)

RH = Relative humidity (%)

Tdp = 15-(100-58)/5

=15-(42)/5

= 15-8.4

= 6.6 ^{0}C

*****

EXERCISE : 6

MEASUREMENT OF RAINFALL AND EVAPORATION MEASURING INSTRUMENTS

MEASUREMENT OF RAINFALL

AIM: To measure amount, duration and intensity of rainfall.

Name of instrument:

1. Ordinary raingauge with measuring cylinder
2. Self-recording raingauge

Ordinary Rain gauge: It is an instrument used for measuring the amount of rainfall. It consists of five parts (1) Funnel (2) Receiver (3) Body (4) Base (5) Measuring cylinder.

The funnel is provided with a brass rim, which is truly circular and exactly 5" (127mm) in diameter. The rim of the rain gauge should be 12" above ground level and 10" above cemented platform. The rain is collected in receiver and is measured by standard measuring cylinder provided with the instrument.

INSTALLATION:

The raingauge should be fixed on masonry or a concrete foundation of 60 cm X 60 cm X 60 cm sunk in the ground. The base of the gauge is cemented into the foundation so that the rim of the raingauge is exactly 30 cm above the ground level. The height is chosen in order to minimize water splashing into the raingauge. If the height of the rim is more, the rain water collected would decrease because of the change in the wind structure near the raingauge. The top of the rim of the raingauge should be perfectly horizontal.

EXPOSURE:

A raingauge should be installed on a level ground, not upon a slope or terrace or never on a wall or roof. In order to avoid the loss of raindrops due to obstruction, the distance any object should be at least twice the height of the object above the rim of the raingauge.

MEASUREMENT OF RAINFALL:

The rain falling into the funnel of the raingauge is collected in the receiver kept inside the body and is measured by means of a special measuring glass cylinder graduated in milli meters. Ten milli meters of rain means that if that rainfall is allowed to be collected on a flat surface, the height of water collected would be 10 mm. In case, the special measuring glass cylinder is not available, rainwater can be measured by commonly available measuring glass graduated in ml. In such cases, 126.7 ml of water measured is equal to 10 mm of rainfall. This conversion is applicable to a rainfall spell.

Self-recording Rain gauge : The instrument is designed to measure the duration, amount and rate of rainfall. It consists of a float chamber containing a light hollow float. As the water collected by the outer funnel is led into this chamber, the float rises along with the water level and the vertical movemen t of the float is recorded on a pen on chart fixed on a rotating clock drum. This chart has a range of 10 mm or 25 mm. As soon as 10 mm or 25 mm if rain falls, the pen reaches the top line of the chart. But the instrument has a siphoning arrangement so, the water in the chamber gets emptied and the pen and floa t come to the initial position immediately. If there is further rain, the pen continues to rise and record the rainfall in the manner. If there is no rain the pen traces the horizontal line from where it leaves off rising.

INTENSITY OF RAINFALL SPELL:

The intensity of a rainfall spell is defined as the ratio of the total amount of rainfall recorded dur ing the spell to the total duration of the spell. It is expressed in mm per hr.

MEASUREMENT OF RATE OF EVAPORTION

AIM: To measure the rate and amount of evaporation of water by means of a pan evaporimeter.

Part of Pan evaporimeter:

1. Class 'A' pan evaporimeter	2. Still well	3. Measuring cylinder
4. Thermometer	5. Wooden frame	6. Wire mesh

Evaporation is measured by means of pan evaporimeter. This instrument is used to measure the evaporation of water near the ground. The class A pan evaporimeter which is commonly used in India, consists of a large cylindrical pan made of copper or tin with 120 cm diameter and 25cm depth. The pan is made of 20 gauge of copper sheet tinned inside and painted outside. A still well is provided inside the pan so that there would undisturbed water surface inside the well and ripples would be broken. It consists of a brass cylinder mounted on a heavy circular base provided with three circular holes at the bottom. The reference pointed is provided by a brass rods fixed at the centre of a still well.

For measuring evaporation, a graduated measuring cylinder made of brass is also provided with the instrument. It has a scale of 0.20 cm engraved inside it along its height. The reservoir of the Evaporimeter rests on a wooden platform120cmx120cm, placed on the ground. The height of wooden platform is 10cm so that the rim of the reservoir is 40 cm above the ground. The reservoir is covered wi th wire mesh to check water loss by birds etc

PROCEDURE:

1. Note the water temperature correct to 0.1 ^{O}C.
2. If the water level below the tip of the rod, add sufficient water slowly with the help of the measuring cylinder so that the water level again coincides with the reference level.
3. Note the amount of water added by taking into account the number of cylinders of water added and parts thereof.

4. If rainfall has occurred during 24 hrs ending 08:30 hrs IST and still the water level has fallen below the reference point and water has to be added to bring the water level to the reference level, this amount of water should be added to the rainfall amount in mm to get th e total evaporation for the day. If however, the rainfall has been heavy and water level has gone above the reference point at the time of observation, remove water with the help of the measuring cylinder in order to bring the water level back to the reference point. Subtract from the rainfall the amount of water removed in order to get the total evaporation for the day.
5. If on any day, due to occurrence of very heavy rainfall, the water level has risen up to the rim of the pan and some water has over flown. So, entry '**over flown'** should be made in the observation register.

OBSERVATIONS TO BE RECORDED:

1. Temperature of water in the pan.
2. Amount of water added or removed to bring back the water level to the reference point.
3. Amount of rainfall, of any, during the past 24 hours.

INSTALLATION:

The evaporimeter should be installed at an open sight with no obstruction casting shadow on the pan. The pan should be placed on the wooden grill kept on a fixed foundation so that the edge of the pan is on level and is exactly at 30 cm above the ground. The rate of evapo ration is measured daily at 08:30 hours IST.

Evaporigraph: This instrument is used for recording continuously the evaporating power of the air.

Time of Observation

Ordinary rain gauge and self recording rainguage and Open pan Evaporimeter observations a re recorded and set at 0830hours IST (Indian Standard Time).

*****

EXERCISE : 7

ANALYSIS OF RAINFALL DATA FOR CLIMATOLOGICAL STUDIES

Introduction:

Study of rainfall over a long period is called rainfall climatology. It reveals the general pattern and characteristics of rainfall of a particular place or region.

- It helps in understanding the amount, intensity, and distribution of rainfall of a place.
- It helps in classification of climate.
- Understanding the rainfall climatology can develop suitable and efficient cropping systems.
- It helps in taking decisions on time of sowing, scheduling of irrigation, time of harvesting, growing period etc.

Only rainfall total or its mean over certain period is of little use in agriculture. As the crops are affected by rainfall amount, distribution, dry spells, wet spells, length of growing season etc. their determination in required. Also some parameters giving probability, variability, and dependability are important in crop planning and monitoring.

Following characteristics of rainfall can be useful in agriculture:

1. Total rainfall
2. Onset of monsoon / sowing rains.
3. Cessation of monsoon.
4. Duration of dry spell / wet spell.
5. Rainfall intensity.
6. Rainy days and their distribution
7. Effectiveness of rainfall.
8. Rainfall range
9. Mean rainfall.
10. Dependability of rainfall
11. Probability of getting specific amount of rains.
12. Mean deviation.
13. Standard deviation.
14. Coefficient of variation.
15. Rainfall trend
16. Conditional probability.
17. Dependability of rainfall

Objectives:

1. To maintain the rainfall data, daily, weekly, seasonal and annual basis.
2. To compute distribution, variability, probability, dependability of rainfall by statistical constants like mean, standard deviation, coefficient of variation (CV %) etc.
3. To calculate length of growing season and effectiveness of rainfall.

Standard Meteorological week

World Meteorological Organization (WMO) has divided a calender year into 12 durations of 30 days each – called **Periods** and 52 weeks – called meteorological weeks of 7 days each. The first week starts from 1st January and ends on 7th January and so on. The 9th (26th Feb. to 4th march) week in a leap year and the 52nd week consists of 8 days.

Meteorological Seasons

The whole year can be divided into 4 seasons such as pre-monsoon or summer (March to May), monsoon or Kharif season (June to September), Post-monsoon season (October to November) and winter or Rabi season (December to February).

Methodology

a) Central tendency of rainfall expressed through mean, mode, and median.

b) Dispersion of rainfall about mean expressed through mean deviation, standard deviation and coefficient of variation.

c) Dependability of rainfall through probability and coefficient of variation.

d) Rainfall trend through moving average.

A) Central tendency

1. Mean rainfall

Mean is the average value of rainfall for some years whereas decennial rainfall is the mean of the total rainfall during the past 10 years and normal rainfall is the mean of more than 30 years. The later represents the typical value of a whole distribution over the region. It is given by the formula

$R = \Sigma r_1 / n$

Where R = mean rainfall, r_1 = rainfall of i^{th} year, n = total no. of years.

2. Median

The median of a rainfall series is the value, which divides the total frequency into equal parts when the series is arranged in ascending or descending order.

For example,

1995	1996	1997	1998	1999	2000	2001
547	850	639	725	602	580	810

Arrange the rainfall in descending order irrespective of years

850, 810, 725, 639, 602, 580, 547.

ANS. 639 is the median value of the rainfall series.

3. Mode

Mode of a frequency distribution is defined as that value of the variable for which the frequency is maximum or the amount of rainfall which occurs most frequently.

4. Range

It is the difference between the highest and the lowest values of the rainfall series.

B) Dispersion of Rainfall

1) Mean Deviation (MD)

The mean deviation is defined as the mean of the absolute values of the deviations from the mean. It is a measure of variability. It shows the degree of scatter or disperses from the average or central value.

$$MD = \frac{\Sigma (X - \bar{X})}{n-1}$$

It does not take positive or negative signs unto consideration.

2) Standard Deviation (SD)

It is defined as the square root of the mean of the squares of deviations of the rainfall values from the arithmetic mean of all such rainfalls. It is a measure of variability or the scatter or the dispersion about the mean values. It is given by the following formula.

$$SD (\sigma) = \sqrt{\frac{\Sigma (Xi - \bar{X})^2}{n-1}}$$

3) Coefficient of Variation (CV %)

CV is defined as the standard deviation divided by the mean value of rainfall. It shows the variability of rainfall in percentage. Higher the CV % lower is the dependability and vice versa.
It is give by the formula

$$CV (\%) = \frac{SD}{Mean} \times 100$$

For weekly rainfall series

If CV % < 100 it is highly dependable or reliable.

If CV % is 100-150, it is dependable or reliable .

If CV % is > 150, it is not dependable or not reliable**.**

The coefficient of variation of rainfall in a humid region is quite lower than the CV of rainfall in arid and semi-arid regions. If the annual variability is more than 20 percent presents a great risk in rain fed faming.

C) Dependability of Rainfall

Dependable rainfall for a given period can be defined as a quality of rainfall received at 75 % probability on long term basis. This is also known as assumed rainfall. Generally following probability levels are considered.

- 75 % level or a value of rainfall expected in 3 out of 4 years.
- 80 % level or a value of rainfall expected in 4 out of 5 years.
- 90 % level or a value of rainfall expected in 9 out of 10 yrars.

Dependable rainfall for a week or month or a season or a year is computed as follows:-

Procedure:

- Use rainfall data for more than 30 years.
- Arrange the data in descending order.

- Assign a number to each entry value – called as rank number.
- Give 1 number to the highest value and than an increasing number to decreasing values.
- Calculate probability for each rank by following formula:

  $Fa(m) = \frac{100\ m}{n+1}$, where m = rank number

  n = no. of observation / years

  $m = \frac{Fa\ X\ (n+1)}{100}$

  Fa = level of percentage
- Preparation vertical scale and plot rainfall accounting to Fa position on log - normal probability paper.
- Expected value of rainfall at 50, 75, 80 or 90 % probability can be obtained from the the graph plotted or by finding rank number corresponding to the 50, 75, 80, and 90 probability level and finding corresponding rainfall.

Example: Annual rainfall

Year	Rainfall	Descending Order	Rank No. (m)	Plotting
1990				
1991				
1992				
1993				

Rainfall characteristics

1. Mean rainfall
2. Median
3. Mode
4. Mean Deviation
5. Standard Deviation
6. CV %
7. Range
8. Rainfall at 75 % probability
9. Rainfall at 80 % probability
10. Rainfall at 90 % probability

*****

EXERCISE : 8

MEASUREMENT OF ATMOSPHERIC PRESSURE AND ANALYSIS OF ATMOSPHERIC CONDITIONS

Technically, pressure is defined as the force per unit area. But, the pressure exerted by the atmosphere on the earth's surface is called atmospheric pressure. It is defined as the pressure exerted by a column of air with a cross sectional area of a given unit extending from the earth's surface to the upper most boundary of the atmosphere. The standard sea level pressure is given as 1013 mb or 76 cm or 29.92" at a temperature of 15°C and 45° north latitude. Atmospheric pressure does not have direct influence on crop growth. It is however, an important weather parameter in weather forecasting.

Instruments:

An instrument called as barometer measures atmospheric pressure. There are four types of barometers:

1. Fortin's barometer
2. Kew pattern barometer
3. Aneroid barometer
4. Barograph

The standard instruments for measuring atmospheric pressure are aneroid barometer and barograph.

1. Fortin's barometer

This barometer is standard and accurate instrument for measuring pressure. It consists of a small cistern vessel containing mercury with a flexible leather bag and a screw at its bottom. The mercury level can be raised or lowered with the help of the screw. In the cistern vessel, a glass tube filled with mercury is kept inverted. In this vessel there is a pouted ivory pointer. from the lower tip of this pointer, the zero of the scale starts and therefore while taking reading, the mercury level in cistern vessel must touch the lower tip. There are two scales on two sides of the tube, one in centimeters and the other in inches. Vernier calipers are also attached for accurate reading. To take pressure reading the height of mercury column is measured on main scale and then Vernier scale is read.

Atmospheric pressure = MSR + VSR X Vernier constant

The metal scale and the mercury expand differently at different temperatures. They are, therefore transformed to one common temperature which is zero degree centigrade or 273^0 K. The gravitational pull changes according to latitude. Hence, the gravitational correction is applied and all the readings are transformed into one common latitude i.e. 45° N. All the readings are transformed to sea level height. Thus, three corrections such as temperature, gravity and latitude are applied.

2. Kew pattern barometer

This is also similar to Fortin's barometer were the cistern vessel is fixed and has no adjusting screw. The divisions are made unequal in order to allow rise or fall of mercury column in the cistern. In this barometer initial adjustment of cistern is not required.

3. Aneroid barometer

This barometer does not contain any liquid. It consists of a evacuated box with a corrugated sheet of metal lid held in position by means of a spring to avoid collapse of the top and bottom. This box is called as siphon cell and is sensitive to change in pressure. When the pressure increases the cell is compressed and when it decreases the cell is expanded. These variations are magnified with the help of levers and are communicated through chain and pulley to the pointer, which moves on graduated scale. This pointer gives direct pressure reading. This is not an accurate instrument.

4. Barograph

This instrument is used for automatic and continuous record of atmospheric pressure; it is a special type of aneroid barometer having recording system. It consists of several vacuum boxes simil ar to aneroid barometer placed one above another. The combined motion of these vacuum boxes becomes appreciable and is then communicated to a level system. The changes are marked on a chart paper fixe d on the clock driven rotating drum. The chart is calibrated in cm or inches on one axis and hrs/days of week on another axis. Thus, a continuous record of atmospheric pressure is obtained.

Before use the instrument must be standardized with the help of Fortin's barometer. This instrument does not give correct pressure readings. However, it is helpful in recording the ba rometric tendencies.

Use of barometer

It is used for approximate forecasting, to measure atmospheric pressure and to measure height of a given station above mean sea level.

Weather and pressure:

All the weather changes are closely related to pressure variations.

1. Falling barometer indicates rain or storm (bad weather).
2. Rising barometer indicates fair weather (clear and stable).
3. Steady barometer indicates steady or settled weather.
4. A continually rising pressure indicates fine and settled weather and a steadily falling pressure indicates occurrence of unsettled and cloudy weather.

Units of pressure

The pressure is measured in following units.

1 atmospheric pressure = 29.92" = 76 cms = 760 mm

= 1013 millibar

= 101.32 kilopascal(Kpa)

= 14.7 lbs/inch^2

= 1.014 X 10^6 dynes /cm^2

= 1 bar

1. Height of mercury column in inches or cms or mm

2. Bar is force equal to 10^6 dynes /cm^2. This is big unit and is therefore divided into smaller units

   1 bar = 1000 mb

3. In standard international unit of pressure is Pascal

   1 Pascal = force of 1 Newton/ sq.m.

CALCULATION BASED ON AIR DENSITY AND ATMOSPHERIC PRESSURE.

Ex.-1: Calculate the standard sea level air density, if the standard sea level pressure is 1013 hPa and temperature is 15.0^{0}C

Absolute temperature = C+273
= 15.0+273.0
= 288 ^{0}K
Air density = P/RT
Where P = Atmospheric pressure at msl
R = Gas constant = 2.87
T = Absolute temperature

Air density (kg/m^3) = 1013/2.87*288
= 1013/826.56
= 1.225

Ex.-2: Calculate the mean sea level pressure ,if the air density and air temperature are 1.165 kg/m^3 and 30.0^{0}C respectively.

Absolute temperature = C+273
= 30.0+273.0
= 303 ^{0}K

Air density (kg/m^3) = 1013/2.87
1.165 = P/2.87
= 1013 hPa

*****

EXERCISE : 9

ESTIMATION OF HEAT INDICES

Introduction:

The accumulated heat unit system or degree-day concept can be used for the prediction of crop maturity dates in a region. The concept assumes that there is a direct and linear relationship between growth and temperature. The assumption is that a crop requires a definite amount of accumulated heat energy for completion of its life cycle.

Objectives:

(1) To familiar the students with the definition and concept of degree day.
(2) To calculate mean, SD, CV%, GDD, PTU, and HTU units from the given data.
(3) To forecast the crop stages on the basis of GDD.

Definition:

(a) Phenology:

The periodic biological events and their dates of occurrence in the plant life in relation to the influence of weather are called phenology. **OR** It is the branch of science which studies the periodical biological events with respect to calendar days.

(b) Growing Degree day (GDD):

The degree-day or heat unit is the departure from the mean daily temperature above the minimum threshold or base temperature or critical temperature. **OR** It is the difference between daily mean temperature and base temperature.

(c) Base temperature (Tb):

The temperature below which growth does not take place is known as base temperature. The value for majority of the plants ranges from 3.5 to 12.0 ^{o}c.

Base temperature of some crops (in degree Celsius)

Crop	Base Temperature ($^{\circ}$C)	Crop	Base Temperature ($^{\circ}$C)
Pea	1 – 2	Oats	4 – 5
Wheat	3.0 - 4.5	Groundnut	8 - 10
Barley	3.0 - 4.5	Tobacco	13-14
Sugar beet	4 – 5	Pumpkin	12
Rice	10-12	Lentils	4 - 5
Sorghum	8 - 10	Carrot	4 - 5
Maize	8 - 10		

(d) Photo-thermal unit (PTU):

The product of GDD and maximum bright sunshine hours of any day is called photo thermal unit (PTU).

(e) Helio-Thermal Unit (HTU):

The Product of GDD and the number of actual bright sunshine hours on the day is called helio-thermal unit (HTU).

(f) Hydrothermal unit (HYTU): The product of GDD and relative humidity is called HYTU

Materials:

Data on daily maximum temp; daily minimum temp., day length and daily number of actual bright sunshine hours during the growing period of the crop and base temperature of crop (Tb).

Methodology:

(1) GDD = $\Sigma \frac{(T_{max} + T_{min})}{2} - T_b$ Where, Tb is base temperature of crop

(2) PTU = GDD x Day length (hours) or max. possible bright sunshine hours.

(3) HTU= GDD x No. of actual bright sunshine hours

(4) Trange = Tmax-Tmin

(5) Heat Use Efficiency (HUE) = $\frac{\text{Yield (Kg/ha)}}{\text{GDD (Degree day)}}$

(6) Radiation Use Efficiency (RUE) = $\frac{\text{Yield (Kg/ha)}}{\text{PTU (Degree day hrs)}}$

(7) Heliothermal Use Efficiency = $\frac{\text{Yield (Kg/ha)}}{\text{HTU(Degree day hrs)}}$

(8) Hydrothermal use efficiency (HYTUE) = $\frac{\text{Yeild (kg/has)}}{\text{HYTU } (^{o}\text{C day \%})}$

Assignment:

From the given data calculate mean, SD, CV%, GDD,PTU, and HTU for the wheat crop on Nov.1st (Taking Tb= 5^{o} C)

Date	Tmax(^{o}C)	Tmin(^{o}C)	Day length (hrs.)	Sunshine hours (No.)
1				
2				
3				
4				
5				
6				
7				
8				
9				

*****

EXERCISE : 10

COMPUTATION OF PET AND AET

ESTIMATION OF POTENTIAL EVAPOTRANSPIRATION

Introduction:

The total water loss from soil surface through evaporation and that as water vapour from plant canopies through transpiration together is estimated as evapotranspiration. The concept of potential evapotranspiration (PET) is an attempt to characterize the climatic environment in terms of its evaporative power the maximal evaporation rate which the atmosphere is capable of extracting from a well watered field under a given meteorological regime from a field of given surface condition, PET is a useful standard of reference for the comparison of climatic regimes or seasons.

Methodology:

(1) PET estimation by Thornthwaite method

$$E = 1.6\ (10T / I)^{a}$$

Where,

E = Unadjusted PET in cm, per month (30 day, 12 hours day)

T = Mean air temperature

$$I = \text{Annual heat index} = \sum_{I=1}^{12} i$$

$$i = \text{Monthly heat index} = (T / 5)^{1.514}$$

$$a = 6.75\times10^{-7}.I^{3}-7.71\times10^{-5}.I^{2}\times17.92\times10^{-3}.I + 0.49239$$

For calculation of daily value of PET

$$PET = \frac{K\ X\ E\ X\ 10}{\text{No. of days in month}} \quad (\text{mm day}^{-1})$$

K = Adjustment factor for which table value are given

(2) PET by Modified Penman Method

Doorenbos and Pruitt (1975) proposed a modified Penman method as below for estimating fairly accurately the reference crop ET and gave tables for necessary computations.

$ET_C = C\ [W \times Rn + (1-W) \times F\ (U) \times (ea-ed)]$

Where, ET_C = The reference crop ET in $mmday^{-1}$ (not adjusted)

Rn = Net radiation ($mmday^{-1}$)

ea = SVP in milibar at mean air temp (c^{o})

ed = Mean AVP of the air in the milibar

= ea × RH min/100

f(U) = a wind related function

F (U) = 0.27 (1+U/100) with U in kmday^{-1} measured at 2 mt, ht.

(1-W) = a temp. and elevation related weighing factor for the factor and effects of wind and humidity on ET_C.

W = a temp. and elevation related weighing factor for the factor and effects of radiation on ET_C.

C = adjustment factor for the ration U day/ U night for RN max and for Rs.

Rn = net radiation (mmday^{-1}) or Rn = 0.75 Rs – Rnl

Rs is incoming short wave radiation (mmday^{-1}) or obtained from Rs = (0.25 = 0.50 n/N) Ra.

Ra : is extra terrestrial radiation (mmday^{-1})

n : mean actual sunshine duration (hrday^{-1})

N : maximum possible duration and sunshine (hrday^{-1})

Rnl: Net long wave radiation (mmday^{-1}) a function of f (T)of avp, fed) and sunshine duration f (n/N). Rnl = f(T) × f(d) × f(n/N)

Example:

Latitude = 15.0^{0}C

Altitude = 200 m

T mean = 30^{0}C

Day wind = 15 km hr^{-1}

Night wind velocity = 12 km hr^{-1}

Mean sunshine (n) hr = 8 hr day^{-1}

RH_{max} = 60 per cent

RH_{min} = 40 per cent

ea	T = 30^{0}C	Table 1	42.40 mb
ed	ea × RH_{min}/100		
	42.4 × 40/100	Calc	16.96 mb
ea – ed	42.40 – 16.96	Calc	25.44 mb
f (U)	0.27 × (1 + U/100)		

$$U_{mean} = \frac{15 + 12}{2} \times 24$$

= 324 km day^{-1}

$$\frac{0.27 \times (1 + 324)}{100}$$ Calc 1.15

R_a	15^0N, June	Table 6	15.8 mm day^{-1}
N	15^0N, June	Table 7	13.00 hr day^{-1}
R_s	$(0.25 + 0.50 \times n/N) \times R_a$		
	$= (0.25 + 0.5 \times 8/13) \times 15.8$	Calc	8.81 mm day^{-1}
f(T)	Temp. 30^0C	Table 2	16.70
f(ed)	16.96 mb	Table 3	0.16
f(n/N)	8/13 = 0.62	Table 4	0.66
R_{nl}	$f(T) \times f(ed) \times f(n/N)$		
	$= 16.7 \times 0.16 \times 0.66$	Calc	1.76 mm day^{-1}
R_n	$(0.75 \times R_s) - R_{nl}$		
	$= (0.75 \times 8.81) - 1.76$	Calc	4.85 mm day^{-1}
W	= Temp. 30^0C, 200 m	Table 8	0.78
C	RH_{max} 60%, R_s 8.81, U day/U night 1.25	Table 5	1.05

$ET_0 = C \times [W \times Rn + (1 - W) \times f(U) \times (ea-ed)]$

$= 1.05 \times [0.78 \times 4.85 + (1 - 0.78) \times 1.15 \times (25.44)]$

$= 1.05 \times [3.783 + (0.22 \times 1.15 \times 25.44)]$

$= 1.05 \times (3.783 + 6.436)$

$= 1.05 \times (10.219)$ Calc = **10.73 mm day^{-1}**

Modified Penman and Radiation method offer the best results for periods as short as 10 days followed by pan evaporation method.

Table 1: SVP (Ea) in mb as a function of Mean Air Temperature

Temperature (^{0}C)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ea (mb)	6.1	6.6	7.1	7.6	8.1	8.7	9.6	10.0	10.7	11.5	12.3
Temperature ^{0}C)	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
ea (mb)	13.1	14.0	15.0	16.1	17.0	18.2	19.4	20.6	22.0	23.4	24.9
Temperature(^{0}C)	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
ea (mb)	26.4	28.1	29.8	31.7	33.6	35.7	37.8	40.1	42.4	44.9	47.6
Temperature(^{0}C)	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**			
ea (mb)	50.3	53.2	56.2	56.4	62.8	66.3	69.9	73.6			

Table 2: Effect Of Temperature [F(T)] On Long Wave Radiation (Rnl)

T^{0}C	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**
f(T)	11.0	11.4	11.7	12.0	12.4	12.7	13.1	13.5	13.8	14.2

T^{0}C	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	
f(T)	14.6	15.0	15.4	15.9	16.3	16.7	17.2	17.7	18.1	

Table 3: Effect of vapour pressure [f(ed)] on long wave radiation (rnl)

ed(mb)	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**
f (ed)	0.23	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.12
ed(mb)	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**		
f (ed)	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.06		

Table 4: Effect of the ratio of actual and maximum bright sunshine hours (f(n/N)] on long wave radiation (rnl)

n/N	**0**	**0.05**	**0.10**	**0.15**	**0.20**	**0.25**	**0.30**	**0.35**	**0.40**
f(n/N)	0.10	0.15	0.19	0.24	0.28	0.33	0.37	0.42	0.46
n/N	**0.45**	**0.50**	**0.55**	**0.60**	**0.65**	**0.70**	**0.75**	**0.80**	**0.85**
f(n/N)	0.51	0.55	0.60	0.64	0.69	0.73	0.78	0.82	0.87
n/N	**0.90**	**0.95**	**1.0**						
f(n/N)	0.91	0.96	1.0						

Table 5: adjustment factor (c) in Penman equation

Rs (mm day^{-1})					**RHmax= 30%**				**RHmax = 60%**				**RHmax=90%**			
U day ms-1)	**3**	**6**	**9**	**12**	**3**	**6**	**9**	**12**	**3**	**6**	**9**	**12**
U day/U night = 4.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.79	0.84	0.92	0.97	0.92	1.00	1.11	1.19	0.99	1.10	1.27	1.32
6	0.68	0.84	0.92	0.93	0.85	0.96	1.11	1.19	0.94	1.10	1.26	1.33
9	0.55	0.65	0.78	0.90	0.76	0.88	1.02	1.14	0.88	1.01	1.16	1.27
U day/U night = 3.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.76	0.81	0.88	0.94	0.87	0.96	1.06	1.12	0.94	1.04	1.18	1.28
6	0.61	0.88	0.81	0.88	0.77	0.88	1.02	1.10	0.86	1.01	1.15	1.22
9	0.46	0.56	0.72	0.82	0.67	0.79	0.88	1.05	0.78	0.92	1.06	1.18
U day/U night = 2.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.69	0.76	0.85	0.92	0.83	0.91	0.99	1.05	0.89	0.98	1.10	1.14
6	0.53	0.61	0.74	0.84	0.70	0.80	0.94	1.02	0.79	0.92	1.05	1.12
9	0.37	0.48	0.65	0.76	0.59	0.70	0.84	0.95	0.71	0.81	0.96	1.06
U day/U night = 1.0												
0	0.86	0.90	1.00	1.00	0.96	0.98	1.05	1.05	1.02	1.06	1.10	1.10
3	0.64	0.71	0.82	0.89	0.78	0.86	0.94	0.99	0.85	0.92	1.01	1.05
6	0.43	0.53	0.68	0.79	0.62	0.78	0.84	0.93	0.72	0.82	0.95	1.00
9	0.27	0.41	0.59	0.70	0.50	0.60	0.75	0.76	0.62	0.72	0.87	0.96

+Table 6 : Extra terrestrial radiation (r_a) expressed in equivalent evaporation (mm day^{-1}) for northern and southern hemisphere

Lat.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Northern hemisphere												
50	3.8	6.1	9.4	12.7	15.8	17.5	16.4	14.1	10.9	7.4	4.5	3.2
40	6.4	8.6	11.4	14.3	16.4	17.3	16.7	15.2	12.5	9.6	7.0	5.7
30	8.8	10.7	13.1	15.2	16.5	17.0	16.8	15.7	13.9	11.6	9.5	8.3
20	11.2	12.7	14.4	15.6	16.3	16.4	16.3	15.9	14.8	13.3	11.6	10.7
10	13.2	14.2	15.3	15.7	15.5	15.3	15.3	15.5	15.3	14.7	13.6	12.9
0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8
Southern hemisphere												
50	17.5	14.7	10.9	7.0	4.2	3.1	3.5	5.5	8.9	12.9	16.5	18.2
40	17.9	15.7	12.5	9.2	6.6	5.3	5.9	7.9	11.0	14.2	16.9	18.3
30	17.8	16.4	14.0	11.3	8.9	7.8	8.1	10.1	12.7	15.3	17.3	18.1
20	17.3	16.5	15.0	13.0	11.0	10.0	10.4	12.0	13.9	15.8	17.0	17.4
10	16.4	16.3	15.5	14.2	12.8	12.0	12.4	13.5	14.8	15.9	16.2	16.2
0	15.0	15.5	15.7	15.3	14.4	13.9	14.1	14.8	15.3	15.4	15.1	14.8

Table 7: Mean daily duration of maximum possible sunshine hours (n) for different months in north and south latitudes

N lat.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
S lat.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
0	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
5	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
10	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
15	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
20	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.8	11.2	10.9
25	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
30	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2
35	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
40	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
50	8.5	10.1	11.8	13.8	15.4	15.7	15.9	14.5	12.7	10.8	9.1	8.1

Table 8: Values of weightage factor (w) for the influence of radiation on et $_0$ at different temperatures and altitudes

Temp. (^{0}C)	Altitude					
	0	500	1000	2000	3000	4000
2	0.43	0.45	0.46	0.49	0.52	0.55
6	0.49	0.51	0.52	0.55	0.58	0.61
10	0.55	0.57	0.58	0.61	0.64	0.66
14	0.61	0.62	0.64	0.66	0.69	0.71
18	0.66	0.67	0.69	0.71	0.73	0.76
22	0.71	0.72	0.73	0.75	0.77	0.79
26	0.75	0.76	0.77	0.79	0.81	0.83
30	0.78	0.79	0.80	0.82	0.84	0.85
34	0.82	0.82	0.83	0.85	0.86	0.88
36	0.83	0.84	0.85	0.86	0.87	0.89
38	0.84	0.85	0.86	0.87	0.88	0.90
40	0.85	0.86	0.87	0.88	0.89	0.90

*****

NOTES

College of Agriculture
Navsari Agricultural University
Waghai - 394730

NAVSARI AGRICULTURAL UNIVERSITY

भाकृअनुप
ICAR

Practical Manual

Ag. Micro. 1.1 (1 + 1)

Agricultural Microbiology

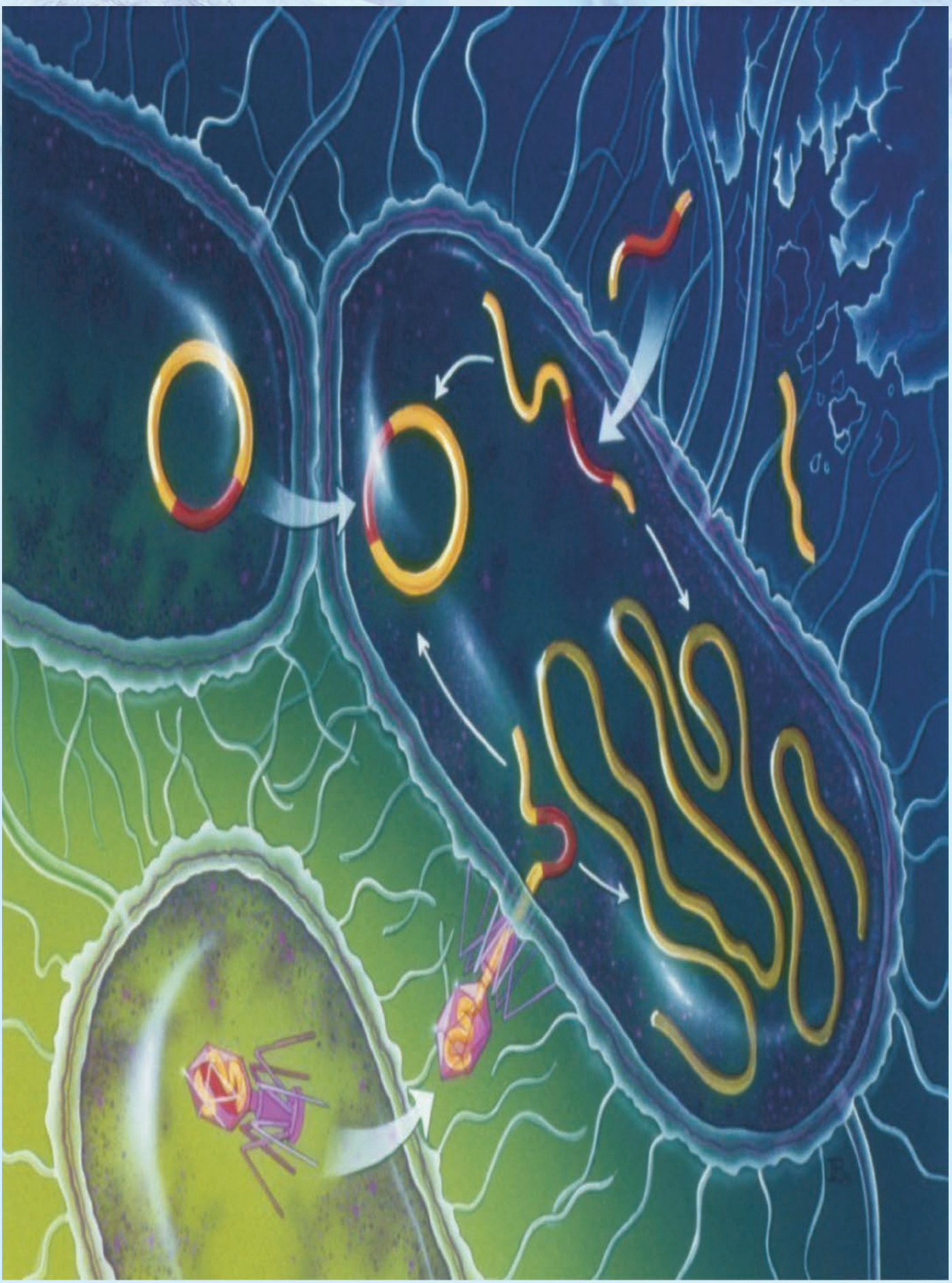
Prepared by

Prof. R. P. Bambharolia
Assistant Professor

Dr. Pushpendra Singh
Associate Professor

Dr. A. J. Deshmukh
Assistant Professor

College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.



NAVSARI AGRICULTURAL UNIVERSITY

ICAR

Practical Manual

Ag. Micro. 1.1 (1 + 1)

Agricultural Microbiology

Prepared by

Dr. Pushpendra Singh
Associate Professor

Prof. R. P. Bambharolia
Assistant Professor

Dr. A. J. Deshmukh
Assistant Professor

College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

Publisher
Principal
College of Agriculture,
Navsari Agricultural University,
Waghai-394 730 (Gujarat)
Phone No. 02631 – 246688
Fax No. 02631 - 246622

Edition : First: January, 2019

Copies: 300

Department of Microbiology
College of Agriculture,
Navsari Agricultural University,
Waghai (Dangs) – 394730.

University Publication No.: 148/2018-19

Dr. Z. P. Patel
Dean & Principal
M. 9624363999

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

Phone No. : 02631 - 246688
Fax No. : 02631 - 246622
Email : zprin@nau.in, caw@nau.in

FOREWORD

It gives me great pleasure to write the foreword of the Laboratory Manual of "Agricultural Microbiology" prepared by Prof. R. P. Bambharolia, Dr. Pushpendra Singh and Dr. Amol Deshmukh of the Department of Plant Pathology. As a matter of fact, I have always been of view and opinion that the students must get a laboratory guide where what to do, how to do and finally what to get are precisely described as it would save time that is otherwise unnecessarily wasted. This manual is being brought out of the efforts of the teachers of the Department of Plant Pathology, College of Agriculture, NAU, Wagahi (Dangs). This is one of the most unique and fundamentals practical books available for fulfilling the requirements of the undergraduate students and has been prepared as per the latest syllabus prescribed by the ICAR. However, it is equally useful for the Post-graduate students, scholars, teachers and scientists working in the basic and applied aspects of agricultural microbiology.

This manual entitled "***Agricultural Microbiology***" A Practical Manual consists exercises which are comprehensive and exhaustive in enriching the knowledge of fundamental techniques of agricultural microbiology

I appreciate and congratulate *Prof. R. P. Bambharolia and Prof. H. P. Patel for their commendable efforts in bringing out this practical manual* for their efforts.

January, 2019

(Z. P. Patel)

Preface

Microbiology is one of the important subjects of the life science and knowledge of its practical aspects is absolutely essential for students and the researcher. Practical manual on "***Agricultural Microbiology***" is a fundamental book which highlights and makes the readers aware of the important techniques of microbiology. This book has been especially designed keeping in view the latest syllabus prescribed by the ICAR as per the 5th dean committee recommendation for first semester undergraduate agriculture students.

However, it is equally useful for the post graduate students, research scholars, teachers and scientists working on the basic and applied aspects of microbiology. In this manual the exercises are followed by questions which will be helpful to the readers in enriching their knowledge about the subject. The genesis of this manual lies in the problem faced by the students and their teachers to carry out the practical classes, as no standard study material was available for it. Keeping in view, the authors along with the Principal (CAW, NAU, Waghai) decided to provide printed practical manual of the said course (Ag. Micro. 1.1) to the students from the academic year 2019. The format of the exercises is appropriate for use as a workbook. It is hoped that this practical manual will be highly useful for the students in learning the fundamental techniques of microbiology. The editors welcome suggestions from users, students as well as instructors/teachers for its future improvement.

R. P. Bambharolia
Pushpendra Singh
A. J. Deshmukh

Certificate

Reg. No. : _____ **Batch No.: _____**

Roll No. : _____ **Uni Seat No.: _____**

This is to certify that the practical exercises duly signed were performed in the subject of ***Microbiology, Course No. Ag. Micro. 1.1 (1+1) [Agricultural Microbiology] as a part and partial requirement of the Course by Mr./Ms.*** _____

Roll No. _____ of ***First Semester*** *class during academic year 20___.*

The numbers of practical performed were _____ out of _____.

Course Teacher **Professor & Head**

Examiner
(Internal Exam.)

Examiner
(External Exam.)

Index

PRACTICAL 1: Microbiology Lab Practices and Safety Rules

1. Wash your hands with disinfectant soap when you arrive at the lab and again before you leave.
2. Absolutely no food, drinks, chewing gum, or smoking is allowed in the laboratory. Do not put anything in your mouth such as pencils, pens, labels, or fingers. Do not store food in areas where microorganisms are stored.
3. Purchase a lab coat and safety glasses, bring them to class, and use them. Alternatively, a long sleeved shirt that buttons or snaps closed is acceptable protective clothing. This garment must cover your arms and be able to be removed without pulling it over your head. Leave protective clothing in the lab and do not wear it to other non-lab areas.
4. Avoid loose fitting items of clothing. Wear appropriate shoes (sandals are not allowed) in the laboratory.
5. Keep your workspace free of all unnecessary materials. Backpacks, purses, and coats should be placed in the cubbyholes by the front door of the lab. Place needed items on the floor near your feet, but not in the aisle.
6. Disinfect work areas before and after use with 70% ethanol or fresh 10% bleach. Laboratory equipment and work surfaces should be decontaminated with an appropriate disinfectant on a routine basis, and especially after spills, splashes, or other contamination.
7. Label everything clearly.
8. Replace caps on reagents, solution bottles, and bacterial cultures. Do not open Petri dishes in the lab unless absolutely necessary.
9. Inoculating loops and needles should be flame sterilized in a Bunsen burner before you lay them down.
10. Turn off Bunsen burners when not is use. Long hair must be restrained if Bunsen burners are in use.
11. When you flame sterilize with alcohol, be sure that you do not have any papers under you.
12. Treat all microorganisms as potential pathogens. Use appropriate care and do not take cultures out of the laboratory.
13. Wear disposable gloves when working with potentially infectious microbes or samples (e.g., sewage). If you are working with a sample that may contain a pathogen, then be extremely careful to use good bacteriological technique.
14. Sterilize equipment and materials.
15. Never pipette by mouth. Use a pipetting aid or adjustable volume pipettors. [In the distant past, some lab personnel were taught to mouth pipette. This practice has been known to result in many laboratory-acquired infections. With the availability of mechanical pipetting devices, mouth pipetting is strictly prohibited.]
16. Consider everything a biohazard. Do not pour anything down the sink. Autoclave liquids and broth cultures to sterilize them before discarding.
17. Dispose of all solid waste material in a biohazard bag and autoclave it before discarding in the regular trash.
18. Familiarize yourself with the location of safety equipment in the lab (e.g., eye-wash station, shower, sinks, fire extinguisher, biological safety cabinet, first aid kit, emergency gas valve).
19. Dispose of broken glass in the broken glass container.
20. Dispose of razor blades, syringe needles, and sharp metal objects in the “sharps” container.
21. Report spills and accidents immediately to your instructor. Clean small spills with care (see instructions below). Seek help for large spills.
22. Report all injuries or accidents immediately to the instructor, no matter how small they seem.

PRACTICAL 2: MICROBIOLOGICAL APPARATUS AND EQUIPMENTS

INTRODUCTION

Microbiology, as you may know by now, is a science dealing with study of structure, functions and applications of microbes. To study different aspects of microbes, microbiologists require certain equipments in the laboratory for isolation and culturing of these microorganisms in pure form. These equipments can be classified as:

(a) ***Instruments required for sterilization:***

- Autoclave
- Oven
- Membrane filter assembly.

(b) ***Instruments and Tools required for isolation, culturing and maintenance:***

- Bunsen Burner or Spirit Lamp
- Water Bath
- Laminar Flow Safety Hood
- Incubators
- Refrigerators
- Inoculating loop or needle
- Magnetic Stirrer
- Vortex Mixture
- Balances
- Homogenizers`

(c) ***Instruments and tools required for microbial observations and assays:***

- Microscope
- Centrifuge
- Spectrophotometer
- Quebec Colony Counter
- Camera Lucida
- Photo Micrographic Camera
- Dissecting Needles and Forcep
- Ocular and Stage Micrometer
- Burette Set Up
- Thermometer

(d) ***Glassware:***

- Petri Dishes
- Conical Flasks
- Culture Tubes
- Beakers
- Funnels
- Graduated Cylinders
- Graduated Pipettes
- Dropper Bottle for staining reagents
- Glass Microscopic Slides
- Cover Slips

(e) ***Miscellaneous items:***

- Test Tube Rack
- Ingredients for Culture Media and other Chemicals
- Non-absorbent Cotton and
  Gauze for Cotton Plugs
- Petri Dish and Pipette Cans
- Muslin Cloth
- Brown Paper and Rubber Bands
- Permanent Markers
- Rubber Bulb for Pipettes
- Blotting Paper, Lens Paper, etc.
- Distilled Water
- Discard Container
- Immersion Oil

1.1 INSTRUMENTS REQUIRED FOR STERILIZATION

The word sterilization is derived from the Latin word *'Sterilic'* meaning unable to produce offsprings. Sterilization, therefore, is a process of making an object free from all living organisms either by *destroying* or *removing them* from the object. This control of microorganisms is very important in microbiological research, preservation of food, prevention of diseases and in various industries. Sterilization can be carried out either by employing:

(a) Physical Agents, or
(b) Chemical Agents.

These agents being microbicidal (i.e. kill the microorganisms) or microbiostatic (i.e. inhibit microbial growth) control the microorganisms by adversely damaging the essential cell structure and functions. The mode of action of these agents varies. You would realize that there are physical and chemical methods also to control microorganisms. Let us get to learn about these methods, next.

1.1.1 Physical Methods to Control Microorganisms

The physical methods to control microorganisms involve heat, filtration or radiations. Temperature influences microorganisms by altering their enzyme systems. Low temperature, you may recall studying in the theory Course, inactivates the enzymes while high temperature destroys them. Heat is commonly employed for controlling microorganisms. Both moist heat and dry heat can be used for this purpose. Moist heat results in coagulation of proteins and degrades nucleic acid and may even disrupt cell membrane. Moist heat has more penetrability than dry heat and kills the cells more rapidly that too at a lower temperature. Microbes exhibit difference in their resistance to moist heat. Generally, bacterial spores require temperature above 100°C for destruction. Moist heat can either sterilize or disinfect the object depending upon the temperature employed. Moist heat can be used either,
(1) at temperature >100°C (pasteurization-used to remove pathogens), (2) as free flowing
steam at 100°C (by boiling or tyndallisation) or (3) by saturated steam under pressure (autoclaving).

Let us get to know about autoclaving, which uses moist heat method for sterilization.

1. ***Autoclave:*** For sterilization, steam under pressure is generally employed using an instrument called autoclave. Figure illustrates the autoclave. Autoclave was developed by Chamberland in 1884. As you may have noticed in Figure, autoclave is a double walled cylindrical metal vessel made of stainless steel or copper. Autoclave lid is provided with the pressure gauze for monitoring the pressure, exhaust valve to remove the air and safety valve to avoid explosion during operation. The articles are kept loosely in the autoclave chamber and then water is boiled and steam is released into the autoclave's chamber. The exhaust valve is kept open till the air present in the chamber is out. The exhaust valve is then closed and

pressure of the steam in the chamber is allowed to reach to the desired value. The temperature of the steam inside the chamber depends on the pressure in autoclave. Relation of autoclave pressure with the temperature of steam is presented in the Table.

Table : Relation of Autoclave pressure with the temperature of steam

Pressure (Pounds/square inch-psi)	Temperature (°C)	Time (minutes)
0	**100**	**-**
5	**108**	> 20
10	**115**	20
15	**121**	15
20	**126**	10
30	**134**	3

More the pressure, higher is the temperature and less is the time used for autoclaving. Generally, pressure of 15 pounds with temperature at 121°C is employed for 15-20 minutes for autoclaving.

Saturated steam heats an object about 2500 times more efficiently than dry heat at the same temperature. Steam condenses on the cooler surface of the object and transfer its heat energy to the object and sterilize it. Autoclave can be used for sterilizing culture media, scalpel and other heat resistance instruments, glasswares, etc. but not for oils, powders and plastics.

Where autoclave is not available, pressure cooker can be used. It works on the same principle as of autoclave.

Note: Following points should be kept in mind while working with autoclave.

1. Autoclave should not be packed tightly otherwise steam won't be able to come in contact with every object in the autoclave.
2. The air initially present in autoclave chamber should be removed before closing exhaust valve, otherwise temperature won't reach to 121°C though the pressure would be 15 pounds.
3. For larger sample of liquid, autoclave time should be increased so that centre of the liquid should reach to 121°C.
4. After autoclaving, steam should be released slowly otherwise liquid media would come out.

Besides autoclave, hot air ovens are also used for sterilization. Let us get to know about hot air ovens.

2. Hot Air Oven :

Hot air oven sterilizes the object by hot dry air. It kills the microorganismsby oxidizing cellular constituents. Dry Heat is less effective in killing microorganisms than moist heat. Higher temperature for a longer time period is used with dry air because it-

(i) has less penetration power, and

(ii) removes moisture from microorganisms and thus interferes with coagulation of microbial proteins.

Hot air oven can be used at different temperatures. Operating time depends on the temperatures used as highlighted in Table

Temperature (°C)	Time (Hours)
140	3
150	2½
160	2
170	1

You would realize that the most commonly used temperature is 160 °C for 2 hours. We are all familiar with hot air ovens. Hot air oven contains an insulated cabinet kept at constant temperature by electric heating mechanism and thermostat. Look at Figure, which illustrates the hot air oven. Air keeps on circulating within the cabinet through a fan. For proper circulation of hot air, the shelves are perforated. An oven is used to sterilize glassware, corrodeable metal instruments, powder, oil etc. which can tolerate prolonged heat exposure but get spoiled by moist heat. However, it is not suitable for heat sensitive materials, like plastic and rubber items.

1.2 INSTRUMENTS NEEDED FOR ISOLATION, CULTIVATION AND MAINTENANCE OF MICROBES

A wide variety of instruments are available for isolation, cultivation and maintenance of microbes. These are illustrated and described in this section. We begin with bunsen burner.

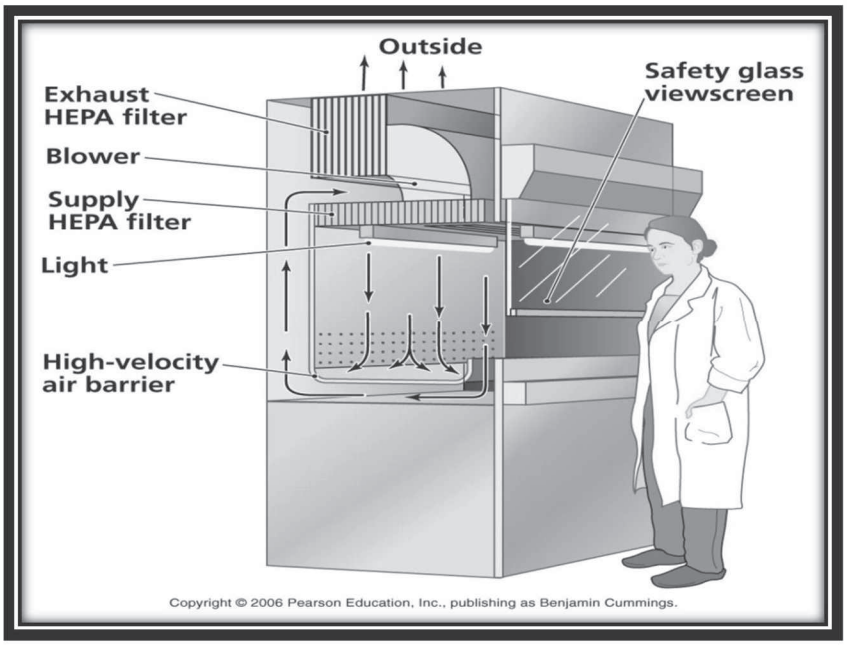
1. Bunsen Burner - It is a type of gas burner that gives very hot flame by allowing air to enter at the base and mix with the gas. It is used –

(a) for sterilizing inoculating loop/needle/forcep etc.
(b) for sterilizing mouth of the flask, test tubes and other glass apparatus.
(c) at the time of culturing or transferring the microorganisms to avoid contamination.

Here the sterilization is done with dry heat. If bunsen burner is not available, spirit lamp can be used.

2. *Laminar Flow Hood (biological safety cabinet)* - Look at the Figure. It illustrates the laminar flow hood. As you can see, this biological safety cabinet contains HEPA (high efficiency particulate air) filters which remove, 99.97% of the particles having size more than 0.3 µm. Air is forced through these HEPA filters and a vertical column of sterilize air gets formed across the cabinet opening. It prevents the contamination of room and the workers from microorganisms. The cabinet also has UV light, which is switched on about 15-20 minutes earlier before and after the work is finished to make the working surface sterile. Laminar flow hood is employed in the research labs and in industries, for conducting assays, preparing media and culturing microbes.

Note : (i) Never switch on the UV light while working in the laminar chamber.
(ii) Air flow should be on, at the time of working in the chamber.



3. *Incubator* - The growth of the microorganisms is altered by the chemical and physical nature of its surrounding. Most important environmental features altering microbial growth are pH, water activity, oxygen level and temperature. Each microorganism has specific requirement of temperature for its growth. The cardinal temperatures, i.e., minimum, optimum and maximum growth temperatures, varies greatly with the type of microorganisms. Therefore, for cultivation of microorganisms, prime requirement is to provide the optimum temperature for growth. This can be achieved by using incubators and shaking water bath.

An incubator is an insulated cabinet fitted with heating element at the bottom. It has perforated shelves and is provided with double door. Inner door is of glass to view the content of incubator. Like an oven, most of the incubators use dry heat for temperature control. Moist environment can be provided by keeping a beaker of water inside the cabinet. Incubator is used for culturing the organism at its optimum temperature. Here temperature can be adjusted according to organism's requirement and then maintained at a desired level thermostatically.

Shaking water baths as illustrated in the Figure can also be used for microbe's cultivation. Here also temperature is maintained thermostatically. However, it can be used only for liquid culture. The advantages of using shaking water baths are:(a) Uniform and rapid transfer of heat to the culture can be obtained, and (b) Enhanced aeration is possible because of agitation.

4. Magnetic Stirrer - It can be used for mixing ingredients at the time of media or reagents preparation. Mixing happens with spinning of a teflon coated magnetic bar inside the container under a magnetic field created by magnetic stirrer. illustrates the magnetic stirrer.

5. *Vortex Mixture* - It is also used to mix the reagents during microbiological assay by vortex effect.

6. *Quebec Colony Counter* – It is used for counting the number of colonies in a plate. Culture plate is kept on the screen which is illuminated from beneath. Counting is done by using a magnifying glass (magnification1.5X) above the plate as shown in Figure. Counting can also be done manually.

7. *Centrifuge* – Centrifuge is used for separating the substance in liquid or concentrating the microorganisms on the basis of size or mass under centrifugal force (noted as rpm). Depending upon the speed limit, centrifuges may be –

(a) Low Speed (Maximum Speed 5000 rpm)
(b) High Speed (18000 rpm)
(c) Ultra Centrifuges (20000 to 60000 rpm)

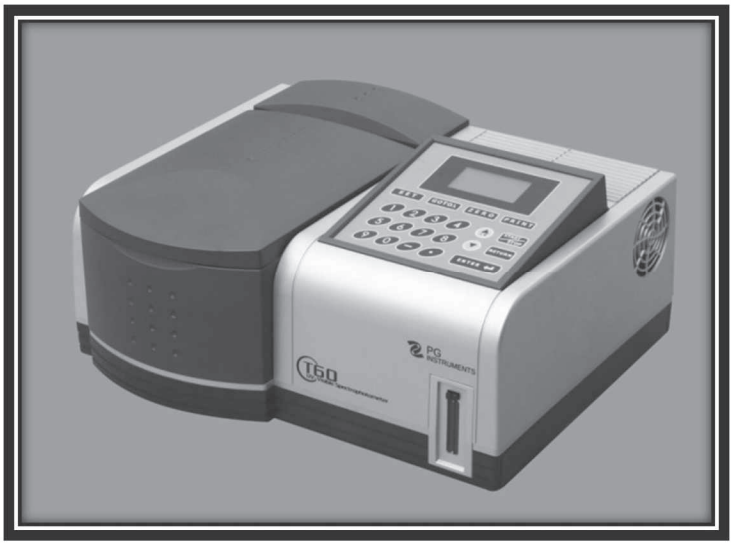
The centrifuge consists of a head or rotor (of various sizes), which hold the tubes containing the material to be separated. The rotor is revolved by an upright motor. After completion of centrifugation, particulate matter settles down at the bottom of tubes and can be separated.

8. *pH meter* – pH is a negative logarithm of H^+ ion concentration. Its value remains between 0 and 14. Pure water has a pH of 7 (neutral). pH value less than 7 is acidic and more than 7 is basic. The measurement of pH can be done by using pH meter. pH meter is used to measure and set the pH of culture media or reagents used for microbiological and biochemical assays. It is important as different microbes have different pH requirements for growth. Most of the bacteria, in general, have optimum pH for growth between 6.5 to 7.5, thought here are certain exceptions. Some bacteria are acidophiles (grow at acidic pH) or alkalophiles (needs high pH in alkaline range for growth). Most fungi have pH optima around 4 to 6 and yeasts need pH around 3 to 5.The pH meter has a glass electrode for measuring the pH. During determination of pH, first the instrument is calibrated with standard buffers of pH 4, 7 and 9. Then the pH of the sample solution is determined by dipping the glass electrode in the solution and pH is read directly from the pH meter scale.

9. Refrigerator – Refrigerator is a basic requirement in microbiological laboratory. It is used for maintaining microbial cultures, keeping media to prevent dehydration, for storing thermolabile solutions, antibiotics, serum and biochemical agents.

10. *Spectrophotometer* or *Colorimeter* – These can be used to measure the microbial growth or can be used in various microbial and biochemical assays.

Spectrophotometer measures either the amount of light transmitted (% transmission) or the amount of light absorbed (A) by a sample. Here monochromatic light (beam of light at a single wavelength) is passed through a liquid sample. Depending upon the cells suspended in the culture, light is scattered. The scattering of light is directly proportional to the cell mass or indirectly to the cell number.



More the number of cells, more would be scattering of light. The unscattered light is measured by a photoelectric cell and is recorded as 0% to 100% transmission (T). However, in practice, cell density is represented in form of optical density or absorbance because it is directly proportional to the cell concentration while transmission is inversely related to cell density. Population growth can be easily measured spectrophotometrically as long as the population is high enough to give detectable turbidity. At very high concentration of cells, light scattered by one cell may be rescattered by another cell and it may appear as unscattered. This results in the loss of linearity between cell number and turbidity at very high cell concentration. Commonly used wavelengths for bacterial turbidity measurements are 540 nm (green), 600 (orange) or 660 nm (red). Estimation of cell number is based on turbidity measurement. Turbidity increases as the cell number increases. The discussion so far focussed on the study of the apparatus/equipments required for the sterilization, isolation or cultivation of microbes. Next, we will review, the tools we would need for inoculating and culturing microorganisms in the laboratory.

No.	Question
1	Write down Principle of Autoclave.
2	Explain relation between pressure and temperature in autoclave
3	Application of Spectrophotometer.
4	Explain: Operation of pH mater

5	Application of Bunsen burner
6	Define sterilization and methods of sterilization.

PRACTICAL 3: MICROSCOPE-PARTS, PRINCIPLES OF MICROSCOPY, RESOLVING POWER AND NUMERICAL APERTURE

Historians credit the invention of the compound microscope to the Dutch spectacle maker, Zacharias Janssen, around the year 1590. The compound microscope uses lenses and light to enlarge the image and is also called an optical or light microscope (versus an electron microscope). The simplest optical microscope is the magnifying glass and is good to about ten times (10x) magnification. The compound microscope has two systems of lenses for greater magnification, 1) the ocular, or eyepiece lens that one looks into and 2) the objective lens, or the lens closest to the object. Before purchasing or using a microscope, it is important to know the functions of each part.

Eyepiece Lens: the lens at the top of the microscope that you look through. They eyepiece is usually 10x or 15x power.

Tube: Connects the eyepiece to the objective lenses.

Arm: Supports the tube and connects it to the base of the microscope.

Base: The bottom of the microscope, used for support.

Illuminator: A steady light source (110v) used in place of a mirror. If your microscope has a mirror, it is used to reflect light from an external light source up through the bottom of the stage.

Stage: The flat platform where you place your slides. Stage clips hold the slides in place. If your microscope has a mechanical stage, you will be able to move the slide around by turning two knobs. One moves it left and right, the other moves it forward and back.

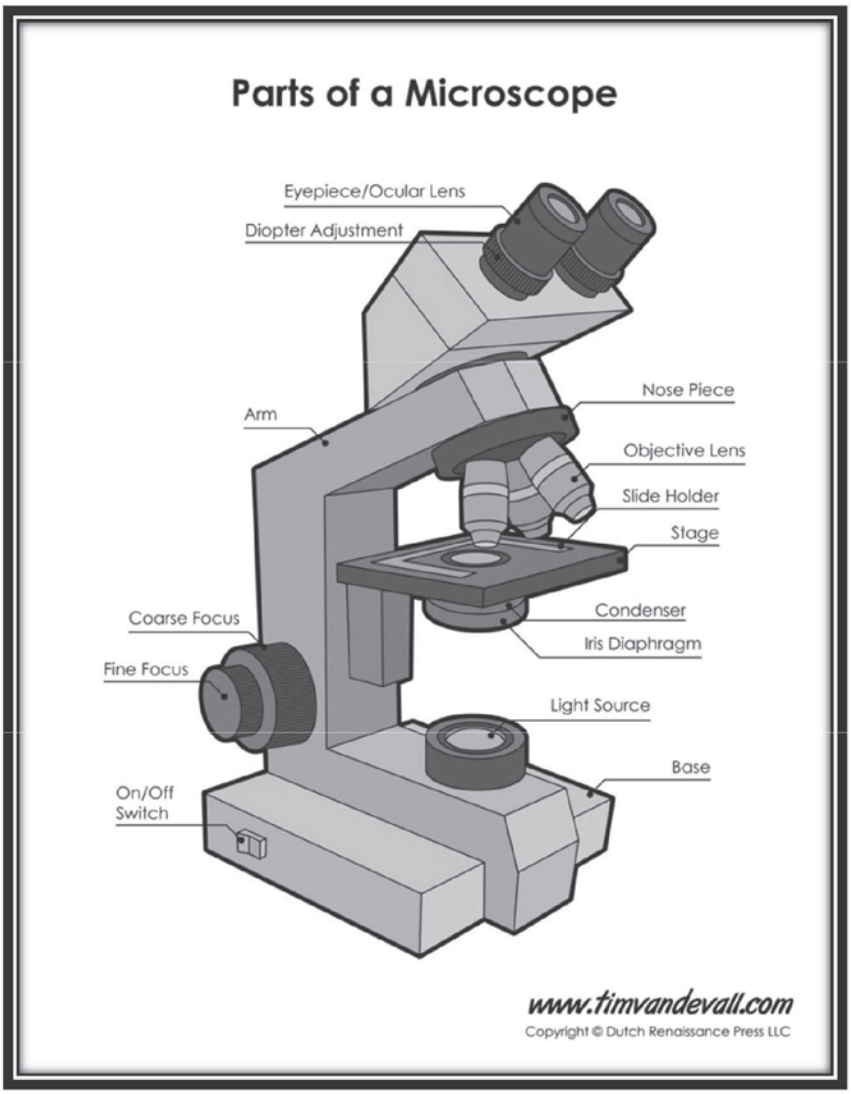
Removing Nosepiece or Turret: This is the part of the microscope that holds two or more objective lenses and can be rotated to easily change power (magnification).

Objective Lenses: Usually you will find 3 or 4 objective lenses on a microscope. They almost always consist of 4x, 10x, 40x and 100x powers. When coupled with a 10x (most common) eyepiece lens, we get total magnification of 40x (4x times 10x), 100x, 400x, and 1000x. To have good resolution at 1000x, you will need a relatively sophisticated microscope with an Abbe condenser. The shortest lens is the lowest power, the longest one is the lens with the greatest power. Lenses are color coded and if built to DIN standards are interchangeable between microscopes. The high power objective lenses are retractable (ie 40xr). This means that if they hit a slide, the end of the lens will push in (spring loaded) thereby protecting the lens and the slide. All quality microscopes have achromatic, parcentered, parfocal lenses.

Rack Stop: This is an adjustment that determines how close the objective lens can get to the slide. It is set at the factory and keeps students from cranking the high power objective lens down into the slide and breaking things. You would only need to adjust this if you were using very thin slides and you weren't able to focus on the specimen at high power. (Tip: If you are using thin slides and can't focus, rather than adjust the rack stop, place a clear glass slide under the original slide to raise it a bit higher).

Condenser Lens: The purpose of the condenser lens is to focus the light onto the specimen. Condenser lenses are most useful at the highest powers (400x and above). Microscopes with a stage condenser lens render a sharper image than those with no lens (at 400x). If your microscope has a maximum power of 400x, you will get the maximum benefit by using a condenser lenses rated at 0.65 NA or greater. 0.65 NA condenser lenses may be mounted in the stage and work quite well. A big advantage to a stage mounted lens is that there is one less focusing item to deal with. If you go to 1000x then you should have a focusable condenser lens with an N.A. of 1.25 or greater. Most 1000x microscopes use 1.25 Abbe condenser lens systems. The Abbe condenser lens can be moved up and down. It is set very close to the slide at 1000x and moved further away at the lower powers.

Diaphragm or Iris: Many microscopes have a rotating disk under the stage. This diaphragm has different sized holes and is used to vary the intensity and size of the cone of light that is projected upward into the slide. There is no set rule regarding which setting to use for a particular power. Rather, the setting is a function of the transparency of the specimen, the degree of contrast you desire and the particular objective lens in use.



Magnification is the factor by which an image appears to be enlarged. It will be a whole number greater than 1 and is usually followed by an “x”, as in 10x magnification.

When you look through microscope eyepieces, you are seeing a virtual image because in reality, what you are looking at is not as large as it appears through the eyepieces, and because there can be some distortion of the image.

Resolution is the shortest distance between two points that can still be visually distinguished as separate. The resolution of a typical unaided human eye is about 200 µm. Using a microscope decreases the resolution to distances as short as 0.2 µm. Resolution is a property of the eye.

Resolving power is the ability of a lens to show two adjacent objects as discrete. Resolving power is a property of a lens.

Each lens in a microscope has a numerical aperture, or NA, value. This has to do with the angles of light that enter and exit a lens. Its applications are beyond the scope of this lab, but numerical aperture does influence the resolution possible with a particular lens, and so the NA value for the lens is usually printed on each objective. It will be a number less than 1.0, and you can ignore it for our purposes.

Each lens in a microscope also has a magnifying factor. This is the degree to which that lens magnifies an image. It will be a number larger than 1.0. For instance a 10x objective magnifies the image ten-fold. The magnifying factor for each objective always printed on it, and the magnifying factor for each eyepiece is usually printed on it. (If the eyepiece is missing a printed magnifying factor, you can usually assume it is 10x.)

The total magnification for any image viewed under a compound microscope is calculated by using the formula:

Total Magnification = eyepiece magnifying factor * objective magnifying factor

So, each time you switch objectives, you change the total magnification. Total magnification does not have units, but is usually indicated by an “x”, as in “total magnification = 100x.”

How to Use a Microscope

A microscope is a high quality instrument and should last 25-30 years if treated properly and with care. Following these simple instructions will not only help you care for your microscope and keep it in good working condition, but will also help you get the most out of your microscope.

1. When moving your microscope, always carry it with both hands (Figure 1, at left). Grasp the arm with one hand and place the other hand under the base for support.

2. Turn the revolving nosepiece so that the lowest power objective lens is "clicked" into position (This is also the shortest objective lens).

3. Your microscope slide should be prepared by placing a coverslip or cover glass over the specimen. This will help protect the objective lenses if they touch the slide. Place the microscope slide on the stage and fasten it with the stage clips. You can push down on the back end of the stage clip to open it.

4. Look at the objective lens and the stage from the side (Figure 2, at right) and turn the coarse focus knob so that the objective lens moves downward (or the stage, if it moves, goes upward). Move it as far as it will go ***without touching the slide****!*

5. Now, look through the eyepiece and adjust the illuminator (or mirror) and diaphragm (Figure 3,at left) for the greatest amount of light.

6. Slowly turn the coarse adjustment so that the objective lens goes *up* (away from the slide). Continue until the image comes into focus. Use the fine adjustment, if available, for fine focusing. If you have a microscope with a moving stage, then turn the coarse knob so the stage moves downward or away from the objective lens.

7. Move the microscope slide around so that the image is in the center of the field of view and readjust the mirror, illuminator or diaphragm for the clearest image.

8. Now, you should be able to change to the next objective lens with only minimal use of the focusing adjustment. Use the fine adjustment, if available. If you cannot focus on your specimen, repeat steps 4 through 7 with the higher power objective lens in place. **Do not allow the objective lens to touch the slide!**

9. The proper way to use a monocular microscope is to look through the eyepiece with one eye and keep the other eye open (this helps avoid eye strain). If you have to close one eye when looking into the microscope, it's ok. Remember, everything is upside down and backwards. When you move the slide to the right, the image goes to the left!

10. Do not touch the glass part of the lenses with your fingers. Use only special lens paper to clean the lenses.

11. When finished, raise the tube (or lower the stage), click the low power lens into position and remove the slide.

12. Always keep your microscope covered when not in use. Dust is the number one enemy!

No.	Question
1	Explain various parts of microscope
2	What is magnification?
3	Explain Resolving power and numerical aperture.
4	Explain operation of microscope.

5	Draw labelled diagram of Microscope

PRACTICAL 4: METHODS OF STERILIZATION

Introduction: Sterilization can be defined as any process that effectively kills or eliminates transmissible agents (such as fungi, bacteria, viruses and prions) from a surface, equipment, foods, medications, or biological culture medium. In practice sterility is achieved by exposure of the object to be sterilized to chemical or physical agent for a specified time. Various agents used as steriliants are: elevated temperature, ionizing radiation, chemical liquids or gases etc. The success of the process depends upon the choice of the method adopted for sterilization.

Methods of Sterilization The various methods of sterilization are:

1. Physical Method a. Thermal (Heat) methods b. Radiation method c. Filtration method

2. Chemical Method a. Gaseous method

1. Heat Sterilization: Heat sterilization is the most widely used and reliable method of sterilization, involving destruction of enzymes and other essential cell constituents. The process is more effective in hydrated state where under conditions of high humidity, hydrolysis and denaturation occur, thus lower heat input is required. Under dry state, oxidative changes take place, and higher heat input is required. This method of sterilization can be applied only to the thermostable products, but it can be used for moisture-sensitive materials for which dry heat (160-1800 °C) sterilization, and for moisture resistant materials for which moist heat (121-134 °C) sterilization is used. The efficiency with which heat is able to inactivate microorganisms is dependent upon the degree of heat, the exposure time and the presence of water. The action of heat will be due to induction of lethal chemical events mediated through the action of water and oxygen. In the presence of water much lower temperature time exposures are required to kill microbe than in the absence of water. In this processes both dry and moist heat are used for sterilization.

a. Dry Heat Sterilization:

Examples of Dry heat sterilization are:

1. Incineration 2. Red heat 3. Flaming 4. Hot air oven

It employs higher temperatures in the range of 160-1800 C and requires exposures time up to 2 hours, depending upon the temperature employed. The benefit of dry heat includes good penetrability and non-corrosive nature which makes it applicable for sterilizing glasswares and metal surgical instruments. It is also used for sterilizing non-aqueous thermostable liquids and thermostable powders. Dry heat destroys bacterial endotoxins (or pyrogens) which are difficult to eliminate by other means and this property makes it applicable for sterilizing glass bottles which are to be filled aseptically

Hot-air oven Dry heat sterilization is usually carried out in a hot air oven.

b. Moist Heat Sterilization: Moist heat may be used in three forms to achieve microbial inactivation 1. Dry saturated steam – Autoclaving 2. Boiling water/ steam at atmospheric pressure 3. Hot water below boiling point Moist heat sterilization involves the use of steam in the range of 121-134 °C. Steam under pressure is used to generate high temperature needed for sterilization. Saturated steam (steam in thermal

equilibrium with water from which it is derived) acts as an effective sterilizing agent. Steam for sterilization can be either wet saturated steam (containing entrained water droplets) or dry saturated steam (no entrained water droplets). Autoclaves use pressurized steam to destroy microorganisms, and are the most dependable systems available for the decontamination of laboratory waste and the sterilization of laboratory glassware, media, and reagents. For efficient heat transfer, steam must flush the air out of the autoclave chamber. Before using the autoclave, check the drain screen at the bottom of the chamber and clean if blocked. If the sieve is blocked with debris, a layer of air may form at the bottom of the autoclave, preventing efficient operation. Autoclaves should be tested periodically with biological indicators like cultures of Bacillus stearothermophilus to ensure proper function. This method of sterilization works well for many metal and glass items but is not acceptable for rubber, plastics, and equipment that would be damaged by high temperatures.

Gaseous Sterilization The chemically reactive gases such as formaldehyde, (methanol,CH_2HO) and ethylene oxide $(CH_2)_2O$ possess biocidal activity. Ethylene oxide is a colorless, odorless, and flammable gas. The mechanism of antimicrobial action of the two gases is assumed to be through alkylations of sulphydryl, amino, hydroxyl and carboxyl groups on proteins and amino groups of nucleic acids. The concentration ranges (weight of gas per unit chamber volume) are usually in range of 800- 1200 mg/L for ethylene oxide and 15-100 mg/L for formaldehyde with operating temperatures of 45-63°C and 70-75°C respectively. Both of these gases being alkylating agents are potentially mutagenic and carcinogenic. They also produce acute toxicity including irritation of the skin, conjunctiva and nasal mucosa.

a. Ethylene oxide sterilizer: An ethylene oxide sterilizer consists of a chamber of 100-300- Litre capacity and surrounded by a water jacket. Air is removed from sterilizer by evacuation, humidification and conditioning of the load is done by passing sub-atmospheric pressure steam, then evacuation is done again and preheated vaporized ethylene oxide is passed. After treatment, the gases are evacuated either directly to the outside atmosphere or through a special exhaust system. Ethylene oxide gas has been used widely to process heat-sensitive devices, but the aeration times needed at the end of the cycle to eliminate the gas made this method slow.

b. Low temperature steam formaldehyde (LTSF) sterilizer: An LTSF sterilizer operates with sub atmospheric pressure steam. At first, air is removed by evacuation and steam is admitted to the chamber.

Liquid Sterilization

a. Peracetic Acid liquid sterilization: Peracetic acid was found to be sporicidal at low concentrations. It was also found to be water soluble, and left no residue after rinsing. It was also shown to have no harmful health or environmental effects. It disrupts bonds in proteins and enzymes and may also interfere with cell membrane transportation through the rupture of cell walls and may oxidize essential enzymes and impair vital biochemical pathways.

b. Hydrogen Peroxide Sterilization: This method disperses a hydrogen peroxide solution in a vacuum chamber, creating a plasma cloud. This agent sterilizes by oxidizing key cellular components, which inactivates the microorganisms. The plasma cloud exists only while the energy source is turned on. When the energy source is turned off, water vapor and oxygen are formed, resulting in no toxic residues and harmful emissions. The temperature of this sterilization method is maintained in the 40-50°C range,

which makes it particularly well-suited for use with heat-sensitive and moisture-sensitive medical devices. The instruments are wrapped prior to sterilization, and can either be stored or used immediately.

Radiation Sterilization Many types of radiation are used for sterilization like electromagnetic radiation (e.g. gamma rays and UV light), particulate radiation (e.g. accelerated electrons).The major target for these radiation is microbial DNA. Gamma rays and electrons cause ionization and free radical production while UV light causes excitation. Radiation sterilization with high energy gamma rays or accelerated electrons has proven to be a useful method for the industrial sterilization of heat sensitive products. But some undesirable changes occur in irradiated products, an example is aqueous solution where radiolysis of water occurs. Radiation sterilization is generally applied to articles in the dry state; including surgical instruments, sutures, prostheses, unit dose ointments, plastic syringes and dry pharmaceutical products.

UV light, with its much lower energy, and poor penetrability finds uses in the sterilization of air, for surface sterilization of aseptic work areas, for treatment of manufacturing grade water, but is not suitable for sterilization of pharmaceutical dosage forms.

a. **Gamma ray Sterilizer:** Gamma rays for sterilization are usually derived from cobalt-60 source, the isotope is held as pellets packed in metal rods, each rod carefully arranged within the source and containing 20 KCi of activity. This source is housed within a reinforced concrete building with 2 m thick walls. Articles being sterilized are passed through the irradiation chamber on a conveyor belt and move around the raised source.
b. **Ultraviolet Irradiation:** The optimum wavelength for UV sterilization is 260 nm. A mercury lamp giving peak emission at 254 nm is the suitable source of UV light in this region.

Filtration Sterilization Filtration process does not destroy but removes the microorganisms. It is used for both the clarification and sterilization of liquids and gases as it is capable of preventing the passage of both viable and non viable particles. The major mechanisms of filtration are sieving, adsorption and trapping within the matrix of the filter material. Sterilizing grade filters are used in the treatment of heat sensitive injections and ophthalmic solutions, biological products and air and other gases for supply to aseptic areas. They are also used in industry as part of the venting systems on fermentors, centrifuges, autoclaves and freeze driers. Membrane filters are used for sterility testing.

Application of filtration for sterilization of gases: HEPA (High efficiency particulate air) filters can remove up to 99.97% of particles >0.3 micrometer in diameter. Air is first passed through prefilters to remove larger particles and then passed through HEPA filters. The performance of HEPA filter is monitored by pressure differential and airflow rate measurements.

No.	Question
1	Define sterilization. Explain methods of sterilization.
2	Write a short note on dry heat sterilization.
3	Explain method of gaseous sterilization.
4	What is radiation sterilization? Explain it.

5	Explain filtration sterilization.

PRACTICAL:5 NUTRITIONAL MEDIA AND THEIR PREPARATION

The culture media (nutrients) consist of chemicals which support the growth of culture or microorganisms. Microbes can use the nutrients of culture media as their food is necessary for cultivating them in vitro.

Types of Culture Media:

The first medium prepared was meat-infusion broth. As most pathogenic microbes require complex food similar in composition to the fluids of the animal body, it was Robert Koch and his colleagues who used meat infusion and meat extracts as basic ingredients in their culture media for the isolation of pathogenic microbes, while one of his assistant named Petri designed and developed glass dishes, known today as Petri dishes, are used in microbiological work.

On the basis of chemical composition, the culture media are classified into two types:

(i) Synthetic or chemically defined medium:

These media are prepared by mixing all the pure chemicals of known composition for e.g. Czapek Dox medium.

(ii) Semi-synthetic or undefined medium:

Such are those media, where exact chemical composition is unknown e.g. potato dextrose agar or MacConkey agar medium.

On the basis of consistency, the culture media are of three types:

(a) Solid medium or synthetic medium:

When 5-7% agar agar or 10-20% gelatin is added the liquid broth becomes solidified. Such media are used for making agar slants or slopes and agar stab.

(b) Liquid medium or broth:

In such cases no agar is added or used while preparing the medium. After inoculation and later incubation, the growth of cells becomes visible in the form of small mass on the top of the broth.

(c) Semi-solid or floppy agar medium:

Such media are prepared by adding half quantity of agar (1/2 than required for solid medium) i.e. about 0.5% in the medium. This type of medium may be selective which promote the growth of one organism and retards the growth of the other organism. On the other hand, there are differential media which serve to differentiate organisms growing together.

Preparation of Medium:

The liquid medium or broth is prepared by dissolving the known amounts of chemicals in distilled water; the pH is adjusted by adding N/10 HCl or 1N NaOH. The liquid medium is dissolved into either Erlenmeyer flasks or rimless clean test tubes.

In 15 ml capacity of test tube, 5 ml medium should be poured while in flask of 250 ml capacity, the amount of the medium should be 100 ml. These are then plugged with non-adsorbent cotton plugs. The plugged tubes or flasks should be wrapped by brown paper and placed for sterilization by autoclaving at a pressure of 15 lbs/inch^2 (at temperature 121°C), for 15 min.

The heat sensitive substances (protein or enzymes etc.) should be sterilized by using membrane filters (millipore). The agar agar is to be dissolved separately and dispensed after dissolving all ingredients of the medium. It is first to be noted that all the glassware in use should be sterilized in oven at 170°C for 3 h before using them. Such sterilized glassware is needed for pouring the medium used for culturing the microorganisms.

Each and every biological process requires energy for their vital activities. The basic cell building requirements are supplied by the nutrition, which is manipulated according to its requirement. Nutrition not only provides energy but also acts as precursors for growth of microorganisms.

The nutritional requirement of an organism depends upon the biochemical capacity. If an organism is capable of synthesizing its own food using various inorganic components, requires a simple nutritional diet whereas organism unable to meet such synthesis requires complex organic substances.

Composition of N-agar

Beef Extract……..……..3.0 g
Peptone……..…….……5.0 g
Agar…….……..15.0 g
Distilled Water…….……1000 ml
Final pH 6.8 +/- 0.2.
Composition of Nutrient Broth: Nutrient broth contains same ingredients except agar.

Preparation of culture media

1. Dissolve the dehydrated medium in the appropriate volume of distilled water i.e., 23 gm dehydrated nutrient agar in 1000 ml distilled water.
2. Heat with frequent agitation and boil for 1 minute to completely dissolve the powder
3. Sterilized the medium by autoclaving (121°C for 15 min)
4. Dispense the medium in to tubes or plates. Left the agar medium to solidify and store.
5. Determine the pH of the medium (pH 6.8 +/- 0.2) with a pH meter and adjust if necessary.

No.	Question
1	Composition of N-agar
2	Explain types of media
3	Explain preparation of culture media.
4	Define culture media

PRACTICAL: 6 ENUMERATION OF MICROBIAL POPULATION IN SOIL – BACTERIA, FUNGI, ACTINOMYCETES

I. OBJECTIVES

• To learn the different techniques used to count the number of microorganisms in a sample.

• To be able to differentiate between different enumeration techniques and learn when each should be used.

• To have more practice in serial dilutions and calculations.

II. INTRODUCTION For unicellular microorganisms, such as bacteria, the reproduction of the cell reproduces the entire organism. Therefore, microbial growth is essentially synonymous with microbial reproduction. To determine rates of microbial growth and death, it is necessary to enumerate microorganisms, that is, to determine their numbers. It is also often essential to determine the number of microorganisms in a given sample. For example, the ability to determine the safety of many foods and drugs depends on knowing the levels of microorganisms in those products. A variety of methods has been developed for the enumeration of microbes. These methods measure cell numbers, cell mass, or cell constituents that are proportional to cell number. The four general approaches used for estimating the sizes of microbial populations are direct and indirect counts of cells and direct and indirect measurements of microbial biomass. Each method will be described in more detail below.

1. Direct Count of Cells Cells are counted directly under the microscope or by an electronic particle counter. Two of the most common procedures used in microbiology are discussed below.

Direct Count Using a Counting Chamber: Direct microscopic counts are performed by spreading a measured volume of sample over a known area of a slide, counting representative microscopic fields, and relating the averages back to the appropriate volume-area factors. Specially constructed counting chambers, such as the Petroff-Hauser and Levy counting chambers, simplify the direct counting procedure because they are made with depressions in which a known volume overlies an area that is ruled into squares. The ability to count a defined area and convert the numbers observed directly to volume makes the direct enumeration procedure relatively easy. Direct counting procedures are rapid but have the disadvantage that they do not discriminate between living and dead cells. This method is used to assess the sanitation level of a food product and in performing blood cell counts in hematology. The differential white blood cell count, which is used as an indication of the nature of a microbial infection, involves direct counting of blood cells that have been stained to differentiate different types of white blood cells.

Direct Count Using a Counting Chamber

1. Clean a counting chamber with methanol and lens paper and then place it on the microscope stage.

2. Using the 4X objective find the ruled area on one side of the chamber and note the size and arrangements of larger squares and their small square subdivisions.

3. Shake the yeast suspension to distribute the cells evenly. Take out the counting chamber without changing the focus on the 4X objective. Place a coverslip over the calibrated surface of the counting chamber.

4. Using a transfer pipette, transfer some of the yeast suspension to the groove of the counting chamber to fill the chamber by capillary action.

5. Carefully place the counting chamber back onto the microscopic stage and observe the cells under 4X. You may need to reduce the amount of light by closing the diaphragm of the condenser to be able see the cells

6. Switch to the high-dry objective (40 X) and count the number of yeast cells in at least 50 of the small squares. If cells fall on a line, include in your count those on the top and left-hand lines and exclude those on the bottom and right-hand lines. (If the yeast cells are too dense to count, dilute your sample and start again.)

7. Calculate the average number of yeast cells per small square. Then calculate the number of yeasts per ml by dividing the average number of yeasts per small square by the volume of each small square which is 0.00025 µl. If you diluted the sample you must also multiply your results by the dilution factor to determine the concentration of yeast cells in the original sample. Record your calculations and results.

2. Indirect Count of Cells Microorganisms in a sample are diluted or concentrated and grown on a suitable medium; the development of growing microorganisms (for example, colony formation on agar plates) is then used to estimate the numbers of microorganisms in the original sample.

Viable Count The most common procedure for the enumeration of bacteria is the viable plate count. In this method, serial dilutions of a sample containing viable microorganisms are plated onto a suitable growth medium. The suspension is either spread onto the surface of agar plates (spread plate method), or is mixed with molten agar, poured into plates, and allowed to solidify (pour plate method). The plates are then incubated under conditions that permit microbial reproduction so that colonies develop that can be seen without the aid of a microscope. It is assumed that each bacterial colony arises from an individual cell that has undergone cell division. Therefore, by counting the number of colonies and accounting for the dilution factor, the number of bacteria in the original sample can be determined.

There are several drawbacks to the viable count method. The major disadvantage is that it is selective and therefore biased. The nature of the growth conditions, including the composition and pH of the medium used as well as the conditions such as temperature, determines which bacteria in a mixed population can grow. Since there is no universal set of conditions that permits the growth of all microorganisms, it is impossible to enumerate all microorganisms by viable plating. This same disadvantage, however, becomes advantageous when one is interested in only a specific microbial population.

For example, we can design selective procedures for the enumeration of coliforms and other physiologically defined microbial groups. The viable count is an estimate of the number of cells. Because some organisms exist as pairs or groups and because mixing and shaking of the sample does not always separate all the cells, we actually get a count of the "colony forming units". One cell or group of cells will

produce one colony, therefore when we record results for a viable count, it is customary to record the results as colony forming units per ml (cfu/ml) or per gram (cfu/g) of test material.

Because we generally have no idea of how many bacteria are in a sample, it is almost always necessary to prepare a dilution series to ensure that we obtain a dilution containing a reasonable number of bacteria to count. Dilutions in the range 10^{-1} (1/10) to 10^{-8} (1/100,000,000) are generally used, although with particular types of samples the range of dilutions can be restricted. For example, for water that is not turbid, the maximal dilution needed is 10-6 because we know that if there were 107 or more bacteria per milliliter, the water would be turbid.

Viable Plate Count

1. Label four 9.9 ml saline tubes 10^{-2}, 10^{-4}, 10^{-6}, and 10^{-8}, respectively. Label six BHI plates 10^{-4} to 10^{-9}.

2. Vortex the unknown sample to ensure an even distribution of bacteria. Aseptically remove 0.1 ml of sample with a sterile pipette and transfer it to the 10-2 dilution tube (see diagram).

3. Vortex the 10 -2 tube and transfer 0.1 ml to the 10^{-4} tube.

4. Again vortex the 10-4 dilution tube and transfer 0.1 ml to the 10^{-6} tube. Vortex this last tube well.

5. Vortex the 10^{-6} tube, transfer 0.1 ml to 10^{-8} tube and vortex again.

6. Using a new sterile pipette, aseptically transfer 1.0 ml from the 10^{-4} dilution tube to the plate labeled 10^{-4} and 0.1 ml to the plate labeled 10^{-5}. Spread the inoculum on the surface of the agar in each plate using an alcohol-dipped, flamed, metal spreader. Dip the spreader into the alcohol jar and quickly take it through the flame and let the alcohol burn off after each spreading. Do not allow the spreader to get too hot. Never hold the spreader in the flame for more than a second.

7. Repeat the above to transfer 1.0 and 0.1 ml from the 10^{-6} dilution tube to the 10^{-6} and 10^{-7} plates, respectively. In the same manner establish the 10^{-8} and 10^{-9} plates. Do not discard your dilution tubes.

8. Allow the surface of the agar to dry before you move or invert the plates. Incubate the plates at 37°C for 2 days.

No.	Question
1	What is the objective of enumeration of microbial population?
2	Explain method of direct counting by counting chamber.
3	Explain enumeration by viable count.

4	Difference between direct count and viable count

PRACTICAL:7 METHODS OF ISOLATION AND PURIFICATION OF MICROBIAL CULTURE

Isolation of Microorganisms:

Microorganisms occur in natural environment like soil. They are mixed with several other forms of life. Many microbes are pathogenic. They cause a number of diseases with a variety of symptoms, depending on how they interact with the patient. The isolation and growth of suspected microbe in pure culture is essential for the identification and control the infectious agent.

The primary culture from natural source will normally be a mixed culture containing microbes of different kinds. But in laboratory, the various species may be isolated from one another. A culture which contains just one species of microorganism is called a pure culture. The process of obtaining a pure culture by separating one species of microbe from a mixture of other species, is known as isolation of the organisms.

Methods of Isolation:

There are special techniques employed to obtain pure cultures of microorganisms. In few cases it is possible to secure pure culture by direct isolation or direct transfer. This can be done only in those situations in which pure culture occurs naturally. Kinds of specimens taken for culturing will depend on the nature and habitat of microbes.

Different pathogens can be isolated from body tissues and fluids such as blood, urine, sputum, pus, faces, spinal fluid, bile, pleural fluids, stomach fluids etc. In the blood stream of a patient suffering with typhoid fever, the bacteria *Salmonella typhosa* may be present.

A pure culture of this bacterium may be obtained by drawing blood sample using a sterilized hypodermic syringe and treating the blood with anticoagulant such as heparin and potassium oxalate. The presence of the anticoagulant prevents the pathogenic microbe from entrapping in fibrin clot. The sample of the blood may be inoculated into a suitable medium.

Following isolation methods are employed to isolate microbes from mixed cultures:

1. Streaking
2. Plating
3. Dilution
4. Enriched procedure, and
5. Single cell technique.

1. Streaking:

This is most widely used method of isolation. The technique consists of pouring a suitable sterile medium into sterile petriplate and allowing the medium to solidify. By means of a sterile loope or straight needle or a sterile bent glass-rod a small amount of growth preferably from a broth culture or bacterial suspension is streaked back and forth across the surface of agar until about one third of the diameter of the plate has been covered.

The needle is then flamed and streaking in done at right angles to and across the first streak. This serves to drag bacteria out in a long line from the initial streak. When this streaking is completed the needle is again flamed and streaking is done at right angles to the second streak and parallel to the first.

2. Plating:

It includes diluting of a mixture of microorganisms until only a few hundred bacteria are left in each millilitre of the suspension. A very small amount of the dilution is then placed in a sterile petrip lateby means of a sterile loop or pipette. The melted agar medium is cooled to about 45°C and is poured into plate. The microorganism and agar are well mixed. When the agar is solidified the individual bacterium will be held in place and will grow to a visible colony.

3. Dilution:

This method is used for the microorganisms which cannot be easily isolated by streaking or plating method. Sometimes when several organisms are present in a mixture, with one organism predominating, the predominating form may be isolated by this method. For example, when raw milk is allowed to sour at room temperature it will, at the time of curding, have a mixture of microorganisms with high percentage of Streptococcus lactis.

If 1 ml of the sour milk is taken into a tube containing 9 ml. of sterile milk (in which no organisms are present) then 1 ml. of this mixture is transferred with a sterile pipette into a second tube of sterile milk and the procedure is repeated i.e. from second to third tube, third to fourth tube until a series of about 10 tubes are inoculated. By this serial dilution, the chances are that a pure culture of S. lactis will be obtained.

4. Enrichment Procedure:

This procedure involves the use of media and conditions of cultivation which favour the growth of the desired species. For example, when a man suffers with typhoid, the intestinal discharge posses small number of Salmonella typhosa when compared with *E. coli* and other forms.

It is almost impossible to isolate the typhoid organisms because they represent only a fraction of a per cent of the total microorganisms present. The media are therefore derived, which allow the rapid growth of the desired organisms, at the same time inhibiting the growth of other microorganisms.

No.	Question
1	Define isolation. Explain method of isolation.
2	Draw the labelled diagram direct streaking and sector method.

PRACTICAL: 8 ISOLATION OF *RHIZOBIUM* FROM LEGUME ROOT NODULES

PRINCIPLE :

Rhizobium is known to survive a soil and in roots of legumes as well as non leguminous plants. Bacteria depends on root exudates which stimulate the growth of rhizobial cells. *Rhizobium* secretes extracellular polysaccharides which helps to find soil particles.

REQUIREMENTS:

Legume plant roots, sterile distilled water, pipettes, testtubes, YEMA plates, 70% ethanol, 0.1% mercurous chloride solution.

PROCEDURE:

Collection of Root Nodules:

Leguminous plants are carefully uprooted and the rootsystem is washed under running water to remove the adhesive soil particles. The colour of the nodules varies from brown to pink. Depending on the state of pigment present in them. For experiment healthy unbroken pink nodules are selected.

Surface Sterilisation of Leguminous Root Nodules:

The nodules must be surface sterilised by the sterilising agent and sterilising agent must be washed of from the nodules before they are used for isolation. The sterilising agent used us 0.1 % mercuric chloride or 3-5% hydrogen peroxids. The nodules are immersed in sterilising agents for 4-5 mints and are washed repeatedly with sterile distilled water. Then they are washed in 70% ethylalcohol followed by washing with sterile distilled water.

Isolation of *Rhizobium* by Serial Dilution Method:

Nodules are washed in a small aliquot of sterile distilled water with the help of a glass rod. YEMA plates are prepared and sterilised by autoclave. 10 fold serial dilution of nodular extract is prepared by taking 1gm of nodular extract into 10 ml of sterile distilled water and mixed well to get nodular extract suspension. 1ml of nodular extract suspension is diluted with 9ml of sterile distilled water making the dilution to 10 to the power of -2 similarly making the dilution upto 10 to the power of -8 are made separately for each nodular extract. Suspension 0.1ml of nodular extract suspension from 10 to the power of -3 to -8 dilutions are inoculated into sterile YEMA plates. The sample is spread throughout the YEMA plates and inoculates petriplates are incubated for 4-7 days in an incubator at 37 degree celcius.

Observation:

Rhizobium colonies are observed as large mucoid elevated colonies.

No	Question
1	Define nitrogen fixation.
2	Write down requirement for isolation of *Rhizobium*.
3	Give example of various species of *Rhizobium*.
4	Write a procedure for isolation of *Rhizobium*

PRACTICAL: 9 ISOLATION OF *AZOTOBACTER* FROM SOIL.

PRINCIPLE :

Soil is the natural habitat of different microorganisms. The quality and quantity of microbes depends upon the physiochemical characteristics of soil profile.

According to Alexander, the values of viable plate count in the fertile soil have been reported as 10 to the power of 8 to 10 bacteria, 10 to the power of 6 to 8 Actinomycetes and 10 power 4–6 fungal spores/gm of dry soil. Plate count enumeration is based on selection of a particular class of organisms through the presence or absence of specific nutrients (or) inhibitors placed in the nutrient medium.

REQUIREMENTS:

Soil sample, sterile distilled water, sterile pipettes, sterile petriplates, Ashaby's medium.

PROCEDURE:

Ashbay's medium is prepared and sterilised in an autoclave. About 15-20 ml of Ashbay's medium is poured into each sterile petriplate under asceptic conditions and allowed to solidify. 10 fold serial dilution of the soil smaple is prepared by taking 1 gm of soil sample into 10 ml of sterile distilled water and mixed well to get soil suspension. 1ml of a soil suspension is diluted with 9ml of sterile distilled water asceptically to get 10 power -1 dilution. Further 1ml of suspension from 10 power -1 dilution is attained aseptically transferred to 9ml of sterile distilled water making the dilution 10 power -2. Similarly higher serial dilutions upto 10 power -8 are made separately for each soil sampel. 0.1 ml of soil suspension from 10 power -3 to 10 power -8 are inoculated into sterile nutrient medium plates. The samples are spread uniformly, throughout the petriplates and then inoculated petriplates are incubated at 37 degree celcius fro 24 hrs for the isolation of bacteria. Duplicates are also maintinaed fro each dilution.

OBSERVATION :

Large raised mucoid colonies were observed.

No	Question
1	Give composition Ashbay's medium.
2	Write down requirement for isolation of *Azotobacter*.

3	Give example of various species of *Azotobacter*.
4	Write a procedure for isolation of *Azotobacter*

PRACTICAL: 10 STAINING AND MICROSCOPIC EXAMINATION OF MICROBES

A. Simple Stain

Introduction:

Stains attach to something because of charge differences between the object and the stain. Different stains can appear as a different color because they contain different chromophore groups, which vary in the wavelength of light they absorb. In general there are two main stain types. Positively charged stains have a positive chromophore. The second type, negatively charged stains, has a chromophore that carries a negative charge. Positively charged stains are excellent in binding negatively charged structures such as bacterial cell walls and, if they can enter the cell, many macromolecular structures such as DNA and proteins.

Cationic (basic) stains have a positive charge associated with them while anionic (acidic) stains carry a negative charge. Examples of cationic stains include crystal violet, safranin, basic fuschin, & methylene blue. Examples of anionic stains include eosin, nigrosin, & congo red. Acid dyes are often used to stain the slide background, which leaves the microbe transparent. Thus, in the field of view the microbe will appear as clear dots against an opaque background. Stains require a short exposure time to their target followed by a brief, light rinse with deionized (DI) water. This removes any excess stain and allows better viewing of the cells that carry the stain.

Materials:

- Safranin & crystal violet
- Overnight bacterial cultures of S. aureus & B. megaterium
- Glass slide
- Nichrome loop

Preparation of a smear and heat fixing

1. Using a sterilized inoculating loop, transfer loopful of liquid suspension containing bacteria to a slide (clean grease free microscopic slide) or transfer an isolated colony from a culture plate to a slide with a water drop.
2. Disperse the bacteria on the loop in the drop of water on the slide and spread the drop over an area the size of a dime. It should be a thin, even smear.
3. Allow the smear to dry thoroughly.
4. Heat-fix the smear cautiously by passing the underside of the slide through the burner flame two or three times. It fixes the cell in the slide. Do not overheat the slide as it will distort the bacterial cells.

Staining

1. Cover the smear with methylene blue and allow the dye to remain in the smear for approximately one minute (Staining time is not critical here; somewhere between 30 seconds to 2 minutes should give you an acceptable stain, the longer you leave the dye in it, the darker will be the stain).
2. Using distilled water wash bottle, gently wash off the excess methylene blue from the slide by directing a gentle stream of water over the surface of the slide.

3. Wash off any stain that got on the bottom of the slide as well.
4. Saturate the smear again but this time with Iodine. Iodine will set the stain
5. Wash of any excess iodine with gently running tap water. Rinse thoroughly. (You may not get mention about step 4 and 5 in some text books)
6. Wipe the back of the slide and blot the stained surface with bibulous paper or with a paper towel.
7. Place the stained smear on the microscope stage smear side up and focus the smear using the 10X objective.
8. Choose an area of the smear in which the cells are well spread in a monolayer. Center the area to be studied, apply immersion oil directly to the smear, and focus the smear under oil with the 100X objective.

B. Gram Staining

Introduction

The Gram staining method is named after Hans Christian Gram, the Danish bacteriologist who originally devised it in 1844, and is one of the most important staining techniques in microbiology. It is almost always the first test performed for the identification of bacteria. The primary stain of this method is Crystal Violet, which can be sometimes substituted with equally effective Methylene Blue. The microorganisms that retain the crystal violet-iodine complex appear purple brown under microscopic examination. Stained microorganisms are classified as gram positive, while the unstained are classified as gram negative. While there is a wide range of staining methods available, the procedures for those are similar to that of Gram's stain. By using appropriate dyes, different parts of the cell structure such as capsules, flagella, granules or spores can be stained. Staining techniques visualize components that are too difficult to see under an ordinary light microscope either because of lack of color contrast between background and object being examined or because of the limited power of the light microscope. In addition, these techniques are useful in the detection or absence of cell components. This simple differentiation technique ranks among the most important diagnostic tools in biological science.

Gram's Method uses retained crystal violet dye during solvent treatment to amplify the difference in the microbial cell wall. The cell walls for gram-positive microorganisms have a higher lipid content than gram-negative cells. First, crystal violet ions penetrate the cell wall of both types of cells. Then, iodine is added to form a complex that makes the dye difficult to remove, in a step referred to as "fixing" the dye. Following iodine, the cells are treated with decolorizer, a mixture of ethanol and acetone, which dissolves the lipid layer from the gramnegative cells, and dehydrating the thicker gram-positive cell wall. As a result, the stain leaches from gram-negative cells and is sealed in gram-positive cells. With expedient removal of the decolorizer, cells will remain stained. The addition of a safranin counterstain to dye the gramnegative cells with a pink color for easier observation under a microscope. Thus, gram-positive cells will be stained purple and gram-negative cells will be stained pink.

Materials

Crystal Violet, Potassium Iodide, Ethanol, 95% • Acetone • Ammonium oxalate • Iodine • Sodium bicarbonate • Safranin O • Bunsen Burner • Microscope • Slide • Cloth pin x dH2O

Method

1. Add about 5 drops of crystal violet stain over the fixed culture. Let stand for 60 seconds. Note that a clothes pin is used to hold the slide during the staining procedure to avoid staining one's hand.
2. Pour off the stain and gently rinse the excess stain with a stream of dH2O. Note: The objective of this step is to wash off the stain, not the fixed culture.
3. Add about 5 drops of the iodine solution on the smear, enough to cover the fixed culture. Let stand for 30 seconds.
4. Pour off the iodine solution and rinse the slides with running water. Shake off excess water from the surface.
5. Add a few drops of decolorizer so the solution trickles down the slide. Rinse it off with water after 5 seconds. Stop when the solvent is no longer colored as it flows over the slide.
6. Counterstain with 5 drops of the Safranin solution for 20 seconds.
7. Wash off the red Safranin solution with water. Blot with bibulous paper to remove any excess water. Alternatively, the slide may be shaken to remove most of the water and air -dried.
8. Liberally wash off any spilled stain immediately with water to avoid leaving permanent marks on the sink, lab bench or glassware.
9. Examine the finished slide under a microscope.

C. Negative Staining

The main purpose of Negative staining is to study the morphological shape, size and arrangement of the bacteria cells that is difficult to stain. eg: *Spirilla.* It can also be used to stain cells that are too delicate to be heat-fixed.

It is also used to prepare biological samples for electron microscopy. It is used to view viruses, bacteria, bacterial flagella, biological membrane structures and proteins or protein aggregates, which all have a low electron-scattering power. It is also used for the study and identification of aqueous lipid aggregates like lamellar liposomes (le), inverted spherical micelles (M) and inverted hexagonal HII cylindrical (H) phases by Negative staining transmission electron microscopy.

Principle of Negative Staining

Negative staining requires an acidic dye such as **India Ink or Nigrosin.**

India Ink or Nigrosin is an acidic stain. This means that the stain readily gives up a hydrogen ion (proton) and the chromophore of the dye becomes negatively charged. Since the surface of most bacterial cells is negatively charged, the cell surface repels the stain. The glass of the slide will stain, but the bacterial cells will not. The bacteria will show up as clear spots against a dark background.

Reagents of Negative Staining

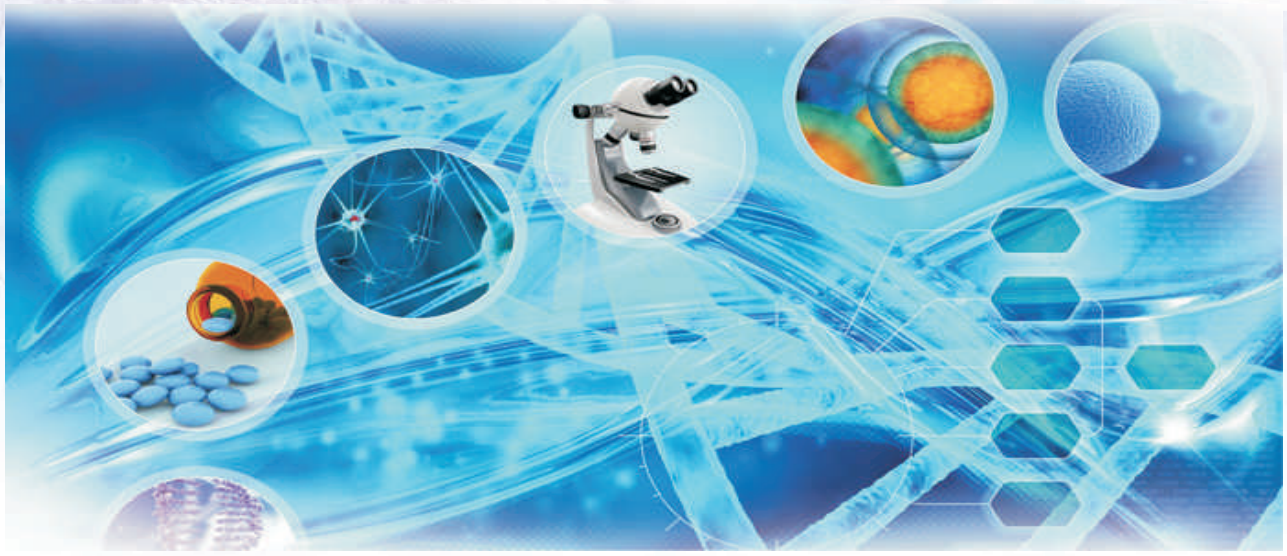
India ink
Nigrosin
Procedure of Negative Staining

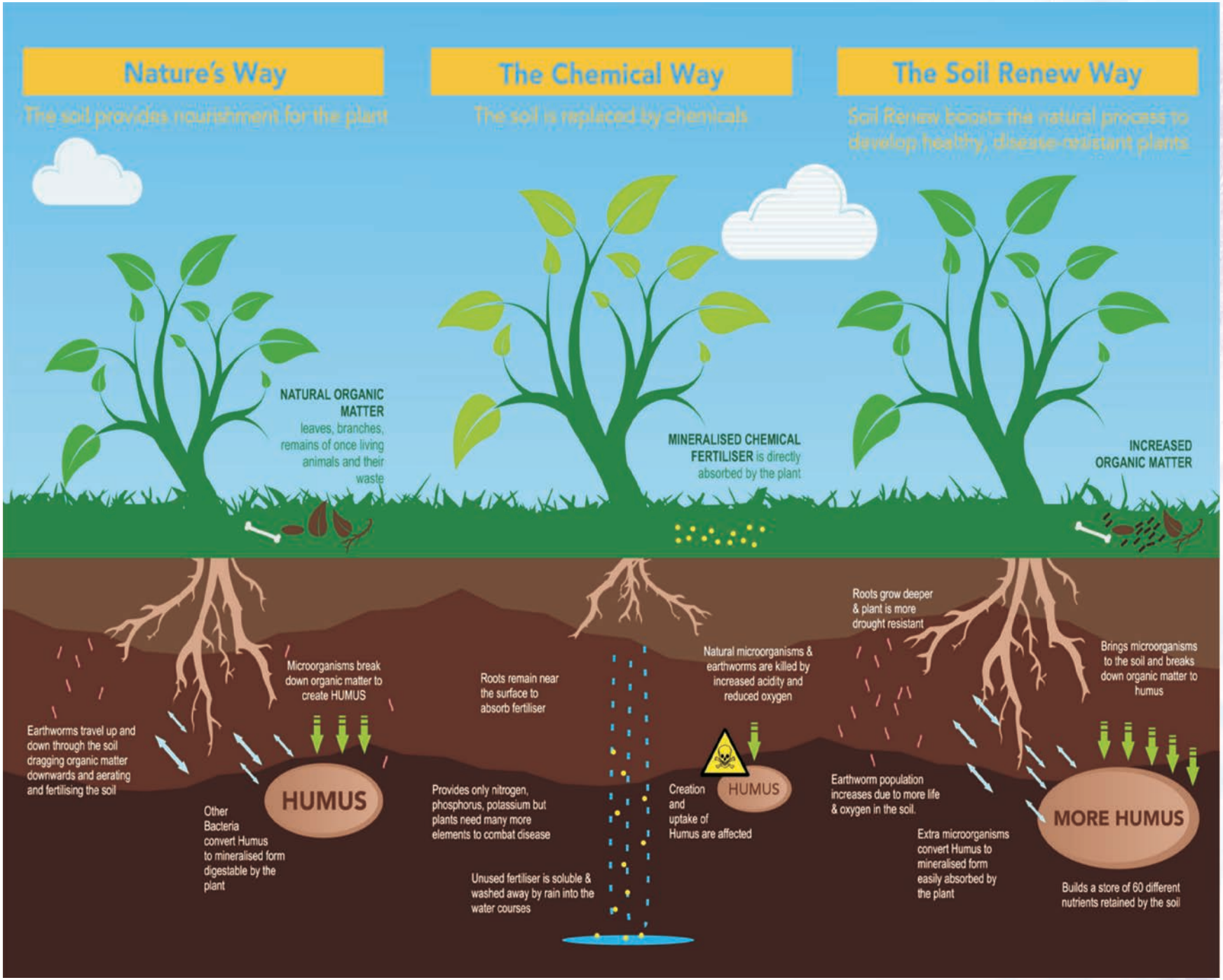
1. Place a very small drop (more than a loop full, less than a free falling drop from the dropper) of nigrosinnear one end of a well-cleaned and flamed slide.
2. Remove a small amount of the culture from the slant with an inoculating loop and disperse it in the drop of stain without spreading the drop.
3. Use another clean slide to spread the drop of stain containing the organism using the following technique.
4. Rest one end of the clean slide on the center of the slide with the stain. Tilt the clean slide toward the drop forming an acute angle and draw that slide toward the drop until it touches the drop and causes it to spread along the edge of the spreader slide. Maintaining a small acute angle between the slides, push the spreader slide toward the clean end of the slide being stained dragging the drop behind the spreader slide and producing a broad, even, thin smear.
5. Allow the smear to dry without heating.
6. Focus a thin area under oil immersion and observe the unstained cells surrounded by the gray stain.

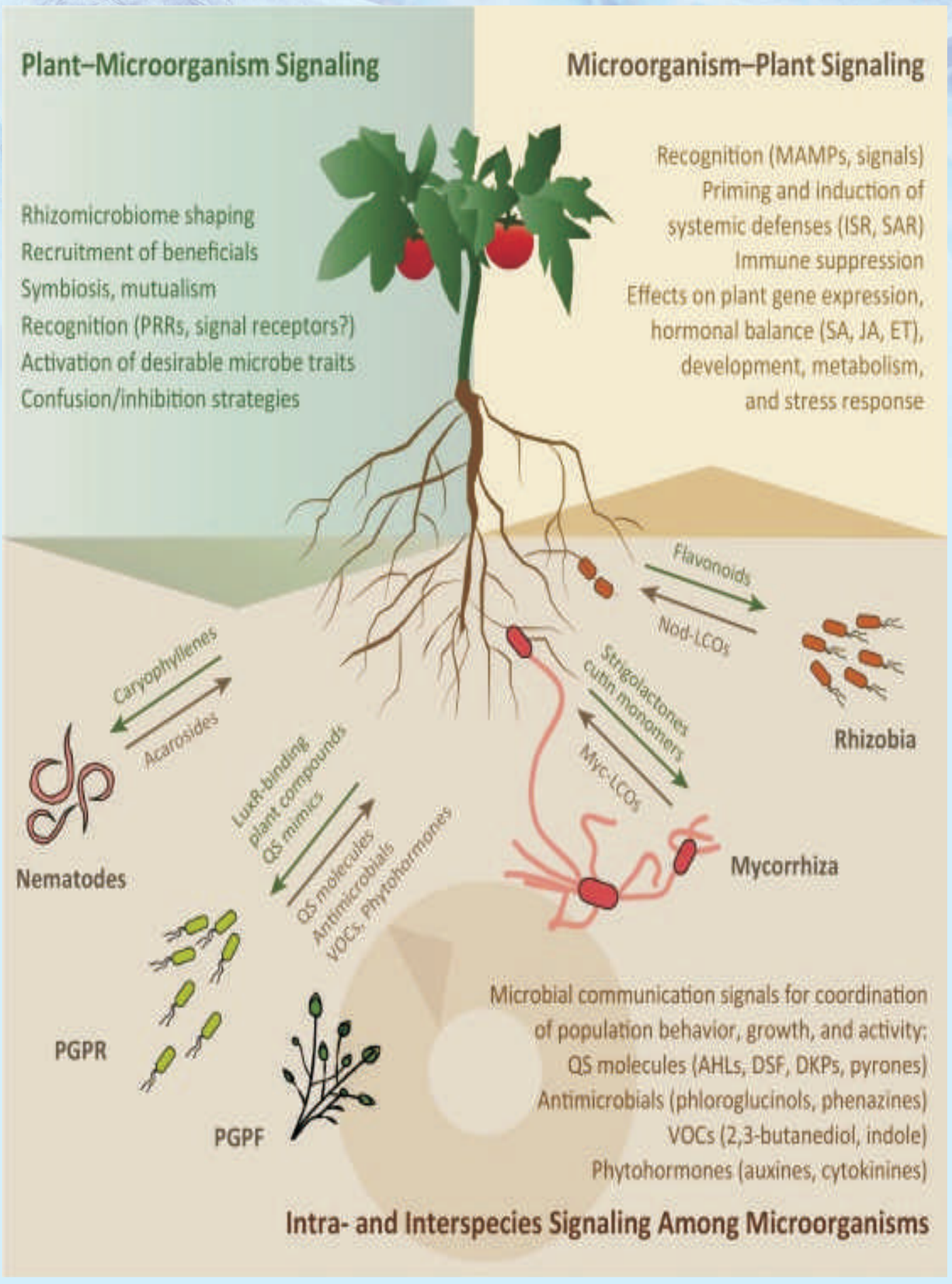
No.	Question
1	Define staining
2	What is chromophore and auxochrome group?
3	Explain principle of monochrome staining.

4	Explain principle of Negative staining.
5	Explain principle of Gram staining.
6	Give example of anionic and cationic dye.
7	Give preparation of smear and heat fixing

8	Explain procedure of Gram staining
9	Write a short note on procedure of negative staining.




Nature's Way
The soil provides nourishment for the plant
The Chemical Way
The soil is replaced by chemicals
The Soil Renew Way
Soil Renew boosts the natural process to develop healthy, disease-resistant plants
NATURAL ORGANIC MATTER
leaves, branches, remains of once living animals and their waste
MINERALISED CHEMICAL FERTILISER is directly absorbed by the plant
INCREASED ORGANIC MATTER
Earthworms travel up and down through the soil dragging organic matter downwards and aerating and fertilising the soil
Microorganisms break down organic matter to create HUMUS
HUMUS
Other Bacteria convert Humus to mineralised form digestable by the plant
Roots remain near the surface to absorb fertiliser
Provides only nitrogen, phosphorus, potassium but plants need many more elements to combat disease
Unused fertiliser is soluble & washed away by rain into the water courses
Natural microorganisms & earthworms are killed by increased acidity and reduced oxygen
Creation and uptake of Humus are affected
HUMUS
Roots grow deeper & plant is more drought resistant
Earthworm population increases due to more life & oxygen in the soil.
Extra microorganisms convert Humus to mineralised form easily absorbed by the plant
Brings microorganisms to the soil and breaks down organic matter to humus
MORE HUMUS
Builds a store of 60 different nutrients retained by the soil


Plant–Microorganism Signaling
Microorganism–Plant Signaling
Rhizomicrobiome shaping
Recruitment of beneficials
Symbiosis, mutualism
Recognition (PRRs, signal receptors?)
Activation of desirable microbe traits
Confusion/inhibition strategies
Recognition (MAMPs, signals)
Priming and induction of systemic defenses (ISR, SAR)
Immune suppression
Effects on plant gene expression, hormonal balance (SA, JA, ET), development, metabolism, and stress response
Flavonoids
Nod-LCOs
Caryophyllenes
Acarosides
Strigolactones cutin monomers
Myc-LCOs
Rhizobia
Nematodes
LuxR-binding plant compounds QS mimics
QS molecules Antimicrobials VOCs, Phytohormones
Mycorrhiza
PGPR
PGPF
Microbial communication signals for coordination of population behavior, growth, and activity:
QS molecules (AHLs, DSF, DKPs, pyrones)
Antimicrobials (phloroglucinols, phenazines)
VOCs (2,3-butanediol, indole)
Phytohormones (auxines, cytokinines)
Intra- and Interspecies Signaling Among Microorganisms

NAVSARI AGRICULTURAL UNIVERSITY

College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

FIRST SEMESTER , B.SC. (HONS) AGRI.

Comprehension and Communication skills in English (Eng. 1.1)

Practical Manual

Prof. Pragnesh I Solanki

NAVSARI AGRICULTURAL UNIVERSITY

भाकृअनुप
ICAR

Listening = *Learning*

COLLEGE OF AGRICULTURE, WAGHAI
NAVSARI AGRICULTURAL UNIVERSITY

Practical Manual
of
Comprehension and Communication skills in English (Eng. 1.1)

Prepared & Compiled
By

Prof. Pragnesh I. Solanki

College of Agriculture
Navsari Agricultural University
Waghai- 394730

Name of Student: _____

Roll. No. _____**University Reg. No.**_____

Publisher
Principal
College of Agriculture,
Navsari Agricultural University,
Waghai-394 730 (Gujarat)
Phone No. 02631 – 246688
Fax No. 02631 - 246622

Edition : First: January, 2019

Copies: 300

College of Agriculture,
Navsari Agricultural University,
Waghai (Dangs) – 394730.

University Publication No.:.....2018-19

Dr. Z. P. Patel
Dean & Principal
M. 9624363999

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

Phone No. : 02631 - 246688
Fax No. : 02631 - 246622
Email : zprin@nau.in, caw@nau.in

FOREWORD

January, 2019

(Z. P. Patel)

CERTIFICATE

This is to certify that the practical work has been satisfactorily carried out by

Mr. /Ms _____ in the course

no. Eng. 1.1 course title Comprehension and Communication Skills in English (1+1) of first

semester B. Sc. (Hons.) Agri., College of Agriculture, Navsari Agricultural University,

Waghai (Dangs) during the academic year 20 - 20

Course Teacher

Unit 1
Listening Comprehension

Audio lesson 1
Fun Day

Q.1 Where does the young girl want to go with her father?

a. to the park

b. to the movies

c. to circus

d. to fun world

Q.2 Who are they going with?

a. the girl's mother

b. the girl's best friend

c. the girl's older brother

d. the girl’s grandmother

Q.3 Based on the conversation, what time will they most likely leave?

a**.** 9:30 AM

b. 12:45 PM

c. 2:00 PM

d. 11.00 PM

Q.4 Where is the girl’s mother busy?

a. in bank

b. in shopping market

c. in office

d. in household work

Q.5 What does the girl want to do later?

a. go to ice-cream store.

b. go to swimming pool

c. go to down to the beach

d. go to park

Conversation writing

Audio lesson 2

Birthday Party

Q.1 What is the boy's name?

a. Matthew

b. Michael

c. Mitchell

Q.2 How old is the boy turning in the conversation?

a. seven

b. eight

c. nine

Q.3 What does he want to do first?

a. play outdoor games

b. open presents

c. eat cake and ice cream

Q.4 Which statement is true about the game at the party?

a. You have to catch a large ball without dropping it.

b. You need to chase children around and touch them

c. You need to hide somewhere so no one can find you

Q.5 Who is coming to the party?

a. aunts, grandparents, and cousins

b. grandparents, cousins, and uncles

c. friends, cousins, and grandparents

Conversation writing

Audio Lesson 3

Hotel reservation

Q.1 On which day the man finally reserves a room?

a. March 20th

b. March 21st

c. March 22nd

Q.2 **What kind of room does the man prefer?**

a. a non-smoking room

b. a smoking room

c. either one is okay

Q.3 **Why doesn't he want to reserve the suite?**

a. outside view is not good

b. does not have sauna bath

c. it is costly

Q.4 How much is the cost of the room including tax?

a. 80 dollars

b. 88 dollars

c. 90 dollars

Q.5 **How do you spell the man's name?**

a. Maxner

b. Maexner

c. Mexner

Conversation writing

Audio Lesson 4

Train Ticket

Q.1 Where does the man want to go?

a. to the science museum

b. to the art museum

c. to the natural history museum

Q.2 **How much is the train ride?**

a. a dollar fifteen

b. a dollar forty

c. a dollar fifty

Q. 3 **Where should the man get on the train?**

a. platform number 3

b. platform number 4

c. platform number 5

Q.4 **How often do the trains come?**

a. about every five minutes

b. about every six minutes

c. about every seven minutes

Q.5 **Where should the man get off the train?**

a. at the State Street Station

b. at the Star Palace Station

c. at the Seventh Street Station

Conversation writing

Audio lesson 5

Picnic Preparation

Q.1 **When is the picnic?**

a. on Thursday
b. on Friday
c. on Saturday
d. on Sunday

Q.2 **Where is the picnic being held?**

a. at a park
b. at Dave's house
c. at the beach
d. by a river

Q.3 **How many packages of hot dogs do they decide to buy?**

a. six
b. seven
c. eight
d. nine

Q.4 Why has Kathy been so busy lately?

a. busy in her job
b. taking care of her mother
c. busy in her studies
d. looking for job

Q.5 What does Dave suggest Scott make for the picnic dessert?

a. cherry pie

b. chocolate cake

c. oatmeal cookies

d. fudge brownies

Conversation writing

Audio lesson 6

Daily schedule

Q.1 What time does the man get up?

a. at 5:00 a.m

b. at 6:00 a.m.

c. at 7:00 a.m.

Q.2 What time does he get to work?

a. at 7:00 a.m.

b. at 8:00 a.m.

c. at 9:00 a.m.

Q.3 What does he do with his family around 6:30 p.m.?

a. read books

b. play games

c. eat dinner

Q.4 What do the man and his wife do after the kids go to bed?

a. watch tv

b. clean their house

c. listen to music

Q.5 What is one thing the man does NOT say about his wife?

a. take their children to school.

b. help the kids to do home work.

c. go shopping

Conversation writing

Audio Lesson 7

Spending money

Q.1 How much does the father owe his son in allowance?

a. three dollars

b. thirteen dollars

c. thirty dollars

Q.2 Why hasn't the father given his son allowance?

a. the father didn’t remember.

b. the father doesn’t have money now.

c. the son already have money

Q.3 When does the father usually give his son money?

a. on Friday

b. on Saturday

c. on Sunday

Q.4 Where does the man get money to pay his son?

a. in his bedroom

b. at the bank

c. from ATM

Q.5 Choose one thing the boy does NOT mention about how he will spend his money.

a. buy some toys

b. save some money

c. give some to poor people

Conversation writing

Audio Lesson 8
Immigration and Custom

Q.1 What is the purpose of the woman's visit?

a. Teacher meeting

b. Traveling

c. teacher meeting and travelling both

Q.2 Where will the woman stay during her trip?

a. friend's home

b. hotel

c. university guest house

Q.3 About how long will the woman be in the country?

a. one or two days

b. three or four days

c. more than four days

Q.4 What things are in the woman's luggage?

a. clothing, computer, and books

b. CD player, clothing, and books

c. books, gifts and computer

Q.5 What other piece of information do we learn about the woman?

a. Born in that country

b. her parents are with her

c. likes travelling

Conversation writing

Audio Lesson 9
College Life

Q.1 What does the man want to do after he graduates?

a. Become a teacher

b. Go to graduate school

c. Work in a hotel

Q.2 What is the woman majoring in?

a. History

b. French

c. Computer science

Q.3 How does the woman pay for college?

a. From her salary

b. From her scholarship

c. Her parents help in fees

Q.4 Where does the man work part-time?

a. At a bakery

b. In a library

c. At a restaurant

Q.5 What thing did the man NOT say about his job?

a. Colleagues are friendly

b. Works long hours

c. Salary is good

Conversation writing

Audio lesson 10
Sightseeing Around Town

Q.1 Where are they planning to go in the morning?

a. to a park

b. to an art museum

c. to a shopping center

_____

Q.2 What kind of restaurant do they want to visit for lunch?

a. Italian

b. Indonesian

c. Indian

_____

Q.3 Why does the man want to visit the zoo in the afternoon?

a.zoo will be closed for the rest of the week

b. the entry is free today

c. there are unique animals in the zoo

_____

Q.4Why does the woman want to go shopping instead?

a. to buy souvenirs.

b. to buy clothes

c. to buy a gift for her friend

_____

Q.5 How do they plan to get to the seashore at the end of the conversation?

a. by taxi

b. by bus

c. by subway

_____

Conversation writing

Unit 2
Reading Comprehension

Read the following passages and answer the questions.

1. Religion is something so high, and politics is so low that one thing has to be remembered : whenever there is a mixture of something lower with something higher, it is always the higher which becomes polluted- not the lower. It is always the higher which loses its quality of being higher. The lower has nothing to lose; it cannot fail anymore- it has already fallen to its uttermost.

Religion and politics should be separate.

And the moment religion becomes organized, it becomes politics. Hence religion should not be organized at all; it should be everybody's private, personal, intimate search. At least some area of life should be left to the individual- where he is totally free, without anybody else deciding for him, where he can open his wings like an eagle and fly across the sun- no chains, no bondages, no hindrances.

Religions blossoms only in a heart which is absolutely free of all doctrines, all beliefs, all churches, all mosques. I want the whole world to be religious but not Christian, not Catholic, not Hindu, not Muslim- just to be religious is enough.

Can't you see these simple facts? Honesty is honesty- it is neither Christian nor Hindu. Truth is simply truth – it cannot be Muslim, it cannot be Christian. Love is simply love – it cannot be Eastern and it cannot be Western. Compassion is compassion- it does not belong to any race, to any country, to any climate; it is not dependent on any history.

Q.1 What happens when there is the mixture of something higher with something lower?

_____
_____
_____
_____

Q.2 What is referred to as 'Higher' and what is referred to as 'lower'?

_____
_____
_____
_____

Q.3 Why should religion not be organized?

_____
_____
_____
_____

Q.4 Where does religion blossom and why?

_____
_____
_____
_____

Q.5 What is religion compared with in the last paragraph?

_____
_____
_____
_____

2. Why exactly do we compare ourselves with others? We compare ourselves because we have never understood ourselves and are not aware of who we are and what we have. It is also because society has conditioned us from our birth to evaluate ourselves based upon others. But there is no scale to compare you with anybody. Each individual is unique. Can you compare a lion and a horse? Do we ever compare ourselves with flowers or birds or mountains? Then why do we have to compare ourselves with other human beings? Just see nature: the rose plant and the mango tree grow in the same garden and prosper because they use all their energy for their own growth instead of using it to compare themselves with the other. Comparison leads to jealousy. We always compare ourselves with others we feel that somebody else has something more than what we have and, we get caught in jealousy. Through comparison we can grow only to the extent of the person with whom you are comparing yourself, not to your own unique level. The whole spiritual knowledge or experience is nothing but realizing you are unique, there is nothing to compare. Comparison is societal. Realizing your uniqueness is natural.

Q.1 **Why do we continuously compare ourselves with others?**

_____
_____
_____
_____

Q.2 What is the main reason of jealousy among human beings?

_____
_____
_____
_____

Q.3 What are the disadvantages of comparing oneself with others?

_____
_____
_____
_____

Q.4 What is the message of spirituality?

_____
_____
_____
_____

Q.5 Give a suitable title to this passage.

_____

3. To succeed in life one needs to cultivate disciplined life. It is the source of self mastery, moral excellence, and greater liveliness in life. But discipline is neither readily attained nor easily maintained. It requires mental stamina to overcome empty passions and faulty habits. It also requires the efforts to resists so many temptations. The art of living consists in knowing which impulse to obey and which must be made to obey. Many people view discipline as absence of freedom but in fact it is source of freedom. The same mind which is source of bondage will become source of liberation. In the initial stage, one has to fight with one's inner laziness with efforts. But after certain stage, it becomes effortless effort. That mind enables us to focus on higher faculties. Discipline requires control of thoughts and focus on the essentials, dispassion towards the essential matters, sticking to time schedule and time limits, maintaining decorum in different social and family settings, avoiding temptations to eat, to sleep or to rest more than what is necessary for the body and courage to say no to useless temptations and irrelevant matters.

1. What is the advantage of cultivating disciplined life?

_____
_____
_____
_____

2. What are the requirements of disciplined life?

_____
_____
_____
_____

3. What are the requirements of discipline?

_____
_____
_____
_____

4. What is the role discipline in our life?

_____
_____
_____
_____

5. Give suitable title to the passage.

_____

4. The Third Great Defect of Our Civilization is that it does not know what to do with its Knowledge. Science has given us powers fit for the gods, yet we use them like small children. For example, we do not know how to manage our machines. Machines were made to be man's servants; yet he has grown so dependent on them that they are in a fair way to become his masters. Already most men spend most of their lives looking after and waiting upon machines. And the machines are very stern masters. They must

be fed with coal, and given petrol to drink, and oil to wash with, and they must be kept at the right Temperature. And If they do not get their meals when they expect them, they grow sulky and refuse to work, or burst with rage, and blow up, and spreads ruin and destruction all round them. So we have to wait upon them very attentively and do all that we can to keep them in a good temper. Already we find it difficult either to work or play without the machines, and a time may come when they will rule us altogether, just as we rule the animals.

And this brings me to the point at which I asked, "What do we do with all the time which the machines have saved for us, and the new energy they have given us?" On the whole, it must be admitted, we do very little. For the most part we use our time and energy to make more and better machines; but more and better machines will only give us still more time and still more energy, and what are we to do with them? The answer, I Think, is that we should try to become mere civilized. For the machines themselves, and the power which the machines have given us, are not civilization but aids to civilization. But you will remember that we agreed at the beginning that being civilized meant making and linking beautiful things, thinking freely, and living right and maintaining justice equally between man and man. Man has a better chance today to do these things that he ever had before; he has more time, more energy, less to fear and less to fight against. If he will give his time and energy which his machines have won for him to making more beautiful things to find out more and more about the universe, to removing the causes of quarrels between nations, to discovering how to prevent poverty, then I think our civilization would undoubtedly be the greater, as it would be the most lasting that there has ever been.

Q.1 How does machine became master of man instead of making our servant?

_____
_____
_____
_____

Q.2 Why does the author consider use of machines has been a curse than a blessing?

_____
_____
_____
_____

Q.3 What exactly is the meaning of "Civilization"? Do you agree with the author's views?

_____
_____
_____
_____

Q.4 What should be done according to the author with the time saved?

_____
_____
_____
_____

Q.5 Give suitable title to the passage?

_____

5. Sports teach us many valuable qualities like co-operation, discipline, regard for rules and love of justice and fair play. These qualities prove very useful to a sportsman in his life. They make for his success in his chosen field. They also make him a good citizen. A sportsman learns many valuable lessons on the playing-field. He comes to realize that it is not victory or defeat that matters, but the spirit in which we play. In fact, failure goads him to still greater efforts. These valuable lessons enable him to face the problems and difficulties of life manfully. Even spiritual leaders have recognized the values of sports. Swami Vivekanand said once, "One could reach Heaven more easily by playing football than by reading the Geeta."

There was a time when sportsmen had no chance of making money. Things are entirely different now. If a player makes it to the top he makes big money. Pele, the greatest footballer of the world, is fabulously rich. Top cricketers of the world roll in wealth. Outstanding sportsmen are offered very good jobs, both by private concerns and government agencies. But professionalism has both advantages as well as disadvantages. Many professional players resort to taking drugs in order to remain in the limelight.

Another factor which has crept into games and sports is the politics and corruption. It is very unfortunate that sometimes the deserving and talented players are ignored, being the victims of regionalism, politics and nepotism. The selectors sometime oblige their relatives, friends and political bosses because professional sports means a lot of money.

Sports make a valuable contribution to national integration and international understanding. At national and international meets, sportsmen of one nation or state get to know from other nations or states. They mix with one another. As a result they shed their prejudices and tend to become broad-minded.

Q.1 What does a sportsman realize?

_____

_____

_____

_____

Q.2 Give in your own words what Swami Vivekanand has said.

_____

_____

_____

_____

Q.3 Give four qualities which sports teach us.

_____

_____

_____

_____

Q.4 Why are deserving sportsmen ignored?

_____

_____

_____

_____

Q.5 Give a suitable title to the passage.

_____

Unit 3
Writing skill

Subject Verb Agreement

RULE 1: ***When two subjects are joined by 'and', the verb is plural.***

For example: My friend and his mother are in town.

RULE 2: ***When two singular nouns joined by 'and' refer to the same person or thing, the verb is singular.***

For example: Bread and butter is the basic need of today's youth.

RULE 3: ***Indefinite pronouns (everyone, each one, someone, somebody, no one, nobody, anyone, anybody etc.) are always singular.***

For example: Everyone is selfish.

We do not use 'are' in this sentence.

This rule does not apply to: few, many, several, both, all, some.

RULE 4: ***When the percentage or a part of something is mentioned with plural meaning the plural verb is used.***

For example: 40 of every 100 children are malnourished.

RULE 5: ***When the subjects joined by 'either or' or 'neither nor' are of different persons, the verb will agree in person and number with the noun nearest to it.***

For example: Neither you nor your dogs know how to behave.

Either of the books is fine for MAT preparation.

Always remember that, when *either* and *neither* are used as pronouns, they are treated as singular and always take the singular verb.

RULE 6: ***If connectives/appositives like along with, together with, as well as, accompanied by etc. are used to combine two subjects, the verb agrees with the subject mentioned first.***

For example: Mr. Ram, accompanied by his wife Sita and his brother, was banished to the forest.

RULE 7: ***A number of/ the number or***

'A number of (some countable noun)' is always plural. 'The number of (some countable noun)' is always singular.

For example: A number of students are going on the trip.

RULE 8: ***The singular verb form is usually used for units of measurement or time.***

For example: Five gallons of oil was required to get the engine running.

RULE 9: ***When any of 'few, many, several, both, all, some' is used with a countable noun, the verb is plural.***

For example: Some men are needed for the battle.

RULE 10: ***When any of 'few, many, several, both, all, some' is used with an uncountable noun, the verb is singular***.

For example: Some milk is spoilt.

Subject-Verb agreement is essential to make sure that a sentence is grammatically correct. Thus, the above ten basic rules can help you to master subject-verb agreement.

Rule 11: ***Use a singular verb with distances, periods of time, sums of money, etc., when considered as a unit.***

Three miles *is* too far to walk.
Five years *is* the maximum sentence for that offense.
Ten dollars *is* a high price to pay.

Rule 12: ***With words that indicate portions—e.g.,*** **a lot, a majority, some, all—*If the noun*** *after* of *is singular, use a singular verb. If it is plural, use a plural verb.*

A lot of time is wasted
A lot of people are joining the rally.
A huge crowd of students has gathered to raise their protest.

Rule 13: ***In sentences beginning with*** **here** ***or*** **there,** ***the true subject follows the verb.***

There are four hurdles to jump.
There is a high hurdle to jump.
Here are the keys.

Worksheet for practice

1. One of my friends .... gone to France. (has/ have)
2. Each of the boys ..... . given a present.(was/ were)
3. He and I .... at Oxford together. (was/ were)
4. Slow and steady ..... the race. (win/ wins)
5. Neither the Minister nor his colleagues .....…… given any explanation for this. (has/ have)
6. A number of students ……. absent today. (are/ is)
7. The list of eligible students ..... been published(has/ have)
8. The news …… false.(is/are)
9. Gulliver's Travels ……. an interesting novel. (is/are)
10. Thousand dollars ……. a huge amount. (is/are)
11. Neither the principal nor the teachers …….. able to give a satisfactory explanation. (was/ were)
12. All the petrol in the tank ___ over (is /are)
13. Neither Bob nor his friends ____ going to the party. (is /are)
14. Here ___ the pictures you need for the project.(is/ are)
15. Gymnastics ___ easy for him. (is/are).
16. A box of apples ___ on the porch. (is /are)
17. Either Rajesh or Harish_____the bills in our house. (pay/pays)
18. Here _____ the family now. (come/ comes)
19. Beyond the mountains there ____ a fertile valley. (is/ are)
20. In a race, few runners _____ the race. (finish/ finishes)

Articles

An article is a determiner that indicates the coming of a noun. The indefinite article ‘a’or ‘an’ means one and is used only with singular countable noun. It leaves indefinite the place or person mentioned.

Example: I bought ‘a house’. (Means ‘any house’)

The definite article ‘the’ points out the person or thing. It refers to a particular person or thing and can be used with both singular and plural nouns and also with uncountable nouns.

Examples: the house that i bought ten years ago is being painted.

The food that i had yesterday was very tasty.

Rules of using “a”

“a” is used

- Before a word beginning with a consonant.
  Examples: ‘a kettle’, ‘a group’, ‘a woman’, ‘a fan’ ‘a chair’,
- Before a word beginning with a vowel with a consonant sound.
  Examples: ‘a university’, ‘a European’, ‘a union’, ‘a useful thing’, ‘a one way track’.
- Before a singular countable noun when it is mentioned for the first time.
  Examples: he bought a raincoat.
- With an expression of quantity.
  Examples: ‘a lot of time’, ‘a great deal of money’, ‘a dozen oranges’, ‘ a little hope’
- With certain numbers.
  Examples: ‘a hundred rupees note’, ‘ a thousand rupees’.
- Before half or when half follows a whole number otherwise after half.
  Examples: ‘one and a half’, ‘two and half a kilos’, ‘ half a liter’.
- Before a proper noun to point out an unfamiliar person, or if we want to express a special meaning.
  Examples: a Jatin Verma rang up in the morning.
  He wants tobe a tendulkar when he grows up.
- In exclamation before nouns
  Examples: ‘what a chance!’, ‘Such a mess!’, ‘What a pity!’, ‘What a lovely flower!’.

Rules of using “an”

“an” is used.

- Before a word beginning with a vowel sound. Examples: ‘an ant’, ‘an egg’, etc.
- Before a silent ‘h’. Examples: ‘an honest man’, ‘an hour’, ‘an hour’, ‘an heir’, etc.
- Before individual letters spoken with a vowel sound. Examples: he is an MP.

OMISSION OF THE ARTICLE

The article is omitted before

- Proper, material, abstract noun (i.e. uncountable nouns) used in a general sense.
  Examples:
  Justice is done.
  Sugar is bad for your teeth.
  Note: uncountable nouns take "the" when used in a particular sense, especially when qualified by an adjective phrase or clause.
  Examples:
  Would you pass me the sugar?
  I can't forget the kindness he showed to me.

- Plural nouns
  Examples:
  Diamonds are very expensive.
  Note: when it is referred to a particular situation "the" is used.
  The diamonds he purchased were fake.

- Uncountable nouns:
  Please give me some water.
  Add few drops of lemon juice.

- Seasons:
  Examples;
  Winters are usually cold in Delhi.

- Languages/academic subjects.
  Examples:
  Hindi, English, Sanskrit, physics, Economics. etc.

- Name of parts of body:
  Example:
  Cut your nails.

- Name of games:
  Examples:
  Cricket, football, hockey. Etc

- The is omitted before certain words such as 'home', 'hospital', 'church', 'court', 'prison', 'school', 'office'
  Examples:
  The patient is in hospital.
  His relatives visited the hospital.

- Names of the relations like ‘father’, ‘aunt’, ‘uncle’, etc.
  Example:
  Father has come home.

- Predictive nouns denoting a unique position, i.e. a position that is normally held at one time by one person only.
  Example:
  He was elected as chairman of the board.

- Certain phrases consisting of a transitive verb followed by its object.
  Examples:
  ‘to catch fire’, to send letter’, ‘to set sail’

- Certain phrases consisting of a preposition followed by its object.
  Examples:
  ‘At home’, ‘in hand’, ‘at day break’

Exercises.

Insert indefinite articles (a/an) wherever necessary.

1. What __ terrible sight this is!
2. She bought ten and half __ kilo of apples.
3. The king needs __ heir to the throne.
4. Jatin is __ naughty boy.
5. This is __ untold story.
6. This is __ beautiful court yard.
7. There is __ great deal of confusion here.
8. Can i barrow __ hundred rupee note?
9. There is no entry here. It is __ one-way lane.
10. You may need one and __ half meters of cloth.
11. They have __ European guest for the dinner.
12. He will come back in __ hour.
13. Please give me __ one rupee note.
14. She didn't get **an** invitation
15. He is **an e**xcellent teacher.
16. Does his name begin with **an** "F"
17. That number is **a** "1".
18. I saw **a r**eally beautiful eagle at the zoo.
19. He is conducting __ empirical research.
20. He bought ___ dozen of apples.

Choose A, AN or (/) for "no article" for each blank below, then click the "Check" button to check your answers.

1. I have __ two sisters and __ brother. My brother has __ son. That makes me __ uncle.

2. Would you like __ orange? Or would you prefer __ banana? We also have __ strawberries.

3. Does anyone have __ cell phone? I need to make __ emergency phone call.

4. Larry doesn't own __car. He rides__ motorcycle to work.

5. Today, you ate __ ice cream cone, __ piece of pizza, __ burrito and__ doughnuts. That's not ex actly __ healthy diet.

6. Let's go see__ movie. There's___ adventure film that I have really been wanting to see.

7. Is there __Internet cafe around here? I need to send__ important email.

8. Instead of making ___traditional turkey for Thanksgiving dinner, she baked __ enormous chicken.

9. It looks like it is going to be ___ rainy day. You should take __umbrella.

10. Phil and Debbie took __ amazing vacation to Switzerland last year. They even climbed__ mountain near Lucerne.

Multiple Choice Exercise

Choose A, AN or THE for each blank below.

1. My mother is __ doctor and my father is __ author.
2. Cindy recommended __ good dentist, but __ dentist doesn't have any openings for two months.
3. Mt. Hood is__volcano in Oregon. It's __ very beautiful mountain.
4. Sam recommended ___ book to Lisa. She didn't like __ book at all.
5. Do you have ___ vacuum? I dropped ___ piece of cake, and I need to clean it up.
6. Honey, where's ____ vacuum? I can't find it. It was in __ closet, but now it's not there.
7. Do you have __ dictionary? I don't have one, and I need to look up __ word.
8. Do you have __ passport? You need ___ passport to travel outside of country.
9. There's __ big bear in backyard. I think ___ bear is looking for something to eat.
10. Do you have ___ computer? I have __ laptop and __ iPad.

Multiple Choice Exercise

1. John bought ___ new car last week. Unfortunately, ___ car broke down after just two days.
2. We went to ___ movie yesterday. Even though it got __ good reviews,___ movie was ab solutely terrible. I was so mad, I went to box office and asked for my money back.
3. Our teacher gave us ___test today. It was ___ really hard test. There were __ questions on them which I didn't even understand.
4. Excuse me, is there ___ post office around here? I need to buy __ stamp.
5. We have beautiful __ lake behind our house. Every winter,___ lake freezes over and we can go ice skating. When I was __ kid, I used to spend hours skating back and forth across __ice.
6. Carrie works for__ amazing organization;___ organization provides ___food and __supplies for children in ___developing world.
7. Is there ___ water on Moon? Yes, scientists have discovered ___ ice there.
8. When I turned on my new laptop,___ screen exploded! Luckily, it has___ good warranty. Either they will replace ___ broken screen or send me ___brand new laptop.
9. I know great new restaurant called ____Mumbai on 8th Avenue. It's___ Indian restaurant with incredible food.
   B: Oh yeah, I know that restaurant; ___chef is___ good friend of mine.
10. Wow, I can't believe how much ____ gallon of gas costs these days. If ___ price keeps going up, I'm going to buy ___ electric car.

Prepositions

A preposition is a word placed before a noun or a pronoun to show in what relation the person or thing denoted by it stands in regard to something else.

Example: the cat jumped off the chair.

Sometimes a preposition follows the object.

Examples:

1. What are you looking at?
2. Here is the book you were looking for.
3. This is the girl who you wanted to speak to.
   Note : the preposition is often placed at the end when the object is an interrogative pronoun as in sentence or a relative pronoun understood as in sentence.

Kinds of prepositions

1. **Simple prepoasitions:**
   'at', 'by', 'for', 'in', 'of', 'off', 'from', 'on', 'out', 'through', 'till', ' to', 'up', 'with', etc.
2. **Compound prepositions:**
   'about', 'across', 'above', 'along', 'amidst', 'among', 'around', 'before', 'behind', 'below', 'beneath', 'beside', 'between', 'beyond', 'inside', 'outside', 'underneath', 'within', and 'without'
3. **Phrase prepositions:**
   These prepositions are group of words with the force of a single preposition.
   'according to', 'by means of', 'by way of', 'in case of', 'in accordance to', 'with regard to', 'with a view to', 'in lieu of', 'in spite of', etc.
   Examples:
   In spite of all persistence efforts, i lost the battle.
   In accordance to the law the rider must wear safety belt while driving a car.
4. **Participial preposition:**
   'barring', 'concerning', 'considering', 'notwithstanding', 'pending', 'regarding', 'respecting', 'touching' etc.
   Notwithstanding he was severely ill, he appeared for the exams.
   Regarding the court notice, five members of the group are summoned.

   1. **At**
      Examples:
      - I have to wake up tomorrow at 6:00.
      - He's at work today.
      - They're **at** church right now.
      - John decided to stay **at** home today because he's sick.
      - My favorite radio station is at 91.1 FM on the radio dial.
      - Andrea lives **at** 2124 Oak Street.

2. **About**.
   - He looks like he's about four years old.
   - She's **about** 12 years old.
   - When he woke up, there were **about** ten people waiting for his garage sale to begin.
   - He's been on the phone for **about** ten minutes.
   - He weighs **about** 240 pounds.
   - He's just about to sneeze.
3. **Above.**
   - The clouds above the trees are moving very slowly today.
   - He lifted his bike above his head.
   - He's so strong, he can lift over 200 pounds above his head.
   - The snow above the valley still hasn't melted yet.
4. **According to:**
   - According to my watch, it's 11:45.
   - The weather tomorrow is going to be nice according to the weatherman.
   - According to this map, we're only 300 miles from our destination.
   - The subway is down here according to the sign.
   - Did you make the cookies according to the recipe?
5. **Across:**
   - To get to the other side of the creek, go across the bridge.
   - These bridges will get you **across** the Han River
   - You have to be careful when you walk **across** the street in a big city.
   - They're traveling **across** the field on horseback.
   - He's traveling **across** the United States on a bike.
6. **After:**
   - It gets dark very quickly after sunset.
   - After 5:00 a lot of people head home from work.
   - Cemeteries get a lot of new visitors after a war.
   - They decided to remain on good terms after their divorce.
7. **Against:**
   - The waves are crashing against the rocks.
   - The fighter in the yellow jersey has his opponent against the ropes, so he'll probably win the fight.
   - She gets angry when something goes against her beliefs.
   - He protested against government spending on the military.
8. **Among:**
   - She's very popular among her friends.
   - Among their three children, one has blond hair and the other two have red hair.
   - The cooperation **among** these four coworkers has improved tremendously in the last year.
   - They enjoy walking among the trees in the forest.

9. Because of:

- She continues to work as a waitress because of the great tips.
- Some people don't like red cabbage **because of** the taste.
- Antique furniture is found in many American homes **because of** its beauty and its value**.**
- Hockey is a sport with a lot of injuries because of the fighting.

10. Before:

- It feels good to wake up before sunrise.
- It's about twenty-five minutes **before** ten.
- These musicians enjoy performing before an audience.
- She stretches her legs **before** a race.
- She has many new challenges before her.

11. Behind:

- The sun is behind the clouds today.
- This boy is hiding behind a tree.
- She's falling behind at work, so now she takes her work home and finishes it on the weekend.

12. Below:

- This man is standing below the transmission tower.
- This building is very tall. There are many buildings below that are shorter.
- Below the ground, the subway carries people around the city.
- The airplane is flying above the clouds. **Below** the clouds, it's raining.
- She works below the assistant manager.
- The temperature is below 10.

13. Between:

- Which flag is flying between the American and the Canadian flags?
- The relationship between a doctor and a patient is confidential.
- There's a very narrow walkway between these two buildings.
- A handshake is often used to indicate an agreement between two people.

14. Beside:

- They're standing **beside** each other.
- The opera house in Sydney is **beside** the ocean.
- The cathedral is **beside** the river.

15. But:

- He teaches nothing but music all day long.
- All **but** one person left the movie theater.
- The company takes nothing but cash for the work that it does.

16. By:

- These beautiful buildings are by the water.
- They're sitting by each other and watching a movie.
- You can learn English by going online.
- You can get around this city very easily by bus.
- He needs to get to his meeting by 5:30.

17. Despite:

- **Despite** the low-cost of commuting by train versus commuting by car, many Americans still choose to drive a car to work.
- Despite the feelings of his coworkers, Robert turns the radio up a little too loud when he's at his desk.
- I woke up late this morning despite setting my alarm clock for 5:30 a.m.

18. **During**:

- She's at work during the day.
- There were a couple of people talking during the movie.
- He was a soldier during World War II.
- They get together during the day for tea.
- He worked on his computer **during** the flight.

19. **Except**:

- He worked on his computer **during** the flight.
- Normally, I eat healthy food **except** for donuts.
- Except for his keyboarding skills, he's pretty good at using a computer.
- The mail is picked up from this mailbox every day except Sunday.

20. For:

- She's posing **for** a picture.
- Window boxes are great **for** growing flowers.
- Brocolli is good **for** you.
- He's making some food **for** his friends.

21. From:

- Aza and her friends moved to the United States **from** Russia.
- This flag is **from** Turkey.
- Sweat is dripping **from** his forehead.
- This picture is **from** a trip I took to Chicago

22. In:

- They're both sitting in a hot tub.
- He's interested in staying healthy, so he exercises regularly.
- Is the doctor in this afternoon?
- She has a cigar in her hand.
- She's in a very good position with the company.
- He gets up early in the morning.

23. In front of:

- They're standing **in front of** their house.
- This dragon statue is **in front of** a temple.
- He's sitting **in front of** his computer.
- The teacher is standing **in front of** the class.

24. Instead of:

- Instead of sports, he likes academics.
- He chose a military career **instead of** going to college.
- It's better for your health to eat a lot of vegetables **instead of** a lot of meat.
- I prefer antique radios instead of new ones.

25. Into:

- These animals are headed **into** the water for some relief from the heat.
- She's diving **into** the water.
- Some heavy fog moved **into** the city from the ocean.

26. **Near:**

- She's sitting near the pool.
- The golf ball is very near the cup.
- This lake is near the mountains.
- She's near the age of 70.

27. Next to:

- They're sitting **next to** each other in the movie theater.
- The dog is **next to** the river
- The boy is sitting **next to** his father.
- There's a church **next to** this house.

28. Of:

- There's a box **of** cereal on the kitchen table.
- Here's a gallon **of** milk.
- I'm going to have a can **of** soup for lunch.
- He's sick of his computer.

29. Off:

- This tire is not on the truck. It's off. It's off the truck.
- He's taking off his hat.
- The lights are off.
- This airplane is off the ground.
- He's taking some cheeseburgers off the grill.

30. On:

- He has a laptop computer **on** his desk.
- She has a ring **on** her finger.
- He has a hat **on** his head.
- The news is **on** TV.
- We have holiday this Friday.

31. On account of:

- The camping trip ended early **on account of** the rain.
- He couldn't go to work **on account of** a head injury.
- The movie theater had to shut down **on account of** a lack of business.
- She had to retire from her job **on account of** her age.

32. Onto:

- This cougar jumped **onto** a tree limb to get a better view of the area.
- This professor decided to put his lectures **onto** the internet so that more people could hear his ideas.
- The waves are crashing **onto** the beach.

33. Out:

- I usually walk **out** the door every morning at 7:00 a.m. to go to work.
- There's a big yard **out** back.
- She's out shopping.
- She went out last night.

34. Over:

- I love the sound of water running **over** rocks in a stream.
- A rainbow appeared **over** the horizon when the sun came out.
- The smoke over the house indicates that someone is inside.

35. Regarding:

- I have some questions for my doctor **regarding** some pain in my lower back.
- The president of the company held a meeting **regarding** the progress of the company over the last year.
- Vince is talking to someone on the phone **regarding** a new business opportunity.

36. Since:

- I haven't spoken on the phone since yesterday.
- We haven't seen them since the wedding.
- She has been learning English since late last year.
- The world seems to have changed a lot since 9/11.

37. Through:

- He's going **through** the drive-thru to pick up some food.
- Buses and cars drive **through** the city.
- She rode **through** the forest on her horse.
- The sun is peeking **through** the clouds.

38. To:

- He brought his radio **to** the beach.
- They have been married **to** each other for five years.
- He's listening **to** the ocean in this shell.
- This is the entrance to Rudolph's house.

39. Towards:

- The boy and the girl are walking **towards** the water.
- The balloon is flying **toward** the mountains.
- They're coming **towards** a boat.
- He swam **towards** the other side of the pool.
- She's working **toward** getting a college degree online.

40. Under:

- The cat is **under** the chair.
- A subway is a train that travels **under** the ground.
- They're selling fruit and vegetables **under** the protection of these colorful umbrellas.
- These greens hills look stunning **under** a clear blue sky.

41. Until:

- The sun doesn't rise until after dawn.
- It's still light outside **until** dusk.
- He can't wait **until** winter.
- She won't leave work today **until** 6:30 p.m.

42. Up:

- They're traveling up the escalator.
- You need to walk **up** the stairs to get to the temple.
- This hot-air balloon is up in the air.

43. Up to:

- An elephant can eat up to 400 pounds of food in one day!
- There are some Americans who spend **up to** eight hours a day watching television.
- Most of the big decisions in the company are left up to him.
- He walked up to a police officer and asked for help in finding his mother.

44. Upon:

- Standing upon a skateboard requires a lot of balance.
- There's a crown **upon** his head.
- She has a big smile upon her face.
- The Christmas season is upon us once again.
- He got down upon his knees and prayed when he learned there was the chance he might lose his job.

45. With:

- He wants to spend the rest of his life **with** her.
- He eats his food **with** chopsticks.
- He likes to eat **with** his hands.
- I painted a table **with** these paint brushes.

Preposition	Meaning	Examples
above	higher than or over	The sun is **above** the clouds.
across	from one side to the other	It's dangerous to run **across** the road.
after	- following something - later than	- The boy ran **after** the ball. - I'll phone you **after** lunch.
against	- in opposition to - in contact with	- Stealing is **against** the law. - The sofa is **against** the wall.
along	from one end to the other	They are walking **along** the street.
among	surrounded by	Peter was a**mong** the spectators.
around	- in a circle - near, approximately	- He walked **around** the table. - It costs **around** 50 euros.
before	- earlier than - in front of	- The day **before** yesterday. - He bowed **before** the king.
behind	at the back of	Passengers sit **behind** the driver.
below	lower than	His shorts are **below** his knees.
beneath	under	The pen was **beneath** the books.
beside	next to	The bank is **beside** the cinema.
between	in the space separating two things	Mary sat **betwee**n Tom and Jane.
by	near, at the side of	The restaurant is **by** the river.
close to	near	The school is **near** the church.
down	from higher to lower	She pulled **down** the blind.
from	where something starts or originates	The wind is blowing **from** the north.
in	at a point within an area	The pen is **in** the drawer.
in front of	directly before	The child ran out **in front of** the bus.
inside	on the inner part of	The bird is **inside** the cage.
into	enter a closed space	He went **into** the shop.
near	close to	The school is **nea**r the church.
next to	beside	The bank is **next to** the cinema.
off	down or away from	He fell **off** the horse.
on	in a position touching a surface	The plate is **on** the table.
onto	move to a position on a surface	The cat jumped **onto** the roof of the car.
opposite	facing, on the other side	Eva sat **opposite** Tom at the table.
out of	- move from a closed space - without	- He got **out of** the taxi. - She's **out of** work.
outside	opposite of inside	The garden is **outside** the house.
over	- above/across - on the surface of	- The plane flew **over** the Atlantic. - She put a sheet **over** the furniture.

past	beyond	She drove **past** the supermarket.
round	in a circular movement	The earth moves **round** the sun.
through	from one side to the other	The Seine flows **through** Paris.
throughout	in every part of	The virus spread **throughout** the country.
to	in the direct of / towards	On the way **to** the station.
towards	in the direction of	The child ran **towards** her father.
under	beneath, below	Water flows **under** the bridge.
underneath	beneath	There was dust **underneath** the rug.
up	towards or in a higher position	She walked **up** the stairs.

Work sheet for practice

Select from (On – in – at)

1. The dictionary in _____ the top shelf.
2. Let's meet _____ the coffee shop beside the cinema.
3. My parents live _____a busy town on the east coast.
4. Sam accidentally dropped the parcel _____ the floor.
5. I found the article _____ a magazine while I was _____ the dentist's.
6. He left school and ran away from home _____ the age of sixteen.
7. Jane works _____ a bank _____ Oxford street.
8. They met _____ a jazz concert _____ London one evening.
9. I spent my childhood _____ a small town. It doubt if it's _____ the map.
10. Jane bumped into Sue _____ the hairdresser's shop _____ the week-end.
11. David is waiting __the bank.
12. I go to my office ___ 8 o'clock__ the morning.
13. The bank is __ the main street.
14. Christmas is celebrated ___ 25th of December every year.
15. I got the message ___ my cell phone.
16. The money is __ the bank.
17. I will complete my project __a week.
18. They are __ trouble.
19. We will visit manali __ next month.
20. Look __ that car.

Work sheet for practice

1. Send your resume to Mr. Martin. He's responsible _____ recruitment.
a. Of b. For c. IN d. At
2. Thank you for offering to help. It's very kind _____ you.
a. Of b. For c. At d. On
3. You must pay _____ the tickets when you order them.
a. In b. At c. For d. of
4. In this company salaries depend _____ the level of responsibility.
a. Of b. In c. On d. From
5. I need this report to be translated _____ English as quickly as possible.
a. To b. In c. Into d. With
6. The winner reminds me _____ my old history teacher.
a. With b. Of c. From d. At
7. The manager didn't take part _____ the discussion.
a. At b. In c. Of d. Into
8. I don't understand the reason _____ the increase _____ price.
a. Of/in b. For/of c. Of/of d. For/in
9. I want to visit the Louvre but Tom isn't interested _____ art.
a. For b. With c. In d. At
10. Jack will liven up the party. He's good _____ telling jokes.
a. In b. For c. At d. With
11. He was driving too fast and crashed _____ a tree.
a. In b. At c. Into d. with
12. I don't agree _____ you. _____my opinion you're wrong.
a. With/in b. With/for c. For/ in d. For/ at

Work sheet for practice

Choose the correct preposition and fill in the blanks.

1. Let us talk _____ something else. (to, about)
2. I have no interest ____ the politics of this game. (in, for)
3. He has the reputation ___ being a good teacher. (of , for)
4. She impressed ___ us the value of discipline. (on, in)
5. Don’t be negligent _____ your duties. (in, of)
6. Apply yourself ____your work with diligence. (with, to)
7. Most Indian roads are not suitable___ fast cars. (for, to)
8. What a contrast _____them! (between, to)
9. I am forever ____ your debt for your help. (in, on)

Tenses

The different tenses and the verb form used in each tense

Name of Tenses	Verb form used in Tense s
Present Simple	Verb + s / es
Present Continous	Is / am / are + ing
Present Perfect	Has / Have + third form of the verb
Present Perfect Continous	Has / Have + been verb + ing
Past Simple	Second form of the verb
Past continous	Was / Were + verb + ing
Past Perfect	Had + third form of the verb
Past Perfect Continous	Had + been verb + ing
Future Simple	Shall / will + verb
Future Continous	Shall / will + be + verb + ing
Future Perfect	Shall / will + Have + third form of the verb
Future Perfect Continous	Shall / will + Have been + verb + ing

Usage of Tenses

1. Uses of Simple present tense

- To express a habitual action

  I get up every day at 5 o'clock.

- To express general truth.

  Fortune favours the brave.

- In vivid narratives,

  Immediately he reaches to save his friend.

- To indicate a future event that is a part of a fixed programme or time tabe.

  The train leaves at 5.20 am.

- To introduce quotations.

  Keats says "A thing of beauty is joy forever"

- In exclamatory sentences beginning with "here" and "there" to express what is actually taking place.

  Here comes the bus!

2. Uses of Present Continuous Tense

- For an action going on at the time of speaking

  The boys are playing cricket in the ground.

- For an action that is started in recent past and is still happening in recent future.

  I am going for cycling now a days.

- To express changing or developing situations.

  India is progressing day by day.

- For an action that is planned or arranged to take place in near future.

  I am going to cinema tonight.

3. Uses of Present Perfect Tense

- To indicate completed activities of recent past.

  He has just gone out.

- To express past actions whose time is not given and not definite – actions with their effect continuing in the present.

  I have never known him to be angry

  Have you ever visited London?

4. Uses of Present Perfect Continuous Tense

- For an action, which began at some time in the past and is still continuing. With present perfect continuous tense an adverb or phrase that express time is used.

  I have been reading this book since morning.

  They have been building this bridge for several months.

5. Uses of Simple Past Tense

- To indicate an action completed in past. Generally adverbs and adverb phrase of time are used in the past simple tense.

  The result was declared last week.

- To express imaginary present situations or future events that may not happen.

  If I got rich I would travel all over the world.

- For past habits

  She used to work for ten hours a day.

6. Uses of Past Continuous Tense

- To denote an action going on at some point of time in the past. The time of action may or may not be indicated.

  It was getting dark.

  We were listening to the radio all evening.

- When a new action takes place in the middle of a longer action. In this case Past Simple and Past Continuous are used together. Past Simple is used for new action.

  Light went out while I was reading.

- For persisting habit of the past

  She was always reading during free time.

7. Uses of Past Perfect Tense

- When two actions happened in the past. In this case the action that takes place earlier is Past Perfect tense.

  When I reached the station the train had started.

8. Uses of Past Perfect Continuous Tense

- An action began at certain point of time in the past and was continuing at the given point of time in sentence. A time expression like *since last year, for last few months* etc are used.

  At that time he had been writing a novel for two months.

9. Uses of Simple Future Tense

- ❖ For an action that is still to take place.

  I shall do it tomorrow.

  Next month will be a busy period.

10. Uses of Future Continuous Tense

- ❖ To indicate the completion of an event by a certain future time.

  I shall have written my exercise by tomorrow evening.

11. Uses of Future Perfect Continuous Tense

- ❖ To refer to action in progress over a period of time that will end in the future.

  By next month I shall have been working here for 6 years.

Work sheet for practice

1. We always _____ (take) breakfast before seven.
2. Listen, someone _____(knock)at the door
3. He _____ (send) the email many days ago.
4. I think I _____(start) my trip tomorrow.
5. I _____(do) my home work few minutes back.
6. When I opened my eyes , I ____(see) a strange thing.
7. Every morning she _____ (wake) up early and _____(do) her work.
8. We _____ Mumbai next month.
9. I _____ (work) as Assistant Professor since 2013.
10. The actors _____ (rehearse) their dialogues now.
11. Every morning she _____ (get) up early and gets ready for work.
12. I ____ (complete)the assignment just now.
13. I _____(teach)English for ten years.
14. Look, the plane _____ (fly)in the sky
15. They ____ (go)their holidays in Paris last summer.
16. I _____ (finish)it by the end of this month.
17. Tom ____ (move) to his home town in 1994.
18. The head master ____(want) to talk to you
19. Look! The aero plane _____(fly) in the sky.
20. He _____ (join) the college in 2013
21. The library _____ (open) at 9 o'clock every day.
22. We _____ (visit) Kashmir in next the Summer vacation.

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE, WAGHAI

NAVSARI AGRICULTURAL UNIVERSITY

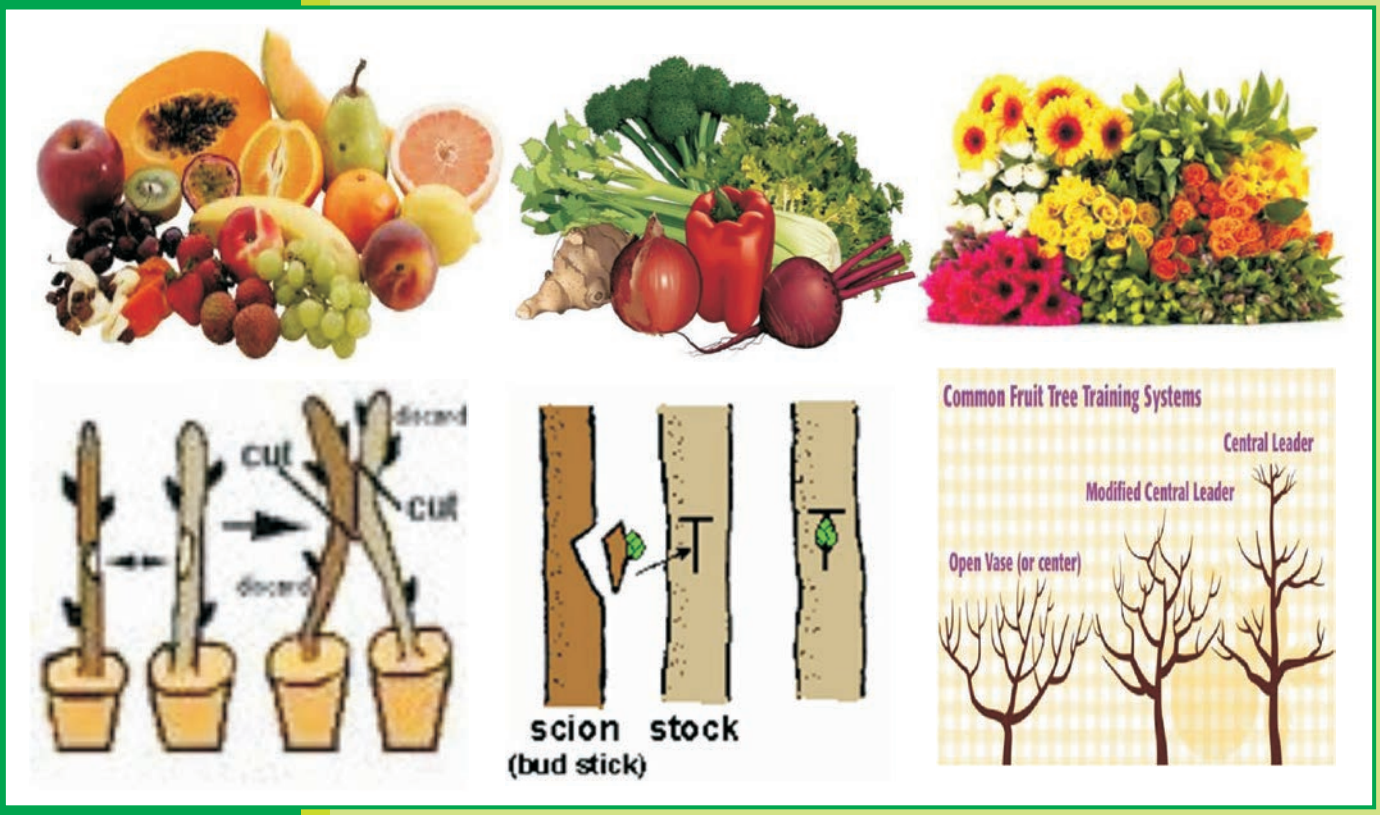
NAVSARI AGRICULTURAL UNIVERSITY

ICAR

PRACTICAL MANUAL

HORT. 1.1

Fundamentals of Horticulture (1+1)



Department of Horticulture
College of Agriculture
Navsari Agricultural University
Waghai-394 730 (Dangs), Gujarat

Prepared and Compiled By:
Dr. S.A. Aklade , Dr. B. Chakraborty
Dr. M. Sarkar, and Prof. H.A. Prajapati

Axe

Billhook

Budding and grafting knife

Chain Saw

Gardening Claws

Garden Fork

Garden *Khurpa*

Hedge Shear

Hedge Trimmer

Hoe

Pruning Shear

Rake

Saw

Secateurs

Sickles

Shovel

NAVSARI AGRICULTURAL UNIVERSITY

ICAR

PRACTICAL MANUAL

(As per 5th Dean)

Course No.	:	**Hort: 1.1**
Credits	:	**1+1**
Course Title	:	**Fundamentals of Horticulture**
Semester	:	**First**
Degree	:	**B.Sc (Hons.) Agri.**
College	:	**CoA, NAU, Waghai**
Department	:	**Horticulture**
Prepared & Compiled by	:	**Dr. S. A. Aklade**
		Dr. Binayak Chakraborty
		Dr. Mangaldeep Sarkar &
		Prof. H. A. Prajapati

Name of Student: _____

Registration No.: _____

Roll No.: _____

Dr. Z. P. Patel
Dean & Principal
M. 9624363999

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

Phone No. : 02631 - 246688
Fax No. : 02631 - 246622
Email : zprin@nau.in, caw@nau.in

FOREWORD

January, 2019

(Z. P. Patel)

CERTIFICATE

This is to be certified that Mr./Mrs _____ (Registration No.:_____/Roll No.: _____) studying in 1st Semester of B.Sc (Hons.) Agri. in College of Agriculture, Navsari Agriculture University, Waghai (Dangs) has satisfactorily carried out all the Practical Exercises in Course No. **Hort: 1.1;** Title: **Fundamentals of Horticulture** (1+1) during the year 20____.

Date: / /20____ **Place: Waghai**

Signature
Course Teacher

Signature
External Examiner

HoD (Horticulture)
CoA, NAU, Waghai

Principal
CoA, NAU, Waghai

INDEX

Reference Books:

- Singh, N.P. 2005. Basic Concepts of Fruit Science. International Book Distribution Company, Lucknow.
- Prasad, S. and Kumar, U. 2005. Principles of Horticulture. Agribios. Jodhpur.
- Singh, J. 2011. Basic Horticulture. Kalyani Publisher.
- Singh, J. 2016. Fundamental of Horticulture. Kalyani Publisher.
- Chadha, K.L. 2005. Handbook of Horticulture. ICAR Publication.

-----xxx-----

EXERCISE-01

IDENTIFICATION OF GARDEN TOOLS

Date: _____

Objective: To identify different garden tools and implements used in horticultural crop production.

Horticultural tools are made for gardening or orcharding. Many of them overlaps with the tools made for agricultural operations. The tools used for horticultural purpose can be operated either hand or power. Description and use of some popular horticultural tools are given below:

1. **Axe:** The axe is a simple hand tool, which consists of cutting edge and an eye for fixing of a handle.
   Use: Axe is multipurpose cutting tool used for felling and delimbing of trees, splitting of logs for fire wood and dressing of logs for timber conversion.

2. **Billhook:** Billhook is operated manually by hand. It consists of a curved blade in hook shape and a tang to which a wooden or plastic handle is attached.
   Uses: The billhook is used for lopping of branches and cutting of shrubs.

3. **Budding and grafting knife:** The budding and grafting knife is a multipurpose knife to accomplish both budding and grafting jobs. This is the most popular instruments for the gardener and nurserymen
   Uses: For budding and grafting in fruits, flowers and vegetables. The knife is also used for cutting of thin unwanted twigs, defoliation of leaves and general cutting works in nurseries and orchards.

4. **Chain saw:** This portable machine can be operated by one person driven through power. The cutting operation is carried out by an endless chain fitted with cutters, which runs around a flat piece called the bar.
   Use: For cutting limbs, branches etc.

5. **Gardening Claws:** This instrument generally consists of 3-5 claws attached in a wooden handle.
   Use: To loose soil and better aeration in the rhizosphere. It also helps to remove deep rooted weeds.

6. **Garden Fork:** A garden fork is a gardening implement, with a handle and several (usually four) short, sturdy tines. The garden fork has more lengthy handle than garden claws.
   Use: It is also used for loosening, lifting and turning over soil in gardens, orchards and nurseries.
7. **Garden *Khurpa*:** It is small had operated tool, consists of a sharp edge in a flat iron structure. The handle of *khurpa* is generally made of wood.

Use: it is very suitable for loosening the soil and weeding in between two rows of plants. Therefore, it is used extensively in nurseries.

8. **Hedge Shear:** It is manually operated hand tool for pruning, trimming and cutting of hedges and shrubs. The tool consists of two blades with tangs. The tangs are inserted in the wooden handle and protected by ferrule.
   Use: The hedge shear is used for pruning and trimming of hedge and giving it desired shape. It is also used for cutting of shrubs and removing of haphazard growth in gardens and lawns.

9. **Hedge Trimmer:** Hedge trimmer consists of a cutter bar having two sets of reciprocating blades. The teeth along the top blade are diamond round and double edged to stay sharp for long. It can cut even branches of up to 16 mm in diameter. The cutter bar is driven either by engine or motor.
   Use: Hedge trimmer is used for trimming hedges, shrubs and brambles. It is also used for contouring plants in desired shapes and sizes for enhancing the aesthetics of the garden.

10. **Hoe:** A hoe consists of a blade like structure, which is attached with a wooden handle almost at right angle.
    Use: Use to dig a pit, remove grasses from a hard surface. It can also be use to lift soil, FYM, crop residues etc.

11. **One/two hand pruning shear (lopper):** It is known also known as lopper. This instrument has long handles, which allow the blades to exert more cutting pressure on the stock.
    Use: Used extensively for cutting the thick branches, twigs (up to 60 mm) or bushes in standing position.

12. **Rake:** A rake is like a broom for outside use. It has a toothed bar fixed transversely to a long handle.
    Use: To collect leaves, hay, grass, etc., and, in gardening, for loosening the soil, light weeding and leveling, removing dead grass from lawns, and generally for purposes performed in agriculture by the harrow.

13. **Saw:** It is a tool consisting of hard blade hard blade, wire, or chain with a toothed edge.
    Use: In horticulture saw is generally applied to cut or split the big branches, stems or trunk.
14. **Secateurs:** Secateurs also known as pruning shears resembles a multipurpose combination pliers used in a workshop. Those branches which are not easy to cut with pruning knives can be cut by secateurs. Hence, it is considered to be an essential tool of the gardener in plant propagation.
    Use: For cutting unwanted branches or twigs of the orchard tree, vines, scion sticks, defoliation etc.

Axe

Billhook

Budding and grafting knife

Chain Saw

Gardening Claws

Garden Fork

Garden *Khurpa*

Hedge Shear

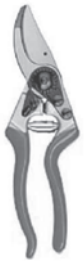
Hedge Trimmer

Hoe

Pruning Shear

Rake

Saw



Secateurs

Sickles

Shovel

15. **Sickles:** A sickle has a curved body operated manually by hand. It is considered as one of the oldest agricultural tool used by mankind.
    Use: To harvest the grain crops. To cut long grasses at bottom of the fruit trees.

16. **Shovels:** A shovel consists of flat plate like structure made of iron, which is attached with a long wooden handle in a typical angle**.**
    Use: it is used for digging, lifting, and moving bulk materials, such as soil, FYM, compost, fertilizers etc.

Lawn Mower

Root Trainer

Sprayer

Watering Can

17. **Lawn Mower:** Lawn mowers utilized a blade that rotates about a vertical axis are known as *rotary* mowers. Many designs have been made, each suited to a particular purpose. The smallest types can be operated by a human, are suitable for small residential lawns or gardens, while larger, self-contained, ride-on mowers are suitable for large lawns, and the largest, multi-gang mowers pulled behind a tractor, are designed for large expanses of grass such as golf courses and municipal parks.

18. **Root trainer:** A root trainer, root-training pot is used for growing young plants and trees in nurseries. There are many different designs of pots that will train the roots. One example is a truncated plastic cone in which a seedling is planted. There is a drainage hole at the bottom and the main tap root tends to grow towards this.

19. **Sprayer:** A sprayer has spray nozzles to apply herbicides, pesticides and water soluble fertilizers to agricultural/horticultural crops. A range of sprayer is available in market, which can be operated by hand or can be connected to a tractor or self-propelled units.

20. **Watering can:** A watering can (or watering pot) is a portable container, usually with a handle and a spout, used to water plants by hand. It is used for many other uses too, as it is a fairly versatile tool**.**

QUESTIONNAIRES

1. Describe briefly about uses of ten implements used in horticultural practices.
2. Write down the use of sprayer, water can in horticultural nurseries.

-----xxx-----

EXERCISE-02

IDENTIFICATION OF HORTICULTURAL CROPS

Objective: To identify major fruit, vegetable and flower crops. **Date:** _____

1. FRUIT CROPS:

Fruit: It is a developed or matured ovary with or without accessory parts and which is generally eaten as raw. The science which deals with the study of fruit crops is called as pomology.

SN	Crop (English Name)	Local Name	Botanical Name	Family	Important Varieties
1	Mango	Aam / Ambo	*Mangifera indica* L.	Anacardaceae	Alphanso, Kesar, Dasheri, Rajapuri, Langra, Totapuri, Neelum, Sardar, Amrapali, Mallaika, Chausa, Pairi, Ratna, Sindhu, Benganpalli. (Gujarat Hybrids: Neeleshan, Neeleshwari, Neelphanso, Son Pari), Amruntang.
2	Banana	Kela	*Musa paradisiaca* L.	Musaceae	Grand Naine, Dwarf Cavendish, Robusta, Basrai, Harichhal, Gross Michel, Lal kela, Safed Velchi, etc. (Poovan & Nendran for vegetable purpose).
3	Citrus Group:				
i	Sweet Orange	Mosambi	*Citrus sinensis*	Rutaceae	Mosambhi, Sathgudi, Blood Red Malta, etc.
ii	Mandarin	Santra	*Citrus reticuleta*	Rutaceae	Nagpur Santra, Kinnow, Coorg Mandarin, etc.
iii	Acid lime	Nimbu	*Citrus aurantifolia*	Rutaceae	Kagzi lime, Vikram, Pramalini, etc.
4	Sapota	Chikoo	*Manilkara achras* (Mill) Fosberg	Sapotaceae	Kallipatti, Cricket Ball, DHS-1 & 2, Kirtibarthi, Bhuripatti, Pilipatti, Dholka Diwani, Jhumakhia, CO-1 & 2, PKM-1.

5	Guava	Jamphal	*Psidium guajava* L.	Myrtaceae	Allahabad Safeda, Lucknow 49 (L-49)- Sardar, Arka Mridula, Chittidar, Apple colour (Red flesh), etc.
6	Papaya	Papaya	*Carica papaya* L.	Caricaceae	Pusa Delicious, Pusa Majesty, Pusa Dwarf, Pusa Gaint, Pusa Nanha, CO-1,2,3,4,5 & 6, Wasington, Coorg Honey Dew, Lady Taiwan-786.
7	Grapes	Draksa	*Vitis vinifera* L.	Vitaceae	Thompson Seedless, Beauty seedless, Bengalore Blue, Anab-E-Shahi, Sharad Seedless, Perlette. Hybrids: Arka Kanchan, Arka Shyam, Arka Hans.
8	Pineapple	Ananas	*Ananas comosus* Mirr.	Bromeliaceae	Kew, Giant Kew, Queen, Mauritious, Jaldhup and Lakhat.
9	Ber	Bor	*Zizyphus mauritiana*	Rhamnaceae	• Early ripening (Feb.): Gola, Seb, Safeda. • Mid season (I^{st}- III^{rd} week of March.): Kaithali, Reshmi. • Late ripening (IV^{th} week of March-mid April.): Umran, Kantha, Elaichi.
10	Custard apple	Sitaphal	*Annona squamosa* L.	Annonaceae	Sindhan, Mammoth, Balanagar, Red sitaphal, etc.
11	Pomegranate	Daadam	*Punica granatum.* L.	Punicaceae	Bhagwa (Sinduri), Ganesh, Dholka, Bhavnagari, Mridula, Muskat, Jallore Seedless, etc.
12	Jackfruit	Fanas	*Artocarpus heterophyllus*	Moraceae	Kathal, Kathali, Barmasi. Gulabi, Champa and Hazar.

13	Aonla	Amla	*Phyllanthus emblica* L.	Euphorbiaceae	Banarasi, Chakaiya, Francis, NA-4(Krishna), NA-5 (Kanchan), NA-6, NA-7 (Promising variety, NA-10, BSR-1 (Bhavanisagar), Gujarat Aonla-1.
14	Fig	Anjeer	*Ficus carica*	*Moraceae*	Poona Fig, Turkish Brown, Black Ischia, Bengalora
15	Phalsa	Phalsa	*Grewia asiatica* L.	Tiliaceae	Sharbati, Local.

Classification of fruit crops:

A. Based on nature of growth:

1. Herbaceous: Banana and Pineapple, etc.
2. Shrubaceous: Karonda, Phalsa, Pomegranate, etc.
3. Woody (Tree): Mango, Sapota, Ber, Guava, Jamun, Apple, etc.
4. Evergreen: Mango, Sapota, etc.
5. Deciduous: Apple, Plum, Peach, etc.

B. Based on climatic requirement:

1. Temperate Fruits: Apple, Pear, Peach, Apricot, Almond, Plum, Walnut, etc.
2. Sub-tropical fruits: Citrus, Grape, Guava, Pomegranate, Ber, Phalsa, etc.
3. Tropical fruits**:** Mango, Banana, Sapota, Papaya, Pineapple, Jackfruit, etc.

C. Based on botanical relationship

1. Monocot: Banana, Pineapple, etc.
2. Dicot: Mango, Sapota, Jamun, Custard apple, etc.

2. VEGETABLE CROPS:

The term vegetable is applied to the edible herbaceous plants or parts of plant which are commonly used for culinary purposes. The edible portion may be root, tuber, bulb, stem, petiole, leaf, flower or flower bud, seed and fruit.

Types of plant according to life-cycle:

(a) Annual: The plants which complete their life cycle in one season or within one year are known as annual plant. e.g. Brinjal, Tomato, Okra, Chilli, *etc*.

(b) Biennials: The plants which complete their life cycle in two seasons or two years are known as biennial plants e.g. Garlic, Onion *etc*.

(c) Perennials: The plants which complete their life cycle in more than two years are known as perennial plants. e.g. Elephant foot yam, Parwal, Arvi, Drumstick, Curry leaf etc.

Classification of vegetables according to the season of growth:

Vegetable crops can be divided in following groups:

(a) Cool or *rabi* or winter season vegetables: Cabbage, Cauliflower, Carrot, Onion, Lettuce, Beet, Coriander, Methi, Palak, Radish, Turnip, Garlic, Asparagus, Broccoli, Brussel's sprouts, Knol-khol, Amaranthus, Peas and Beans, Potato, Sweet potato and Celery.

(b) Hot season or summer season Vegetables: Tomato, Okra, Brinjal, Bitter gourd, Bottle gourd, Sponge gourd, Parwal, Little gourd, Cucumber, Cowpea, Cluster bean, French bean, Chillies, Cucurbits *etc*.

(c) Rainy or *Kharif* season Vegetables: Okra, Brinjal, Colocassia, Suran, Chillies, Amaranthus, Yam, Indian bean, Cucurbits except Watermelon and Muskmelon.

Identification:

(a) Monocotyledoneae -- One seed leaf.

Sr.No.	Family	Name of crop	Botanical name
i	Amaryllidaceae	Onion	*Allium cepa*
		Garlic	*Allium sativum*
ii	Araceae	Elephant foot (Suran)	*Amorphophallus paeoniifolius*
		Colocasia (Arvi)	*Colocasia esculenta*
iii	Dioscoreaceae	Yam	*Dioscorea alata*
iv	Lilliaceae	Asparagus	*Asparagus officinalis*
v	Poiaceae (Gramineae)	Sweet corn var. rugosa	*Zea mays*

(b) Dicotyledoneae: Two seed leaf.

Sr. No	Family	Name of crop	Botanical name
i)	Aizoaceae	New Zealand spinach	*Tetragonia expensa*
ii)	Chenopodiaceae	Beetroot	*Beta vulgaris var.bengalensis*
		Spinach (palak)	*Spinacia oleracea*
iii)	Asteraceae (Compositae)	Lettuce	*Lactuca sativa*
		Artichoke	*Cynara scolymus*
		Chicory	*Cichorium intybus*
iv)	Convolvulaceae	Sweet potato	*Ipomea batatas* Lam
v)	Brasicaceae (Cruciferae)	Cabbage	*Brassica oleracea* L. var. Capitata
		Cauliflower	*Brassica oleracea* L. var. botrytis
		Knolkhol	*Brassica oleracea* L. var.*caulorapa*
		Radish	*Raphanus sativum*
		Turnip	*Brassica oleracea* var. rapa L.
		Broccoli	*Brassica oleracea* L. var. italica
		Brussels sprouts	*Brassica oleracea* L. var. gemmifera
		Kale	*Brassica oleracea* L. var. acephala
vi)	Cucurbitaceae	Cucumber, khera	*Cucumis sativa*
		Bitter gourd	*Momordica charantia* L.
		Sponge gourds	*Luffa cylindrical* Roem.
		Pointed gourd (parwal)	*Trichosanthes dioica* (Roxb.)

		Bottle gourd	*Lagenaria siceraria* standl.
		Water melon	*Citrullus lanatus*
		Gherkin	*Cucumis anguria*
		Musk melon	*Cucumis melo*
		Summer squash	*Cucurbita pepo*
		Ridge gourd	*Luffa acutangula*
		Pumpkin	*Cucurbita moschata*
		Chow chow	*Sechium edule*
		Little gourd	*Coccinia indica*
		Tinda/Round melon	*Citrullus vulgaris*
vii)	Euphorbiaceae	Tapioca	*Manihot esculenta*
viii)	Leguminosae (Fabaceae)	Cluster bean	*Cyamopsis tetragonaloba*
		Cowpea	*Vigna unguiculata*
		Indian bean	*Dolichos lablab*
		Fenugreek	*Trigonella foenum graecum*
		French bean	*Phaseolus vulgaris*
		Asparagus bean	*Vigna sinensis var sesquipedalis*
		Pea	*Pisium sativum L.*
ix)	Malvaceae	Okra (Ladies finger)	*Abelmoschus esculentus Moench*
x)	Solanaceae	Tomato	*Lycopersicon esculentum* Mill
		Brinjal (egg plant)	*Solanum melon*gena L.
		Chillies /summer pepper	*Capsicum annuum*
		Hot pepper	*Capsicum frutescens*
		Potato.	*Solanum tuberosum* L.
xi)	Umbelliferae (Apiaceae)	Carrot	*Daucus carota* L.
		Celery	*Apium graveolens*
xii)	Polygonaceae	Rhubarb	*Rheum rhaponticum*
xii)	Moringaceae	Drumstick	*Moringa oleraceae*
xiii)	Amaranthaceae	Amaranthus	*Amaranth spp.*

(III) Classification based on part used as food: The vegetables could be grouped according to part of plant which is used as vegetable or eaten.

i)	Stem	Asparagus, potato, onion, garlic, artichoke, yam, turmeric.
ii)	Leaves	Methi, palak, coriander, arvi, amaranthus, cabbage, spinach, Lettuce, Leek.
iii)	Fruits	Tomato, Brinjal, okra, beans, watermelon, chillies. parwal, sponge gourd Bottle gourd, Snake gourd, Pointed gourd, Pea, Guar.
iv)	Flower part	Cauliflower, broccoli, globe –artichoke.
v)	Root	Radish, carrot, beetroot, turnip, sweet potato.

(VI) Based on method of raising:

This classification is only helpful to the farmers to certain extent as their cultural requirements with respect to propagation, more or less similar method of raising, and crops given bellow.

(a)	Direct sown crops	Okra, carrot, radish, beans, peas, etc.
(b)	Transplanted crops	Tomato,Brinjal, chillies, cabbage, cauliflower, onion, etc.
(C)	Planting vines & cuttings	Sweet potato, cassava, pointed gourd, etc.
(d)	Bits of tuber & corms	Potato, yams.
(e)	Planting of bulbs	Onion. Garlic.

3. FLOWER CROPS:

Flower: The reproductive structure of angiosperms consisting of stamens (male part) and pistillate (female parts) surrounded by petals and sepals is called as flower.

Classification:

I. According to their growing season the annuals may be classified in three groups:

An annual is a class of plants which attain their full growth from seed, flower and die in one year or one season. Mostly they complete their life cycle during 3 to 6 months.

1. Rainy season annuals:

These can stand before rain and flower during the rainy season. The sowing time for rainy season annuals is from April-June. E.g. Ageratum, amaranthus, balsam, cacalia, cleome, clleus, coreopsis, cosmos, gaillardia, gomphrena, kochia, love-lies-bleeding, petunia, portulaca, sunflower, marigold, zinnia, etc.

2. Cold or winter season annuals:

These thrive and bloom best during winter season. These are sown in Oct.-Nov. e.g. Acrolinium, ageratum, alyssum, amaranthus, anchusa, antirrhinum, arctosis, china aster, balasam, chrysanthemum, coleus, coreopsis, cornflower, cosmos,dahlia, dianthus, dimorphotheca, echium,, gypsophilla, helichrysum, kochia, linaria, linum, amaranthus, marigold, lupinous, nasturtium, pansy, petunia, phlox, poppy, portulaca, salvia, statice, stock, sweet pea, sweet sultan, verbena, wallflower and zinnia.

3. Hot weather or summer annuals:

These are required high temperature and long light period during March-May for blooming. They are sown in December to January. E.g. Cacalia, celosia, cleome, cockscomb, globe amaranthus (gomphrena), petunia, portulaca, sunflower, marigold, zinnia, etc.

II. Based on Growth Behavior:

1. Herbs: Phlox, Verbena, Candytuft, Petunia, Dianthus, etc.
2. Shrubs: Rose, Jasmine, Tecoma, Nyctanthes, etc.
3. Trees: *Delonix regia* (Gulmohar), *Cassia fistula* (Garmalo), *Saraca indica* (Ashoka), etc.

III. Based on Growing Condition:

1. Flowers suitable for protected cultivation: Rose, Chrysanthemum, Gerbera, Carnation, Anthurium, Orchid.
2. Flowers suitable for open field cultivation: Marigold, Jasmine, Gladiolus, Tuberose, Spider lily.

IV. Based on Utility:

1. Cut flower: Rose, Chrysanthemum, Gerbera, Carnation, *Anthurium*, Gladiolus, Tuberose.
2. Loose flower: Jasmine, Marigold, Spider lily, Crossandra.

Commercially important flower crops:

SN	Name	B.N	Family
1	Rose	*Rosa spp.*	Rosaceae
2	Gerbera	*Gerbera jamesonii*	Asteraceae
3	Chrysanthemum	*Chrysanthemum morifolium / Dendranthema grandiflora*	Asteraceae
4	Carnation	*Dianthus caryophyllus* L.	Caryophyllaceae
5	Orchid	*Cymbidium, Dendrobium, Phalaenopsis, Aerides, Cattleya, Paphiopedilum, Vanda, etc are the important genera.*	Orchidaceae
6	*Anthurium*	*Anthurium andreanum*	Araceae
7	*Heliconia*	*Heliconia spp*	*Heliconiaceae*
8	Bird of paradise	*Strelitzia reginae*	Strelitziaceae
9	Marigold	*Tagetes erecta & Tagetes patula*	Asteraceae
10	Gladiolus	*Gladiolus grandiflorus*	Iridaceae
11	Tuberose	*Polianthes tuberosa* L.	*Amaryllidaceae*
12	Jasmine	*Jasminum sambac (Mogra) Jasminum grandiflorum (Chameli) Jasminum auriculatum (Jooee)*	Oleaceae

13	Golden Rod	*Salidago canadensis*	Asteraceae
14	Spider lily	*Hymenocallis littoralis* L.	*Amaryllidaceae*
15	China aster	*Callistephus chinensis*	Asteraceae

------xxxxx------

EXERCISE-03

PREPARATION OF SEED BED / NURSERY BED, TRANSPLANTING AND CARE OF VEGETABLE SEEDLINGS

Date: _____

A. SEEDBED/ NURSERY BEDS:

Objective: To know the methods of raising healthy vegetables seedlings (Nursery management)

Raising of seedlings becomes important in a few vegetable crops in which direct sowing of seed results in poor growth and yield. The vegetable crops like tomato, Brinjal, chillies, cauliflower, cabbage, knol-khol, onion etc. respond well to transplanting because they are able to regenerate roots large in number within a short period after transplanting.

Advantages of raising vegetables seedlings:

1. It is easy and convenient to manage because requires less area for nursery.
2. Effectively and timely plant protection measures are taken at initial stage.
3. Seedlings can easily be provided with good conditions for their growth and development.
4. In unfavorable environment condition seeds are sown in nursery under protected structure like green houses.
5. Land can be used economically as more plants are raised on a piece of land for transplanting in a large area.
6. There is an economy in seed as most of the vegetable seeds are rather costly.
7. Early crops can be obtained in some vegetable by double transplanting of seedlings in nursery bed.

Points to be considered for raising seedlings

(a) Selection of site: As far as possible nursery bed should be selected in open place. The site which is known for incidence of pest and diseases should be avoided. The site should be nearer to irrigation facilities. Raised area should be preferred, so that there is no fear of water stagnation during rains.

(b) Selection of soil: Selection of soil for raising seedling is very important. As far as possible, soil should be sandy loam, or loamy soils. It should be well drained and rich in organic matter. Acidic and saline soils are not suitable for raising of nursery.

(c) Soil solarization: Nursery area burns by using dry grasses and dry leaves of 15 cm layer is called as rabbing. If rabbing is not possible, black thin plastic are used for solarization of soil in which black plastic are covered on nursery area for 10 to 20days. This practices help to destroy harmful fungi, insect eggs and pupa, worms and weed seeds by producing high heat.

(d) Soil preparation: The cross harrowing is done in order to make soil porous, well aerated and less compactness. FYM or compost should be incorporated during land preparation which improves physical conditions and also provides nutrients to growing plants.

(e) Selection of seed bed or nursery beds: Are discussed as below in this exercise.

(f) Selection of seed and seed treatment: Select true to type seeds, improved type, high germination percentage and free from insects, diseases and weed seeds. Seed treatment is Ggiven to prevent seeds from diseases and to enhance germination. Fungicide chemicals like Ceresan, Thirum, Captan, Agrosan are generally used @ 2-3 grams per kg of seeds.

(g) Sowing: Seeds are sown either by broadcasting or in rows in lines. Small seeds should be sown 1 to 1.5 cm deep. Light seeds (like Amaranthus) should be mixed with sand or wood ash to maintain seed rate and uniformity in sowing.

(h) Care after sowing:

(1) After sowing, nursery beds are covered with dry grasses or plastic for better germination. After sufficient germination, materials should remove.

(2) Watering is done at frequent interval. Uniform supply of water is desirable. Excessive watering should be avoided.

(3) Thinning, Weeding and Plant protection measures should be carried out as per need.

Types of Seedbed or Nursery beds:

(I) Raised nursery bed:

On well cultivated field, 3.6 meter long and 1.8 meter wide bed should be demarcated. Inside demarcated area, soil is drawn from the sides so that the level of bed is raised to 15-20 cm from the natural level of plot. The furrows 2-3 cm deep and 5-7 cm apart are opened, and seeds are sown. The depth of seed will be 5 to 10 mm and it should be covered with fine layer of soil and compost.

Advantages of raise bed:

i. It facilitates proper drainage, so it is highly suitable for high rainfall area.

ii. It prevents anaerobic condition and thus overcomes microbial rotting of seeds.

iii. Surface of bed remains soft therefore uprooting of seedlings becomes easy.

Disadvantages of raised bed: Preparation of raised nursery bed is more labouries and expensive also.

(II) Flat nursery bed:

During spring-summer, seedlings are raised in flat bed. It is more preferred in areas where less rainfall, well drained and leveled field. Finally, soil is dug 15-20 cm deep and all clods are broken with the help of *kudali* or spade. Irrigation channels runs in between two rows of the beds and each bed is connected with it.

Advantage of flat bed:

(i) Flat bed is easy to prepare (ii) Cost for preparation is less

Disadvantage of flat bed:

(i) More chances of excess irrigation water which is always harmful to the plants.

(ii) Soil become more compact, therefore uprooting of seedlings becomes difficult.

(III) Sunken nursery bed:

It is a soil bed set below the main level of the ground surrounding it. For areas in arid climates, sunken beds offer several advantages to raised beds and ground level beds. They are designed to capture maximum rainfall and retain moisture, so they dry out less quickly, keep roots cooler, and lessen the need for irrigation. Below grade walls also cast a small amount of shade, which gives garden plants a slight reprieve from scorching summer temperatures. They also provide adequate cooling for plant roots. Since water runs down hill, sunken gardens are created to "catch" available moisture as water runs down the edges and onto the plants below.

Raised Bed **Flat Bed** **Sunken Bed**

B. TRANSPLANTING AND CARE OF VEGETABLE SEEDLINGS:

Objective: To know transplanting of different vegetable crops in main field.

What is planting? Planting is raising of crop by using vegetative plant part e.g. tuber of potato, yam, elephant foot, bulbs of onion, cloves of garlic, vine cuttings of sweet potato, pointed gourd, little gourd etc.

What is transplanting? Transplanting is defined as a process in which seedlings, rooted cuttings of vegetable crops are planted from one place (nursery bed, pot and container) to another place, usually on permanent site where they grow where they produce flowers and fruits.

Why some vegetables require transplanting?

a. Vegetable crops viz. tomato, Brinjal, chillies, cabbage, cauliflower, onion, grow successfully when they are raised through transplanting of seedlings.
b. Those crops which can tolerate transplanting shocks very well.
c. They have to ability of forming secondary roots (feeding roots) in large number in short period after transplanting.

d. The period of crops are reduced in the main field.
e. Some vegetables seeds are smaller, lighter and costly.
f. Good care is taken at initial stage.

Benefits of transplanting:

1) There is an economic use of seed and land.
2) It is easy to raise seedlings on small scale.
3) Seedlings can be grown under controlled condition even during off season.
4) Uniform plant stand can be achieved due to availability of healthy transplants.
5) Higher yield of vegetables is obtained.

Selection of seedlings: At the time of selection of seedlings for transplanting following points should be kept in mind.

1) Seedlings should be stocky and sturdy.
2) Seedlings should have attained proper age at the time of transplanting.
3) They should have good root system.
4) They should be free from any insect, pest and diseases.

Precautions in transplanting:

a. The bed should be lightly irrigated before 24 hours of uprooting the seedlings for transplanting to avoid root injury.
b. Uprooting of seedling should be followed by transplanting, as far as possible transplanting should be performed in afternoon avoiding the period of high temperature.
c. At time of transplanting, presence of sufficient soil moisture is essential.
d. The depth of transplanting should be such that it could accommodate root system properly. There should not be any coiling of roots.
e. Seedlings should be planted in position and pressed gently around the base so that air-pockets are removed from root zone.
f. While transplanting, additional leaves and root may be trimmed from seedlings, if essential depending upon crop.
g. Wherever, it is essential, stalking of seedling may be done.
h. In case of onion, de-topping of seedling just before transplanting is beneficial in term of early establishment and higher survival percentage of seedlings. De-topping resulted in the reduction of total leaf area for transpiration. Besides, an individual seedling carries comparatively little load and that provides an additional support to seedling to remain in standing position.

Table: Time of sowing and transplanting, seedling age and seedling growth.

Name of crop	Time of nursery sowing	Time of transplanting	Seed rate per ha (gram)	Seedlings age (weeks)	Seedlings height
Tomato	1)Feb., March 2)October 3) Nov. 4) May-June	1) March-April 2) Nov., Dec. 3) Feb., March 4) June-July	500	4-6	15-20 cm height
Chillies	1) May -June 2) Nov.- Jan.	1) June-July 2) Jan.-March	750 -1000	4-6	15-20 cm height
Brinjal	1) June 2) Nov. 3) Oct. 4) April	1) July 2) Dec. 3) Nov. 4) May.	500 - 750	4-6	15-20 cm height
Cauliflower	1) May - June	1) June - July	500	4-5	10-15 cm and three pair of leaf
Cabbage	1) Sept.- Oct.	1) Oct. - Nov.	500	4-5	10-15 cm and three pair of leaf
Onion	1) Oct.- Nov.	1) Dec.-Jan.	8-10 kg.	7-8	Stalk of pencil thickness 3-4 complete leave

-----xxx-----

EXERCISE-04

PRACTICE OF SEXUAL AND ASEXUAL METHODS OF PROPAGATION

Date: _____

I. SEXUAL PROPAGATION :

Objective: To gain knowledge regarding seed propagation and also identify the fruit crops suitable for seed propagation.

Seed: A seed is a small embryonic plant enclosed in a covering called the seed coat, usually with some stored food. Seed in fruits forms after fusion of male and female germ cells or gametes. Characters of both parents are inherited by the seed. Therefore the new individuals formed in this way are not true-to-type i.e., they are not like parents and moreover they are unlike each other.

Parts of a Seed:

1. **Seed Coat/Testa**: The seed coat consists of one or more protective layers that cover the seed.
2. **Embryo:** An embryo is the young, minute/rudimentary multicellular plant structure that present in seed. Embryo has two parts:
   i. **Epicotyl:** Epicotyls is the portion of the embryonic stem above the point at which the stem is attached to the cotyledon(s).
   ii. **Hypocotyl:** Hypocotyl is the portion below the point of attachment. The hypocotyl is connected to the radicle.
3. **Endosperm:** The endosperm is a source of stored food, consisting primarily of starches.
4. **Cotyledon:** The cotyledon is described as a seed leaf that stores food in the form of starch and protein for use by the embryo. In some seeds cotyledon act as endosperm.

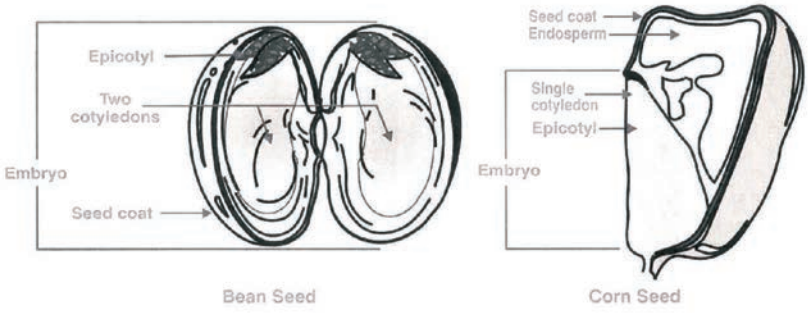
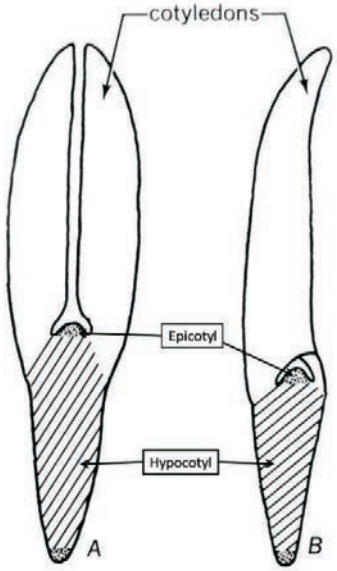


Fig. 1: Parts of Seed

Advantage of Seed Propagation:

1. Simple and cheaper
2. Long life plant of individual
3. Better root system
4. Resistant to insect and pest
5. Root stock for grafting are prepared

6. Hybrids are developed by the method

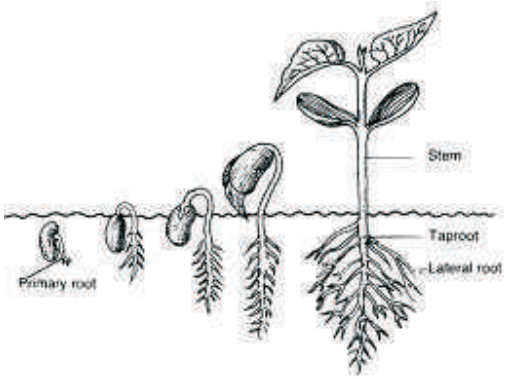


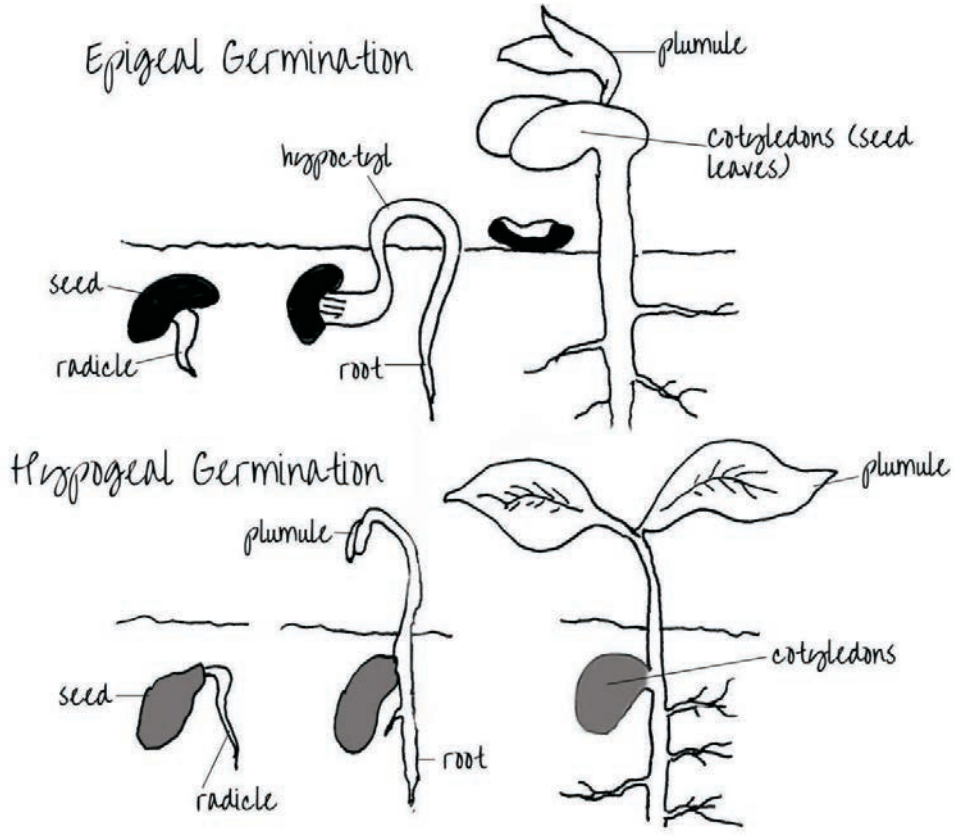
Terminology Related to Seed Propagation:

1. **Germination:** Germination incorporates those events that commence with the uptake of water by the quiescent dry seed and terminate with the elongation of the embryonic axis.
2. **Viability:** Capacity to germinate is known as viability
3. **Vitality:** The health and vigour of embryo is called as vitality
4. **Emergence:** Appearance of seedling above the soil surface is known as emergence
5. **Dormancy:** Seed dormancy is defined as the failure of an intact viable seed to complete germination under favorable conditions
6. **Hypogeal germination:** Seeds leave the cotyledons in the soil upon germination. Examples: *Pisum*, *Zea*.
7. **Epigeal germination:** Cotyledons are elevated above the soil upon germination. Examples: Phaseolus *Linum* and many other dicots.

Events during Seed Germination:

1. Absorption of water
2. Activation of enzymes
3. Degradation of complex starchy material
4. Translocation of food
5. Increase respiration and elongation of cell
6. Growth of radicle followed by plumule





Seed dormancy: The viable seed do not germinate even under favourable condition like moisture, air, temperature and light. Some seed have very hard seed coat which does not easily become soft.

Methods to overcome seed dormancy:

1. Mechanical Treatment: Breaking of seed coat (scarification)
2. Chemical Treatment: Thiourea, KNO_3, Gibberellic acid are used
3. Soaking of water: Seeds are soaked in water for a particular period to enhance germination
4. Stratification: Cold temperature treatment in seeds like apple, peach, pear etc.

Example: Papaya, Acid lime, winter and summer annuals and vegetables are propagated by seed.

II. ASEXUAL PROPAGATION :

Objective: To acquire knowledge regarding vegetative propagation and also identify the fruit crops suitable for the vegetative/asexual method of propagation.

Asexual Propagation:

This method involves the reproduction from vegetative parts of plant and possible because the vegetative organs of the plants have the capacity for regeneration. The different asexual methods of propagation followed in plant propagation are described below:

A. PROPAGATION BY SPECIALIZED PLANT STRUCTURES (BULB S):

1. **Corm:** A corm is a short, vertical, swollen underground modified stem that serves as a storage organ and usually covered with dry scaly leaves. It has nodes and internodes. eg. Suran (Elephant Foot Yam), Gladiolus, Crocus etc.

2. **Bulb:** Bulb is a swollen underground modified stem (flattened) which is enclosed with fleshy scale leaves. eg. Tuberose, Spider Lily etc.

3. **Rhizome:** Rhizome is a modified subterranean stem of a plant that usually found underground and grows horizontally. The vertical shoots and roots arise from the node of rhizome. eg. Ginger, Turmeric, Canna etc.

4. **Suckers:** A shoot arising on an old stem of underground part of the stem or horizontal root systems is known as suckers. These shoots separated from the mother plant with root system intact during propagation. Eg. Banana, Pineapple etc.

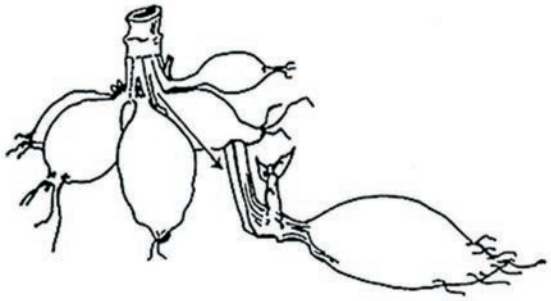
5. **Offset**: An offset is characterized type of a lateral shoot or branch that develop from the base of the main stem. Offsets are removed by cuffing them close to main stem with a sharp knife. Eg. Pineapple, Date Palm etc.

6. **Runner:** A shoot that bends to the ground or that grows horizontally above the ground and produces roots and shoots at the nodes. eg. Strawberry.

7. **Stolon:** A stolon is a fairly thick branch originating from base of the stem just below the soil surface. The stolon grows obliquely upward (arches) above the ground to some extent and then bends down to the ground. Root arises at contact with soil and produces bud which develops daughter plants. eg. Wild strawberry.

8. **Tuberous Root:** Tuberous root are fleshy modified roots acting as a storage organ, bearing growing point on the crown or stem end without nodes and internodes. Care should be taken while separating the tuberous root from mother plant so that each carries at least a small portion of the stem as well as a new growing point from the point of attachment with the stem. eg. Dahlia.

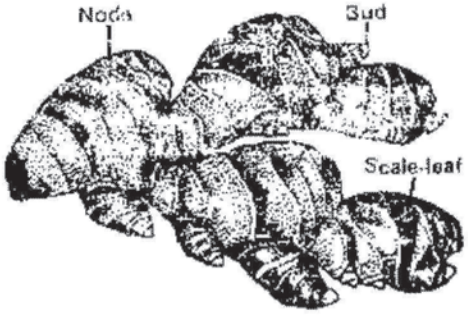
9. **Tuber:** A tuber is a fleshy underground modified stem, containing food reserves and functions as an organ for vegetative propagation. A tuber consists of all parts of the stem i.e., nodes, internodes, lateral and terminal bud. The eyes in the tuber representing nodes. Each eye consists of one or more buds surrounded by leaf scar. Tubers can be planted as a whole part of cut pieces. During cutting the cut portion should bear at least one eye. eg. Potato.



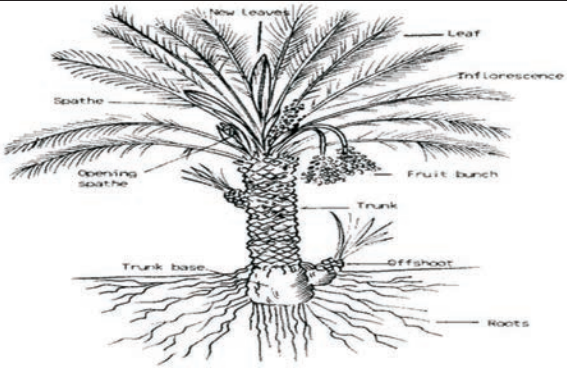
Tuberous Root (eg. Dahlia)

Runners (eg. Strawberry)

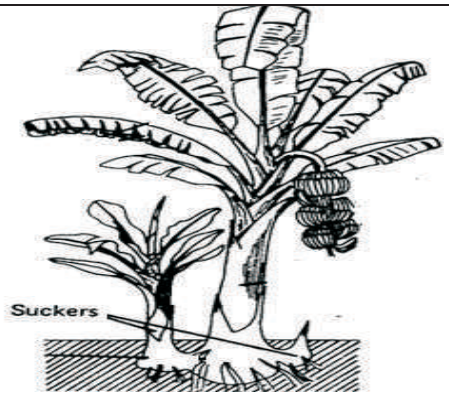
Corms & cormels (eg. Gladiolus)



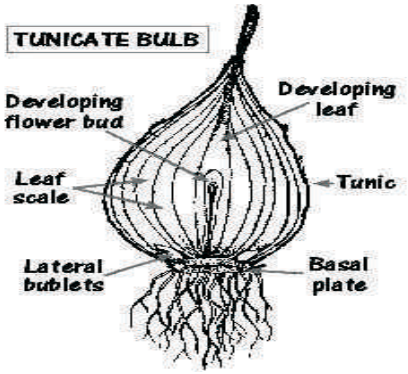
Rhizome (eg. Turmeric)



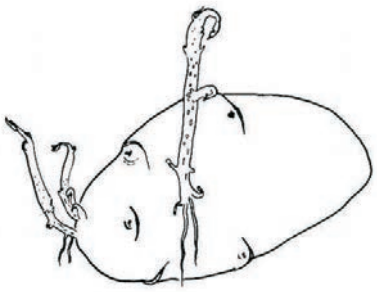
Offsets (eg. Datepalm)



Sukers (eg. Banana)



Bulb (eg. Onion)



Tuber (eg. Potato)

Stolen (eg. Strawberry)

B. CUTTINGS: Cutting can be different types. These are as follows:

1. **Stem Cutting:** Based on hardness of the selected stem cutting this method is divided in following categories
    a) **Soft wood/Herbaceous cutting:** *Duranta*, *Iresine*, *Alternanthera* etc.
    b) **Semi-hard wood cutting:** Croton and Poinsettia etc.
    c) **Hardwood cutting:** Grape

2. **Root cutting:** Root cuttings of woody plants are usually taken from plants during the dormant season, when carbohydrate levels are high. eg. Raspberry, Blackberry and Fig (injir), Curry leaf etc.

3. **Leaf Cutting:** Some plants can be propagated from just a leaf or a section of a leaf. Leaf cuttings of most plants will not generate a new plant; they usually produce only a few roots or just decay. eg. *Bryophyllum*, Snake Plant (*Sansevieria*) etc.

#. Procedure followed during hard wood stem cuttings:

1. **Selection of Stem:** A mature woody stem about 1.0-2.0 cm in diameter can be considered as ideal. The stem portion should contain some woody portion. In deciduous fruit trees cutting should be prepared during dormant period (i.e., December-Januray), while for sweet lime stem should be selected during February-March or rainy season.
2. **Preparation of cutting:** The stem should be cut at a length of 20-25 cm and contain at least 3-4 dormant buds. A horizontal cut should be given in upper portion of the stem whereas; at lower portion a slanting cut is given. The apical 2.00 cm portion is discarded to maintain the polarity of the shoot. Cuttings thus prepared should be bundled and put for 25-30 min. in growth regulator solutions (like IBA, NAA etc.) to enhance rooting. Growth regulators can also be pasted as lanolin paste form at bottom of the cut portion.
3. **Planting of treated cuttings:** Cuttings should be planted in growing media as soon as after treatment with growth regulators. Insert at least ⅓ portion of its length in the soil at 45° angle.

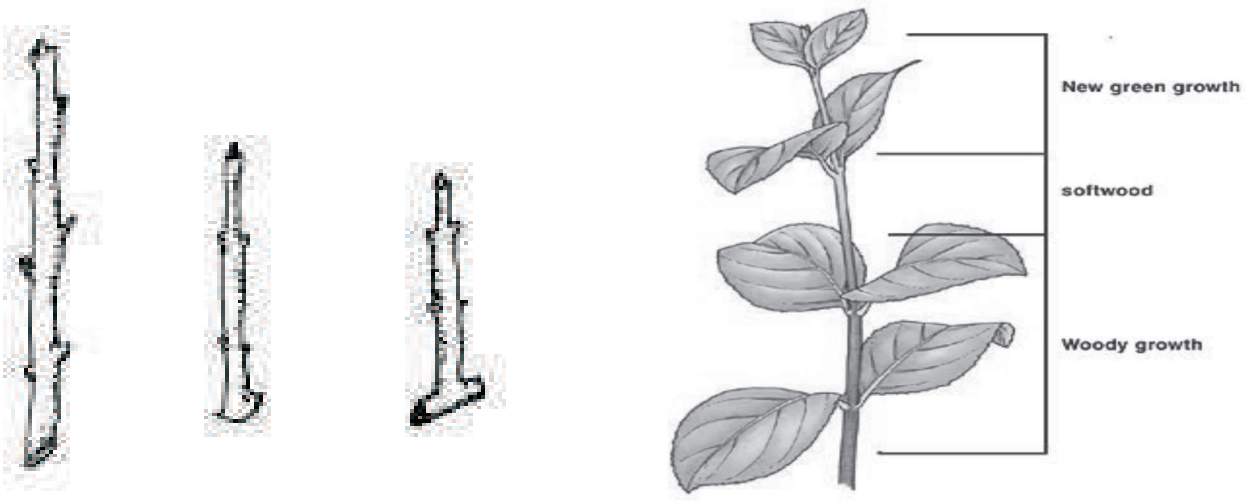
#. Procedure followed during root cuttings:

1. **Selection of Root:** Select roots of more than one cm in diameter, which are healthy and matured.
2. **Preparation of root cuttings:** Prepare cutting of length about 8-15 cm. Give a slant cut towards distal end, to identify the polarity.
3. **Planting of cuttings:** Plant the cuttings either vertically or horizontally. During vertical planting the end near the crown of the parent plant should be upper most.

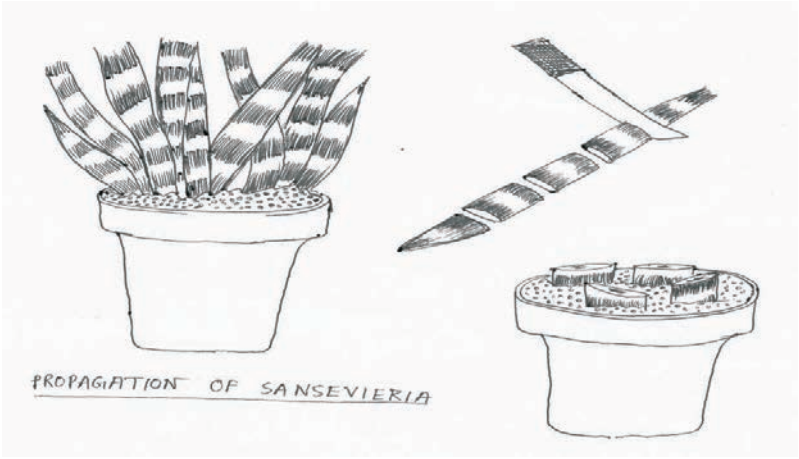
#. Procedure followed during leaf cutting:

1. **Selection of Leaf:** A mature leaf should be selected for leaf cutting. At first the leaf has to be removed from the mother plant.

2. **Preparation of leaf cuttings:** Give a slanting cut at base of towards the base of the cutting. Measure a length about 7-10 cm and give a horizontal cut towards terminal end.
3. **Planting of leaf cuttings:** Insert leaf cutting up to ¾th of its length in the soil. Press the soil all round the leaf and watered the cutting immediately after planting.



Stem Cuttings



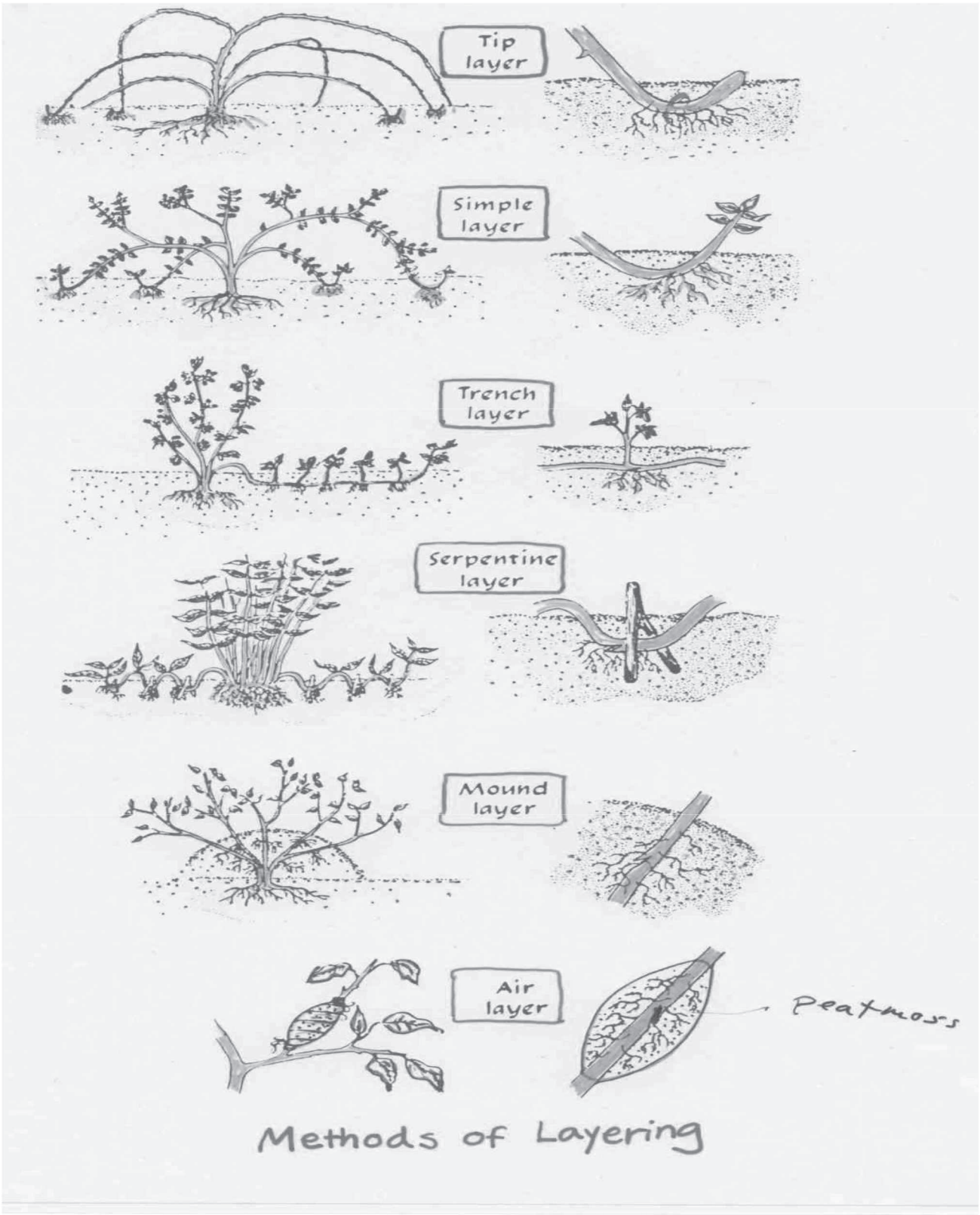
Leaf Cutting

C. LAYERING:

1. Simple or Ground Layering:

- Bend the cane tip down to ground level.
- Remove a ring of bark or make a notch only at 20 to 25 cm away from the growing tip.
- Notch is prepared in a length of 2 to 5 cm and below node half way through the thickness, and facing toward the trunk.
- Remove the ground soil up to 7.5 - 10 cm depth.
- Burry the injured cane portion in the soil and cover.
- If necessary put a piece of stone to hold the cane in its position.
- Give a bamboo support for keeping the growing shoot vertical.

- Keep the soil wet where cane is buried for developing the roots.
- The roots will develop within 4 to 6 weeks.
- Separate the layered branch by giving two cuts at the interval of about a week at the crown side of the branch.



2. Compound layering:

- This method is same as the simple layering but the long branch is buried at more than one places. Thus we can get more plants from a single branch.
- Select a lengthy branch, which is near to the ground level.
- At a point 15 to 20 cm back from the tip of the branch prepare a notch.
- Leave 2-3 buds and prepare second notch. Repeat the same as many times as possible depending upon the length of the branch and its flexibility.
- Covers the treated areas under soil exposing the tip of the shoot and the buds left in between the two treatments and keep weight on covered heaps of soil.
- Watered the buried portion regularly.

3. Stooling or Mound Layering:

- Select a plant to be mound layered.
- Head back the plant to the height of 20-25 cm from the ground level in dormant season. Allow the new shoots to develop.
- When these shoots have grown 7-15 cm, draw up the loose soil around each to half of its height.
- When the shoots have grown to 20-24 cm add soil again, to half of the height of the shoots.
- Add soil again when the shoots have grown to a height of about 35-45cm.
- Water the heaped soil regularly and allow sufficient time for the initiation of roots. A depression can be made in the centre of the heap to hold water.
- Carefully remove the soil regularly and separate the new plants.

e.g., Guava and Apple.

4. Trench Layering:

- One year of plant is planted slantingly at an angle of 30^0 to 45^0 at a distance of 90 to 120 cm apart in the ground.
- After establishment, these parent layers are bent over and laid flat on the bottom of a trench dug along the row about 5 cm deep.
- When buds start to swell, a layer of 2-5 cm soil is placed on the branch.
- As the shoots grow, more soil is added until they are covered to depth of about 12 to 15 cm. Shoots are etiolated and form roots.

e.g. Plum Apple and Guava.

5. Air Layering:

The rooting media will be tied to the shoot for achieving root initiation. Best rooting medium for air layering is Sphagnum moss as it holds large amount of moisture so as to apply moisture to the layered shoot for a longer period and proper root initiation.

- Select 1 or 2 years old branch of pencil thickness.
- Would the branch by girdling just below a node (about 25-35 cm) away from the growing tip.

- Remove the bark completely from the girdled area (about 25-35 cm). Scrap the exposed surface lightly to remove any trace phloem of cambium left over.
- Place a handful of the moist sphagnum moss around the wounded area.
- Wrap carefully with a piece of a polythene film of 20-25 cm in each side to cover the sphagnum moss completely.
- Tie both the ends firmly
- Roots will be visible after three weeks through the plastic film at this time these layers can be detached from the parent and planted in nursery.

¾ eg. Litchi, Guava, Pomegranate, *Ficus benjamina*, croton etc.

D. GRAFTING:

The term grafting includes all form of grafting and budding. It is the art of joining the parts of two plants together in such a way that they will unite and continue their growth as single plant. A grafted plant consists of two entities, rootstock and the scion.

Rootstocks:

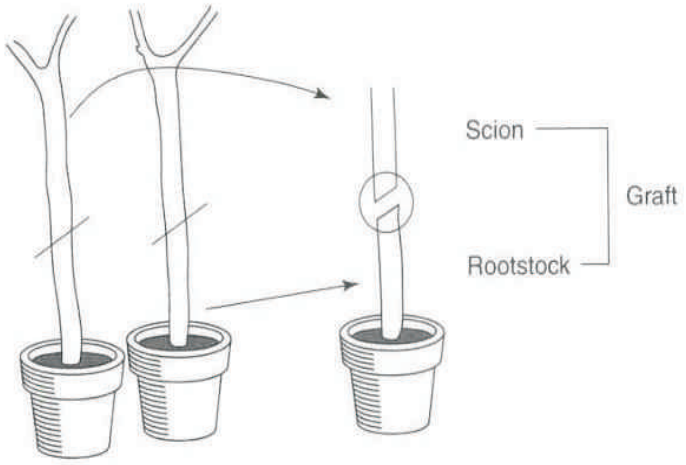
Also known as under stock or stock. The part of the graft combination which form the lower portion or roots and performs the function of fixing itself in the soil, absorbs moisture and nutrient from the soil is known as rootstock.

Scion:

The part of the graft combination which is to become the upper portion of top and performs the function of production of flowers and fruits of better quality is known as scion. Scion is to be from mother plants.

Grafting: When the scion part of a branch containing more than one bud, the operation is termed as grafting, when is tied with root-stock. The budding and grafting are possible between varieties in a species or between the species of a genus and sometimes between different genera of the family. Better results are expected when the root stock and scion are of equal thickness and are of one to two years of age. The best time for grafting and budding is spring for ever green plants. Whereas for deciduous plant the period when they are dormant.

Budding: When the scion part of a small piece of bark containing only bud and the operation is termed budding, when this bud is inserting on root-stock.



Different Methods of Grafting:

1. Simple approach grafting:

- Select one year old root stock plant.
- Place the stock plant to the side of the mother plant (Scion plant) and select scion branch of same thickness.
- Place the scion branch running parallel to the stock plant.
- Mark out an area of 3.75 to 5 cm in length where stock and scion pieces meet together easily.
- Slice out the bark and wood about 5 to 7.5 cm long and less than 1/3 of the diameter in depth with grafting knife from both stock and scion. The cuts should be perfectly smooth and as nearly flat as possible so that when they are pressed together there is close contact of the cambium layers.
- Bring together two cut surfaces as soon as possible.
- Tie the cut surfaces together with plastic tape or flat tape of banana leaf sheath (Spout) and then with a jute string (Sutali) in such a manner that no space is left in between them.
- Apply water to the root stock pot daily for 2-3 months during which period union must take place. The scion branches are detached from below the graft union from the mother tree gradually. First cut is made up to the half the thickness. There after another fortnight the scion is completely detached from the mother tree.
- The graft is kept in shady place.
- The original top of the stock plant above the graft joint is headed back after transplanting.
- e.g. Mango and Sapota.

2. Veneer grafting:

- On the stock plant at the desirable height preferably on inter nodal region a shallow downward and inward cut running to a length of about 2.5 to 6.0 cm to be made.

- At the base of the first cut, another short inward and downward cut is given. This cut should intersect the first cut.
- Now the piece of wood and bark is removed.
- On the scion, towards the bottom a long cut to length of about 2.5 to 6.0 cm is given along one side.
- At the base of the scion on the opposite side, a very short cut is given.
- e.g. Mango.
- The cut given on the scion should be of the same length and width as the cut given on the stock as to get close contact of the cambium layers.
- The scion is now inserted on the stock, taking care to see that good contact of cambium layers is established.
- The graft union is than tied with any tying material.
- All the cut surfaces should be covered with grafting wax.

3. Soft wood (Wedge grafting):

Mango approach grafts purchased from nurseries do not established successfully in the fields in semiarid regions like middle north Gujarat and Saurashtra due to tap root is cut out at time of potting of root stock. The soft wood wedge grafting is a new technique developed at Anand Campus and it is useful in overcoming this difficulty.

a. Raising of root-stock:

Pits of 90 x 90 x 90 cm are prepared in summer at a site where the grafted mango are desired to grow and allowed to expose to sunlight for a few days. The pits should be filled with the mixture of soil and manures (50 kg. FYM) leaving about 30 cm and upper portion unfilled. Then their remaining top portion of the pit should be filled up with alternate layer of dry leaves and soil each 5 cm. Then 3 large sized heavy in weight stones of country mango should be placed in the triangular manner and covered with 5 cm layer of soil. The mango stones will germinate on account of rain. Eight to ten months old mango seedlings having bronzes colored leaves can be used as a root-stock, during Feb. to Sep.

b. Preparing the scion:

Terminal branches of more than 3 months old and pencil thickness having swollen bud are selected on the desired mother tree of mango. The selected scion branches are defoliated before 10 days of actual grafting time, but remain slight petiole. When petioles are fall down after 8-10 days at that day bud sticks are separate from mother tree, for grafting.

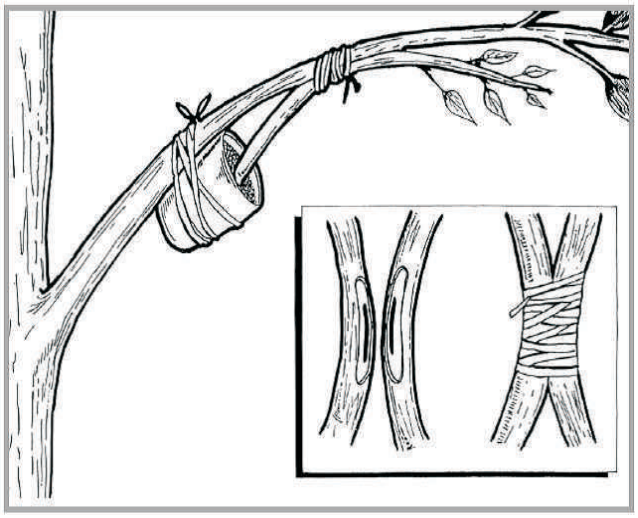
c. Procedure for grafting:

- Prepare a wedge (3 cm.) at the bottom of the scion branch retain some bark on both sides of the wedge.
- Cut off the top portion of bronze coloured shoot of root stock retains about-8 cm. length on developing shoot.

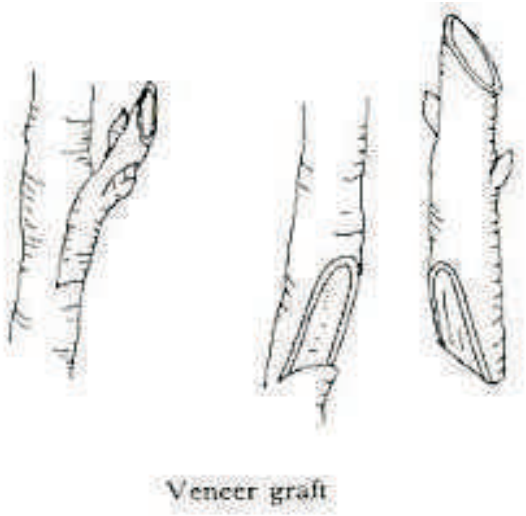
- Fit the wedge in this shoot after splitting the shoot (3 cm.) vertically from the top.
- Tie the graft with a polythene tape.
- Remove new growth arising on root stock below the union.
- Remove polythene tape after 4 to 6 weeks.
- Keep best one graft after proper established.

Other methods of grafting:

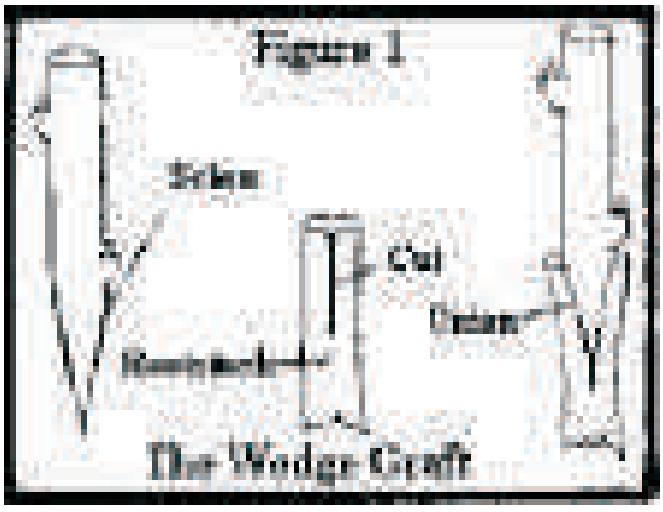
1. Tongue grafting
2. Saddle grafting
3. Whip grafting
4. Wedge grafting
5. Side grafting
6. Cleft grafting
7. Whip grafting
8. Epicotyls grafting
9. Bridge grafting.



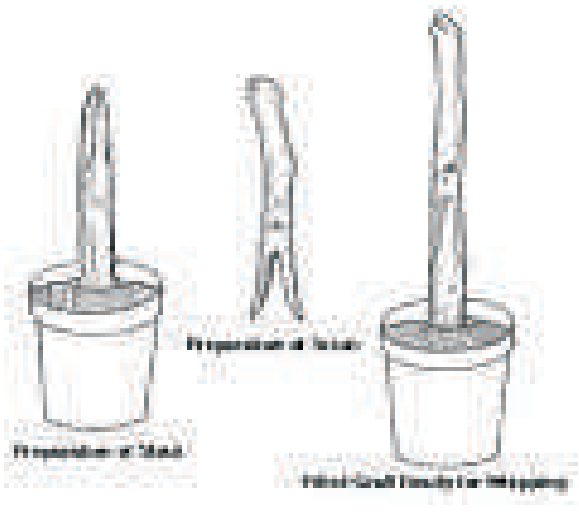
Simple Approach Grafting



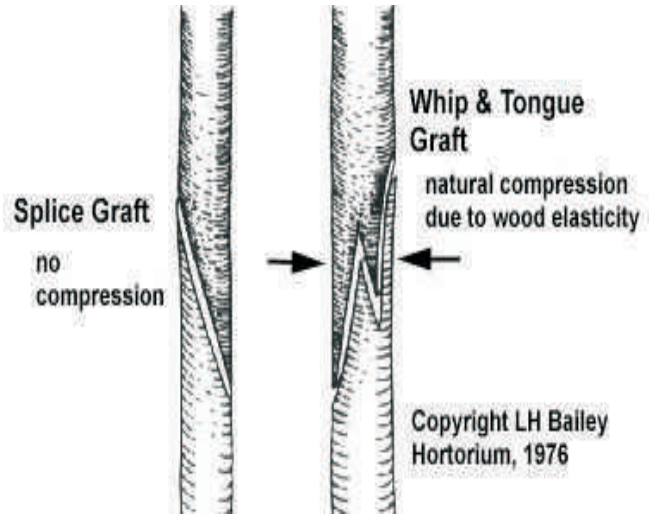
Veneer Grafting



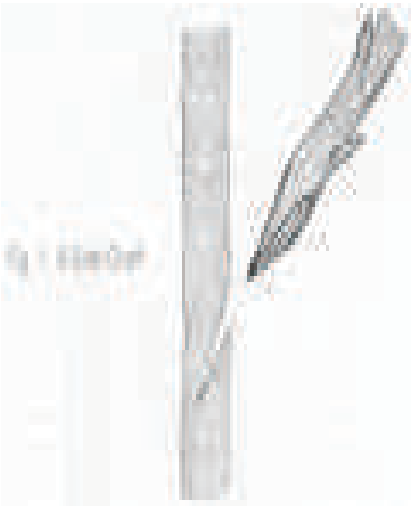
Wedge Grafting (Smillar- Softwood grafting)



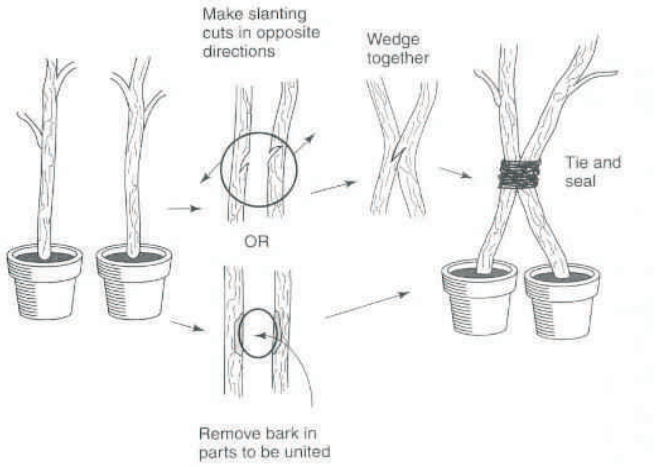
Saddle Grafting



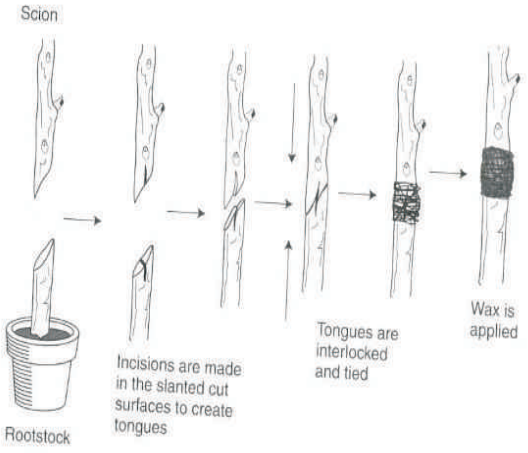
Splice or Whip Grafting



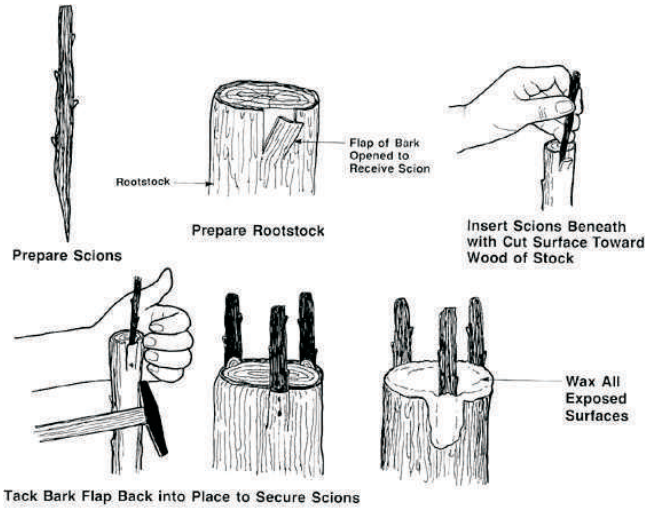
Side Grafting



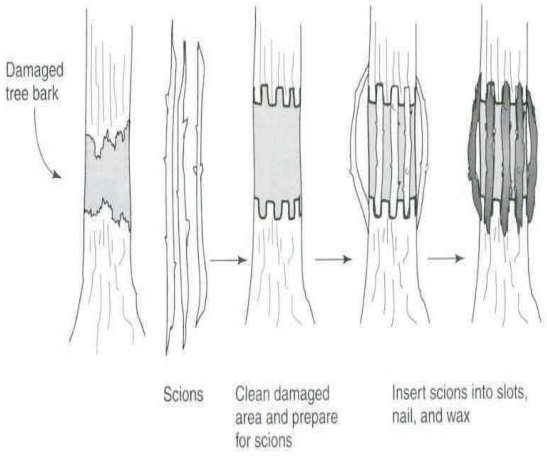
Tongue Approach Grafting



Tongue Grafting



Cleft Grafting



Bridge Grafting

E. BUDDING:

The union of two separate buds is called budding. Budding is also a method of old grafting where in only a single bud with a piece of bark is used as the scion material. The plant that grows after successful union of the stock and bud is known as budding. A budding is the critically a method similar to grafting, it is also known as bud grafting and will have all the advantages of grafting.

1. Shield budding or T budding:

This method is known as T budding as the cuts given on the stock are of the shape of the letter T, and shield budding as the bud prepared will look like a shield or patch. This method is widely used for propagating fruit trees and many ornamental plants. The stock plant should be about 0.75 to 1.5 cm in diameter and the bark should be slipping very easily.

Operations on the stock:

- Select healthy, uniform stock plant of about lead pencil thickness.
- Remove the thorns and side branches up to a height of 20-25 cm from the ground level and select the spot in between two internodes which is smooth.
- With the help of a sharp knife, make a horizontal cut of about 1.25 to 1.8 cm length, deep enough to cut bark only.
- Starting from the centre of the horizontal cut make vertical of about 2.5 to 3.75 cm long making the shape 'T'
- Open the flaps with help of knife blade or back of the budding knife.

Operation on the scion:

- Slice out the bud with petiole from the bud stick of about 2.5 to 3. 75 cm long with consideration that bud lies in the centre in shield shape.
- Hold the bud in such a manner that the eye of the bud is facing upward.
- Push down the bud into the 'T' shaped cut on the stock. Continuous pushing of the bud till the entire bud is covered by vertical cut on the stock and eye lies almost in the centre.
- Tie the bud firmly with polythene strips. While tying, care is to be taken that a space of about 0.6 cm about the leaf petiole is left for the growth of bud.
- Care should be taken that very little time is elapsed between opening and inserting of bud.

2. Inverted 'T' budding:

This method is directly opposite to that of 'T' method. In 'T' method, there is every possibility of water drops running on the stem getting in to the cuts and spoiling the bud inside. In case of inverted T shape budding, the horizontal cut will be at the bottom of its vertical cut as such the fraps of bark will be covering the bud. So any drops of water running on the stem will just slip on the bark flaps and there are no chances of water entering in to the cut portion. Operation on the scion and tying procedure is same as described above except that the shield piece containing bud is inserted in to the vertical cut from the lower part of the cut. The bud is pushed upward till the entire cut is covered. e.g. Lime.

3.'I' budding:

In case of 'I' budding only vertical cut is given on the rootstock. Operation on the scion and tying procedure is same as described in shield budding. This method is difficult because of only 'I' cut made on rootstock, so insertion of bud is difficult.

4. Patch budding:

In this method, a rectangular patch of bark is completely removed from the stock plant replaced with a patch of bark of the same size containing a bud. For this method the bark of stock and the bud stock should be easily slipping. The diameter of the stock and bud stick should be same preferably, may be about 1.0 and 2.5 cm.

Operation on the stock:

- Select root stock 1 to 1/2 years old of about a lead pencil thickness.
- About 15 to 20 cm above the surface soil, make two horizontal cuts of 1.25 to 1.8 cm length on the root stock deep enough to cut the bark only and about 2.5 to 3.75 cm apart from each other, with the help of a knife.
- Join these parallel cuts by two vertical cuts. Thus a rectangular patch of bark mode above is removed from the stock plants.

Operation on the scion and tying:

- From the selected scion branch, remove a rectangular piece of bark containing on eye (bud) of same size as of the patch removed from the stock.
- Place the scion patch of bark on the stock and see that all the four sides of scion patch are in close contact with stock plant.
- Tie the bud with polythene strip leaving room 0.62 cm for the bud.

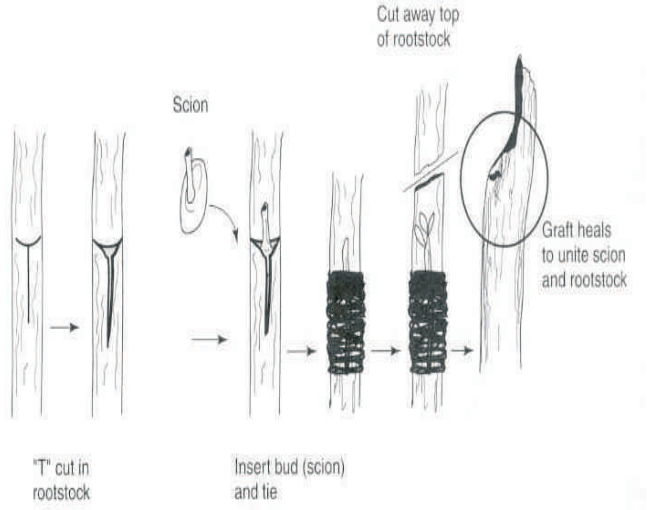
5. Ring budding:

Operation on the stock:

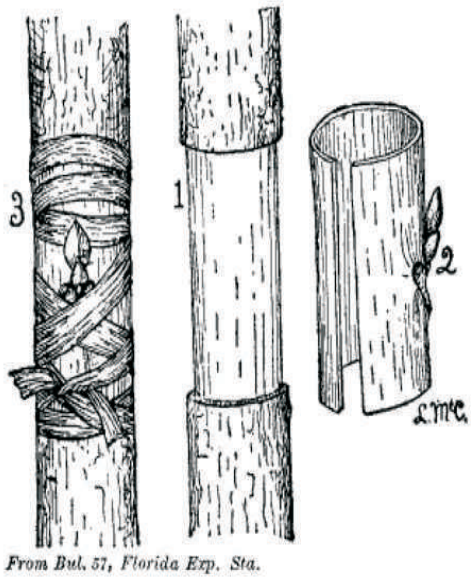
- Select healthy stock plants of one or one and half year old and about a lead pencil thickness.
- Head back the plants at a height of 10 to 15 cm from soil surface.
- Remove a ring of bark 4 to 6 cm in width from the top of the stock. e.g. Ber.

Operations on the scion:

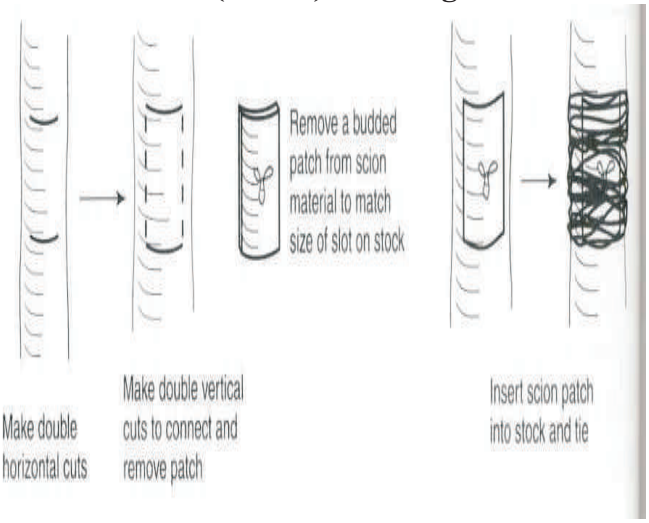
- Select scion branches of the same thickness as of root stock.
- Remove the leaves keeping the petiole intact.
- Make two circular cuts one above and one below the bud and join both the circular cuts with a vertical cut on the opposite side of the bud and remove bud ring of same size.
- Now, slip the scion ring down over the bark less stock, till it reaches the bark.
- If the ring does not fit tightly more bark from the stock is removed and ring lowered.
- Tie the bud firmly leaving enough space for the sprouting of bud.



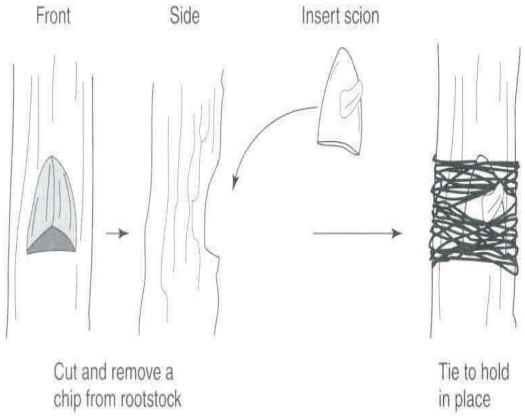
T (Shield) Budding



Ring Budding



Patch Budding



Chip Budding

-----xxx-----

EXERCISE-05

LAYOUT AND PLANTING OF ORCHARD PLANTS

Date: _____

Objective: To make out orchard layout and familiar with different planting systems of fruit trees.

Establishment of Orchard Layout:

Proper layout is necessary to establish a fruit orchard. The system of layout and distance of planting is decided according to canopy volume of the fruit trees. Laying out an orchard on level land has to be started by forming a straight baseline, usually next to a fence or roadway. Then, lines at right angles to the baseline established at both ends of the plot and one or two places in the middle. An easy way to establish these angles is to use three ropes whose lengths are in 3:4:5 proportions. Put 4 m rope along the baseline, then place 3 m rope at approximately a right angle, and finally, close the triangle with the 5 m rope (Fig. 4.1).

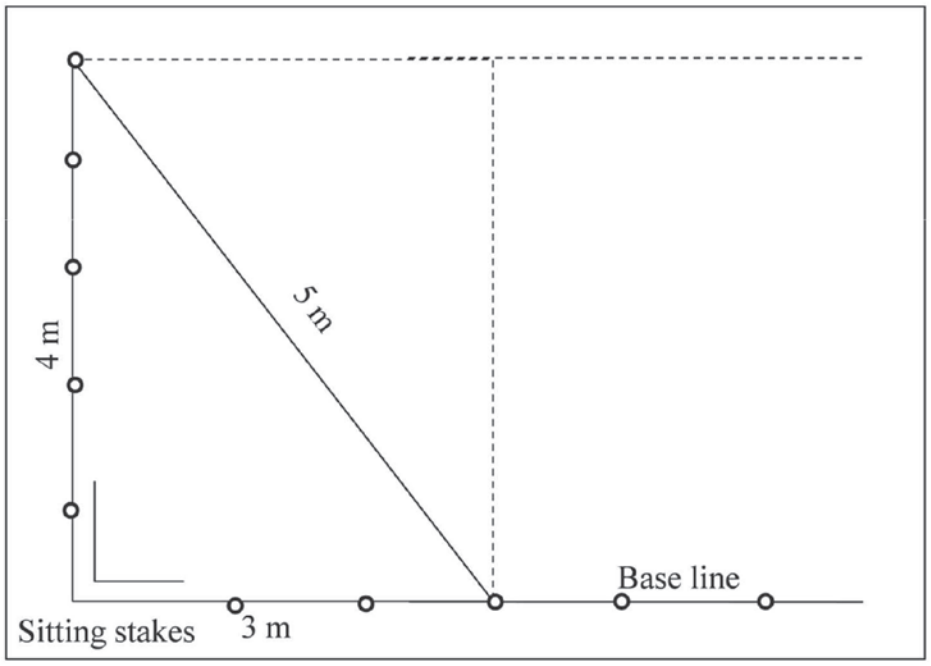


Fig. 4.1: Orchard layout based on triangle

Adjust the 3 m segment in either direction so that it just touches the end of the 5 m piece. Ensure that the 3 m section is at a right angle to the baseline. Next, place stakes along the baseline and the right angle line for sighting to extend these lines. From this point on, any desired row and tree spacing can be established using a tape measure or knotted rope to measure at the proper intervals. When boundary lines are drawn, it becomes easy to divide the whole orchard area into squares or rectangles with the help of measuring tapes and pegs.

The benefits of proper layout are:

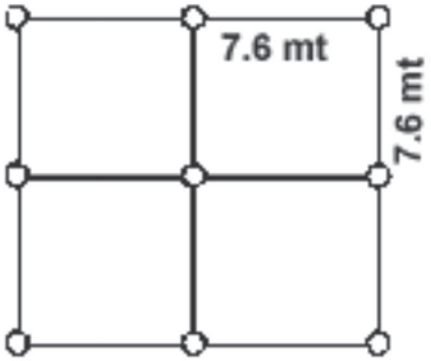
1. Orchard operations like interculturing and irrigation are carried out easily.
2. It enables equal distribution of area under each tree.
3. It results in least wastage of land.
4. It makes supervision more easy and effective.
5. There is room for systematic extension of the orchard

Any method of layout should aim at providing maximum number of trees per hectare, adequate space for proper development of the trees and ensuring convenience in orchard cultural practices. The system of layout can be grouped under two broad categories viz. (a) vertical row planting pattern and (b) alternate row planting pattern. In the former planting pattern (e.g. square system, rectangular system), the trees set in a row is exactly perpendicular to those. Trees set in their adjacent rows. In the latter planting pattern (i.e. Hexagonal, Quincunx and Triangular), the trees in the adjacent rows are not exactly vertical instead the trees in the even rows are midway between those in the odd rows.

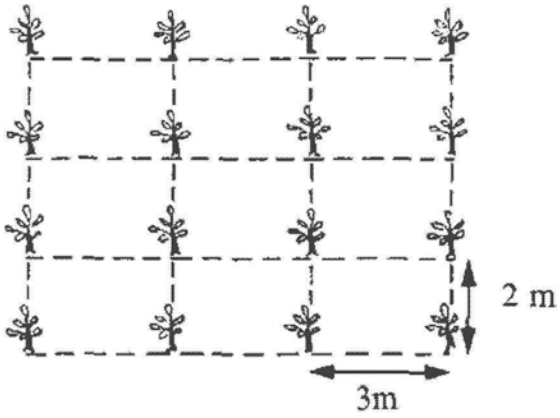
<u>The various layout or planting systems used are as below:</u>

1. Square system:

In this system, trees are planted on each comer of a square whatever may be the planting distance. This is the most commonly followed system and is very easy to layout. The central place between four trees may be advantageously used to raise short lived filler trees. This system permits inter cropping and cultivation in two directions.



(a) Square system of planting



(b) Rectangle system of planting

2. Rectangular system:

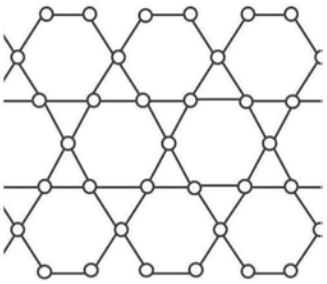
In this system, trees are planted on each corner of a rectangle. As the distance between any two rows is more than the distance between any two trees in a row, there is no equal distribution of space per tree. The wider alley spaces available between rows of trees permit easy intercultural operations and even the use of mechanical operations.

3. Hexagonal System:

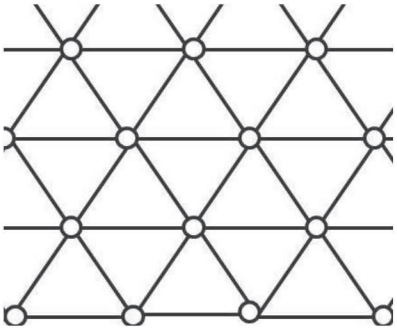
In this method, the trees are planted in each comer of an equilateral triangle. This way six trees form a hexagon with the seventh tree in the centre. Therefore this system is also called as 'septule' as a seventh tree is accommodated in the centre of hexagon. This system provides equal spacing but it is difficult to layout. The perpendicular distance between any two adjacent rows is equal to the product of 0.866 x the distance between any two trees. As the perpendicular distance between any two row is less than unity, this system accommodates 15% more trees than the square system. The limitations of this system are that it is difficult to layout and the cultivation is not so easily done as in the square system.

4. Diagonal or quincunx system:

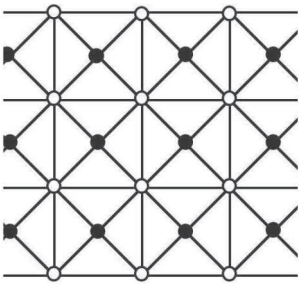
This is the square method but with one more plant in the centre of the square. This will accommodate double the number of plants, but does not provide equal spacing. The central (filler) tree chosen may be a short lived one. This system can be followed when the distance between the permanent trees is more than 10m. As there will be competition between permanent and filler trees, the filler trees should be removed after a few years when main trees come to bearing.



Hexagonal system



Triangular system



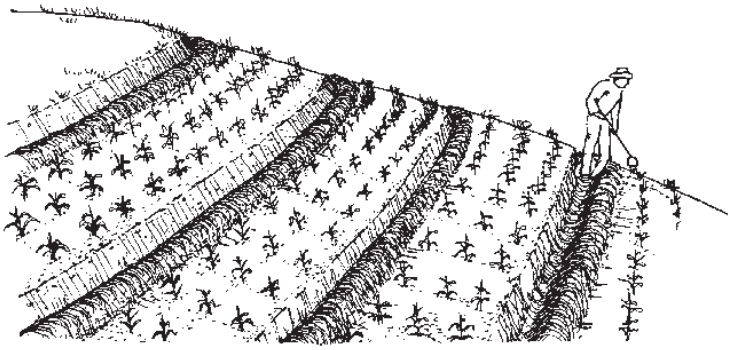
Quincunx system

5. Triangular system:

The trees are planted as in square system but the difference being that those in the even numbered rows are midway between those in the odd rows instead of opposite to them. Triangular system is based on the principle of isolateral triangle. The distance between any two adjacent trees in a row is equal to the perpendicular distance between any two adjacent rows. However, the vertical distance, between immediate two trees in the adjacent rows, is equal to the product of (1.118 x distance between two trees in a row). When compared to square system, each tree occupies more area and hence it accommodates few trees per hectare than the square system.

6. Contour system:

It is generally followed on the hills where the plants are planted along the contour across the slope. It particularly suits to land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult. The main purpose of this system is to minimize land erosion and to conserve soil moisture so as to make the slope fit for growing fruits and plantation crops. The contour line is so designed and graded in such a way that the flow of water in the irrigation channel becomes slow and thus finds time to penetrate into the, soil without causing erosion. The width of the contour terrace varies according to the nature of the slope. If the slope becomes stiff, the width of terrace is narrower and vice-versa. The planting distance under the contour system may not be uniform.



Beside the above planting systems, some other new planting systems have been develop like double hedge row (Pineapple), paired/hedge row (Banana), meadow orchard (Guava), etc. to increase the production and productivity of fruit crops.

QUESTIONNAIRES:

1. Enlist what are the new planting systems developed for fruit production.
2. Differentiate square *Vs* Hexagonal planting system.
3. What are the advantages of establishing fruit trees in a systematic manner?

-----xxx-----

EXERCISE-06

TRAINING AND PRUNING OF FRUIT TREES

Date: _____

Objective: To understand different methods of training and pruning practiced in fruit trees.

A. Training:

During early years of orchard establishment more emphasis is given on development of framework. Pruning at this stage is a constructive operation which determines general outline of the tree. This is also referred to as "pruning for training". The first pruning cut is made on a newly planted layered/grafted/budded plant to reduce the size of the top to compensate for roots that were lost during digging planting operation in the nursery and to establish the trunk height.

1. Central Leader System

A central leader tree is characterized by one main, upright trunk, referred to as the leader. Branching generally begins on the leader 24 to 36 inches above the soil surface to allow movement under the tree. The first year, 3 to 4 branches, collectively called a *scaffold whorl*, are selected. The selected scaffolds should be uniformly spaced around the trunk, not directly across from or above one another. Above the first scaffold whorl, leave an area of approximately 18 to 24 inches without any branches to allow light into the center of the tree. This light slot is followed with another whorl of scaffolds. Alternating scaffold whorls and light slots are maintained up the leader to the desired maximum tree height.

2. Open Centre

With the open centre system, the leader is removed, leaving an open centre. Instead of having a central leader, the open centre tree has 3 to 5 major limbs, called scaffolds, coming out from the trunk. This training system allows for adequate light penetration into the tree, which minimizes the shading problem prevalent in higher vigour trees such as peach.

3. Modified Leader/Modified Central Leader

It is intermediate between central leader and open centre system of training. In this method trees are developed first training the tree in leader type allowing the central stem to grow unhampered for the first 2-5 years. Then the central stem is headed back and lateral branches are allowed to grow as in the open central system. This results in a fairly strong and moderately spreading tree.

Difference between training and pruning:

I. Training is mainly concerned with giving a form or shape to the plant, while pruning has an effect on the function of the plant.

II. Training determines the general character and even details of the plant's outline like its branching and frame work, while pruning is meant to assist more in determines what the tree does in respect of fruiting.

Central Leader **Open Centre** **Modified Leader**

Fig. 1: Diagrammatic difference between different systems of training in fruit crops

B. PRUNING:

Pruning is a horticultural practice involving the selective removal of parts of a plant, such as branches, buds, or roots. Reasons to prune plants include deadwood removal, shaping (by controlling or directing growth), improving or maintaining health, reducing risk from falling branches, preparing nursery specimens for transplanting, and both harvesting and increasing the yield or quality of flowers and fruits.

Different Types / methods of Pruning in Fruit Crops:

a. Thinning out:

The complete removal of a branch at its point of origin is known as thinning out (Fig. 1). The response to thinning is fairly evenly distributed throughout a plant. A thinned plant becomes more open and is more likely to retain its natural form. More light penetrates a plant that has been thinned and interior branches and foliage will be retained nearer the center of a tree.

b. Heading back:

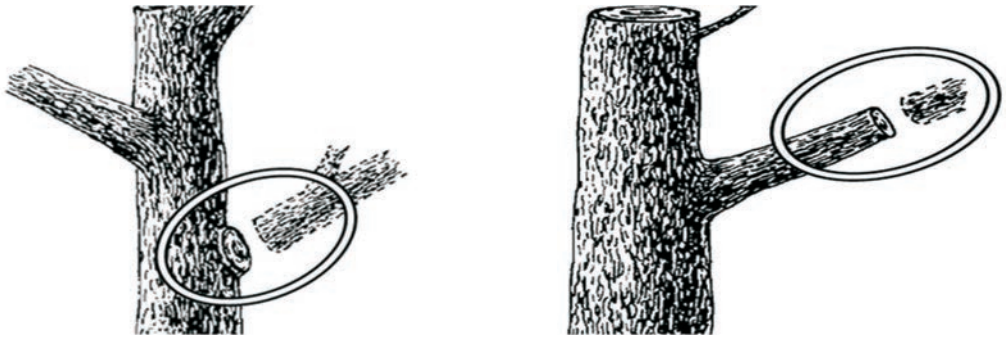
Removal of the upper portion of the branch, leaving the leader intact with the main stem is known as heading back.

c. Pollarding or Dehorning:

When the trees are aged and don‘t give good yields, their branches may be pollarded or dehorned. In this method the branches are cut leaving 30 cm in length at their origin. The cut branches produce enormous shoots and flowers and ultimately give high yields.

d. Root Pruning:

Root pruning is usually practiced when the tree is making too much vegetative growth particularly in heavy soil. The objective is to restrict the vegetative growth and encourage the tree to bear a good crop. A wide trench is dug around the canopy area to prune the root. Because of the severe damage done to litchi’s shallow root system, this practice should be done carefully. This practice can also be followed to regulate the crop in guava, pomegranate and citrus.



Thinning out **Heading back**

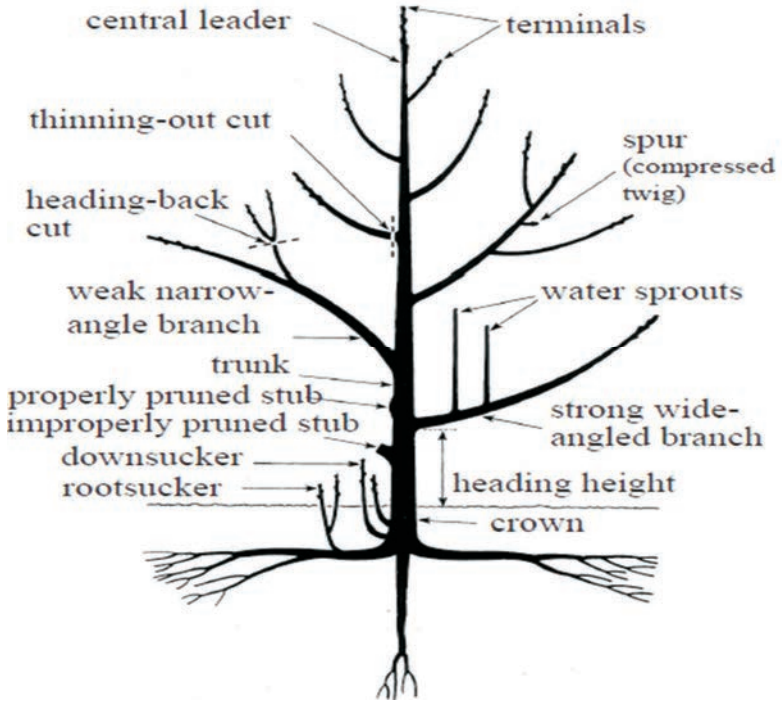
Fig. 2: Difference in position of cut in thinning out and heading back pruning.

e. Rejuvenating Pruning:

In case of rejuvenation, heavy reiterative pruning of fruit tree is done at the height of 2-3 m depending upon the girth and type of main trunk. About 3-5 main branches with outward growth from the base are marked for pruning at required height, with a plan of developing umbrella like or semi circular frame work of tree canopy. Pruning can be done either with manual saw or power operated saw. Care should be taken to avoid bark splitting or debarking at the cut end due to falling of heavy branches at the time of pruning. It is always advised to go for reiterative pruning for rejuvenation in phase manner starting from the top light pruning to reduce weight upto the final point. After care is very important for successful rejuvenation, to avoid any external infection at the cut portion, it should be pasted with Bordeaux mixture or Copper-oxychloride (Blitox) immediately after pruning.

QUESTIONNAIRES

1. Differentiate between training and pruning.
2. Differentiate between thinning out and heading back.



-----xxx-----

EXERCISE-07

MAKING OF HERBACEOUS AND SHRUBBERY BORDERS

Date: _____

Objective: Identification and preparation of herbaceous plant, shrubs, hedge and border making.

A. BORDERS:

Beds which are more in length than breadth and contain of a heterogeneous character are known as borders. There are three different types of borders, namely, herbaceous, border, annual mixed border and mixed border.

1. Herbaceous border:

It contains hardy perennial herbaceous plants which die down to ground level after flowering, but put up new growth from the roots in the next season. Herbaceous border needs a good depth of soil and a sunny situation. The border may be placed against a wall, a fence, shrubs, a hedge or form a double border divided by a grass path. In an informal design the border should have curved margins.

Some characteristics of herbaceous borders:

(a) Frontage: The best frontage is a stretch of neatly kept lawn because this provides a good foreground colour. A paved brick or stone walk is considere d the best because this provides a firm and clean walk throughout the year.

(b) Height and arrangement: In a wide border, plants of all heights are accommodated. The grower has to give enough attention on the staking of tallest plants. The maximum height should be limited to 3 m.

(c) Grouping and colour: In an average sized border each group will consist of 4-5 plants, while in large borders it may vary from 5 to 7 plants. Each group should be planted in drifts of irregular shapes than being put in box or round shaped drift as this may look patchy. Though generally the gradation in a herbaceous border is from dwarf to taller placed towards the back, it can be broken here and there to avoid monotony or too formal look.

There are two extreme views regarding colour schemes. One group of gardeners feel that colour schemes should harmonize, i.e. light shades leading to dark shades and vice-versa, while the other prevailing opinion is that nature never clashes. In small boarder it is not possible to have more colours.

(d) Planting: The scale should not be less than 1:15. Pegs and canes of same height as the plants to be grown may be placed in position and a rough idea made as to how they will look. One has to consider time and duration of flowering and for these plants are grouped in such a way. In India most of planting may be done in September. Once planted, herbaceous border will remain in same position for about three years after which some replanting is necessary mainly for thinning out and invigoration.

Choice of plants:

The main aim of herbaceous border is to have colour in the garden throughout the year and to exhibit the proper plant material in a most artistic way. For year round flowering, plants are complied in such way that in every season some of these are in flowering. Some examples are listed here which are commonly used for herbaceous borders:

Amaryllis (different cultivars), *Asystasia* species, *Beloperone guttata, Canna* different cultivars, *Clerodendron balfourii, Chrysanthemum, Coreopsis grandiflora, Crossandra* different species, *Eranthemum, Gaillardia perennis, Lantana sellowiana, Michaelmas Daisies, Plumbago copensis , Portulaca*, Perennial *Rudbeckia, Ruellia* different speciea, *Russelia juncea* and *R. floribunda, Salvia, Solidago canadensis*, Perennial *Verbena, Vinca* different species and *Zephyranthes* in different colours, *Dianthus chinensis, Sedum spectabile, Statice latifolia, Viola cornuta, Delphinium belladonna* (different cultivars), *Gypsophila elegans, Lupins, Phlox decussata, Tradescantia Helianthus annuus, Hollyhocks* and *Peony.*

Herbaceous perennials:

Herbaceous perennials are those perennial plants with soft succulent stems (as compared to shrubs which have woody stems). They are propagated by seeds, cuttings, offset and slips. They are useful as herbaceous or mixed borders or for pot culture. E.g. Chrysanthemum, *Solidago (*golden rods), *Gazania splendens, Pelargoniums*, etc.

1. **Chrysanthemum:** Flowers are single or double available in attractive colours. Perennial species include *C. frutescens* and *C. maximum* and its varieties. Propagated easily by suckers.
2. ***Solidago:*** Popularly known as 'golden rods' producing erect feathery rod-like trusses crowded with pretty golden yellow flowers. They are suitable for mass planting in beds and borders in and adjoining lawn. They are raised by suckers.
3. **Gerbera*:*** Stemless perennial herbs with radical stalked leaves, flower heads are solitary, large and sterile with varying colours. Propagation by division of clumps or from seed.
4. ***Gazania splendens:***Perennial plant about 20 cm high, with pointed leaves with silver, and bearing beautiful daisy like flowers, in yellow orange shades; useful in beds, borders for edging and carpet bedding and on rockeries, propagated by seed or suckers.
5. **Perstemon*:*** It has large erect spikes of tubular, open-mouthed, gloxinia - like flowers, which are available in several shades of colours, a good bedding plant, propagated by seeds, cuttings or division.
6. **Pelargoniums:** It is commonly known as geraniums, a popular herbaceous perennial pot plants grown for the beauty of their flowers which are borne in large trusses propagated by cuttings or from seed.
7. **Chrysanthemum:** Flowers are single or double available in attractive colours. Perennial species include *C. frutescens* and *C. maximum* and its varieties. Propagated easily by suckers.

B. SHRUBS & SHRUBBERY:

- Shrubs are plants with many woody branches arising from the base of the plant and are smaller (0.5 to 4 m in height) than trees but bigger than herbaceous plants.
- A typical shrub will have several stems arising from the main stem at ground level itself.
- They can be either evergreen or deciduous.
- Some are attractive in their foliage, some produce attractive flowers and some are grown for their attractive berries.

Importance/ Uses of shrubs in garden:

- A stretch of shrubs are established as borders on the sides of walks and paths.
- Shrubs are planted at the corners of lawn in a curving line.
- **A shrubbery** is an area planted with different kinds of shrubs and a **shrub border** is one where only one kind of shrub is used.
- Shrubs that stand frequent pruning and trimming can be used for topiary work.
- Tall growing shrubs can be used to screen the disagreeable object and backyard. Handsome shrubs can make attractive pot plants for indoor and outdoor decoration.
- Shrubs can prevent architectural features like glass doors and windows from conducting heat thereby keeping the overall temperature of the interiors down.
- Being permanent, they form part of the frame work of the garden.
- Shrubs which are amenable for frequent training are chosen for topiary work.
- Tall growing shrubs often serve as screen.
- They are useful as a single specimen in the lawn.
- They can be trained to form standards i.e., trained to single stem and allowed to branch out and form a handsome head only above a particular height e.g. Bougainvillea, Ixora, *Murrya exotica*.

This is also an essential feature of garden. Shrubs are of permanent nature and once planted will become a permanent feature unlike the seasonal flowers which are to be replaced every season. From planting shrubs in shrubbery point of view, shrubs are classified as:

a) Shrubs having ornamental foliage and attractive foliage, eg: Acalypha, Duranta, Variegated Hibiscus, Pedilanthus, etc

b) Flowering shrubs, eg: Pentas, Ixora, Tabernaemontana, Hibiscus, Mussaenda, cassia glauca, Caesalpinia, callindra, Bauhinia purpurea, Hemelia patens, Jatropha rosea, plumbago, Meyenia erecta, etc, and

c) Shrubs which bearing berries, eg: *Braya ebens, Duranta, Rauwolfia serpentine, Carissa caronda, Poincirus trifoliate, Ochna kirkii, O. squarrosa*, etc.

Shrubbery: Growing of shrubs in a group is called shrubbery. It is of two types:

(i) Pure shrubbery.

(ii) Mixed shrubbery.

Pure shrubbery refers to planting of entire selected area with a single species and the opposite holds good for mixed shrubbery.

Shrubs for showy or attractive flowers (e.g.) *Hibiscus, Ixora*, *Mussanda,* Night queen, Euphorbia etc., Shrubs for fragrance (e.g.) Jasmine, Rose, Nandiayavattai (*Tabernaemontana*), Pavalamalli (Nyctanthes) etc. Shrubs for foliage (e.g.) *Crotons, Polycias, Eranthemum, graptophyllum,* etc.

Importance of shrubs in garden

- Being permanent, they form part of the frame work of the garden.
- They form the chief features of landscape gardenings placed in front of tall trees and joining the spacious lawn etc.
- Shrubs which are amenable for frequent training are chosen for topiary work.
- Tall growing shrubs often serve as screen.
- They are useful as a single specimen in the lawn.
- They can be trained to form standards i.e., trained to single stem and allowed to branch out and form a handsome head only above a particular height e.g. Bougainvillea, Ixora, etc.

C. Hedge and Edge:

Hedge:

Shrubs, trees, succulents and cactus planted at regular intervals to form continuous screen is called a hedge.

Use of hedge:

¾ A garden hedge can serve the purpose of a compound wall, gives shelter, and ensures privacy.

¾ Serve the purpose of a screen, form a background for floral display such as herbaceous border.

¾ As a part of the garden on its own merit, separate one component of a garden from the other (E.g. the vegetable garden from the flower garden).

¾ Screen the ugly and unwanted spots such manure pits, lavatory, servant's quarters etc. in the garden.

Criterion for selecting a hedge plant:

In a garden, a hedge is planted with two motives.

(a) Protective hedge: - Which means protection against theft, wind etc. and for this the hedge plant should have the following characteristic. Quick growing, hardy, including drought resistant character, thorny, dense, should respond to frequent pruning and clipping and can be raised quickly by seeds or cuttings. Attractive foliage and flower is not a criterion in this category.

(b) Ornamental hedges: Should have attractive foliage and flowers, should be dense in growth habit and stand regular clipping. The ornamental hedges are generally low in height. And they do not obstruct the view completely since the other portion is visible over the hedge.

Plants suitable for hedge:

1. Ornamental hedge: Acalypha, Bougainvillea, Clerodendron, Duranta, Eranthemum, Hamelia, Hibiscus, Lantana, Kamini.
2. Boundary or tall hedge : Gultora, Saru, Karonda, Jetropha, Snow bush, Tecoma.
3. Trees as a hedge: Accacia (babul), Asopalav, Karen, Saru.

Edge:

Lining of borders of flower beds, paths, lawn and shrubbery with brick, concrete, living plants etc., is known as edging, Edging may be two types.

1) Formal: - Made of stone, bricks, tiles etc.
2) Informal: - Consisting of living plants.

There are certain plants which are very suitable for edging purposes and these are known as edge plants. Edge plants, unlike hedges should grow very low as the purpose is not for screening but to provide a lining only for the purpose of decoration or demarcation.

A grass grown between a bed or border and the road or walk is pleasing the eye and it further reserved as a foil to the brilliant colour beyond it. The grass strip should be kept in good condition by manuring, watering, clipping and rolling. To be effective, it should be more than 60 cm wide.

Plants suitable for edge:

(1) Alternathera (2) Caladium (3) Coleus (4) Ribbon grass (5) Pilea (6) Aralia (7) Begonia (8) Golden duranta (9) Eranthemum (10) Arvea sangunia (11) Eupatorium (12) Jaffer lily (13) Justucia.

-----xxxxx-----

EXERCISE-08

PREPARATION OF POTTING MIXTURE, POTTING AND REPOTTING

Date: _____

Objective: To know different containers and potting mixtures used in horticultural crop production as well as the potting, repotting and depotting techniques.

CONTAINERS:

Containers in gardening are used for growing plants. Different type's containers are available in the market. They are varied according to size and shape. The size of container should be selected according to growth habit of the plant species to be grown on it. The shape should be as per grower's choice. Containers used in gardening are either made of clay or plastic or wood.

A. Clay pots: Clay pots provide a healthy environment for most plants. It is preferred over plastic pots when used outdoor conditions.

Advantages:

1. The porosity of clay allows air and moisture to penetrate from the sides of the pot.
2. It also acts like a wick to remove excess moisture from the potting soil.
3. Thick walls of clay plot protect the plant rhizosphere from rapid changes in atmospheric temperature.
4. Eco-friendly.

Disadvantages:

1. Clay pots have a fair amount of weight.
2. It dries quickly.
3. Formation of white crusty layer on the outside of the pot due to salt deposition.
4. Clay pots are highly fragile in nature.

B. Plastic pots: Plastic pots are made of inert materials and are considered safe for growing plants. These pots are suitable for indoor conditions.

Advantages:

1. Plastic pots are light in weight, strong and flexible.
2. Plastic does not have the wicking action, therefore not to water the plants as frequently as plants are in clay pots.
3. Life span is more.

Disadvantages:

1. Sunlight on plastic causing fading and brittleness.
2. Plants in dark colored plastic containers have a tendency to wilt quickly.
3. Black plastic pots can actually act as a solar collector, thereof, heating up the potting medium.

C. Wooden pots: These pots are rarely used for gardening purposes. However, sometimes used for indoor gardening.

Advantages:

1. Attractive in nature.
2. Retention capacity of water is more since wooden part absorbs water.
3. Eco-friendly.

Disadvantages:

1. Heavy weight.

2. Lifespan is less.

POTTING MIXTURE:

Plants growing in containers require much more attention than those grown in the ground. The media used in potting should not be only soil. It should contain a balanced mixture of certain potting ingredients, which could keeps the plant in place, holds water for the plants and provides sufficient amount of nutrients that feed the plant. There are four different types of potting soils, including all purpose (needs addition of nutrient), premium (suitable for drainage of water and aeration), professional (high quality) and plant specific. The cost of each varies, according to the specific ingredients and the amounts included in the soil. The different types of ingredients' used in potting mixtures are discussed below:

A. Soil:

Soilless mixtures are more popular due to density and disease concerns. Some organic blends still use soil. Clean topsoil or garden soil can be used and should be sterilized to kill disease organisms and weeds. For sterilization, spread soil in a tray and bake at 200º F for twenty minutes, stirring every five minutes.

B. Peat and Peat-Like Materials:

Peat moss is formed by the accumulation of plant materials in poorly drained areas. The type of plant material and degree of decomposition largely determine its quality of growing medium. Although the composition of different peat deposits varies widely, four distinct categories may be identified:

1. **Sphagnum Moss:** Sphagnum moss is perhaps the most desirable form of organic matter for the preparation of growing media. It is widely available and inexpensive. Sphagnum moss is used to improve the drainage and aeration in heavier soils while in light soil it is added to increase the moisture and nutrient retention power. The light weight sphagnum moss has the capacity to absorb 10 to 20 times more water of its weight in water holding cells. Lime is usually added to mixes to balance the build up acidity in Sphagnum moss medium.

2. **Hypnaceous Moss:** This type of peat consists of the partially decomposed remains of hyprum, polytrichum and other mosses of the Hypanaceae family. It decomposes more rapidly than some other peat types. Hence, it is suitable for media use.

3. **Reed and Sedge:** These types of peats derived from the moderately decomposed remains of rushes, coarse grasses, sedges, reeds and similar plants. These are fine textured materials, less acidic and contain relatively less fibrous particles. However, these kinds of materials are not suitable for potting media.

4. **Humus:** It is derived from the decomposed debris of finely divided plant materials of unknown origin. Humus often contains large quantities of silt and clay particles, and when mixed with soil does not improve drainage or aeration. Due to its rapid rate of decomposition and particle size, humus is considered to be undesirable for growing media use.

C. Residues derived from plant parts:

1. **Leaf Mold:** Leaf mold is prepared by placing leaves and soil in alternate layer for 12 to 18 months. Small amount of nitrogenous compound is added to accelerate the decomposition process. Use of leaf mold improves aeration, drainage and water holding capacity of a potting mixture. However, it is not extensively used in container production.

2. **Sawdust:** The tree species from which sawdust is prepared largely determines the quality of potting mixture. Tree species having phytotoxic effects are not suitable for sawdust used in potting media. Excessive use of sawdust may restrict the growth of the plants due to presence of high amount of cellulose and lignin. Insufficient N sometimes creates depletion problems. However, supplemental applications of nitrogen can reduce this problem.

3. **Barks:** Physical properties of tree barks are as similar as Sphagnum moss. These are primarily a bi-product of the pulp, paper and plywood industries. Suitable particle size can be obtained by hammer milling and screening for potting media purpose.

4. **Bagasse:** It is a waste bi-product of the sugar industry. It may be shredded and/or composted to produce a material which can facilitate the aeration and drainage of container media. High sugar content coupled with rapid microbial activity decreases the durability and longevity of bagasse and influences N levels in potting media. Although bagasse is readily available at low cost, (usually transportation), its use is limited.

5. **Rice** Hulls: These are a biproduct of the rice milling industry. They are extremely light in weight. Rice hulls are very effective at improving drainage in potting media. The particle size and resistance to decomposition of rice hulls and sawdust are very similar. However N depletion is not as serious of a problem in media amended with rice hulls.

6. **Coco Peat / Coco Coir / Coco Husk Fiber:** It is made from coconut husk. Plants growing in coco peat usually have strong root and vigor. It absorbs water readily (holds 8-9 times its weight in water) and re-wets easily, thus reducing the need for wetting agents as well as frequency of watering. Potting media containing coco peat generally have pH range 5.7-6.8 and excellent drainage and aeration capacity. It has the ability to retain nutrients against leaching and to buffer supply. Use of cocopeat as potting media is increasing day by day also due to light in weight and odorless properties. It is now available in 12"x12"x 6" brick, compression ratio is 5:1.

D. Sand: Sand, a basic component of soil, ranges in particle size from 0.05 mm to 2.0 mm in diameter. Physical properties of potting media are largely dependent upon particle size of sands. Fine sands (0.05mm–0.25mm) may result in reduced drainage and aeration. Medium and coarse sand particles provide optimum adjustments in media texture. It is least expensive of all inorganic amendments and it is also the heaviest.

E. Clay particles:

1. **Perlite:** It is a silicous mineral of volcanic origin. The materials used as container media are first crushed and then heated until the vaporization of combined water expands it to a light powdery substance. Lightness and uniformity of perlite material are very useful for increasing aeration and drainage. It has a tendency to float to the top of a container during irrigation. It has also been reported that perlite contains potentially toxic levels of fluorine. Although costs are moderate, perlite is an effective amendment for growing media.

2. **Vermiculite:** Vermiculite is a micacious mineral generated by heating to approximately 745 °C. Very high water holding capacity of vermiculite can be used as aid in aeration and drainage for the potting media. Additionally, it has excellent cation exchange and buffering capacities. Vermiculite also supplies little amount of potassium and magnesium for the plant. Although it is less durable than sand and perlite, its chemical and physical properties are very desirable for container media.

3. **Calcined Clays:** Calcined clays are formed by heating montmorrillonitic clay minerals to approximately 690 °C. The calcined clays have a relatively high cation exchange as well as water holding capacity. It is very durable and useful amendment for potting media.

POTTING:

It can be defined as an operation in which plants are placed in containers/pots. Before going for potting some points should be kept in mind:

1. **Selection of container:** Container should not be so large or so small. It should have a drainage hole a bottom. Selection of potting size should be done according to growth habit of the plant. For outdoor condition earthen pots are suitable while for indoors plastic pots are preferred.
2. **Preparation of a right potting mixture:** This is the most important consideration while potting. Since, it determines the nutrient availability and physical properties of the rhizosphere for root development of growing plants. It should be firm enough to hold the plants in correct position.
3. Potting media should be sterilized before placing in pots. The container should be cleaned with detergent while using.

Method: Select a container according to the growth habit of the plant. Prepare potting mixture for the particular species to be grown. Sterilize the potting mixture by heating and clean the pots with detergent. Fill up ¾ th empty space of the pot with potting mixture. Place root zone of the plant at

center of the pot. Hold the plant in one hand and by other hand add potting mixture in remaining space of the pot. Press the potting mixture with both hands around the plant so that it should remains in correct position. Little space must be left above the pot to facilitate watering. Light irrigation should be provided after potting.

REPOTTING:

Repotting of plants is carried out by removing the plants from container when roots emerging from the drainage hole at bottom of the pot or on the surface of soil. In such situation, growth of the plant has been slowed down. Roots coiled at periphery of the pot. Offsets produced by plants can become crowded in the pot and need to be separated and propagated in their own containers. Plants easily remove from the pot by slight turn on its side. Repotting of plants is required to rejuvenate the growth and development. The details procedure followed during repotting and repotting are described below:

Steps followed during repotting:

Step 1: A day before plan to repot, give plants a thorough watering because they're easier to repot when the growing mix is moist.

Step 2: To remove the plant from its original pot, turn it on its side and ease the plant gently from the pot. If the plant won't move, tap the bottom of the pot on a hard surface to loosen it. Otherwise, slide a trowel or knife round the inside of the pot, taking care not to damage the rootball.

Step 3: Pull the roots straight with fingers which are coiled around the bottom. Prune the roots before potting. Pruning will stimulate new root growth and help the plant establish in its new container.

Step 4: Remove about one-third of the old potting mix from the root ball, loosening it gently with your fingers, a stake, a pencil, or a chopstick inserted straight down into the roots.

Step 5: Disinfect the pots with detergent.

Step 6: Separate each suckers from mother plant. Now, each suckers will be considered as a new plantlet.

Step 7: Pour in a layer of the premoistened potting mix made

Step 8: Set the plant in the pot, make sure it is completely centered, and begin adding soil. Add the potting medium until the roots are well covered, and then even out the mix with your fingers or a spoon.

Step 9: Light watering should be provided after competition of the entire operation.

QUESTIONNAIRES

1. Describe briefly about the physical properties of different potting ingredients.

-----xxx-----

EXERCISE-09

PREPARATION OF POTTING MIXTURE, POTTING AND REPOTTING

Date: _____

Objective: To study the different methods of fertilizer application in horticultural crops.

In order to get maximum benefit from manures and fertilizers, they should not only be applied in proper time and in right manner but any other aspects should also be given careful consideration. Different soils react differently with fertilizer application. Similarly, the N, P, K requirements of different fruit crops are different and even for a single a crop the nutrient requirements are not the same at different stages of growth.

The aspects that require consideration in fertilizer application are listed below:

1. Availability of nutrients in soil.
2. Nutrient requirements of crops at different stages of crop growth.
3. Time of application.
4. Methods of application, placement of fertilizers or foliar application.
5. Crop response to fertilizers application and interaction of N, P, and K.
6. Residual effect of manures and fertilizers.
7. Crop response to different nutrient carrier.
8. Unit cost of nutrients and economics of manuring.

Fertilizers are applied by different methods mainly for 3 purposes:

1. To make the nutrients easily available to crops.
2. To reduce fertilizer losses.
3. To ease the application.

The time and method of fertilizer application vary in relation to:

1) The nature of fertilizer.
2) Soil type.
3) The differences in nutrient requirement and nature of fruit crops.

A. Application of fertilizers in solid form: It includes the methods like

1. **Broadcasting:** Even and uniform spreading of manure or fertilizers by hand over the entire surface of field while cultivation or after the planting in standing crop, termed as broad casting. Depending upon the time of fertilizer application, there are two types of broadcasting:
   a) Broadcasting at planting
   b) Top dressing

a) Broadcasting at planting: Broadcasting of manure and fertilizers is done at planting or sowing of the crops with the following objectives:

- To distribute the fertilizer evenly and to incorporate it with part of, or throughout the plough layer

- To apply larger quantities that can be safely applied at the time of planting/sowing with a seed-cum-fertilizer driller.

b) Top Dressing: Spreading or broadcasting of fertilizers in the standing crop (after emergence of crop) is known as top-dressing. Generally, NO3 – N fertilizers are top dressed to the closely spaced crops like wheat, paddy. E.g.: Sodium Nitrate, Ammonium Nitrate and urea, so as to supply N in readily available from the growing plants.

2. Localized placement:

It refers to the application of fertilizers into the soil close to the trees. It is usually employed when relatively small quantities of fertilizers are to be applied. It includes methods like:

Advantages:

i) The roots of the young plant are assured of an adequate supply of nutrients.
ii) Promotes a rapid early growth.
iii) Make early Inter-cultivation possible for better weed control.
iv) Reduces fixation of P and K.

Though there are many methods of localized application of fertilizer to the plants like contact placement, row placement, pellet placement and band placement, in case of fruit trees, fertilizers in standing trees applied in ring methods.

Ring method: In ring method, a ring is formed by digging soil around trunk of the tree and fertilizers are applied in this ring. After application of fertilizer, the ring is filled with uplifted soil. The distance from trunk and depth of ring are depending upon age and tree species to be fertilized. Fertilizers are aimed to apply as close as possible to feeder root of the tree.

B. Application of fertilizer in liquid form:

1. **Foliar fertilization:** Foliar feeding refers to the application of fertilizers to a plant's leaves. It is not a substitute for maintaining adequate levels of plant nutrients in the soil but can be beneficial in certain circumstances. Most commonly, it is recommended for alleviating specific micronutrient deficiencies.

A range of other benefits are associated with foliar fertilization. A few points are listed below:

1. Rapid results.
2. Prolonged blooming.
3. Improved plant health.
4. Increased crop yields.
5. Reduced growth stress.
6. Growth during dry spells.
7. Better cold and heat tolerance.
8. Improved resistance to disease.

2. **Fertigation:** It is the method of applying fertilizer, soil amendments and other water soluble products required for plant growth and development through drip/sprinkler system.

Advantages of fertigation:

1. Increases yield by 25-30 %.
2. Saving fertilizer by 20-30%.
3. Precise application and uniform distribution of fertilizer.
4. Nutrients can be applied as per plant requirements.
5. Acidic nature helps in avoiding clogging of drippers.
6. Minimize nutrient losses.
7. Macro and micro nutrients can be applied in one solution with irrigation.
8. Fertilizers can be injected as per required concentration.
9. Saving in time, labour and cost.
10. Light soils can be brought under cultivation.

3. Trunk injection

Trunk injection is an alternative application method for introducing chemical compounds into trees.

Injections have many advantages

1. Offers an efficient use of chemicals.
2. Reduces environmental pollution.
3. Useful when soil and foliar applications are either ineffective or too difficult.

QUESTIONNAIRES

1. What are the methods of fertilizer application in solid form?
2. Describe various methods of fertilizer application in liquid form.
3. Write advantages of foliar application of fertilizer.

-----xxx-----

EXERCISE-10

VISITS TO COMMERCIAL NURSERIES OR ORCHARD

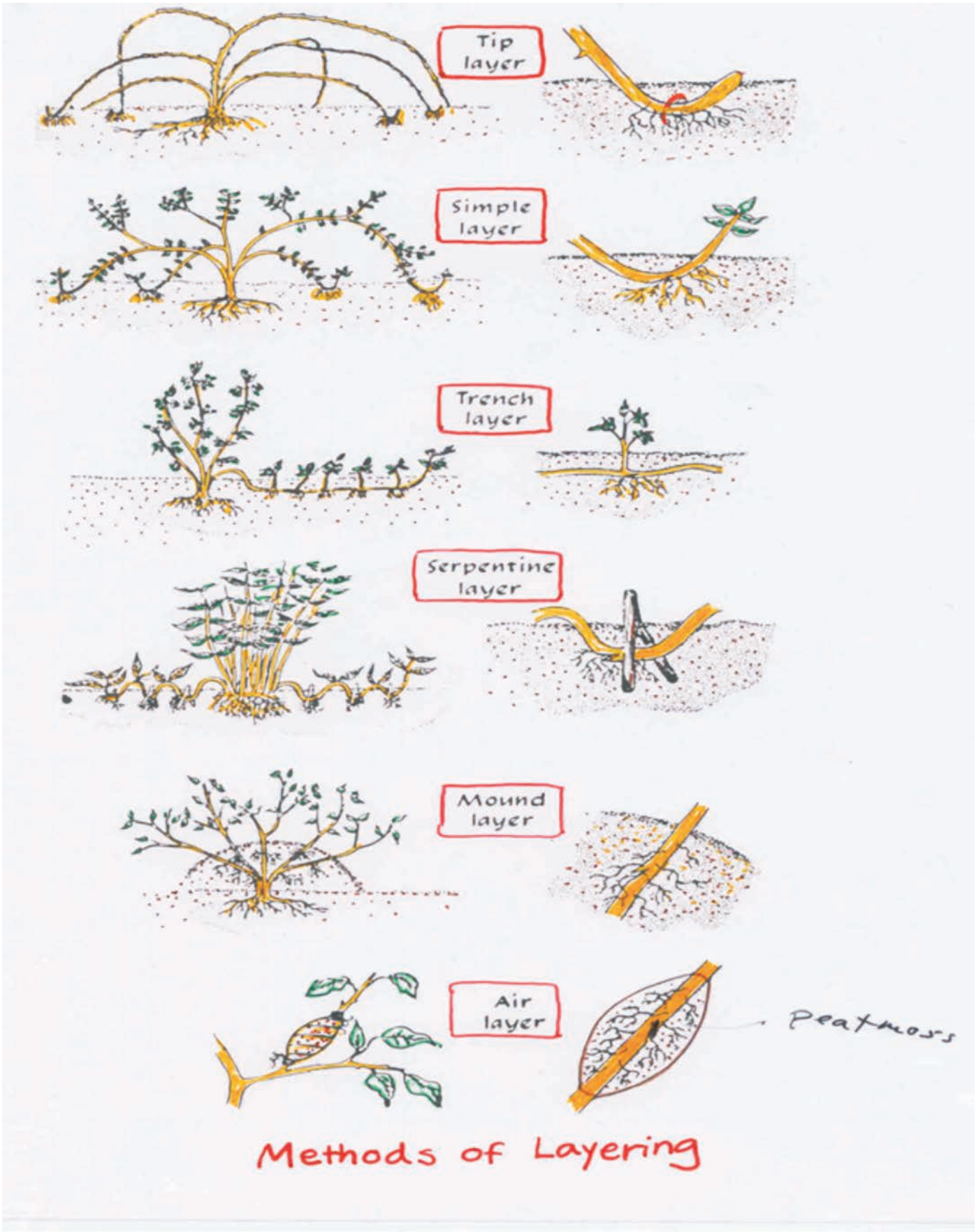
Date: _____

1.	**Location/Name**	**:**	
2.	**Area in ha.**	**:**	
3.	**Crops & variety**	**:**	
4.	**Spacing in meter**	**:**	
5.	**Source of Irrigation**	**:**	
6.	**Method of irrigation**	**:**	
7.	**Age of trees**	**:**	
8.	**Other Observations**	**:**	

------xxxxx------

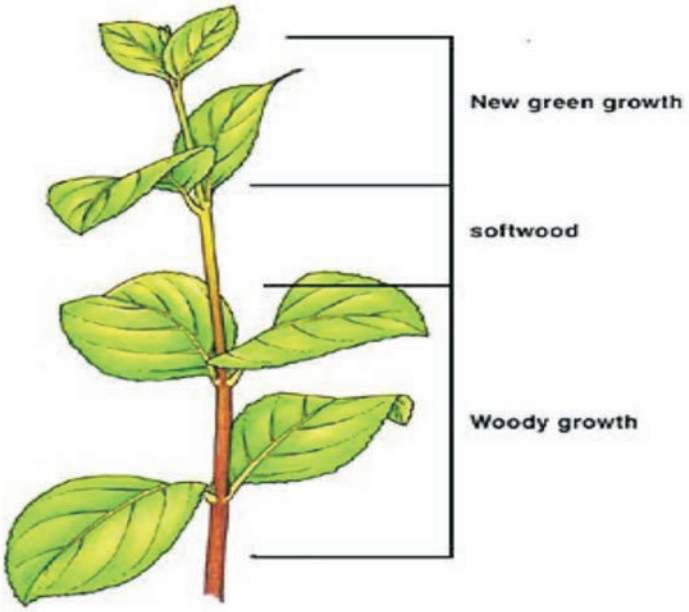
NOTES

NOTES



Methods of Layering

Raised Bed



Flat Bed

Sunken Bed

Lawn Mowe

Root Trainer

Sprayer

Watering Can

NAVSARI AGRICULTURAL UNIVERSITY

TUTORIAL BOOK

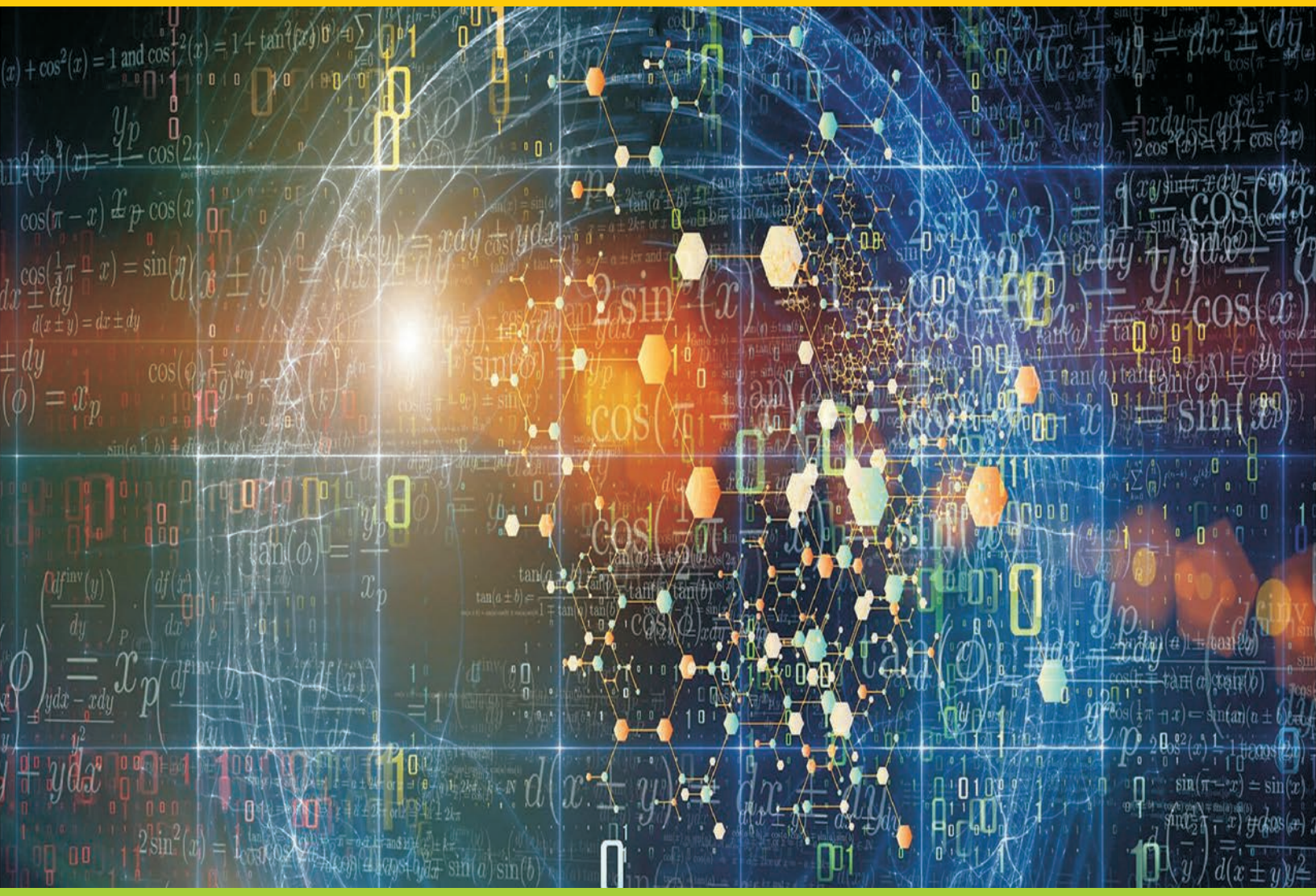
OF

ELEMENTARY MATHEMATICS

(MATHS 1.1)

FIRST SEMESTER

B.Sc. (Hons.) Agriculture



Dr. TEJASH U. CHAUDHARI

भाकृअनुप
ICAR

TUTORIAL BOOK

OF

ELEMENTARY MATHEMATICS

(MATHS 1.1)

FIRST SEMESTER

B.Sc. (Hons.) Agriculture

PREPARED BY

DR. TEJASH CHAUDHARI

Assistant Professor

College of Agriculture

Navsari Agricultural University

Waghai - 394730

Publisher
Principal
College of Agriculture,
Navsari Agricultural University,
Waghai-394 730 (Gujarat)
Phone No. 02631 – 246688
Fax No. 02631 - 246622

Edition : First: January, 2019

Copies: 300

College of Agriculture,
Navsari Agricultural University,
Waghai (Dangs) – 394730.

University Publication No.:.....2018-19

Dr. Z. P. Patel
Dean & Principal
M. 9624363999

NAVSARI AGRICULTURAL UNIVERSITY

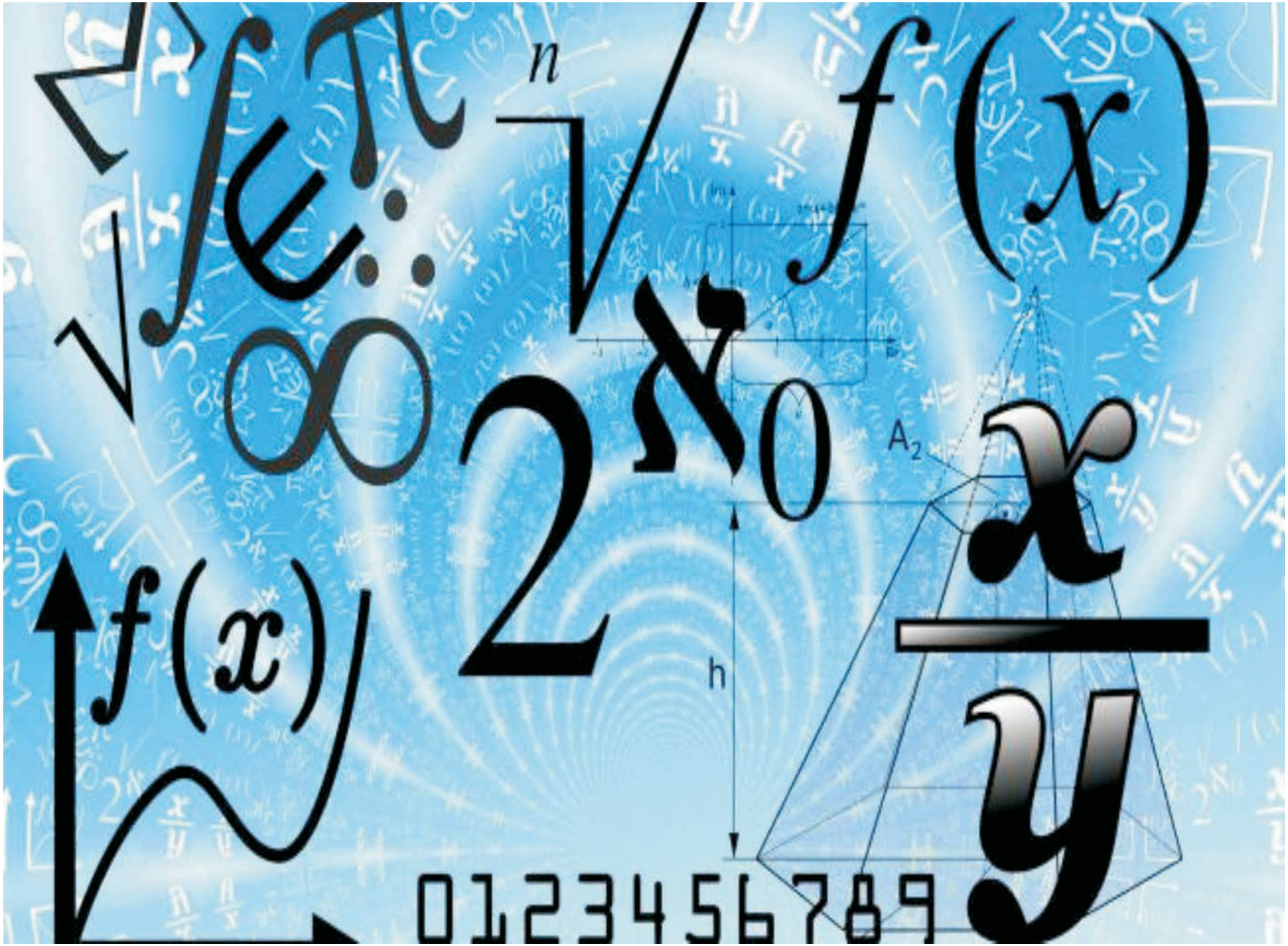
COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

Phone No. : 02631 - 246688
Fax No. : 02631 - 246622
Email : zprin@nau.in, caw@nau.in

FOREWORD

January, 2019

(Z. P. Patel)


$\sqrt{\pi}$
$\sqrt[n]{f(x)}$
∞
$2^{\aleph_0}$
A_2
$\frac{x}{y}$
$f(x)$
h
0123456789

CERTIFICATE

University Seat no.:……

Registration no.:……..

This is to certify that the tutorial work has been satisfactorily carried out by Mr. / Ms. _____ in the course no. Maths 1.1 title Elementary mathematics (2+0) of first semester B.Sc. (Hons.) Agri., college of Agriculture, Navsari Agricultural University, waghai (Dangs) during the academic year- _____.

Course Teacher

INDEX

Sr. No.	Title of topic	Date of Assignment	Date of Submission	Sign.
01	Functions			
02	Limits			
03	Continuity			
04	Differentiation			
05	Integration			
06	Determinants			
07	Matrices			

FUNCTION

[1] If $f(x) = x^3 + 3$, then find the value of $f(3), f(0), f(-2)$ and $f(\sqrt{3})$.

[2] If $f(x) = x^2 - 3x + 2$, then for what values of x, $f(x)$ is equal to zero?

[3] If $f(x) = x^2 - x + 1$, then find the value of $f(x - 1)$ and $f(x + 1)$.

[4] If $f(x) = \sin x$, then find the value of $\frac{f(x+h)-f(x)}{h}$.

[5] If $f(x) = \frac{x^2}{1+x^2}$ then prove that $\frac{f\left(\frac{p}{q}\right)}{f\left(\frac{q}{p}\right)} = \frac{p^2}{q^2}$

LIMIT

[1] Find the limits of the function: $\frac{(x+h)^2-x^2}{h}$, when $h \to 0$ [2017-18] (3 –Marks)

[2] Find the value of $\lim_{x\to\infty} \frac{x^2+3x+4}{3x^2+5x+7}$

[3] Find the limit of $\frac{3x^2-4x+1}{x^2-4x+3}$ at $x = 1$.

[4] Find the limit of $\frac{x^2-10x+25}{x-5}$, when $x \to 5$

[5] ***Find the value of*** $\lim_{x\to\infty} \frac{2x^2+1}{6+x-3x^2}$ [2018-19] (3 marks)

[6] Find the value of $\lim_{x\to-4} \left(\frac{2x}{x+4} + \frac{8}{x+4}\right)$

[7] ***Find the value of*** $\lim_{x \to 1} \frac{3x^2+x-4}{2x^2-3x+1}$ [2017-18] (3 marks)

[8] Evaluate : $\lim_{x \to 1} \frac{x^2-1}{x-1}$

[9] Write down properties of the Limits.

CONTINUITY

[1] Is the function, $f(x) = \begin{cases} -x^3 + x + 1, & x \leq 1 \\ 2x^2 + 3x - 2, & x > 1 \end{cases}$ continuous at $x = 1$?

[2] Find the value of the constant k, that make the function continuous,

$$f(x) = \begin{cases} x^2, & x \leq 5 \\ x + k, & x > 5 \end{cases}$$

[3] Check whether given function is continuous or discontinues at given points,

$$f(x) = \begin{cases} 1 - 3x, & x < -6 \\ 7, & x = -6 \\ x^3, & -6 < x < 1 \\ 1, & x = 1 \\ 2 - x, & x > 1 \end{cases}$$

(a) $x = -6$ (b) $x = 1$

[4] Let

$$f(x) = \begin{cases} x^2 + 2, & x < 0 \\ ax + b, & 0 \leq x < 1 \\ 3 + 2x - x^2, & x \geq 1 \end{cases}$$

Determine a and b so that the function $f(x)$ is continuous everywhere.

[5] Discuss the continuity of given function at $x = 2$ [2017-18] (3 marks)

$$f(x) = \begin{cases} \dfrac{x^2 - 4}{x - 2}, & \text{at } x \neq 2 \\ 4, & \text{at } x = 2 \end{cases}$$

[6] Discuss the continuity of given function at $x = -4$ [2018-19] (3 marks)

$$f(x) = \begin{cases} \dfrac{x^2 - 16}{x + 4}, & \text{at } x \neq 4 \\ -8, & \text{at } x = -4 \end{cases}$$

[7] If

$$f(x) = \begin{cases} 1, & \text{at } x < 2 \\ ax + b, & \text{at } 2 \leq x < 4 \\ 5, & \text{at } x \geq 4 \end{cases}$$

[2018-19]
(3 marks)

is continuous at $x = 2$ and $x = 4$ then find a & b.

DIFFERENTIATION

[1] Find derivative by using $\Delta - method$, $3x^2 + 8x + 2$.

[2] Find derivative by using $\Delta - method$, $3ax^2 + 2bx + c$.

[3] Find the derivative of the following:

i) $15x^3 - 6\sin x + 2e^x - 5\log x + 7$

ii) If $y = 3x^6$, prove that $x \cdot \frac{dy}{dx} - 6y = 0$

iii) $\frac{5x^2+6x+7}{2x^2+3x+4}$

iv) $e^x \cdot \sin 2x$

[4] Find the maximum and minimum value of the function [2017-18]
(3 Marks)

$$x^3 - 6x^2 + 9x + 2$$

[5] A tank is to be constructed with a square horizontal base and rectangular vertical sides. There is no top. The tank must hold $4\ m^3$ of water. The material of which the tank is to be constructed costs $Rs.10 / m^2$. What dimensions for the tank minimize the cost of material?

[6] During the course of an epidemic, the number of people infected at time t is given by

$$N = f(t) = A \cdot t^{\frac{5}{2}} \cdot e^{-t}$$

Where, t is measured in weeks from the start of the epidemic, and A is positive constant. Find the value of t at which the number of infected people is a maximum, and find also the maximum value of N.

[7] A farmer has 200 yards of fencing with which he wish to enclose a rectangular field. One side of the field can make use of a fence that already exist. What is the maximum area he can enclose?

[8] A farmer wishes to enclose a rectangular paddock using only 100 yd of fencing. What is the largest area he can enclose?

[9] A forest company plans to log a certain area of fir trees after a given number of years. The average number of board feet obtained per tree over the given period is known to be equal to $(50 - 0.5\,x)$, where x is the number of trees per acre and x lies between 35 and 80. What density of trees should be maintained in order to maximize the amount of timber per acre?

INTEGRATION

[1] Evaluate following Integration.

i) $\int x^2 \cdot sinx \ dx$

ii) $\int e^x \cdot x \ dx$

iii) $\int \frac{dx}{1-\sin x}$

iv) $\int x^3 \cdot \log x \ dx$

v) $\int \frac{xe^x}{(x+1)^2} \ dx$

vi) $\int_a^b x^{\frac{3}{2}}\,dx$

vii) $\int_0^{\frac{\pi}{4}} \tan^2 x\,dx$

viii) $\int_0^1 \frac{1-x}{1+x}\,dx$

ix) $\int_0^{\frac{\pi}{2}} (3\cos x - 4\sin x)\,dx$

x) $\int_0^1 x^2 \cdot e^x\,dx$

[2] Find the area of the region bounded by the curve $y = sinx$, x axis and the ordinates $x = 0, x = 2\pi$

[3] Find the area bounded by the curve $y = e^x$, x axis and the ordinates $x = 0, x = c$

[4] Find the area under the curve $y = x^2 + 1$ between $x = 0,$ and $x = 4.$

DETERMINANTS

[1] Prove that… $\begin{vmatrix} 1 & 1 & 1 \\ 1 & 1+a & 1 \\ 1 & 1 & 1+b \end{vmatrix} = ab$

[2] Evaluate… $\begin{vmatrix} 2 & -3 & 0 \\ 1 & 4 & -5 \\ 3 & 1 & 2 \end{vmatrix}$

[3] Evaluate.... $\begin{vmatrix} \sin x & \cos x \\ -\cos x & \sin x \end{vmatrix}$

[4] Evaluate.... $\begin{vmatrix} 1 & xy & yz+zx \\ 1 & yz & xy+zx \\ 1 & xz & xy+yz \end{vmatrix}$

[5] Prove that.... $\begin{vmatrix} x & x^2 & x^3 \\ y & y^2 & y^3 \\ z & z^2 & z^3 \end{vmatrix} = xyz(x-y)(y-z)(z-x)$

MATRICES

[1] Is the addition of following matrices possible? Give reasons.

i) $\begin{bmatrix} 1 & -3 \\ 2 & 5 \end{bmatrix}$ and $\begin{bmatrix} 1 & 0 \\ 6 & 5 \end{bmatrix}$

ii) $\begin{bmatrix} 3 & 2 & -1 \\ 0 & 4 & 6 \end{bmatrix}$ and $\begin{bmatrix} 2 & 7 \\ 1 & 3 \\ 0 & 5 \end{bmatrix}$

[2] If $A = \begin{bmatrix} 1 & 2 & -3 \\ 5 & 0 & 2 \\ 1 & -1 & 1 \end{bmatrix}, B = \begin{bmatrix} 3 & -1 & 2 \\ 4 & 2 & 5 \\ 2 & 0 & 3 \end{bmatrix}$ and $C = \begin{bmatrix} 4 & 1 & 2 \\ 0 & 3 & 3 \\ 1 & -2 & 3 \end{bmatrix}$
then find,

$A + 2B - C.$

[3] If $A = \begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$, find B such that $A^2 + 2A + B = 0.$

[4] If $A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$, $B = \begin{bmatrix} 3 & 1 \\ 4 & 5 \end{bmatrix}$ and $C = \begin{bmatrix} 1 & 1 \\ 2 & 2 \end{bmatrix}$ then prove that,

$$A(B + C) = AB + AC$$

[5] If $A = \begin{bmatrix} 1 & 1 & -1 \\ 2 & -3 & 4 \\ 3 & -2 & 3 \end{bmatrix}, B = \begin{bmatrix} -1 & -2 & -1 \\ 6 & 12 & 6 \\ 5 & 10 & 5 \end{bmatrix}$ $and\ C = \begin{bmatrix} -1 & -1 & 1 \\ 2 & 2 & -2 \\ -3 & -3 & 3 \end{bmatrix}$
Then prove that, AB and CA are null matrices.

[6] Given $A = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$, $B = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$, prove that...$A^2 = B^2 = I$

[7] If $A = \begin{bmatrix} 1 & 2 & -1 \\ 3 & 0 & 2 \\ 4 & 5 & 0 \end{bmatrix}$ and $B = \begin{bmatrix} 1 & 0 & 0 \\ 2 & 1 & 0 \\ 0 & 1 & 3 \end{bmatrix}$ then prove that $(AB)' = B'A'$

[8] If $= \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}, B = \begin{bmatrix} b+c & c-a & b-a \\ c-b & c+a & a-b \\ b-c & a-c & a+b \end{bmatrix}$ show that ABA^{-1} is a diagonal matrix.

[9] Find Inverse of $A = \begin{bmatrix} 0 & 1 & 2 \\ 1 & 2 & 3 \\ 3 & 1 & 1 \end{bmatrix}$.

[10] Two different crops X and Y requires the nutrients per acre for two different farms of 5 acre and 8 acre as follows

$$\begin{array}{llll} X- & N\ 70\ kg & P\ 35\ kg & K\ 40\ kg \\ Y- & N\ 60kg & P\ 25\ kg & K\ 20\ kg \end{array}$$

Calculate the total requirement of nutrients for each of the two farms using matrices.

TRIGNOMETRY

$$\sin 2\theta = 2\sin\theta\cos\theta$$

$$\cos 2\theta = \cos^2\theta - \sin^2\theta$$
$$= 2\cos^2\theta - 1$$
$$= 1 - 2\sin^2\theta$$

$$\sin^2\theta = \frac{1-\cos 2\theta}{2}$$

$$\cos^2\theta = \frac{1+\cos 2\theta}{2}$$

$$\sin 2\theta = \frac{2\tan\theta}{1+\tan^2\theta}$$

$$\cos 2\theta = \frac{1-\tan^2\theta}{1+\tan^2\theta}$$

$$\tan 2\theta = \frac{2\tan\theta}{1-\tan^2\theta}$$

$$\sin 3\theta = 3\sin\theta - 4\sin^3\theta$$

$$\tan 3\theta = \frac{3\tan\theta-\tan^3\theta}{1-3\tan^2\theta}$$

$$\tan(A+B) = \frac{\tan A+\tan B}{1-\tan A\tan B}$$

$$\tan(A-B) = \frac{\tan A-\tan B}{1+\tan A\tan B}$$

$$\cot(A+B) = \frac{\cot A\cot B-1}{\cot B+\cot A}$$

$$\cot(A-B) = \frac{\cot A\cot B+1}{\cot B-\cot A}$$

$$\sin A+\sin B = 2\sin\frac{A+B}{2}\cos\frac{A-B}{2}$$

$$\sin A-\sin B = 2\cos\frac{A+B}{2}\sin\frac{A-B}{2}$$

$$\cos A+\cos B = 2\cos\frac{A+B}{2}\cos\frac{A-B}{2}$$

$$\cos A-\cos B = -2\sin\frac{A+B}{2}\sin\frac{A-B}{2}$$

BINOMIAL THEOREM

If n ne a positive integer and a is any number, then

$$(x+a)^n$$
$$= \binom{n}{0}x^n + \binom{n}{1}x^{n-1}\cdot a + \binom{n}{2}x^{n-2}\cdot a^2$$
$$+ \cdots\cdots\cdots\cdots\cdots + \binom{n}{n-1}x^{n-(n-1)}\cdot a^{n-1}$$
$$+ \binom{n}{n}a^n$$

INTEGRATION

$$\int x^n\,dx = \frac{x^{n+1}}{n+1}$$

$$\int \frac{1}{x}dx = \log x$$

$$\int e^x\,dx = e^x$$

$$\int a^x\,dx = \frac{a^x}{\log a}$$

$$\int \sin x\,dx = -\cos x$$

$$\int \cos x\,dx = \sin x$$

$$\int \sec^2 x\,dx = \tan x$$

$$\int cosec^2 x\,dx = -\cot x$$

$$\int \sec x\tan x\,dx = \sec x$$

$$\int cosec\,x\cot x\,dx = -cosec\,x$$

$$\int \tan x\,dx = \log\sec x$$

$$\int \cot x\,dx = \log\sin x$$

$$\int \sec x\,dx = \log(\sec x+\tan x)$$
$$= \log\tan\left(\frac{x}{2}+\frac{\pi}{4}\right)$$

$$\int \operatorname{cosec} x\,dx = \log(\operatorname{cosec} x-\cot x)$$
$$= \log\tan\left(\frac{x}{2}\right)$$

DIFFERENTIATION

y	$\frac{dy}{dx}$
c, where c = constant	0
x^n	x^{n-1}
x	1
$\log x$	$\frac{1}{x}$
e^x	e^x
a^x	$a^x\log a$
$\sin x$	$\cos x$
$\cos x$	$-\sin x$
$\tan x$	$\sec^2 x$
$cosec\,x$	$-cosec\,x\cot x$
$\sec x$	$\sec x\tan x$
$\cot x$	$-cosec^2 x$

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI-394 730

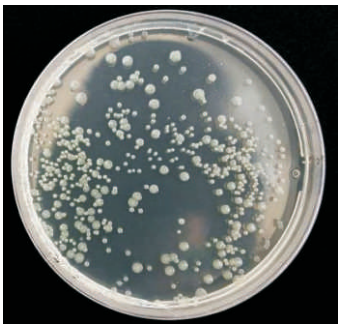
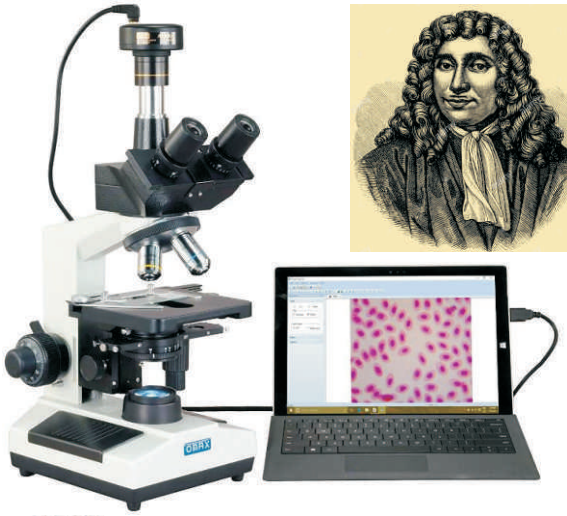
NAVSARI AGRICULTURAL UNIVERSITY

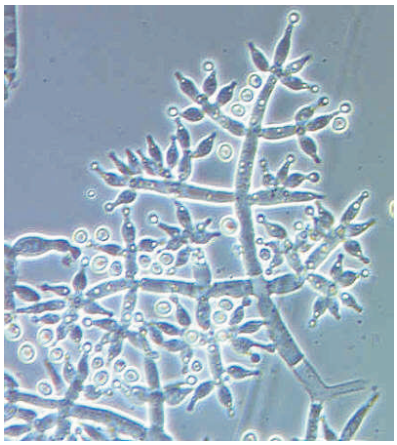
PRACTICAL MANUAL

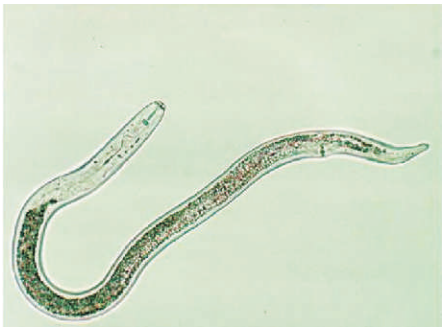
Pl. Path. 1.1 (2 + 1)

Fundamentals of Plant Pathology

First Semester B.Sc. (Hons.) Agriculture




:: PREPARED BY ::

Dr. Amol J. Deshmukh
Assistant Professor

Dr. Pushpendra Singh
Associate Professor

Prof. R. P. Bambharolia
Assistant Professor

College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

Autoclave

Centrifuge

Hot air oven

Incubator

Laminar air flow

Refrigerator

Shaker

Simple micrscope

Weighing balance

PRACTICAL MANUAL

Pl. Path. 1.1 (2 + 1)
Fundamentals of Plant Pathology

First Semester B.Sc. (Hons.) Agriculture

कृषिमूला ऋद्धिः

NAVSARI AGRICULTURAL UNIVERSITY

:: PREPARED BY ::

Dr. Amol J. Deshmukh
Assistant Professor

Dr. Pushpendra Singh
Associate Professor

Prof. R. P. Bambharolia
Assistant Professor

College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

Publication year:
March-2020

Copies:
300

Publisher:
Professor and Head
Department of Plant Pathology
College of Agriculture
Navsari Agricultural University
Waghai (Dangs)- 394 730 Gujarat
Phone: 02631- 246688
Fax:02631-246622

Printed at:
Asian Printery
Near Talati hall, Raipur Darwaja, Raipur, Ahmedabad
Phone: 079-22148826, Email:asianprintery@yahoo.com

Dr. J. J. Pastagia
Principal

COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI- 394 730, Dist- Dangs

NAVSARI AGRICULTURAL UNIVERSITY

Phone No. 02631 - 246688
Fax No. 02631 - 246622
caw@nau.in

:: FOREWORD ::

It gives me great pleasure to write the foreword of the Laboratory Manual of "Fundamentals of Plant Pathology" prepared by Dr. Amol J. Deshmukh, Dr. Pushpendra Singh and Prof. R. P. Bambharolia of the Department of Plant Pathology. As a matter of fact, I have always been of view and opinion that the students must get a laboratory guide where what to do, how to do and finally what to get are precisely described as it would save time that is otherwise unnecessarily wasted. This manual is being brought out of the efforts of the teachers of the Department of Plant Pathology, College of Agriculture, NAU, Wagahi (Dangs). This is one of the most unique and fundamentals practical books available for fulfilling the requirements of the undergraduate students and has been prepared as per the latest syllabus prescribed by the ICAR. However, it is equally useful for the Post-graduate students, scholars, teachers and scientists working in the basic and applied aspects of Fundamentals of Plant Pathology.

This manual entitled "Fundamentals of Plant Pathology" A Practical Manual consists exercises which are comprehensive and exhaustive in enriching the knowledgr of fundamental techniques of Plant Pathology.

I appreciate and congratulate *Dr. Amol J. Deshmukh, Dr. Pushpendra Singh* and *Prof. R. P. Bambharolia for their commendable efforts in bringing out this practical manual* for their efforts.

(J. J. Pastagia)

Preface

Plant Pathology is one of the important subjects of the life science and knowledge of its practical aspects is absolutely essential for students and the researcher. Practical manual on "**Fundamentals of Plant Pathology"** is a fundamental book which highlights and makes the readers aware of the important techniques of microbiology. This book has been especially designed keeping in view the latest syllabus prescribed by the ICAR as per the 5th dean committee recommendation for first semester undergraduate agriculture students.

However, it is equally useful for the post graduate students, research scholars, teachers and scientists working on the basic and applied aspects of microbiology. In this manual the exercises are followed by questions which will be helpful to the readers in enriching their knowledge about the subject. The genesis of this manual lies in the problem faced by the students and their teachers to carry out the practical classes, as no standard study material was available for it. Keeping in view, the authors along with the Principal (CAW, NAU, Waghai) decided to provide printed practical manual of the said course (Pl. Path. 1.1) to the students from the academic year 2020. The format of the exercises is appropriate for use as a workbook. It is hoped that this practical manual will be highly useful for the students in learning the fundamental techniques of Plant Pathology. The editors welcome suggestions from users, students as well as instructors/teachers for its future improvement.

A. J. Deshmukh
Pushpendra Singh
R. P. Bambharolia

Reg. No. : .....

Batch No.: .....

Roll No. : .....

Uni Seat No.: .....

:: CERTIFICATE ::

This is to certify that the practical exercises duly signed were performed in the subject of ***Plant Pathology, Course No. Pl.Path. 1.1 (2+1) [Fundamentals of Plant Pathology]*** *as a part and partial requirement of the Course by Mr./Ms.*_____

Roll No. _____ *of* ***First Semester*** *class during academic year 20*_____.

The numbers of practical performed were _____ *out of* _____.

Course Teacher

Professor & Head

Examiner
(Internal Exam.)

Examiner
(External Exam.)

INDEX

Exercise- 1: Laboratory equipment's and their use

1. **Autoclave/Steam sterilizer:** Moist heat sterilization is the principle of this instrument. Used mainly for the sterilization of liquid media or growth media like Potato Dextrose Agar, Nutrient Agar. Autoclaves may be either vertical or horizontal. Sterilization is generally done at 121^0C temperature /15 psi pressure for 15 minutes.
2. **Pressure cooker:** Domestic pressure cooker can also be utilized as an autoclave to sterilize media in small quantity.
3. **Hot air oven:** Hot air or dry heat sterilization is the principle of this instrument. Used mainly for sterilization of glass wares glass wares like Petri dishes; pipettes, flasks and etc. during many biological exercises. Sterilization is generally done at 180^0C temperature for 20 minutes.
4. **Laminar flow cabinet / Isolation chamber:** This instrument is also called as isolation chamber. Useful in the isolation of fungi, bacteria and other pathogens from diseased plant specimen or from the soil. Laminar flow **provides** an aseptic or micro-organism free environment for performing various activities such as pouring of sterilized media in sterilized plates, isolation and sub culturing etc. These are equipped with HEPA (High Efficiency particulate Air) filters of 0.3µ size and UV lamp to sterilize the working area and to maintain aseptic condition.
5. **Simple microscope:** First time invented by Antony van Leuwenhoek. It is a single lensed microscope. Used first time to observe the microorganisms and named it as "animalcules". Magnification is about 300X.
6. **Compound microscope:** First time invented by Robert hook. It is double lensed microscope, one is optical lens and other is objective lens. Simple light is used as a source of illumination. Magnification is about 1000X.
7. **Electron Microscope:** First time invented by **Knoll and Ruska** in 1931.**U**sed to observe the ultramicroscopic organisms such as viruses. Electrons are used as source of illumination
8. **BOD incubator:** The biological oxygen demand (BOD) incubator maintains a range of ambient temperatures required for growth and multiplication of various micro-organisms. Fungi were generally incubated at 25 ± 2^0C while bacteria were incubated at 30 ± 2^0C temperature. Useful to grow cultures of microorganisms at their ambient temperature.
9. **Centrifuge:** It is used for separation of various particles of different densities from a solution through centrifugal force. Commonly used centrifuge has speed of 3000 rpm and is generally used for routine work. Ultra centrifuge may have a speed as high as 15,000 rpm or even more.
10. **Refrigerator/Deep Freeze:** The maintenance of culture, in general, is carried out at low temperatures (0-5°C) because at lower temperature all life processes slow down and culture may be maintained without losing their identity for a longer period. Deep freeze has all specifications similar to that of refrigerator except that the temperature maintained is below 0°C. Useful for the preservation of pathogen and or microorganism cultures for a long period of time.
11. **Weighing Balance:** Weighing balances are used to weight required quantity of chemicals or materials in an experiment. Many types of balances such as single pan balance, top loading electrical balance, analytical balance, are available for weighing different ingredients required during the course of experimentation. The accuracy of weighing is determined by the sensitivity of the balances which may be as low as 0.0001g. Electrical balances are easy to handle and are more accurate and sensitive.

Uses of some glassware/ plastic ware/ small instruments generally used in plant pathological laboratory

1. Microscope	To observe organisms can't be seen by naked eyes
2. Glass slide	To prepare specimen for observing under microscope
3. Funnel	To pour liquid material in small container
4. Conical flask	To hold or put distilled water or other solution if any
5. Graduated cylinder	Used to measure a precise volume of a liquid
6. Test tube	To prepare PDA and NA slant
7. Test tube rack	To hold the test tubes
8. Pipette	Used to add small amount of liquid
9. Petridish	Discovered by Richard Petri one of the Koch's Assistant. Used mainly for culturing microorganism and also to hold specimens
10. Beaker	Used to measure and hold liquid materials
11. Thermometer	To measure temperature
12. Morter and pastle	Used to grind chemical or other materials
13. Bunsen burner	Used for heating and sterilizing small things like scalpel, wire loop etc
14. Nichrome wire loop	Used to transfer loopful culture to a Petridish
15. Dropper	Used for adding small amount of liquid
16. Dissecting scissor	To cut tissue during isolation or dissection
17. Forcep	Used to grasp small objects
18. Needle	It is useful during dissection, isolation, inoculation etc
19. Test tube brush	To clean test tubes
20. Safety goggle	Used for eye protection
21. Digital balance	Used to weight chemicals and other such materials
22. Scalpel	Used to cut during dissection
23. Coverslip	Used to cover culture on the glass slide
24. Hot plate	Used to heat materials
25. Stirring rod	Used for stirring and mixed liquids and or solid materials
26. Watch glass	Used to hold solids while they are being weighed or used to cover a beaker
27. Wash bottle	Used to rinse pieces of glassware and to add small quantities of water
28. Agar agar	Used as solidifying agent extracted from red algae. Discovered by Hesse one of the Koch's Assistant.

Q.1 Fill in the blanks:

1. _____ has invented first simple microscope.
2. Compound microscope was invented by_____.
3. _____ is a source of illumination in compound microscope while _____ is the sources of illumination in electron microscope.
4. Ultramicroscopic organisms such as viruses are observed under _____ microscope.

5. _____ are used to weight required quantity of chemicals or materials in an experiment.
6. Electron microscope was developed by _____.
7. Deep freeze maintains temperature below _____ ^{0}C.
8. Wet/ moist heat sterilization is the principle of _____ and _____ .
9. Dry heat sterilization is the principle of _____ .
10. In an autoclave growth media are generally sterilized at _____ C temperature for _____ minutes.
11. In a hot air oven glass are generally sterilized at _____ C temperature for _____ minutes.
12. HEPA stands for _____.

Q.2 Match the pairs:

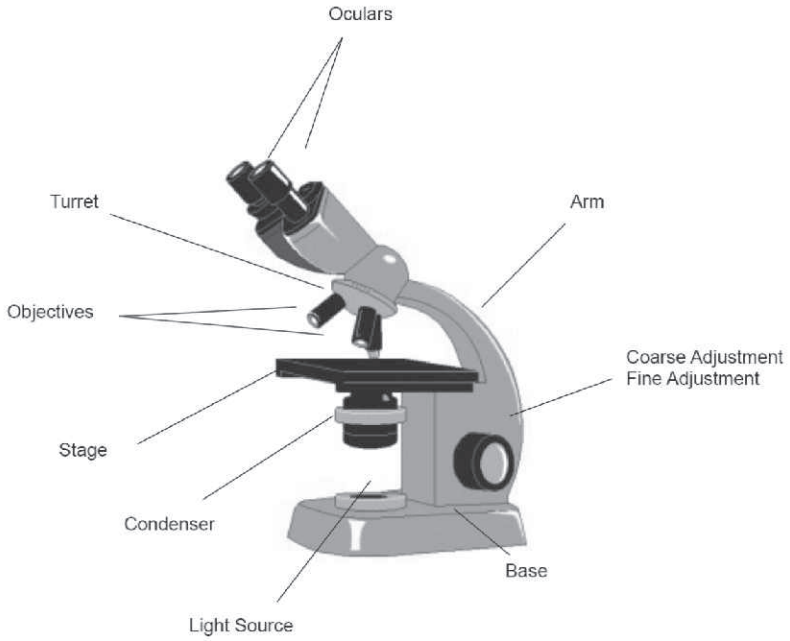
Instrument	Answer	Use
1. Autoclave		A. Isolation of plant pathogen or microbes
2. Hot air oven		B. Separate different density particles from a solution
3. Laminar air flow		C. Preserve cultures of microorganisms
4. Incubator		D. Culture media sterilization
5. Centrifuge		E. Glass ware sterilization

Q.3 Enlist out different glass wares, plastic wares to be used in plant pathological laboratory with their use

Exercise-2: Microscopy

Microorganisms are the organisms which can't be seen by naked eyes. Microscope is an optical instrument used to visualize the microorganisms. Microscopes used in Plant Pathological laboratories are compound light microscopes. A compound microscope consists of at least two magnifying lenses. One magnifying lens is ocular lens and another is an objective lens. Each contributes to the magnification of an object on the stage. **Total magnification of a microscope is determined by multiplying the magnification of objective lens by the magnification of ocular lens.** The turret rotates allowing the objectives to change and thus change the magnification of the microscope. An iris diaphragm below the stage should be used to control the amount of light passing through a specimen.

Distance between the specimen on the stage and the objective is known as the **working distance**. The coarse adjustment knob will cause the working distance to visibly change while the fine adjustment knob is for final, fine focusing. The ability to see things using a microscope is limited by the resolving power of the microscope. The resolving power of a microscope is the distance between two objects and these objects must be apart and still be seen as separate and distinct. For the light microscope this is approximately 0.2 µm. Objects closer together than 0.2 µm will not be distinctly seen. Increasing the magnification will not make the objects more distinct, just bigger. Each objective has the magnification of the objective written on the objective. The magnification of the ocular is also inscribed on the ocular. Low magnifications are used for examining the slide quickly. Higher magnifications allow the examination of a particular object on the slide.



When you look through the ocular you will see a lighted circle. This is known as the field of view or the field. While looking through the microscope move the iris diaphragm lever and notice how the brightness of the light changes. As you move the objectives to provide increased magnification you will look at a smaller section of the slide. Be sure you move the object you want to view into the center of the field before moving to the next objective. These microscopes are par focal. Once you have focused on an object using one objective the object will be approximately in focus on the next objective. Use of the fine focus knob will sharpen the focus. Water is generally used as a mounting medium to observe the microbes under lower magnification but above 1000 X magnification cedar wood oil is used.

Points to be consider while using microscope

1. Always use cover slip
2. Turn off the light and unplug the cord. Store the cord appropriately.
2. Use the coarse adjustment knob to obtain maximum working distance and remove the slide from the stage. Never use the coarse adjustment knob with high power.
3. Use **lens** paper to clean all the lenses starting with 4X to 100X objectives.
4. Clean any oil off of the stage using paper towels.
5. Rotate the scanning objective into place. Use the coarse adjustment knob to obtain minimum working distance.
6. Return the microscope to the appropriate storage area.

Q1. Fill in the blanks:

1. _____ are the organisms which can't be seen by naked eyes.
2. _____ is an optical instrument used to visualize the microorganisms.
3. _____ microscope consists of at least two magnifying lenses, one _____ lens and another is _____ lens.
4. **Magnification of a microscope = magnification of objective lens X magnification of ocular lens.**
5. An _____ is used to control the amount of light passing through a specimen.
6. Distance between the specimen on the stage and the objective is known as the _____.
7. Use _____ oil instead of water while observing microbes under high power objective (100X).
8. Magnification of a microscope having 10 X ocular lens and 45X objective lens is _____ X.

Q2. Calculate total magnification of compound microscope having 15 X ocular lens and 45 X objective lens

Q3. Enlist out different parts of a compound microscope with its use

Exercise-3: Preparation of common culture media

Culture media / Growth media: A growth medium or culture medium is a solid, liquid or semi-solid medium designed to support the growth of microorganisms. Potato dextrose agar (PDA) is very commonly used for isolation of fungus while Nutrient Agar (NA) is for the isolation of bacteria from diseased specimen or soil. Broth is a liquid culture medium without solidifying agent. Agar agar is generally used as a solidifying agent extracted from red algae (*Geledium* sp.) and was first time used and discovered by Hesse, one of the Koch's assistant.

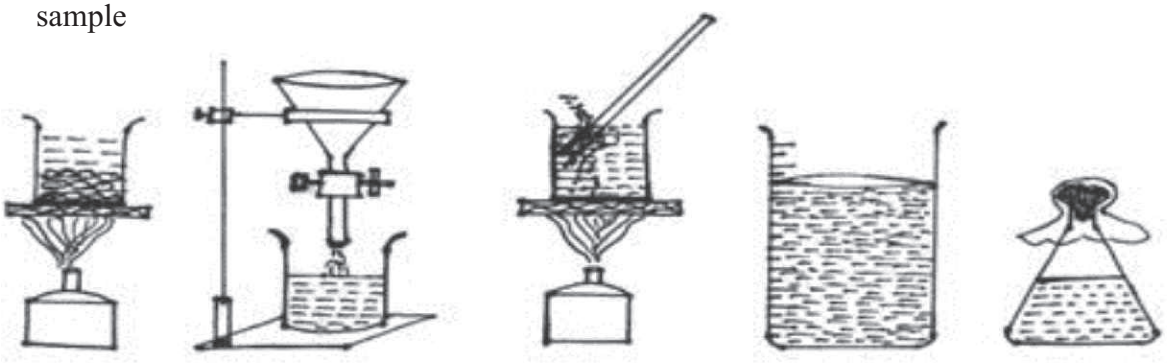
1. PDA and PDA broth

Ingredients:

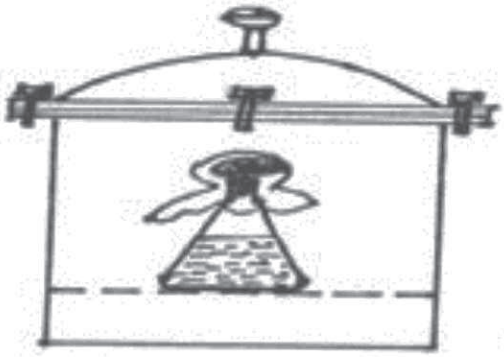
1. **PDA (Potato Dextrose Agar):** Potato: (Peeled potato) -200 g., Dextrose -20g., Agar agar-20 g., Distilled water-1000 ml
2. **PDA Broth (Potato Dextrose Broth):** Potato: (Peeled potato) -200 g., Dextrose -20g., Distilled water-1000 ml

Procedure:

- Wash 250 g potato, peel off the skin, and slice them into small pieces.
- Cook the sliced potato in 500 ml water for 30 minutes in an open vessel for 20 minutes.
- Simultaneously mix 20 g agar with 500 ml. of water and boil in a vessel for 30 minutes.
- Collect the potato extract by filter through muslin cloth or net filter.
- Add 20 g dextrose to the potato extract
- Mix thoroughly the molten agar with the potato- agar mixture and make the volume to 1 litre with distilled water.
- Check the pH of the medium using pH papers.
- Sterilize them in an autoclave or a pressure cooker at 15 lbs pressure or 121^0C temperature for 20 minutes.
- Take out the sterilized media.
- Let it cool down but not solidify (45^0 C Approx.) and use it to pour in petri plate in a laminar air flow cabinet.
- Such petriplates can be used further to isolate fungal pathogens from the infected plant sample or soil sample



Boiling potatoes **boiling agar** **Potato extract + agar+ sugar**



Sterilization

PDA media

Pouring in Petri plates

2. NA and NA broth

Ingredients:

1. **NA (Nutrient Agar):** Peptone-5g, beef extract-1.5g, NaCl- 5g, Yeast extract- 1.5g, Agar agar-20g, Distilled water-1000 ml
2. **NA Broth (Nutrient Agar Broth):** Peptone-5g, beef extract-1.5g, NaCl- 5g, Yeast extract- 1.5g, Distilled water-1000 ml

Procedure of the Nutrient agar preparation

1. Suspend the weighed quantity of ingredients in 1 litre of distilled water except agar agar.
2. Heat this mixture while stirring to fully dissolve all components.
3. Slowly add the 20g agar agar so that it does not form flakes and mix uniformly.
4. Autoclave the dissolved mixture at 121^0C for 15 minutes.
5. Once the nutrient agar has been autoclaved, allow it to cool but not solidify.
6. Pour nutrient agar into petri plate and leave plates on the sterile surface until the agar has solidified.
7. Use such plates to isolate the bacteria from infected plant specimen and soil.

Note: Procedure for the preparation of NA broth is same except need not to add agar agar

Q.1 Fill in the blanks:

1. _____ is a solid, liquid or semi-solid medium designed to support the growth of microorganisms.
2. _____ is very commonly used for isolation of fungus while _____ is commonly useful for the isolation of bacteria from diseased specimen and or soil.
3. _____ is a liquid culture medium without solidifying agent.
4. _____ gm peeled potato are generally required to prepare 1 lit PDA.
5. _____ is generally used as a solidifying agent in culture medium.
6. Agar agar was extracted from _____
7. Agar agar was extracted and used as a solidifying agent first time by _____.
8. PDA stands for _____.

9. NA stands for _____.

10. Culture media is sterilized in _____.

Q.2 Enlist out the ingredients of PDA & NA medium and broth

Exercise-4: Koch's Postulates

Koch's Postulates:

When an animate cause is isolated or identified, its pathogenicity must be proved to confirm that it is the actual cause of the disease. There are many chances that more than one organism will be found in or on the diseased organ. German scientist, **Robert Koch (1882)** proposed a set of rules to demonstrate the association of a microbe with the disease in a host, known as Koch's postulates. The procedure is integrally regarded as Pathogenecity test.

1. The pathogen must be **associated** with the examined symptoms in diseased plant part.
2. The pathogen must be **isolated** and grown in pure form
3. The pathogen must produce the similar diseased symptoms as observed earlier after **inoculation** on healthy host plant.
4. The pathogen must be **reisolated** in pure form and similar as observed earlier.

Important terms

1. **Pathogenicity**:-The capacity of the pathogen to cause the disease.
2. Isolation: Separation of plant pathogen from diseased specimen in pure form
3. **Inoculation**:-Transfer of a pathogen culture onto a susceptible host.
4. **Culture:** Growth of a pathogenic microorganism in a pure form.

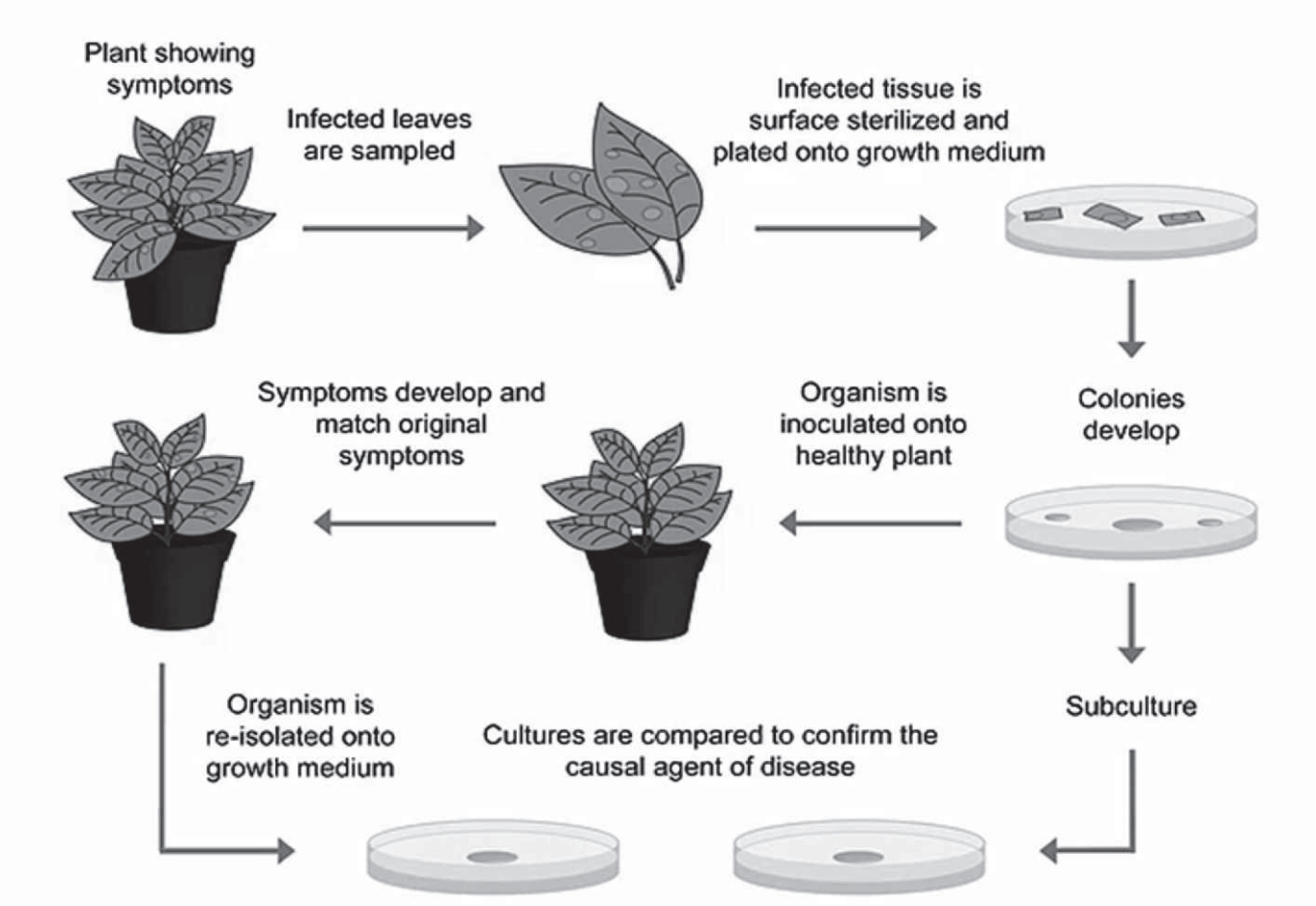


Illustration of the steps to complete Koch's Postulates to prove pathogenicity

Example for Demonstration:

BLB of Paddy (*Xanthomonascampestris*pv. *oryzae*)

Isolation:

1. The bacterial strain was isolated from BLB infected leaves from susceptible entry.
2. Nutrient Agar, a semisolid medium was used for bacterial isolation from infected rice leaves.
3. Infected leaves were cut into small pieces, which were then surface sterilized by immersing them in 70% (v/v) ethanol for 1 min followed by two washings with distilled water.
4. After that the leaf pieces were soaked in 50 ml sterile distilled water for 30 min at room temperature to allow bacteria to disperse into the surrounding liquid.
5. After 30 min the water became cloudy which indicated the presence of a high number of bacteria.
6. A loopful of the washings was streaked onto NA medium and incubated at 30°C for 48 h.
7. After 48 h several yellowish watery colonies appeared on the plate.
8. Further streaking on NA Petri plates allowed single colonies and pure cultures to be obtained.

Growth and maintenance of the bacterial culture:

1. Bacterial isolates were routinely grown on Nutrient Agar broth at 30± 2^0C.
2. Liquid cultures were shaken at 150-200 rpm in an orbital shaker.
3. Cultures for routine use were stored at 4°C in freeze.

Plant germination and growth for pathogenicity tests:

1. Rice seeds were sown in 15 cm diameter plastic pots with optimum irrigation and well sterilized soil with compost.
2. Six to eight week old rice plants were used for the pathogenicity test.

Pathogenicity tests:

1. The bacterial culture containing concentration of 10^9 cfu/ml in Nutrient agar broth is used for inoculation.

Inoculation method:

Inoculum was inoculated on five leaves of each plant examined. Leaves were inoculated by

1. **Cutting and dipping inoculation method:** Leaves were inoculated by cutting the leaf 2-3 cm from the tip and dipping the cut end into the bacterial suspension for 1 min. The bacterial suspension was replaced with sterile water in case of control. Inoculated plants were then kept in a plant growth chamber at optimum temperature and relative humidity.
2. **Cutting and pricking inoculation method:** Leaves were first cut 2 - 3 cm from the tip and then inoculated by pressing the cut end of the leaves with rats-toothed forceps that had been dipped into the bacterial suspension. This was done two to three times for each leaf and plants were then maintained in a plant growth chamber at optimum temperature and relative humidity.

Observation on symptom development: Leaf lesion length was measured from the cut surface at the tip to the distant-most position on the leaf that exhibited a gray, chloric or water-soaked lesion. Data were taken from five leaves of a plant at five-day intervals for up to 15 days after inoculation. The data was then compared with the naturally infected plant for the similar types of symptoms production on the leaves

Reisolation: Disease produced leaves were then used to do reisolation and re confirmation of the similar plant pathogen

Q.1 Draw out a well labeled diagram to prove Pathogenecity of Bacterial Leaf blight of Rice caused by *Xanthomonas oryzae*

Q.2 Fill in the blanks

1. _____ is the capacity of the pathogen to cause the disease.
2. Separation of plant pathogen from diseased specimen in pure form is called as _____
3. Transfer of a pathogen culture onto a susceptible host is called as _____.
4. Growth of a pathogenic microorganism in a pure form is called _____.
5. Pathogenecity of an organism can be proved by_____ test.
6. _____ gave rules to prove Pathogenecity.

Exercise-5: General study of different fungal structures

Fungi are microscopic, eukaryotic, multicellular, heterotrophic organism containing chitin or cellulose in their cell wamm and reproduce both sexually and asexually. Unit structure of a fungus is called hypha. Groups of hypaha (Pleural: Hyphae) can form a tangled network called a mycelium. It further leads to form body of fungus called thallus. Hyphae that have crossnwalls between the cells are called septate hyphae which are present in higher fungi. Hyphae that lack walls and cell membranes between the cells are called nonseptate or coenocytic hyphae and are present in lower fungi.

Somatic structures of fungi:

1. **Haustoria:** They are nothing but organs for absorption. It is the lateral outgrowth of intercellular or superficial hyphae which will help to absorb food and nutrients from the host. They are of different shapes and size ranging from knob like structures to simple, lobed, branched, and coiled and they are able to penetrate only in the cell wall and not in the plasma membrane.
2. **Appressoria (Apprimere to Press Against):** These are localized swellings of the tip of germ tube or older hyphae that develop in response to contact with the host. In simple these are special structures for attachment in the early stage of infection. Form these a minute infection peg usually grows and enters the epidermal cell of the host.

Types of fungal thallus

1. Homothallic Fungi: If male and female sex organs or both the gametes are produced on the same thallus, they are self-fertile or self-compatible. Eg. Powdery mildew of mung *Sapharotheca fulginae*.
2. Heterothallic Fungi: If male and female sex organs or both the gametes are produced on the different thallus, they are self-sterile or self-incompatible. Eg. Rust Fungi.

Fungal Tissue

1. **Plectenchyma :** During certain stages of fungal development, the mycelium becomes organized into loosely or compact woven tissues, as against the loose hyphae ordinarily found in the mycelium. The organized fungal tissues are called Plectenchyma.

The Plectenchyma is of two Types:

a. **Prosenchyma:** The lossely woven tissue which are closely packed, in the form of more or less parallel to one another is called Prosenchyma.

b. **Pseudoparenchyma:** The fungal tissues which are closely packed, in the form of more or less isodiametric or oval cells resembling the parenchyma cells of higher plants are celled Pseudoparenchyma.

Modification of Mycelium or Thallus

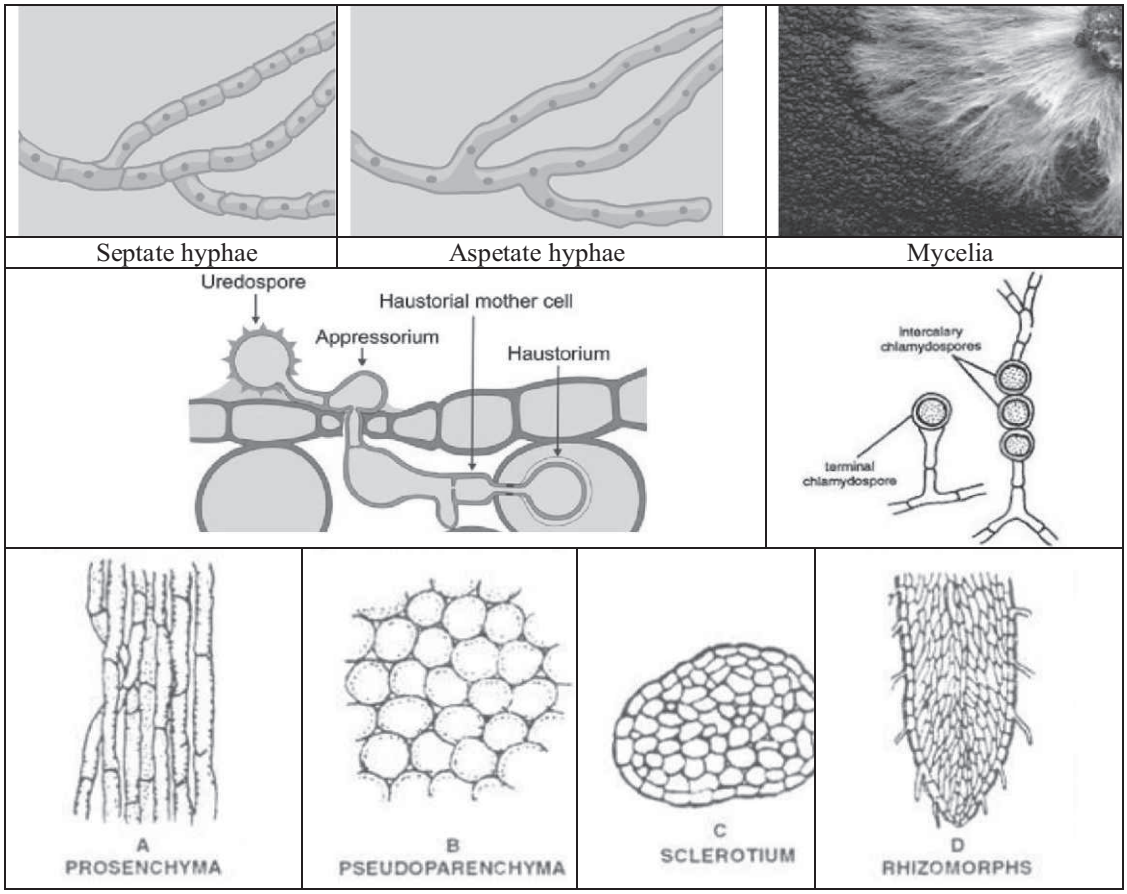
Rhizomorphs: Rhizomorphs are thick stands of mycelium which aggregated longitudinally in varying degrees of complexity in such way to form complex tissue in which hyphae losses their individualitly. Hyphal thread can't be distinguished. They can grow in soil as well as trees trunks. They can withstand unfavourable conditions. They belongs to subdivision Basidiomycotina. E.g. *Armillaria* sp.

Stroma or Stromata: It is a compact mass of the hyphae and appears as pseudoparenchymatous tissue and contains fruiting body of the fungus. Eg. Bajara ergot

Sclerotium: Sclerotium is the modified form of vegetative mycelium, which forms compact mass of the hyphae, becomes hard and acts as resting body which is resistant to unfavourable conditions. It may remain dormant for long periods and germinate under favourable conditions.E.g. *Sclerotium* spp.

Dormant Mycelium: It is the mycelium which hibernates in the host tissue to tide over unfavourable conditions, it remains in a dormant condition for a part of its life cycle and come up into activity when conditions are favourable. Eg. Downey Mildew of Grape, Loose smut of wheat, Koleroga of Arecanut.

Gemmae: These are the chlamydospores produced in lower fungi whose walls are thinner. They occur either singly or in chains and become separated after maturing. Gemmae break free from the mycelium and disperse in water. E.g. Mucorsp, *Saprolegnia* sp.



Q.1 Fill in the blanks

1. Unit structure of a fungus is called _____.
2. Body of fungus is called _____.
3. Septate hyphae are present in _____ fungi
4. Nonseptate or coenocytic hyphae are present in_____ fungi
5. Organ useful for absorption of foods and nutrients from host tissue in fungi is called as _____ _____.
6. Localized swellings of germ tube tip or older hyphae of fungi to form a special structures for attachment with the host cell is called_____
7. In homothallic fungi male and female sex organs are produced on the _____ thallus
8. In heterothallic fungi male and female sex organs are produced on the _____ thallus

Q.2 Draw out figures of: septate hypha, asepate hypha, sclerotia, mycelia, hausteria and appresoria

Exercise-6: Gram's Staining

Gram staining is a technique developed by Danish bacteriologist Hans Christian Gram to distinguish and classify bacterial species into two large groups (gram-positive and gram-negative) by the chemical and physical properties of their cell walls especially by detecting peptidoglycan present in bacterial cell wall. Bacteria having high amount of peptidoglycan retain violet colour of Gram's primary stain crystal violet and thus regarded as Gram-positive. Other group of bacteria also contain peptidoglycan, but in very small amount and is dissolved when the alcohol is added in staining procedure. It will decolorize the cell as the small quantity of peptidoglycon passed out and retain red colour of counter stain safranin and thus regarded as Gram negative.

Smear: Thin layer of bacterial cell colony on the glass slide

Material used: Primary stain: crystal violet, counter stain: safranin, decolorizer: alcohol, mordant: iodine

Procedure

1. Place a drop of distilled water on a slide, transfer A loopful culture from an isolated bacterial colony to the drop of water to form a smear.
2. Heat fix the smear by passing it through flame.
3. Place the slide on the staining rack and flood with crystal violet for 1 minute.
4. Rinse the slide with distilled water, tilting the slide slightly to rinse all the stain from the slide.
5. Place the slide on the staining rack and flood with Gram's iodine for 1 minute.
6. Rinse the slide with water as in step 4.
7. With the slide tilted, slowly drop alcohol decolorizer on the slide. Blue color will run from the smear. Continue to apply decolorizer drop-by-drop until the blue stops running from the smear. This should take approximately 15 seconds.Immediately rinse with water.
8. With the slide slightly tilted add safranin to the slide to replace the rinsed water then lay the slide flat and flood the slide with safranin for 30 seconds.
9. Rinse safranin from the slide with distilled water. Gently tap the slide to remove excess water.
10. Place a piece of bibulous paper or paper towel on the lab table and put the slide on it. Fold the paper over the slide and gently blot the slide to remove the water.
11. If the slide is still damp place a coverslip on it. Otherwise, place a drop of water on the slide and place a coverslip on top.
12. Examine the stained smear with the microscope and record your results. If it shows violet colored colony the bacterium is Gram +ve and if it shoes red color the bacterium in Gram –ve.

Q1-Fill in the blanks:

1. Gram staining is a technique developed by _____ to distinguish and classify bacterial species.
2. Bacteria having high amount of peptidoglycan retain violet colour of Gram's primary stain crystal violet and thus regarded as _____.
3. Bacteria having lower amount of peptidoglycan retain red colour of Gram's counter stain safranin and thus regarded as _____.
4. Thin layer of bacterial cell colony on the glass slide is called as _____.
5. Decolorizer used in gram staining is _____.
6. Mordant used in gram staining is _____

Few seeds plants are parasitic on living plants called as phanerogamic plant Parasites. Phanerogamic parasites are depend physiologically for its existence on host plants while epiphytes are plants which take support or protection from host plant and not classed as parasites.eg. Tropical orchards.

Phanerogamic parasites			
Complete		**Partial**	
Stem	**Root**	**Stem**	**Root**
Dodder (*Cuscuta* spp.)	*Orobanchae* spp.	Giant mistletoe *Dendropthoae* sp. Loranthus sp./ Bunda,	Witch weed /Talop /Turfula (*striga* sp.)
Host Plants: Onion, alfalfa, lucerne, flax, clover, ornamentals.*Cassytha* spp. Citrus, Ornamentals.	**Host Plants:** Tobacco, egg plant, safflower, tomato	**Host Plants:** Mango, citrus, jack, pomegranate, neem	**Host Plants:** Mustard, cumin, sorghum, sugarcane, rice, kodomillet
General characters: No chlorophyll and no true roots	**General characters:** Root seen intertwined with host root system. 15-17 % loss	**General characters:** have chlorophyll but no roots 60-90% loss	**General characters:** Root seen intertwined with host root system
Management: 1. Prevent movement of grazing animals. 2. Selection of dodder free seed 3. Restrict flow of water from infected field 4. Destruction of parasite before seed formation 5. Crop rotation with non-host plants 6. Soil herbicides chloroprophom, DCPA, glyphosate, Dichobenil, Doneseb	**Management:** 1. Destruction of parasite before seed formation 2. Long crop rotation 3. Spray soil with 0.25 % CuSO4. 4. Fumigate soil with methyl bromide	**Management:** 1. Scrapping of parasites before seedling from the infected bunches 2. Sowing of branches sufficient low to the tumors 3. Injection of 2,4-D or CuSo4 into infected bunches. 4. Spraying of 30-40% diesel/ oil emulsion in soap water-0.005%.	**Management:** 1. Destruction of parasite before seed formation 2. Regular interculturing 3. Crop rotation with cotton-jowar- groundnut 4. Weedicides are generally used to control- 2,4-D/MCPA/atrzine/1% TCPA/Deep ploughing/Fallowing soil fumigation with methyl bromide

Q.1 Match the pairs

A. Type of plant parasite	Ans	Plant parasites
1. Complete stem parasite	( )	a. Striga
2. Complete root parasite	( )	b. Loranthus
3. Partial stem parasite	( )	c. Orobanche
4. Partial root parasite	( )	d. Dodder

Type of plant parasite	Ans	Plant parasites
1. Striga	( )	a. Tobacco, egg plant, safflower, tomato
2. Loranthus	( )	b. Mustard, cumin, sorghum, sugarcane, rice, kodomillet
3. Orobanche	( )	c. Onion, alfalfa, lucerne, flax, clover, ornamentals.Cassytha spp. Citrus, Ornamentals
4. Dodder	( )	d. Mango, citrus, jack, pomegranate, neem

Q.2 Define Phanerogamic parasite, write down its classification enlisting examples of host crop

Exercise-8: Plant virus transmission

Transmission: Means spread of viruses/pathogens from one host to another host

Modes of transmission:

1. **Seed :** The seeds are important in the spread of a few viruses of legumes, wild cucumber, tomatoes and curly top virus of sugar beet. Bennett (1969) listed 53 viruses which are transmitted by seeds of about 124 plant species. Eg: Tobacco ring spot virus in soybean, squash mosaic virus in musk melon. barley stripe mosaic virus in barley, mosaic of *Datura stramonium*, curly top virus of sugar beet.
2. **Vegetative Propagation:** It is one of the chief methods of transmission of virus diseases especially of Potato, Rose, Sugarcane, Raspberry, Strawberry, Turnips, Bulb plants, fruit trees and many ornamentals. The vegetative infected parts such as the tubers, bulbs, roots, offshoots, buds and scions which are used for propagation, will contain the virus present in the parent. Eg: Banana mosaic virus
3. **Mechanical Means:** Many mosaic viruses are transmitted mechanically from diseased plants to healthy ones by the following methods: (i) By contact of infected and healthy leaves brought about by wind. (ii) By rubbing the juice of the diseased plants over the surface of the leaves of healthy plants. (iii) By grafting infected buds on to healthy plants.(iv) Agricultural implements also play quite an important part. The knife used for cutting the seed pieces and the pruning shears will spread the disease.(v) Some viruses spread below ground by contact between the roots of diseased and healthy plants.(vi) Handling plants at planting time and in cultural operation will also help in the spread of viruses such as Sugar beet curly top virus, Cucumber mosaic virus, Potato virus (PV-X) and TMV on Tobacco and Tomato.
4. **Phanerogamic parasites:** In many cases Dodder (Cuscuta) serves as a transmitting agent and an effective bridge between the infected host and the healthy plants by establishing intimate biological contact through its haustoria. Eg: Citrus tristeza virus
5. **Soil:** Quite a number of viruses are transmitted through the soil. Common examples of soil borne viruses are potato mosaic virus, oat mosaic, wheat mosaic, etc. In all these cases the disease is contracted from the soil.
6. **Fungi:** The first proof of the fungus as a vector of plant viruses was found by Gorgon in 1958. He found that the diseased lettuce was invariably infected by a soil chytrid, Olpidium. Later he discovered that the fungus acts as a reservoir and vector of the big vein virus. The virus acquired by the fungus remains in the oospore. It latter germinates and produces the zoospores which function as infective agents and penetrate lettuce roots. Similarly tobacco necrosis virus has been reported by Teakle (1960) to enter roots of its host by the zoospores of *Olpidiumbrassicae.*
7. **Nematodes:** Animal viruses may gain access to the higher animals through the mouth and nose from dust or contaminated food. Besides infection from outside, virus may also be transmitted from cell to cell but the internal transmission need not be in the form of virus particles. Eg Grape vine fan leaf virus transmitted by *Xiphinema* sp.
8. **Insect Transmission:** Some plant and animal viruses are spread and complete particles introduced into host cells by arthropod vectors. Among the arthropods most important agents of spread of virus diseases are the insects. The insect which carries the disease is called a vector. The insect vectors which play a major role in the dissemination of plant viruses are the Aphids, Leafhoppers, Flea beetles, Scale insects, thirps and White flies. Most of the insect vectors are sucking insects. Aphids transmit more plant viruses than any other insects. Leafhoppers come next in the list. About three hundred plant virus diseases are known to have insert vectors. The insect obtains virus through its mouth parts at the time of feeding on the diseased plant. It is then inoculated in the healthy plant by means of the mouth part. Inoculation in many cases must be in a certain tissue or upon young leaves. The virus may remain active in the body of the vector for many days. Instances are however, known when infectivity is soon lost. There are also cases where a vector cannot infect a healthy plant immediately after it has fed on a diseased plant. There is delay in the development of infective power within the vector. This period of development of infectivity for the virus within the vector is called the incubation period. The duration of the incubation period varies with different viruses from a few hours to days.There also appears to be some relationship between the plant viruses and the insect vectors which transmit them. The precise nature of this relationship is still unknown. The virus disease of sugar beet known as curly leaf or curly top is spread by the leaf-hopper *Circulifer tenellus*.Other sucking insects which feed on sugar beet are

unable to transmit this virus. On the other hand peach aphid is the vector of Sugar beet mosaic virus. The leafhopper does not transmit this virus. Thrips transmit the spotted-wilt virus. All vectors of yellow group of viruses are leafhoppers and of mosaic group are aphids.

Q.1 Enlist out different modes of virus transmission with suitable examples of each

Exercise-9 : Study of various plant disease symptoms

Some important terms:

Symptom : visual expression of plant disease at the site of infection

Sign : physical evidence or presence of pathogen or its part at the site of infection (e.g., mold or fungal spores, bacterial ooze etc.)

Syndrome : Defined as or sum total of symptoms and signs exhibited by a disease at the site of infection

Types of symptoms:

1. Morphological symptoms:

a. **Necrosis-** 1. Plesionecrosis: yellowing, hydrosis, wilting 2. Holonecrosis: yellowing, hydrosis, wilting

b. **Hypoplasia & hypotrophy-** Atrophy, stunting, dwarfing, rosette, chlorosis

c. **Hyperplasia & Hypertrophy -**Wound tumors, Galls, Witches Broom, Enations

2. Histopathological symptoms:

a. Cuticle thickness, cell wall degeneration, tylose formation in xylem tissues in wilt

3. General symptoms:

a. Downy mildew, Powdery mildew, Scab, Vein clearing, Epinasty, Vein banding, Ergot, Smut, Mold, Ring spot, Stem-pitting, Sooty mold, Scorch etc.

Types of symptoms in detail:

1. Morphological symptoms: Externally detectable symptoms caused by any pathogen

A. Necrosis: Degeneration of protoplast followed by death of the tissue or organ or plant

i) **Plesionecrosis (Nearly dead):** necrotic symptoms expressed before the death of the protoplast are called plesionecrosis. E.g. yellowing, hydrosis, wilting

1. **Yellows/ yellowing:** Appearance of uniform or non-uniform yellowing of leaves due to infection.it is the result of breakdown of the chlorophyll e.g. by fungi (e.g., celery yellows), viruses (e.g., sugar beet yellows virus), bacteria (e.g., coconut lethal yellowing), protozoa (e.g., hart rot), spiroplasmas or phytoplasmas.

2. **Wilt:** A symptom characterized by loss of turgor, which results in drooping of leaves, stems, and flowers. e.g. bacterial wilt of tomato Pathological wilt: caused by pathogen-fungus, bacteria and viruses while Physiological wilt: due to water stress and high temperature

3. **Hydrosis:** appearance of water soaked trnasluscent diseased tissues whose intercellular spaces contains liquid. This type of symptoms precedes holonecroticsymptoms

ii) **Holonecrosis:** necrotic symptoms expressed after the death of the protoplast are called holonecrosis. In this the affected tissue turns brown in colour

Necrosis of the green plant parts

a. **Damping-off:** Itis the collapse and death ofseedlings due to extensivenecrosis of stem tissues before or after they emerge from thesoil (pre-emergence and postemergenc edamping-off, respectively). Caused by *Pythium*and *Rhizoctonia*

b. **Leaf spot:** A wll defined or self-limiting grey,tan or brown necrotic lesion on a leaf

c. **Shot hole:** When a necrotic tissue within aleafspot cracks and fall off, leaving smallholes in their place

d. **Blotch :** A necrotic area covered with brown fungus myceliumon leaves, shoots, and stems. Ex. Purple Blotch of garlic

Necrosis of woody parts

a. **Die back:** extensive necrosis of shootsfrom top/ tip to down ward e.g. die backof chilli/ citrus

b. **Cankers:** Necrosis of the bark tissues e.g.citrus canker

c. **Gummosis:** Oozing of gum like secretionsfrom the woody tissues: Gummosis ofstone fruits

d. **Guttation:** Exudation of water from plants,particularly along the leaf margin

Extensive necrosis

a. **Blight:** A disease characterized by rapid and extensive death (Necrosis) of plant foliage. A general term applied to any of a wide range of unrelatedplant diseases. (e.g., chestnut blight, fire blight, late blight, halo blight)

b. **Anthracnose:** Formation of discrete, dark colored, necrotic lesions on the leaves, stems, and/orfruits. Caused by fungus: *Colletotrichum* spp.

Necrosis of the storage organs

a. **Rot:** The softening, discoloration, and often decay or disintegration of a succulent plant tissue as aresult of fungal or bacterial infection. Buckeye Rot of tomato

b. **Leak:** exudation of juice from tissues with softrot is called leak. Infected apple fruit exuding droplets of fire blight bacteria

c. **Mummification:** Drying of the rotted organs resulting inshriveling and hardening like mummies. brown rot fungus (*Moniliafructicola*) causes mummification the peach fruits

B. Hyperplasia & Hypertrophy

Hyperplasia : A plant overgrowth due to increased cell division. **Hypertrophy:** A plant overgrowth due to abnormal cell enlargement.

a. **Tumor:** An uncontrolled growth of tissue or tissues

b. **Gall:** An abnormal plant structure formed in response to parasitic attack by certain microorganisms (bacteria, fungi, viruses) or insects. Galls may develop either by localized cell proliferation or increase in cell size. Crown galls on peach; *Agrobacterium tumefaciens.*

c. Enation: symptom caused by certain plant viruses in whichthere are small outgrowths on the plant. Leaves of pea (*Pisumsativum* cv. Dark Skinned Perfection) infected with Pea enation mosaic virus (PEMV)

d. Witches broom: An abnormal form of plant growth characterized by profuse outgrowth of lateralbuds to give a broom like appearance. Groundnut witches' broom

C. Hypoplasia & hypotrophy:

Hypoplasia: Plant undergrowth due to decreased cell division.Hypertrophy:Plant undergrowth due to decrease incell size.

a. **Rosette:** in this the internodes do not enlarge and leavesare clustered like petals of rose e.g. Peach rosette, groundnut rosette

b. **Albication:** Complete repression of colour caused byviruses, bacteria, fungi, and iron deficiency

c. **Mosaic :** appearance of dark green and light greenareas on leaves e.g. Tobacco mosaic

d. **Chlorosis:** failure of chlorophyll to develop fully.

2. Histological Symptoms : (can be detected through microscopic studies of the disease sample/ tissue) alsocalled Pathological anatomy orMorbid anatomy. e.g. Cuticle thickness, cell wall degeneration etc.Ex.Tylose formation in xylem vessels due to wilt

3. General disease symptoms:

a. **Downy mildew:** Formation of feathery or downy growth of fungus on lower leaves with consequent yellowing on upper surface

b. **Powdery mildew:** Formation of superficial cottony hyphal growth with spores generally on upper surface of the leaf

c. **Scab:** roughened, crust like diseased area on the surface of a plant organ (e.g., apple scab, potato scab, wheat scab).

d. **Vein clearing:** A symptom of virus-infected leaves in which veinal tissue is lighter green than that of healthy.

e. **Epinasty:** Downward curling of a leaf blade resulting from more rapid cell growth on the upper side of a petiole than on the lower side; often a hyperplastic symptom of plant disease

f. **Vein banding:** A symptom of virus-infected leaves in which tissues along the veins are darker green than other laminar tissue.

g. **Ergot:** Sclerotia that replaces the grain in a diseased inflorescence Eg: grasses and cereals infected with Clavicepspurpurea

h. **Smut:** Appearance of masses of dark, powdery, and sometimes odorous fungal spores on inflorescence e.g. stinking smut of wheat, common smut of maize.

i. **Mold:** A downy fungal growth on rotted or decaying host tissue, usually consisting of mycelium. e.g. grey mold of chickpea

j. **Ring spot:** Appearance of single or concentric rings of discoloration or necrosis, the regions between the concentric rings being green. The center of the lesion may be chlorotic or necrotic

k. **Stem-pitting:** A symptom of some viral diseases characterized by depressions on the stem of the plant. Ex. Stem pitting in apple

l. **Sooty mold:** Appearance of dark, spongy, hyphal mats on the surfaces of certain plants due to organisms that grow on honeydew.

m. **Scorch:** "Burning" of leaf margins as a result of unfavorable environmental conditions (high temperature)

Q.1 Match the pairs:

	Answers	
1. Hyperplasia		A. Plant overgrowth due to increase in cell numbers
2. Hypoplasia		B. Plant overgrowth due to increase in cell size
3. Hypertrohy		C. Plant undergrowth due to decrease in cell size
4. Hypotrophy		D. Plant undergrowth due to decrease in cell numbers

Q.2 Define the terms: symptom, sign, powdery mildew, downy mildew, smut, mosaic, ergot, canker

Exercise-10: Study of representative fungal Genera

(1) *Pythium* Pringsheim

Kingdom Protista
Sub-kingdom Mycota
Division Eumycota
Sub-division Mastigomycotina
Class Oomycetes
Order Peronosporales
Family Pythiaceae
Genus Pythium

Pythium spp. are common as soil inhabitants with long survival rates. They generally parasites on wide host range and mainly causing both pre and post-emergence damping-off; in general root rots of young plants.

(2) *Phytophthora* de Bary

Kingdom Protista
Sub-kingdom Mycota
Division Eumycota
Sub-division Mastigomycotina
Class Oomycetes
Order Peronosporales
Family Pythiaceae
Genus Phytophthora

Phytophthora is one of the most important plant pathogenic genera. Members of this genus frequently cause root rot and pre and post seedling diseases and are more often specialized and destructive plant pathogens.

(3) *Puccinia* Persoon ex Persoon

Kingdom Protista
Sub-kingdom Mycota
Division Eumycota
Sub-division Basidiomycotina
Class Teliomycetes
Order Uredinales
Family Pucciniaceae
Genus Puccinia

Puccinia spp. are causing rust diseases in many economically important crops and substantial losses in family Grammineae. This is the largest genus of rust fungi with 3-4 thousand spp

(4) ***Alternaria*** **Nees ex Fr.**

Kingdom Protista

Sub-kingdom Mycota

Division Eumycota

Sub-division Deuteromycotina

Class Hyphomycetes

Order Hyphomycetales

Family Dematiaceae

Genus Alternaria

The genus causes economically important diseases in various crops, mostly as necrotic lesions on leaves, stems and fruits.

(5) ***Pyricularia*** **Sacc.**

Kingdom Protista

Sub-kingdom Mycota

Division Eumycota

Sub-division Deuteromycotina

Class Hyphomycetes

Order Hyphomycetales

Family Dematiaceae

Genus Pyricularia

The *Pyricularia* spp. is mainly pathogenic to cereals and *P. oryzae* causes rice blast worldwide. Some species are host specific.

(5) ***Fusarium*** **Link ex Fr.**

Kingdom Protista

Sub-kingdom Mycota

Division Eumycota

Sub-division Deuteromycotina

Class Hyphomycetes

Order Tuberculariales

Family Tuberculariaceae

Genus Fusarium

The genus is commonly associated with soil-borne disease wilt in numbers of crops.

(7) ***Sclerotium*** **Sacc.**

Kingdom Protista
Sub-kingdom Mycota
Division Eumycota
Sub-division Deuteromycotina
Class Hyphomycetes
Order Agonomy cetales
Family Agonomy cetaceae
Genus Sclerotium

Sclerotium is an unspecialized parastite, a soil inhabitant and with very wide host range in warm and wet areas. Causes foot rot diseases

(8) ***Colletotrichum*** **Corda.**

Kingdom Protista
Sub-kingdom Mycota
Division Eumycota
Sub-division Deuteromycotina
Class Coelomycetes
Order Melanconiales
Family Melanconiaceae
Genus Colletotricum

The forms of *Colletotrichum* have a very wide range of behavioural patterns in nature, varying from saprophytes to specialized parasites with a narrow host range. The species generally survive for long periods on plant debris, in or on the soil.

Note: Draw out the microscopic structures of individual genus in the provided sqaure

Q.1 Enlist out any five genus we have studied and observed under microscope take the observation on write down its micro morphological features and enlist the diseases caused by them?

Exercise-11: Study of fungicides and their formulations

Fungicide: Fungicides are defined as the chemicals used to kill fungi. The word fungicide is originated from two Greek words Fungus & caedo, where Caedo means to kill.

Classification of fungicides:

I. According to mode of action:

1. **Protectant :** The fungicide, which is effective only if it is applied prior to fungal infection or inhibit the pathogen before established within the plant tissue.

   Contact fungicide – The contact chemicals kill the pathogen already established on the host surface or when it comes in contact with the host. eg. Organic mercurials, lime sulphur.

   Residual fungicide – The fungicide applied on the host plant before fungus reaches it so that they may form a protective layer over the host plant. eg. Zineb, Maneb and Mancozeb.

2. **Therapeutant :** The fungicide which is capable of eradicating a fungus after it has caused infection and thereby curing the plant is known as Therapeutant. eg. 1,4-oxathiin derivatives (i.e. Vitavax and Plantvax).

3. **Eradicant fungicide–** The fungicide, which can eradicate the pathogenic fungi from infectious area of the host around a propagating unit of fungus in which infection could possibly occur. **OR** The fungicide which can eradicate the pathogenic fungi from an infection court. eg. Lime sulphur, organic mercurials and dodine.

4. **Systemic fungicide –** The fungicide can act by entering in to the whole plant system and control the plant pathogen. eg. Plantvax (oxycarboxin), Vitavax (carboxin) and Bavistin (carbendazim).

II. According to chemical nature:

1. **Sulphur Fungicide :**
   - **(a) Organic sulphur:** – eg.thiram, ziram, ferbam, zineb, maneb, nabam, Vapam, mancozeb
   - **(b) Inorganic sulphur**: eg. Lime sulphur, wettable sulphur, powdered sulphur
2. **Copper Fungicide:** Bordeaux Mixture, Chaubbatia paste, Copper- oxychloride (Fytolan, Blue copper) etc.
3. **Mercurial Fungicide :**
   - (a) Organic:-Agrosan, Ceresan, Emisan.
   - (b) Inorganic: – $HgCl_2$
4. **Quinine Fungicide :**Chloronil and dichlone
5. **Heterocyclic nitrogenous Compound :**Captan, Captafol.
6. **Oxathiine Compound :**Vitavax, Plantvax.
7. **Benzimidazoles Compound:**Benomyl, Thiophanate methyl, thiobendazole, Carbendazim.
8. **Antibiotics :**Streptomycine, Streptocycline, Aureofungin.
9. **Miscellaneous Group :** PCNB (Pentachloronitrobenzene)

III. According to general use of fungicide:

1. **Seed Protectent –**Thiram, Captan, MEMC.
2. **Soil Fungicide –** Bordeaux Mixture, Formaldehyde
3. **Foliar Fungicide -**Dithane M -45, Callixin, Bavistin
4. **Wound dressing Fungicide –** B. Paste, C. Paste.

The characteristics of ideal fungicide:

1. High field performance
2. Good coverage of the crop
3. Good initial deposition
4. Optimum residual effect
5. Low phytotoxicity
6. Stability in storage
7. Long shelf life
8. Long stability after dilution
9. Easy to purchase 10. Easy to prepare and apply the solution
11. No operational hazards
12. Low toxicity towards animals
13. Most eco friendly
14. No side effect
15. Economical to industries as well as farmers
16. Wide adaptation among farming community

Antibiotics:

"Antibiotics are substance produced by one microorganism and toxic to another microorganism". Antibiotics have systemic action in plants moving in both direction, from leaves to roots and from roots to the foliage.

The antibiotics used in plant protection mainly belong to groups

1. **Streptomycin group:** Produced by the actinomycete *Streptomyces griseus* Eg: Agrimycin, phytomycin, Orthostreptomycin, Streptocycline etc. Agrimycin and Streptocycline are mixed preparations of Streptomycin and Tetracycline. Streptomycin was the first antibiotic used in plant disease control. It was used against fire blight of pear (*Erwiniaamylovora*) in 1953.
2. **Tetracycline group:** Produced by various species of *Streptomyces*. The group includes the antibiotics are Terramycin (Oxytetracycline), Aureomycin (Chlortetracycline) and Achromycin (Tetracycline), which have been used against plant disease control. These antibiotics are bacteriostatic and bactericidal.
3. **Cycloheximide group:** Extracted from *Streptomyces griseus* as a by-product in the production of Streptomycin. **Eg:** Actidione, Actispray. This antibiotic is antifungal used against powdery mildew of bean (5 ppm), covered smut of oats (10 ppm), powdery mildew of rose (20-100 ppm), bunt and stem rusts of wheat but cause toxicity in number of crop plants.
4. **Griseofulvin group : Extracted** from the fungus *Penicilliumgrise fulvum* and was found to be effective against powdery mildew of rose [*Sphaerothecapannosa*], powdery mildew of cucurbits [*Erysiphecichoracearum*], powdery mildew of beans [*Erysiphepolygoni*], early blight of tomato [*Alternariasolani*], brown rot of apple [*Moniliniafructigena*], Ascochyta blight of pea [*Ascochytapisi*]. However, it gives only a limited degree of control.
5. **Aureofungin group: Extracted from** the submerged cultures of *Streptomyces cinnamomens* var. *terricola*. It was developed at Hindustan Antibiotics Ltd., Pimpri (India). It is recommended for the control of rice leaf spot, rice blast, barley stripe, covered smut of barley through seed treatment and against powdery mildew, anthracnose and Downey mildew of grapes, powdery mildew of apple, leaf rust of wheat and citrus gummosis through foliar spray.
6. **Polyene group :** Pimaricin and Nystatin are other antifungal polyene antibiotics obtained from species of *Streptomyces*. They have a broad spectrum of activity but are not effective against Oomycetes.

Formulations of fungicides

Fungicides are available in the market in different forms. Efficiency of fungicide vary with formulations. These forms are broadly grouped as follows:

(1) Wettable Powder: Most fungicides are prepared as Wettable Powder. They are used as spray materials

after suspended in water. The particle of fungicide does not dissolve but because of their minute size and other physical properties, wettable powder disperses in water in such a way that they can be easily sprayed. eg. Mancozeb 75 WP, Copper oxychloride 50 WP, Bavistin 50 WP, Topsin M70 WP. Agitation is generally necessary to keep uniform suspension.

(2) Flowables, Suspension and Slurries : These are formulation in which a dry form of the active ingredient is mixed with a liquid. Such formulations usually contain a high percentage (25-75%) of active ingredient similar to wettable powders. They are mixed with water for final use and require agitation. These are mostly used as seed dressers in seed processing companies.

(3) Solutions: The solutions are formulation in which the active ingredient and solvent is dissolved in water. Solutions have the advantage of not requiring agitation after the formulation is added in water for use. Some systemic pesticides destined for soil application are in solution form.

(4) Emulsifiable Concentration (EC) : These are liquid in which the active ingredient is dissolved in a solvent. The fungicide and the solvent often not mix with water, so an emulsifying agent are added to water, so milky mixture is formed, which is a suspension of active ingredient and emulsifying solvent in water. eg. Karathane 48EC, Topsin 10EC

(5) Dusts : These formulations consist of small particles (< 30 cm diameter) of inert ingredient fungicide. The active ingredient usually accounts for 4-10% by weights of the dust, the small particles facilitate complete coverage when used as dry dust and enhance the effect of the fungicide. eg. Sulphur, Methyl Parathion 2 %. The commonly used carriers are kaolin, talc, calcium carbonate, magnesium carbonate, gypsum, lime etc.

(6) Granules : The toxicants with inert materials formed into particles about the size of coarse sugar. The percentage of active ingredient is low (3-10%). They can be measured in dry form easily and accurately than dust or wettable powders. Therefore, they are more conveniently used in furrow treatments of soil. They are systemic nematicide/fungicide/insecticide. eg. Phorate 10G, Carbofuran 3G.

Q.1 Answer the followings:

1. Write down classification of fungicide on the basis of chemical nature with suitable example

2. Enlist out different formulation of fungicides and give two example of each formulation

3. Enlist out any ten characters of an ideal fungicide

4. Write down classification of fungicide on the basis of mode of action with suitable example

5. Give short note on antibiotic:

Exercise-12: Fungicide application methods

(1) **Spraying:** Wettable fungicides or materials available in solution or emulsified form are used for spraying the plant with a view to provide a protective covering over the plant surface before the arrival of the pathogen. Many systemic fungicides are used as sprays materials. After absorbed by leaves, they dispersed in leaf tissues and can eradicate the pathogen present there. eg. Bavistin. However, most of common fungicides in extensive use are of protective in nature and non systemic. eg. Dithane M-45, Blitox 50 WP etc.

(2) **Dusting:** Insoluble or non-suspendable materials are used for dusting on foliage (leaf, stem, flower, fruits). Dry powders are used for covering host surface. Dust is an alternative to spraying. The dusting machinery / equipment is lighter and cheaper and can be used under more adverse ground condition. Requires no water and therefore, has less operational difficulties. Materials are ready to use.

(3) **Seed treatment:** Seeds, tubers, bulbs and other propagating materials are given chemical treatment for eradicating the pathogens present on or in them and for preventing the attack of soil borne pathogen after planting. Sometimes, for seed-borne diseases seed treatment is the only effective and economical method of disease control. Fungicides applied to seed may be formulated as dust, WP, solution and suspension. Most chemical used for seed treatment are protectants and disinfectants. eg. Copper, mercury (Agrosan, Ceresan, $HgCl_2$), oxathiins (Vitavax, Plantvax) compounds are used for seed treatment. The seed treatment fungicides are used as dry seed treatment, wet seed treatment, dip or slurry treatment, seedling dip/root dip/set dip. **Seed borne diseases are: (I) Internally Seed borne disease:** Systemic fungicides eg. Vitavax, Plantvax for Loose smut of wheat @ 2-3 gm/kg seed **(II) Externally Seed borne disease:** Sulphur for grain smut of sorghum @ 4 gm/kg seed

(4) **Soil treatment:** Fungicides are applied to soil which eradicate or reduce the inoculum density of soil borne plant pathogen. **(i) Drenching:** Fungicides are made up with water at about the same concentration as for spraying and can be applied before or after sowing of seed. Fungicide solution or suspension is applied to soil surface. This method is used to control damping off disease, root rot disease etc. **(ii) Furrow application: In** this method, fungicides are applied either as dusts or with water to the furrow at the time of planting. In order to reduce the cost of treatment in chemical soil treatment, the most commonly practiced method is furrow application of dusts and granules. This method is possible in crops planted in furrow such as potato and sugarcane. **(iii) Broadcasting of dust powders or granules:** Fungicide are mixed with soil or fertilizer and broadcasted on soil surface. Light ploughing is applied to mix the chemical in sufficient depth. eg. Termite **(iv) Fumigation:** Soil fumigation is usually done to control plant parasitic nematodes. The chemicals used for this purpose are usually volatile and on coming in contact with soil moisture release gases which diffuse in the soil and kill the larvae of the nematodes. Eg. Methyl bromide, carbofuran etc

(5) **Paste and Paint:** In fruit orchards, the wounds created during pruning of trees often serve as opening for entry of pathogens. To protect these wound, fungicidal pastes or paints are used as a protective layer. These pastes are prepared with fungicidal chemicals (copper sulphate and lime, copper carbonate, red lead and antibiotics etc) in a suitable carrier such as raw linseed oil, lanolin or glycerin. The residual effect of the paste lasts long enough to permit natural healing of the cut surfaces. eg. Bordeaux paste, Chaubattia paste etc.

Spraying

Dusting

Dry seed treatment

Wet seed treatment

Soil drenching

Furrow application

Broadcasting of dust powder or granules

Soil fumigation

Paste & Paint

Q.1. Answer the followings:

1. Enlist different methods of application of fungicides.

2. Differentiate between spraying and dusting.

3. Loose smut of wheat is _____ seed borne disease, whereas, grain smut of sorghum is _____ seed borne disease.

4 Enlist the various methods of soil application.

Exercise-13: Calculation of fungicide sprays concentrations

Plant disease reduces a quantity as well as quality of plant produce as a result of plant disease. There has been always a economic loss to the farmers. To overcome these economic loss, knowledge regarding important crop disease as well as their control measures for sustainable and ecofriendly crop production is required. The use of fungicide for disease control is one of the approaches of Integrated Disease Management (IDM) system. So, one should be acquainted with the various forms and formulation of different fungicides available in the market. The active ingredient present in the fungicide is responsible for the control of disease, so to take particular quantity of fungicidal product of that particular active ingredient material available in market must be calculated.

- **Active Ingredient:** The active component of a formulated product responsible for control of a pathogen is called active ingredient. eg. Mancozeb 75% WP , Carbendazim 50% WP
- **Common Name:** The name of fungicide on the basis of active ingredient is called common name.
  eg. Mancozeb ⟶ Dithane M-45
  (Common/Technical Name) (Trade Name)
- **Trade Name:** The patented name under which a product is commercially available.
- **Calculation::**

$$\textbf{Quantity of fungicide required in Kg. or Liter} = \frac{\text{Amount of spray solution to be prepared in liter} \times \text{Concentration to be prepared}}{\text{Per cent a.i. (Presently available) in market product.}}$$

Some fungicides with their common name and trade name:

Sr. No.	Common name	Trade name	Formulation available fungicide	Concentration
1.	Mancozeb	DithaneM-45 Indofil M-45	75 WP	0.2%
2.	Carbendazim	Bavistin, Agrozim, JKstin, Gujcozim	50 WP	0.025 to 0.05% -Spraying 2.0gm/kg-Seed treatment
3.	Metalaxyl MZ	Ridomil MZ	72 WP	0.2%, 2gm/kg ST
4.	Tridemorph	Calixin	80 EC	0.04%
5.	Ediphenphos	Hinosan	50 EC	0.1%
6.	Thiophanate methyl	Topsin-M,	70 WP	0.05%
7.	Hexaconazole	Contaf	5 EC	0.025 to 0.05%
8.	Penconazole	Topas	10 EC	0.025 to 0.05%
9.	Ziram	Cuman L, Zyride	75 WP	2-4gm/kg seed
10.	Benomyl	Benlate	50 WP	0.025 to 0.05%
11.	Chlorothalonil	Kavach	75 WP	0.2%
12.	Captafol	Difolatan, Foltaf	70 WP	0.2%
13.	Dinocap	Karathane	48 EC	0.04%
14.	Propiconazole	Tilt	25 EC	0.025 to 0.05%

15.	Copper oxychloride	Fytolan, Blitox, Blue copper	50 WP	0.2%
16.	Difenoconazole	Score	25 EC	0.025 to 0.05%
17.	Propineb	Antracol	70 WP	0.2%
18.	Triadimefon	Bayleton	25 WP	0.025 to 0.05%
19	Bitertanol	Bacor	25 WP	0.025 to 0.05%
20	Sulphur	Sulfex	80 WP	0.2%
21	Carboxin	Vitavax	75 WP	0.1 to 0.2%, 2gm/kg ST
22	Thiram	Thiram	75 SD	2-4 gm/kg seed
23	Fosetyle Al	Aliete	80 WP	0.15%
24	Oxycarboxin	Plantvax	75 WP	0.1 to 0.2%

Q1. Answer the followings:

1. Define active ingredient. Name two fungicides alongwith active ingredient.

2 write common names of bavistin, plantavax, vitavax, tilt and ridomil

3 Define trade name. Give the trade name of COC and Mancozeb

4 Calculate the following examples.

(1) How much quantity of Dithane M-45 is needed to prepare 1800 liter spray solution having concentration of 0.25 % mancozeb.

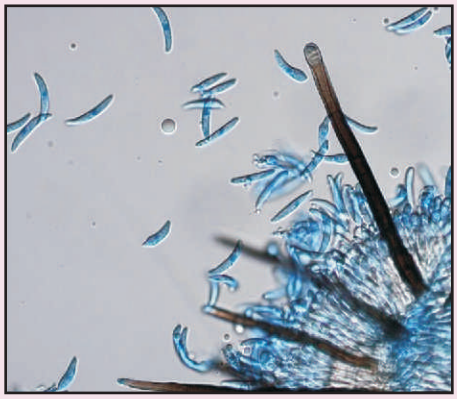
(2) How much quantity of Bavistin is needed to spray 8 ha. of groundnut crop at the rate of 600 lit. spray solution per ha. with concentration of 0.025 % carbendazim.

(3) Calculate quantity of Blue copper needed to spray 5 ha. chilli crop at the rate of 600 lit spray solution / ha. having concentration of 2500 ppm copper oxychloride.

(4) Calculate the quantity of Dithane M-45 to prepare 3000 lit. spray solution having concentration of 0.2% mancozeb.

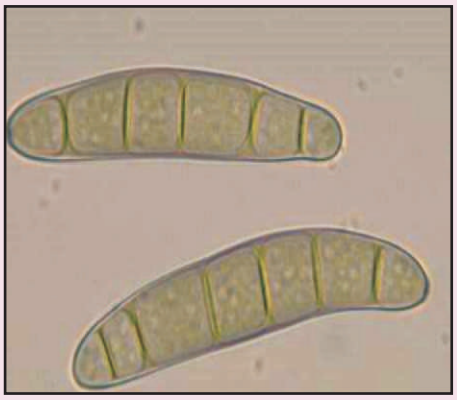
(5) Calculate the quantity of Calixin needed to spray 5 ha. of mustard crop at the rate of 450 liter spray solution/ha. having concentration of 400ppm tridemorph.

Alternaria

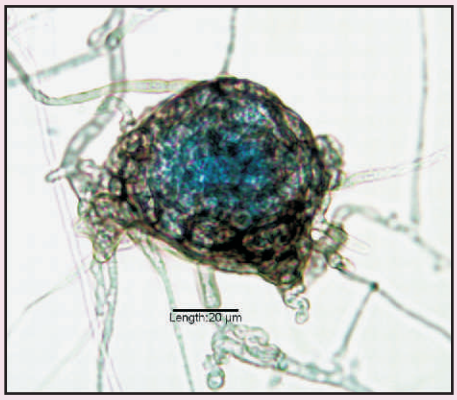


Colletotrichum

Fusarium

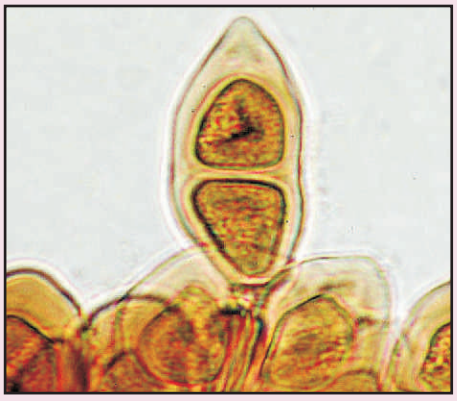


Helminthosporium



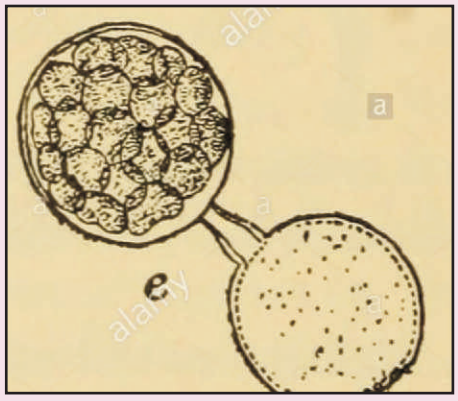
Macrophomina

Phytopthora



Puccinia Teliospore

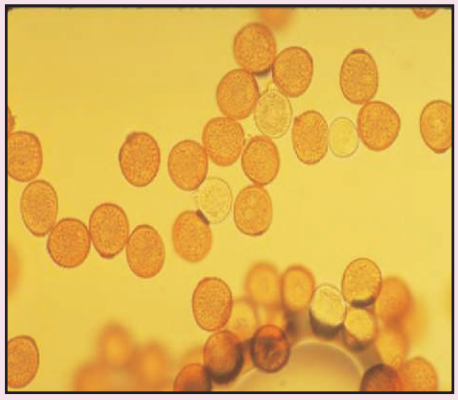
Pyricularia



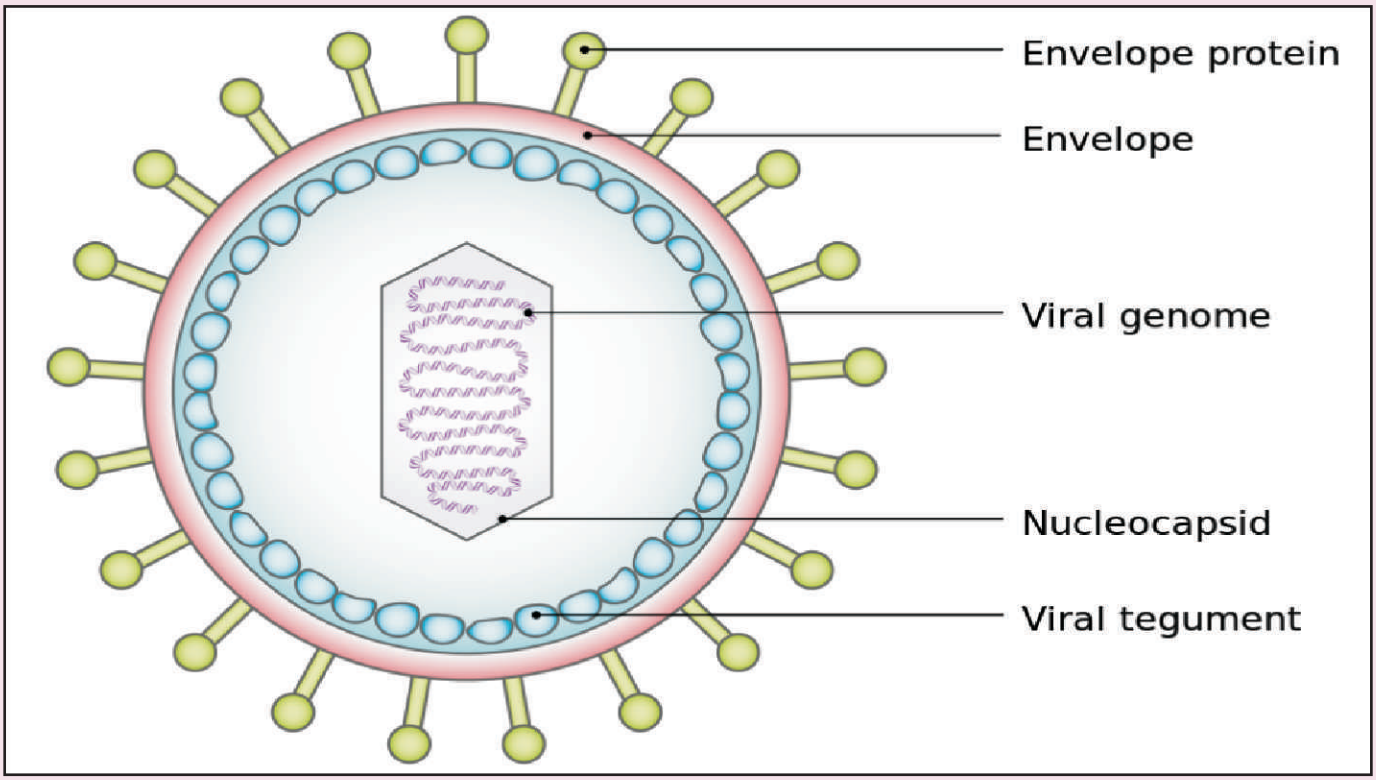
Pythium

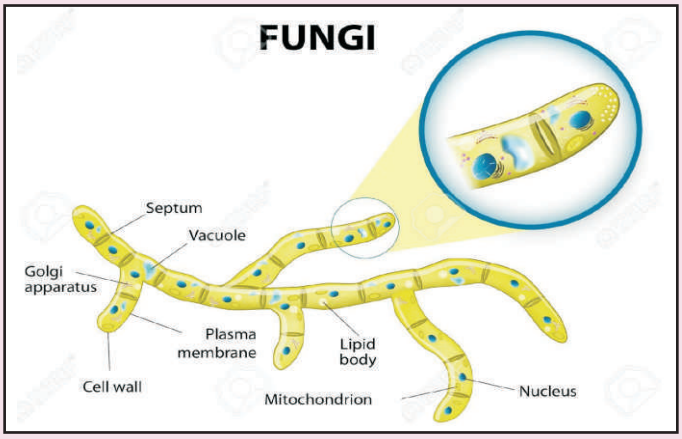
Sclerotium

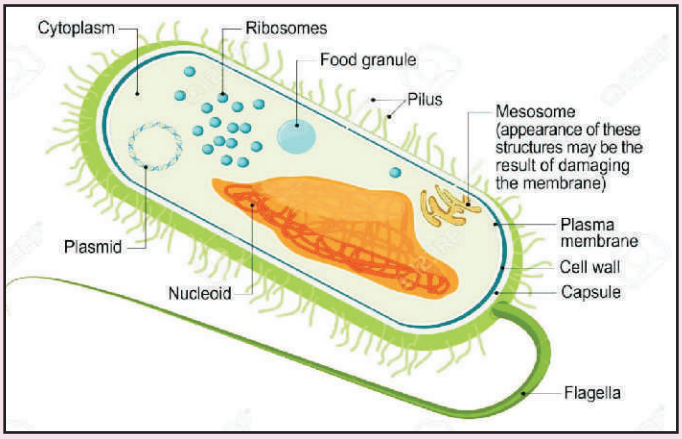
Uncinula



Urediospore


Envelope protein
Envelope
Viral genome
Nucleocapsid
Viral tegument


FUNGI
Septum
Vacuole
Golgi apparatus
Plasma membrane
Lipid body
Cell wall
Mitochondrion
Nucleus


Cytoplasm
Ribosomes
Food granule
Pilus
Mesosome (appearance of these structures may be the result of damaging the membrane)
Plasma membrane
Cell wall
Capsule
Plasmid
Nucleoid
Flagella