NAVSARI AGRICULTURAL UNIVERSITY

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

ICAR

Practical Manual

Ag. Chem. 3.3 (2 + 1)

PROBLEMATIC SOILS AND THEIR MANAGEMENT

Third Semester B.Sc. (Hons.) Agriculture

PREPARED BY

Prof. H. P. Dholariya
Assistant Professor

Dr. Navneet Kumar
Associate Professor

Prof. R. P. Bambharolia
Assistant Professor

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

EC meter

pH- meter

Spectrophotometer

Flame Photometer

AAS

N- Distillation Unit

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

कृषिमूला ऋद्धिः

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COLLEGE OF AGRICULTURE
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FOREWORD

Hon'ble Prime Minister Shri Narendra Modi issued necessary instructions for the entrepreneurship of agriculture graduates while putting emphasis on agricultural education for the upliftment of agriculture throughout the country. Keeping this in view Shri Radha Mohan Singh, Union Agriculture and Farmers Welfare Minister, suggested that a professional curriculum should be framed out on agricultural graduation level while incorporating the basic and fundamental requisites in a traditional agriculture courses. Indian Agricultural Research Council, Department of Agricultural Education and Research, Agriculture and Farmers Welfare Ministry, Government of India had constituted the 5th Dean's Committee under the Chairmanship of Dr. Ram Badan Singh, erstwhile President, Agricultural Scientist Selection Committee and Vice Chancellor, Central Agriculture University, Imphal for contemporary rescheduling of quality curriculums in the field of agriculture graduation education. Through this new curriculum all agriculture based graduation courses will be altered into the professional ones which will be conducive to earn their livelihood in future. The changes have reoriented the system to develop needed skills and entrepreneurial mindset among the graduates to take up self-employment, contribute to enhanced rural livelihood and food security, sustainability of agriculture and be propeller for agricultural transformation.

Implementation of V Dean recommendation from the year 2017-18 along with the detail distribution of courses between the semesters were approved in the 36th Academic Council meeting of NAU, held on 25th April 2017, with item note 36.05.

Soil is the foundation of terrestrial life supporting ecosystem and considering continuously growing multiple demands of fast increasing population and abruptly decreasing land to man ratio, it is essential to bring salt affected and other problem soils under plough after their proper reclamation and management. Thus present laboratory manual **"Problematic soils and their management"** is prepared to provide the complete procedures for chemical analysis of problematic soil and their management along with the assessment of quality of irrigation water as suggested in Fifth Dean Committee of ICAR.

This laboratory manual is useful not only for students of third semester of B.Sc. (Hons.) Agriculture but also for researchers, soil scientists, environmentalists and planners too. I convey my hearty congratulations to Prof. H. P. Dholariya, Dr. Navneetkumar and Prof. R. P. Bambharolia 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. 3.3,** Course Title **"Problematic Soils and Their Management" (2+1)** of third 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 **"Problematic Soils and Their Management".**

External Examiner **Course teacher**

Place :

Date :

INDEX

: Syllabus:

Course No.: Ag. Chem. 3.3
Title: Problematic Soils and Their Management
Credit Hours: (2+1) = 3

Theory:

Soil quality and health, Distribution of Waste land and problem soils in Gujarat and India. Their categorization based on properties. Reclamation and management of Saline and sodic soils, Acid soils, Acid Sulphate soils, Calcareous soil, Eroded and Compacted soils, Flooded soils, Polluted soils. Irrigation water – quality and standards, utilization of saline water in agriculture. Remote sensing and GIS in diagnosis and management of problem soils. Multipurpose tree species, bio remediation through MPTs of soils, land capability and classification, land suitability classification. Problematic soils under different Agro-climatic zones of Gujarat.

Practical:

Preparation of saturation paste and extract of problematic soil. Determination of pHs and ECe of saturation extract of problematic soil.. Estimation of water soluable and exchangeable cations in soil and computation of SAR and ESP and characterization of problematic soil. Determination of Gypsum requirement of alkali/sodic soil. Determination of lime requirement of acidic soil. Determination of Quality of irrigation water (pH, EC, Ca, Mg, Na, CO_3, HCO_3, Cl, SAR and RSC).

1 : Preparation of saturated paste and saturation extract of problematic soil

Plants growing on salt affected soils are directly influenced by the amount of salts present in soil or osmotic pressure of the soil solution. The salt concentration of soil solution varies inversely with the water content of soil at a given amount of soluble salt present in soil. The soil water available to plants vary with in field capacity and permanent wilting point and at equal soluble salt content sandy soils will have five times more salt in soil solution as compared to clayey soils at field capacity as well as at permanent wilting point. This indicated that water content of soil affects the amount of salt extracted from the soil.

The salt extraction at field capacity of water will be suitable water content. But it is very difficult for routine extractions of salt from soil at field capacity moisture content. Therefore, mixing of soil with water to make the saturation paste as suggested by United State National Resources Planning Board (1942) and adapted by U.S. Salinity Laboratory Staff (1954) was also found most suitable for extracting the salt from soil for salinity appraisal and other uses.

1. Preparation of saturation paste

Apparatus

1. Physical balance
2. Moisture Box or Plastic Beaker - 250 ml capacity
3. Spatula
4. Burette

Reagents

1. Distilled water

Procedure

1. Weight 100 g air dried and processed soil sample in a moisture box.
2. Fill the burette with distilled water
3. Add known volume of distilled water to the soil while stirring with spatula.
4. Consolidate the soil water mixture time to time by tapping the moisture box on the working table.
5. At saturation, soil paste glistens as it reflects light and fall freely when the spatula with saturated soil is tapped.
6. At this stage mix the sample again and keep for one hour
7. After one hour, if glistening disappear then again add more distilled water and prepare saturated paste
8. Note the final burette reading

OBSERVATION

1. Weight of soil:________________g
2. Volume of distilled water used for preparation of saturated paste:________ml
3. Saturation percent of soil:____________%

$$SP = \frac{\text{Total weight of water}}{\text{Weight of the oven dry soil}} \times 100$$

2. Preparation of saturation extract

Apparatus

1. Richards or Buechner funnel
2. Filter flask
3. Filter paper
4. Vacuum pump
5. Volumetric flask

Procedure

1. Place the filter paper on the Buechner funnel
2. Keep the Buechner funnel on the filter flask and connect it with vacuum pump.
3. Transfer the saturation paste into the Buechner Funnel.
4. Start the vacuum extraction of paste by starting the vacuum pump.
5. Collect the saturation extract in the filter flask.
6. Stop vacuum extraction if air begins to pass through filter paper.
7. Transfer the saturation extract in the volumetric flask after knowing its volume.

Precautions

1. Do not use Pyrex glass if boron is to be determined.
2. Add 1000 ppm sodium hexametaphosphate solution @ 1 drop per 25 mL of extract before stoppering and storing, if CO_3^- and HCO_3^- are to be determined.
3. If soil contains more amount of free gypsum, allow to increase the EC up to 1-2 mmhos/cm (dSm^{-1}) standing the extract for several hours.
4. For salinity appraisal, extract few minutes after the preparation of saturation paste.
5. For the estimation of chemical constituents keep the saturation paste for 4-16 hours before extraction.

Observations:

Sample	pHs
Saturated paste of soil sample	

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

pHs	
Acidic < 6.5	requires liming for reclamation
Normal 6.6- 7.5	Optimum for most crops
Alkaline 7.6 – 8.5	requires application of org. manures
Alkali >8.6	requires gypsum for amelioration

Relationship between hydrogen ion concentration, hydroxyl ion concentration and pH in a solution

pH	H^+	OH^-
	Moles/liter	
0	10^{0}	10^{-14}
1	10^{-1}	10^{-13}
2	10^{-2}	10^{-12}
3	10^{-3}	10^{-11}
4	10^{-4}	10^{-10}
5	10^{-5}	10^{-9}
6	10^{-6}	10^{-8}
7	10^{-7}	10^{-7}
8	10^{-8}	10^{-6}
9	10^{-9}	10^{-5}
10	10^{-10}	10^{-4}
11	10^{-11}	10^{-3}
12	10^{-12}	10^{-2}
13	10^{-13}	10^{-1}
14	10^{-14}	10^{0}

2 : Determination of pHs of saturation extract of problematic soil

The soil reaction (pH) is meant to express the acidity or 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.

<u>Principle</u>: pH is the negative logarithm of H^+ concentration in moles / liter:

$$pH = -\log [H^+]$$

pH can be determined using either **colorimetric** or **electrometric** methods. The choice of method depends upon the accuracy required, the equipment available, or convenience.The electrometric method works on the principle as mentioned in Nernst equation. It consists of two electrodes.

1) Glass electrode or Indicator electrode: That is sensitive to H^+: there is an exchange of ions between solution and glass.

2) Calomel electrode or Reference electrode: That produces a constant voltage is also required. The electrode pair produces an electromotive force (emf or voltage) that is measured by a millivoltmeter. The relation between emf and pH is governed by the Nernst equation:

$$E = Eo + \frac{RT}{nF}\ln(H)$$

where

E = emf produced by electrode system

Eo = a constant dependent on the electrodes used (0.246 volts at 25?C)

R = gas constant (8.313)

T = absolute temperature (298?K or 25?C)

n = number of electrons involved in equilibrium (1 in this case)

F = Faraday constant (96500)

Note that temperature is a factor in the equation. At 25°C this equation simplifies to

$$E = E° + 0.0591\ pH$$

which means a change of 1 pH unit produces a change in emf of 59.1 mV, at 25°C. This temperature-dependence of pH is important to remember when calibrating a pH meter.

$$pH = \frac{E - 0.246}{0.0591}$$

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) pH meter, (3) Balance, (4) 100 ml plastic Beaker and (5) Glass rod.

Reagents

1. **Buffer solutions:** pH 4.0, 7.0 and 9.2.

Buffer solution pH 4.0: Dissolve 10.21 gm AR grade potassium hydrogenphthalate in warm water and making volume to 1 L. This gives a pH of 4.00 at 25^{o}C and can be used as standard buffer.

Buffer solution pH 7.0 : Dissolve 3.40gm of potassium dihydrogen orthophosphate and 4.45 gm disodium hydrogen orthophosphate dihydrate (Sorenson's salt – $Na_2HPO_4.2H_2O$) to 1 L in distilled water.

Buffer solution pH 9.2 : Dissolve 3.81 gm sodium tetraborate (A.R.) in water and dilute to 1000 ml.

Procedure

1. Prepare Saturated paste as described in Exercise-1
2. Allow the pH meter to warm for 10 minutes before recording the pH.
3. Standardize the pH meter on two pH values (4.0 and 7.0) of known buffer solutions.
4. Insert the pH electrode in to the paste and record representative pHs reading.
5. Classify the soil pH and given your comments.

Questions

1. What p and H stand for?
2. What is the utility of soil pH?
3. What are the constitutes of soil which produce hydrogen ions in soil?
4. What are the factors affecting the soil pH?
5. What is buffering capacity of soil?
6. What is the difference between active and potential soil acidity?
7. What is meant by total acidity?
8. Why does $CaCO_3$ produce mild alkaline reaction?
9. pH of sodic soil is alkaline, Why?
10. Describe the procedure for measurement of pH of saturated soil paste. What is the importance of this value?

Observations:

Sample	ECe(dSm^{-1})	Interpretation
Saturation extract of given soil sample		

Interpretation of the saturated paste soluble salts test (Dahnke and Whitney, 1988):

EC$_e$(dSm^{-1})	Interpretation
0.0 - 2.0	Non-saline
2.1 - 4.0	Slightly saline and critical for salt sensitive crops
4.1 - 8.0	Moderately saline and critical for salt tolerant crops
8.1 - 16.0	Strongly saline
>16.1	Very strongly saline and injurious to most crops

Interferences:

1. Water contents higher or lower than saturation point will affect conductivity measurement.

2. Electrical conductivity increases as temperature increases. Ensure that conductivity readings have been adjusted to 25^{o}C for correct interpretation.

3 : Determination of ECe of saturation extract of problematic soil

The water soluble salts in soils are generally determined by two type of soil water extracts, (i) saturation extract, (ii) 1:2 soil water extract. If EC of soil saturation extract is greater than 2 dSm^{-1} (or more than 1.0 dSm^{-1} in 1:2 soil water extract), the water extract should be retained for determination of soluble ions. The saturation extract considered more reliable because, it is directly related to the field moisture range. However, determination in saturation extract is time consuming, 1:2 soil water extract can be used for rapid determination.

Principle

(1)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} which is the reciprocal of resistance in Ohm's cm^{-1}.

Equipment/Apparatus

(1) EC meter (2) Balance, (3) 100 ml plastic Beaker and (4) Glass rod.

Reagents

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

Procedure

Obtain the saturation extract as described in Exercise-1. Calibrate the EC meter with 0.01N KCl solution. The EC of this solution should be 1.413 dSm^{-1}. Rinse and immerse the conductivity cell in saturation extract of given soil sample. Record the EC of saturation extract. Classify the soil for EC and pH and given your comments.

Questions

1. Define electrical conductivity of soil?
2. What do you measure on the electrical conductivity meter?
3. What is the effect of temperature on electrical conductivity?
4. What is the electrical conductivity of 0.01N KCl solution at 25^{o}C?
5. What is the need of measuring the soil salinity?
6. What is major advantage of measuring conductivity of saturated paste extract?
7. Find out the relationship between different units of electrical conductivity of soil?

Observations:

1. Normality of EDTA = ____________N
2. Weight of the soil =______________g
3. Volume of Water =___________ml
4. EDTA used for Ca^{++} + Mg^{++} (A) = _______________ml
5. EDTA used for Ca^{++} (B) = _______________ml
6. EDTA used Mg^{++} (A-B) = _______________ml
7. Flame photo meter reading for WS K =________ppm
8. Flame photo meter reading for WS Na =____________ppm

Calculation:

(1) Ca^{++} (meq/100g soil) = $\frac{\text{Reading X Normality of EDTA X100 X 100}}{\text{ml of aliquot X soil wt. (g)}}$

(2) Mg^{++} (meq/100g soil) = $\frac{\text{Reading X Normality of EDTA X 100 X 100}}{\text{ml of aliquot X soil wt. (g)}}$

(3) Ca^{++} (ppm) = meq/100g soil of Ca^{++} X Eq.wt. of Ca^{++} (20.0) X 10

(4) Mg^{++} (ppm) = meq/100g soil of Mg^{++} X Eq.wt. of Mg^{++} (12.2) X 10

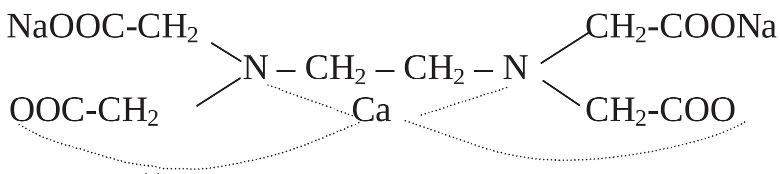
(5) Ca^{++} (%) = $\frac{\text{ppm of } Ca^{++}}{10000}$

(6) Mg^{++} (%) = $\frac{\text{ppm of } Mg^{++}}{10000}$

4 : Determination of water soluble cations (Ca^{++}, Mg^{++}, Na^{+}& K^{+}) from the soil

Although the water soluble cations (Ca^{++}, Mg^{++}, Na^{+}& K^{+}) are essential nutrients. But their excess amount or their imbalance ratios with other nutrients or ions may cause harmful effect to the crop and adversely change the properties of soil. This estimation of cations will be useful for estimating sodium absorption ratio and cation exchange capacity etc. These parameters are essential for establishing sodicity hazard of soil.

The method makes use of the chelating properties of EDTA (ethylene diaminetetraacetic acid or disodium salt of EDTA or versenate). It forms soluble chelate with many divalent cations at different pH values. The end point of titration can be judged by using different indicators owing to speed, convenience and reliability.



Principle (for Ca^{++})

A known volume of the soil extract is titrated with standard versenate (0.01 N EDTA) solution using murexide (ammoniumpurpurate) indicator in the presence of NaOH solution giving pH 12. At the end point, whole of calcium forms a complex with EDTA giving colour change from red to purple (violet).

Principle for (Ca^{++}+ Mg^{++})

A known volume of the water sample is titrated with standard versenate (0.0I N EDTA) solution using Eriochrome Black T (EBT) indicator in the presence of NH_4Cl + NH_4OH buffer to give pH above 10.0. At the end point, whole of Ca^{++} + Mg^{++} forms a complex with EDTA giving colour change from wine red to bluish green or sky blue.

Reagents

(1) **0.01 N EDTA solution** : Dissolved 2 gm of EDTA and 0.05 gm of Magnesium chloride hexahydrate in water and dilute to volume of 1 liter. Standardize it by 0.01 N $CaCl_2$ solution (0.5005 gm $CaCO_3$ + 10 ml 0.2 N HCl / litre).

(2) **Murexide (Ammonium purpurate) indicator**: Mix 0.02 gm ammonium purpurate with 40 gm K_2SO_4throughly.

(3) **4 N NaOH**: Dissolve 160 gm NaOH in 1 litre of distilled water.

(4) **NH_4OH – NH_4Cl buffer solution:** Dissolve 67.5 gm of NH_4Cl in 570 ml of NH_4OH and make it to one liter.

(5) **Eriochrom black T (EBT) indicator:** Dissolve 0.5 g of Eriochrome Black T and 4.5 g Hydroxylamine Hydrochloride in 100 ml of 95 % ethanol.

(6) K^+ (mg/1000g soil) or (ppm) = $\frac{\text{Reading X GF x vol. of water}}{\text{soil wt. (g) X Aliquot}}$

(7) Na^+ (mg/1000g soil) or (ppm) = $\frac{\text{Reading X GF x vol. of water}}{\text{soil wt. (g) X Aliquot}}$

(9) K^+ (meq/100g) = $\frac{\text{ppm of } K^+}{\text{Eq. wt. of K (39.1) X 10}}$

(10) Na^+ (meq/100g) = $\frac{\text{ppm of } Na^+}{\text{Eq. Wt. of Na(23) X 10}}$

(11) K^+ (%) = $\frac{\text{ppm of } K^+}{10000}$

(12) Na^+ (%) = $\frac{\text{ppm of } Na^+}{10000}$

Unit	WS Ca^{++}	WS Mg^{++}	WS K^+	WS Na^+
(meq/100g)				
ppm				
Percent (%)				

Procedure

Take 20 g soil, add 100 ml distilled water. Shake for an hour. Filter it. Use this filter for water soluble Ca and Mg determination.

(A) Determination of calcium

1. Pipette out 10 ml of water sample in a conical flask. Add 1 ml of 4N NaOH and about 50 mg of ammonium purpurate powder and shake the contents well.
2. Titrate this against std. 0.01N EDTA solution until the colour changes from red to purple (violet). Note down the burette reading. Repeat the titration at least three times.
3. Calculate meq/100g, ppm, and percentage of Ca^{++} present in a given soil sample.

(B) Determination of calcium + magnesium

1. Pipette out 10 ml of water sample in a conical flask. Add 1 ml of ammonium hydroxide-ammonium chloride buffer and 3-4 drops of EBT indicator.
2. Titrate this against std. 0.01N EDTA solution until the colour changes form wine red to sky blue. Note down the burette reading. Repeat the titration at least three times.
3. Calculate meq/100g, ppm, and percentage of Ca and Mg present in a given soil sample.

(C) Determination of water soluble $Na^+$and K^+

Principle

The element like K and Na analyzed through atomization of their atoms by Flame photometer. When solution mist are sprayed through flame, the atoms of respective elements get excited by absorbing energy from flame and electron of the last orbit jumped into higher level energy orbit, but being a stable element, this electron return back to its original orbit emit the energy in form of radiation (characteristics wavelength) and this radiation is proportional to the concentration of the element in the solution.

Procedure

Place the filter in previously standardized Flame photo meter with appropriate standards of K and Na (25, 50 and 100 ppm K and Na) and note the reading for WS K and Na.

Questions

1. Write down the principle of determination of Ca and Ca+Mg?
2. What is the function of buffer solution in determination of Ca+Mg?
3. What is the function of NaOH in determination of Ca?
4. Write the principle of Flame photometry?
5. What precautions must be taken while working on flame photometer?

Observations:

1. Normality of EDTA= ____________ N
2. Weight of the soil=______________g
3. Volume of Ammonium Acetate=___________ml
4. EDTA used for Ca^{++} + Mg^{++} (A)= _________________ml
5. EDTA used for Ca^{++} (B) = _________________ml
6. EDTA used Mg^{++} (A-B) = _________________ml
7. Flame photometer reading for K^{+}= ___________ppm
8. Flame photometer reading for Na^{+}=___________ppm

Calculation:

(1) Ca^{++} (meq/100g soil) $= \dfrac{\text{Reading X Normality of EDTA x 50 X 100}}{\text{ml of aliquot X soil wt. (g)}}$

(2) Mg^{++} (meq/100g soil) $= \dfrac{\text{Reading X Normality of EDTA X 50 X 100}}{\text{ml of aliquot X soil wt. (g)}}$

(3) Ca^{++} (ppm) = meq./100g soil of Ca x Eq.wt. of Ca (20) X 10

(4) Mg^{++} (ppm) = meq./100g soil of Mg x Eq.wt. of Mg (12) X 10

(5) Ca^{++} (%) $= \dfrac{\text{ppm of Ca}}{10000}$

(6) Mg^{++} (%) $= \dfrac{\text{ppm of Mg}}{10000}$

5 : Determination of exchangeable cations (Ca^{++}, Mg^{++}, Na^{+}& K^{+}) from the soil

Exchangeable cations are held at negatively charged surfaces of soil solids and are exchanged by all strong cations. To determine the exchangeable + water soluble cations, the soil is treated with neutral normal Ammonium Acetate for half an hour and from filtrate, exchangeable + water soluble cations are determined through Versenate and flame photometric method, respectively.

Principle (for Ca^{++})

A known volume of the soil extract is titrated with standard versenate (0.01 N EDTA) solution using murexide (ammoniumpurpurate) indicator in the presence of NaOH solution giving pH 12. At the end point, whole of calcium forms a complex with EDTA giving colour change from red to purple (viole t).

Principle for (Ca^{++}+ Mg^{++})

A known volume of the water sample is titrated with standard versenate (0.0I N EDTA) solution using Eriochrome Black T (EBT) indicator in the presence of NH_4Cl + NH_4OH buffer to give pH above 10.0. At the end point, whole of Ca^{++} + Mg^{++} forms a complex with EDTA giving colour change from wine red to bluish green or sky blue.

Reagents

1. **IN Ammonium Acetate pH 7.0** : Dissolve 77g of Ammonium Acetate in distilled water and make volume 1 Lit. Adjust the pH of the solution 7.0 through pH meter.

2. **0.01 N EDTA solution** : Dissolved 2 gm of EDTA and 0.05 gm of Magnesium chloride hexahydrate in water and dilute to volume of 1 liter. Standardize it by 0.01 N $CaCl_2$ solution (0.5005 gm $CaCO_3$ + 10 ml 0.2 N HCl / litre).
3. **Murexide (Ammonium purpurate) indicator**: Mix 0.02 gm ammonium purpurate with 40 gm K_2SO_4throughly.
4. **4 N NaOH**: Dissolve 160 gmNaOH in 1litre of distilled water.
5. **NH_4OH – NH_4Cl buffer solution**: Dissolved 67.5 gm of NH_4Cl in 570 ml of NH_4OH and make it to one liter.
6. **EBT indicator**: Dissolved 0.5 gm EBT and 4.5 gm hydroxylamine hydrochloride in 100 ml of 95% ethanol.

(7) K^+ (mg/1000g soil or ppm) = $\frac{\text{Reading X GF x vol. of } NH_4OAc}{\text{soil wt. (g) X Aliquot}}$

(8) Na^+ (mg/1000g soil or ppm) = $\frac{\text{Reading X GF x vol. of } NH_4OAc}{\text{soil wt. (g) X Aliquot}}$

(7) K^+ (meq/100g) = $\frac{\text{ppm of } K^+}{\text{Eq.wt. of } K^+ \text{ (39.1)X 10}}$

(8) Na^+ (meq/100g) = $\frac{\text{ppm } Na^+}{\text{Eq.wt. of } Na^+ \text{ (23) X 10}}$

(11) K^+ (%) = $\frac{\text{ppm of } K^+}{10000}$

(12) Na^+ (%) = $\frac{\text{ppm of } Na^+}{10000}$

Unit	Exch. + WS Ca^{++}	Exch. + WS Mg^{++}	Exch. + WS K^+	Exch. + WS Na^+
meq/100g				
ppm				
Percent (%)				

Calculate the net exchangeable Ca^{++}, Mg^{++}, K^+ and Na^+ (me/100g soil) from previously calculated results of practical No. 4 and 5 as follows.

1. **Water solubleCations (Pract. 4):**

Unit	WS Ca^{++}	WS Mg^{++}	WS K^+	WS Na^+
(meq/100g)				

2. **Water soluble + Exchangeable cations (Pract. 5):**

Unit	Exch.+WS Ca^{++}	Exch.+ WS Mg^{++}	Exch.+WS K^+	Exch.+ WS Na^+
(meq/100g)				

3. **. Exchangeable cations :**

Unit	Exch. Ca^{++}	Exch. Mg^{++}	Exch. K^+	Exch. Na^+
(meq/100g)				

Procedure

Take 10 g soil, add 50 ml neutral normal Ammonium Acetate. Shake for half an hour. Filter it. Use this filter for determination of exchangeable + water soluble Ca, Mg, Na& K

(A) Determination ofCa^{++}

1. Pipette out 10ml of soil extract in a conical flask. Add 1 ml of 4N NaOH and about 50 mg of ammonium purpurate powder and shake the contents well.
2. Titrate this against std. 0.01N EDTA solution until the colour changes from red to purple (violet). Note down the burette reading. Repeat the titration at least three times.
3. Calculate m.e./100g, ppm, and percentage of Ca^{++} present in a given soil sample.

(B) Determination of Ca^{++} + Mg^{++}

1. Pipette out 10 ml of soil extract in a conical flask. Add 1 ml of ammonium hydroxide-ammonium chloride buffer and 3-4 drops of EBT indicator.
2. Titrate this against std. 0.01N EDTA solution until the colour changes form wine red to sky blue. Note down the burette reading. 5. Repeat the titration at least three times.
3. Calculate m.e./100g, ppm, and percentage of Ca and Mg present in a given soil sample.

(C) Determination of water soluble Na^{+} and K^{+}

Principle:

The element like K and Na analyzed through atomization of their atoms by Flame photometer. When solution mist are sprayed through flame, the atoms of respective elements get excited by absorbing energy from flame and e of the last orbit jumped into higher level energy orbit, but being a stable element, this e return back to its original orbit emit the energy in form of radiation (characteristics wavelength) and this radiation is proportional to the concentration of the element in the solution.

Procedure

Place the filter in previously standardized Flame photo meter with appropriate standards of K and Na (25, 50 and 100 ppm K and Na) and note the reading for WS K and Na.

Questions

1. Name the extractant used for determination of exchangeable Ca+Mg..
2. Base saturation is an index of soil fertility-Explain.
3. What is the requirement of pH in determination of Ca^{++} and Ca^{++} + Mg^{++}?
4. Write the principle of Ca^{++} + Mg^{++} determination.
5. Write down principle of flame photometry.

$$SAR = \frac{[Na+]}{\sqrt{([Ca2+] + [Mg2+])}}$$

$$ESP = \frac{100(-0.0126+0.01475\,SAR)}{1+(-0.0126+0.01475\,SAR)}$$

$$Y=0.0673 + 0.035\ X$$

Where Y indicates ESP and
X indicates SAR

EXCHANGEABLE SODIUM PERCENTAGE (ESP) AND SODICITY HAZARD

Approx. ESP	Sodicity hazard	Remarks
< 15	None to slight	The adverse effect of exchangeable sodium on the growth and yield of crops in various classes occurs according to the relative crop tolerance to excess sodicity. Whereas the growth and yield of only sensitive crops are affected at ESP levels below 15, only extremely tolerant native grasses grow at ESP above 70 to 80.
15 - 30	Light to moderate	
30 - 50	Moderate to high	
50 - 70	High to very high	
> 70	Extremely high	

6 : Computation of CEC, SAR and ESP and characterization of problematic soil

Importance of cation exchange capacity in agriculture or plants is just after photosynthesis.Cation exchange capacity indicates the total quantity of negative charges per unit weight of soil or colloid.

CEC (me/100g) =Exch.Ca (me/100g) + Exch.Mg (me/100g) +Exch.K (me/100g) + Exch.Na (me/100g)

Sodium Adsorption Ratio (SAR) — A widely accepted index for characterizing soil sodicity, which describes the proportion of sodium to calcium and magnesium in soil solution. The formula to calculate SAR is given below, with concentrations expressed in milliequivalents per liter (meq/L) analyzed from a saturated paste soil extract.

$$\text{SAR} = \frac{[\text{Na}+]}{\sqrt{([\text{Ca}2+] + [\text{Mg}2+])}}$$

When SAR is greater than 13, the soil is called a sodic soil. Excess sodium in sodic soils causes soil particles to repel each other, preventing the formation of soil aggregates. This results in a very tight soil structure with poor water infiltration, poor aeration and surface crusting, which makes tillage difficult and restricts seedling emergence and root growth.

Exchangeable Sodium Percent (ESP) - The soil is termed sodic when exchangeable sodium percent is fifteen or more out of total quantity of exchangeable cations present and such soil should be reclaimed for getting maximum possible return.

The value of SAR can be used for determination of exchangeable sodium percentage (ESP) of the saturation extract by using the following formula:

$$\text{ESP}=\frac{100(-0.0126+0.01475\,SAR)}{1+(-0.0126+0.01475\,SAR)}$$

Sometimes the following regression equation is used for the appraisal of alkali soil by determining the value of ESP from the value of SAR.

$$Y=0.0673 + 0.035\ X$$

Where Y indicates ESP and

X indicates SAR

Questions

1. What is the importance of CEC in determining nutrient availability to plants?
2. Define SAR and ESP.
3. Describe unique physical and chemical properties of sodic soil.

Observations:

1. Weight of soil sample taken =______g
2. Saturated gypsum solution added in soil =______ml
3. Aliquot taken for titration =______ml
4. Volume of 0.01N EDTA used f or saturated gypsum titration(B) =______ml
5. Volume of 0.01N EDTA used for sample titration (S) =______ml
6. Volume of sat. gypsum used for replacement of Na^+ (S-B) =______ml

Calculation

meq Ca^{++}/5ml = (B-S) x N

meq Ca^{++}/100ml = (B-S)x N x 20

meq Ca^{++}/5g = (B-S) x N x 20

meq Ca^{++}/1000g = (B-S) x N x 20 x 200

mg $CaSO_4.2H_2O$/1000g = (B-S) x N x 20 x 200 x 86

Gypsumrequirement (kg/ha) = (B-S) x N x 20 x 200 x 86 x 2.24

Gypsumrequirement (t/ha) $= \frac{R \times N \times 20 \times 200 \times 86 \times 2.24}{1000}$

Gypsum requirement (t/ha) = (B-S) x N of EDTA x 770.56

Gypsum requirement (t/ha) = (B-S) x 7.7056

7 : Determination of gypsum requirement of alkali/sodic soil (Schoonover, 1952)

Sodic soils have excess amount of sodium on their exchange complex. This amount is more than 15% of the exchange capacity of the soil and in extreme condition it may go as high 80-90% or more. This high sodium adversely affects, the crop growth and yield. Thus sodic soil should be reclaimed by neutralizing excessive alkalinity caused by carbonates and bicarbonates and replacement of sodium from the exchange complex by calcium. This can be done by applying suitable soil amendment. Numerous organic and inorganic amendments are available to reclaim the sodic soils.

Among these gypsum is easily available and cheapest. Thus gypsum is most commonly used for reclaiming sodic soil after determining the gypsum requirement.

Principle

Gypsum requirement of alkali soils can be determined by treating the soil with known excess of saturated gypsum solution and then estimating the unreacted or unutilized amount by versenate titration.

Reagent :

1. **Saturated gypsum solution:** Add 5 g of chemically pure $CaSO_4.2H_2O$ to 1 litre of distilled water. Shake for ½ hour on mechanical shaker and filter through Whatman No. 1 filter paper.
2. **Standard $CaCl_2$ solution (0.01N):** Dissolve 0.5 g of pure $CaCO_3$ (dried at 150 °C) in 5 ml of approximately 6 N HCl and and dilute the solution to a volume of 1 litre.
3. **EDTA (0.01N):** Dissolve 2.0 g of EDTA disodium salt and 0.039 g $MgCl_2.6H_2O$ in distilled water and make volume 1 litre. Standardize it against 0.01 N $CaCl_2$ solution using EBT/Ammonium purpurate as an indicator.
4. **Eriochrom black T (EBT) indicator:** Dissolve 0.5 g of Eriochrome Black T and 4.5 g Hydroxylamine Hydrochloride in 100 ml of 95 % ethanol.
5. **Buffer solution**: Dissolve 67.5 g of ammonium chloride in 570 ml of concentrated ammonium hydroxide (ammonia solution) and make to 1 litre.

Procedure:

1. Weigh 5 g air dry soil in a 250 ml plastic bottle
2. Add 100 ml of saturated gypsum solution and shake for 5 minutes.
3. Filter the contents through Whatman No. 1 filter paper.
4. Transfer 5 ml aliquot of a clear filtrate into 100 or 150 ml conical flask.
5. Add 1 ml of buffer solution and 2 to 3 drops of EBT indicator.
6. Take 0.01 N EDTA solution in a 50 ml burette and titrate the contents in the conical flask until wine red colour starts changing to sky blue.
7. Run a blank using 5 ml of saturated gypsum solution in place of sample aliquot.

Questions

1. What is the effect of gypsum on soils pH of alkali soil?
2. What is the solubility of gypsum in pure water?
3. Write the molecular formula of gypsum. What is equivalent weight of gypsum?
4. What is the direct effect of gypsum on soil?
5. How much amount of gypsum can be added to soil at one time?
6. In which soils gypsum application is recommended.
7. What are the factors that governs the amount of gypsum to be applied to reclaim the sodic soils?

Observation:

1. pH of soil-buffer suspension =____________
2. Lime requirement (t/ha), to raise pH 6.0 =____________(t/ha)
3. Lime requirement (t/ha), to raise pH 6.4 =____________(t/ha)
4. Lime requirement (t/ha), to raise pH 6.8 =____________(t/ha)

Lime requirement for different pH targets

Measured pH of soil-buffer suspension	Lime requirement in tones/ha of pure $CaCO_3$ for achieving different soil pH targets		
	pH 6.0	pH 6.4	pH 6.8
6.7	2.43	2.92	3.40
6.6	3.40	4.13	4.62
6.5	4.37	5.35	6.07
6.4	5.59	6.56	7.53
6.3	6.56	7.78	8.99
6.2	7.53	8.99	10.21
6.1	8.50	10.21	11.66
6.0	9.48	11.42	13.12
5.9	10.69	12.64	14.58
5.8	11.66	13.85	15.79
5.7	12.64	15.07	17.25
5.6	13.61	16.28	18.71
5.5	14.58	17.50	20.17
5.4	15.79	18.71	21.63
5.3	16.77	19.93	22.84
5.2	17.98	20.90	24.30
5.1	18.95	22.11	25.76
5.0	19.93	23.33	27.22
4.9	20.99	24.54	28.67
4.8	22.11	25.76	30.13

8 : Determination of lime requirement of acid soil

While most of the plants grow well in soil pH between 6.5-7.5, some require slight acidic pH. However, higher degree of soil acidity adversely affects plant growth and productivity. Soils below pH 6.6 are termed as acid soils. Maximum production from such soils, can be obtained by applying lime in required quantities which will increase the soil pH up to a desirable level.

Principle:

By way of replacement of H^+ and Al^{3+} ions, the Ca^{2+} ions raise the percentage of base saturation, which leads to a corresponding rise in soil pH. The widely followed method for determination of lime requirement of soil (pH <6.0) is that given by Shoemaker et al. (1961) inwhich the soil is equilibrated with extractant buffer solution of pH 7.5. This brings the reserve H^+ into extract and reduce the pH of buffer solution. The pH of soil buffer suspension quantify lime requirement of acid soil.

Apparatus/Instrument

1. pH meter, 2. 5ml and 10ml pipette, 3. 50ml beaker

Reagent:

1. **Extractant buffer solution**: Dissolve 1.8g of nitrophenol, 2.5ml of triethanolamine, 3.0g of potassium chromate (K_2CrO_4), 2.0g of calcium acetate and 53.1g of calcium chloride dihydrate in one liter of distilled water and adjust the pH to 7.5 using dilute NaOH.
2. **pH buffer solution**: Solution of pH 4.0, 7.0 and 9.2 for standardization of pH meter.

Procedure:

1. Weight 5g of air dry soil sample in 50ml beaker.
2. Add 5 ml of distilled water and 10ml of extractant buffer solution.
3. Stir continuously for 10 minutes or intermittently 20 minutes with glass rod.
4. Measure the pH of soil-buffer suspension on a pH meter after standardizing with known pH buffer solutions.
5. Against the measured pH, find out the amount of lime required to bring the soil pH to a desired level (e.g. 6.0, 6.4 or 6.8) as given in table. Make necessary correction to get the value of agricultural lime based on purity percentage.

Questions

1. List the direct and indirect effects of soil acidity on plant growth.
2. Under what conditions acid soils are formed?
3. How we can ameliorate soil acidity?
4. What is lime requirement? What are the objectives of liming an acid soil?

Observation:

Result:

Irrigation water sample	pH

Based on pH values, natural waters can be divided in to three distinct classes

1. The waters, which contain carbonates, with or without bicarbonates, do not have free carbonic acid. The pH values of these waters are always above 8.
2. Water that contain no carbonate, but contain bicarbonate and carbonic acid, the pH values of these waters range from 4.5 to 8.0. Most of the natural waters fall under this category.
3. Water that contain free acid in addition to carbonic acid, do not contain carbonates or bicarbonates. The pH values of these waters is 4.5 or below.

Result:

Irrigation water sample	EC (dS/m)

Based on EC values, natural waters can be divided in to following distinct Salinity hazard classes

Salinity hazard:

Conductivity (dS/m)	**Class**	**Inference**
0.00 –0.25	Low salinity	(i) Can be used for most soil for most crops (ii) Little likelihood of salinity
0.25 – 0.75	Medium salinity	(i) Can be used with moderate leaching (ii) Moderate salt tolerant crops should be grown
0.75 – 2.25	High salinity	(i) Cannot be used where drainage is restricted (ii) Salt tolerant plant and additional manage-ment practices should be followed
2.25 – 5.00	Very high salinity	(i) Not suitable for irrigation (ii) Can be used occasionally with leaching (iii)Salt tolerant crop should be grown with additional management practices

Result:

9 : Determination of quality of irrigation water (pH, EC, Ca^{2+}, Mg^{2+}, Na^{+} , CO_3^{2-} , HCO_3^{-}, Cl^{-} , SAR and RSC)

Water is an universal solvent. It contains variable quantities of dissolved solids and gases. Sometimes, suspended and colloidal, organic and inorganic material occurs as well Waters are usually classified as hard or soft according to the concentration of calcium and magnesium ions. These ions when present in high concentration, the capacity of water to lather with soap is reduced and such waters are generally termed as "hard waters". A soft water is one that produces lather easily with soap. Water is also called as carbonated, sulphated or nitrated depending upon their concentrations. The irrigation water that contained Ca and Mg ions, is hard and not suitable for domestic use, but makes the agricultural land soft. On the other hand, water that contained Na ions is soft for domestic use, but makes the agricultural land hard. "Hard water makes the land soft and soft water makes the land hard"

I. Determination of pH

The pH value is negative logarithm of hydrogen ion activity (mol L^{-1}). As a result of the presence of strong bases and weak acids e.g. Na_2CO_3 increases the pH values, salts of weak bases and strong acids (e.g. $CaCl_2$) cause decreases. The pH values of natural water usually lie between 6.5 and 7.5 and lower values are a result of free CO_2. Biogenic decalcification in surface waters can cause the pH value to reach 9.5.

Apparatus: pH meter with glass-calomel electrode assembly

Reagents : Buffer solution pH 4, pH 7 and pH 9.2.

Procedure

The pH of the irrigation water is determined by taking 50 ml of water sample in 100 ml beaker. The combined electrode is dipped into it and the pH is recorded as outlined in Exercise-2.

II. Determination of electrical conductivity

Electrical conductivity is a measure of water's capacity to convey electric current. Electrical conductivity of water is directly proportional to its dissolved mineral matter content. Electrical conductivity of water is determined directly by conductivity bridge.

Apparatus: EC meter, beaker

Reagents :0.01 N KCl solution

Procedure

The EC of the irrigation water is determined by taking 100 ml of water sample in 150 ml beaker. The conductivity cell is dipped into it and the EC is recorded as outlined in Exercise-3.

Calculation for carbonate and bicarbonate

i. Let X=______ml of 0.01N H_2SO_4 be required to neutralize half the amount of CO_3^{2-} present in 10ml of the water sample *i.e.* the mean reading with phenolphthalein.

ii. Y=_____ml of 0.01N H_2SO_4 is to be required to neutralize the remaining half amount of CO_3 and the whole amount of HCO_3^- present in 25ml of aliquot *i.e.* the mean reading with methyl orange.

iii. 2X=____ml of 0.01N H_2SO_4 required to neutralize CO_3^{2-} present in 10ml of the aliquot.

iv. (Y-X)=_____ml of 0.01N H_2SO_4 required to neutralize HCO_3^- present in 10ml of the aliquot.

v. Let Z=____ml of 0.05N $AgNO_3$ be required for titration

$$\text{Amount of } CO_3^{2-} \text{ (meq/l)} = \frac{2X \times N \text{ of } H_2SO_4 \times 1000}{\text{Aliquot taken (ml)}}$$

= ______________________

$$\text{Amount of } HCO_3^- \text{ (meq/l)} = \frac{(Y-X) \times N \text{ of } H_2SO_4 \times 1000}{\text{Aliquot taken (ml)}}$$

= ______________________

$$\text{Amount of } Cl^- \text{ (meq/l)} = \frac{Z \times N \text{ of } AgNO_3 \times 1000}{\text{Aliquot taken (ml)}}$$

= ______________________

III. Determination of CO_3^{2-}, HCO_3^-, and Cl^- from irrigation water

Important anions, from water quality point of view are chlorides, carbonates and bicarbonates, sulphates and nitrates. Concentration of chloride generally increases with increase in EC of irrigation waters. Therefore, magnitude of the total salt may be predicted if chloride concentration is known. Sum of the carbonate and bicarbonate ions constitutes to be total alkalinity of water as temporary and raises its pH to more than 7.5. This alkalinity also causes corrosion in the boilers and other metallic pipes, hence, their determination is also important for agricultural as well as industrial purpose.

Principle (Carbonate and Bicarbonate):

Carbonate and bicarbonate ions in the water sample can be determined by titrating it against standard H_2SO_4 using phenolphthalein (working pH range 8.3 to 10.0) and methyl orange (working pH range 2.9 to 4.7) as indicator. Addition of phenolphthalein gives pink

colour in the presence of carbonates and titration with H_2SO_4 converts these CO_3^{2-} in to HCO_3^- and decolourizes the pink colour, the reaction is

$$H_2SO_4 + 2CO_3^{2-} \longrightarrow 2HCO_3^- + SO_4^{2-} \text{ (Colourless)}$$

In colourless solution, methyl orange is added which gives yellow colour. Further titration against H_2SO_4 neutralizes all the HCO_3^- (original + converted from CO_3^{2-}) in to H_2O and CO_2 and the colour changes from yellow to rosy red with following reaction.

$$HCO_3^- + H_2SO_4 \longrightarrow 2H_2O + 2CO_2 + SO_4^{2-} \text{ (Rosy red)}$$

Principle (Chloride):

The determination of chloride is easily made by $AgNO_3$ titration (Mohr's titration) method in which silver reacts with chloride forming white AgCl precipitate. When all the chloride is precipitated, potassium chromate (the indicator used) shows the brick red colour at the end point due to the formation of silver chromate.

$$NaCI + AgNO_3. \longrightarrow \underset{\text{White precipitate}}{AgCI} + NaNO_3$$

$$K_2CrO_4 + 2AgNO_3 \longrightarrow \underset{\text{Brick red colour}}{Ag_2CrO_4} + 2\,KNO_3$$

Apparatus

1. Pipette, 2. burette, 3. conical flask 4. beaker, 5. funnel

Reagents

1. **Std. 0.01N H_2SO_4 solution**: Dilute 0.28 ml of concentrated H_2SO_4 to 1 litre with distilled water. Dilute 100 ml of this solution to again 1 litre for getting 0.01N H_2SO_4. Standardize with 0.01N Na_2CO_3 using methyl orange as indicator
2. **Std. 0.02N $AgNO_3$ solution**: 3.40g of $AgNO_3$is dissolve in double distilled water and make up to 1 litre. This is to be standardize against the standard NaCl or KCl solution and stored in amber coloured bottle away from light
3. **Phenolphthalein indicator**: 0.25% solution in 60% ethyl alcohol
4. **Methyl orange indicator**: 0.1% solution in distilled water
5. **Potassium chromate indicator**: 5% solution in distilled water

Procedure

For carbonate

1. Fill the burette with 0.01 N H_2SO_4solution.
2. Pipette out 10ml of aliquot in a conical flask. Add few drops of phenolphthalein indicator. Pink colour is obtained.
3. Run in 0.01N H_2SO_4solution carefully from the burette till the pink colour just disappear

For bicarbonate

1. Add Methyl orange indicator to same conical flask. Yellow colour is obtained
2. Titrate against 0.01N H_2SO_4 solution carefully till the colour change from yellow to orange and note down the burette reading (Yml).

For Chloride

1. Add Potassiumchromateindicator to same conical flask. Yellow colour is obtained
2. Titrate against 0.05N $AgNO_3$ solution carefully till the colour change from yellow to red and note down the burette reading (Z ml).

IV. Determination of Ca, Mg, K and Na FROM WATER

The main cations present in irrigation water are calcium, magnesium, sodium and potassium. In this section, method for Ca^{2+},Mg^{2+},$Na^{+}$and K^{+} are described. The method makes use of the chelating properties of EDTA (ethylene diamine tetra acetic acid or disodium salt of EDTA or versenate). It forms soluble chelate with many divalent cations at different pH values. The end point of titration can be judged by using different indicators. Owing to speed, convenience and reliability this method is widely used for the determination of calcium and magnesium ions when present in small quantities.

Observation and Calculation

1. Normality of Std. H_2SO_4=---------N

2. Aliquot taken= ---------ml

3. Burette reading for Ca^{++} + Mg^{++} (Xml) = -----------ml

4. Burette reading for Ca^{++} (Yml) = -----------ml

5. Burette reading for Mg^{++} (X- Y)= ---------------ml

6. Flame photometer reading for Na^{+} = ---------

8. GF for Na^{+} = ---------

(1) Ca^{++} (meq/l) = $\frac{\text{Reading (X) x Normality of EDTA x 1000}}{\text{ml of aliquot}}$

=_______________

(2) Mg^{++} (meq/l) = $\frac{\text{Reading (Y-X) x Normality of EDTA x 1000}}{\text{ml of aliquot}}$

=_______________

Principle (for Ca^{++}):

A known volume of the water sample is titrated with standard versenate (0.01N EDTA) solution using murexide (ammonium purpurate) indicator in the presence of NaOH solution giving pH 12. At the end point, whole of calcium forms a complex with EDTA giving colour change from red to purple (viole t).

Principle for (Ca^{++}+ Mg^{++}):

A known volume of the water sample is titrated with standard versenate (0.0IN EDTA) solution using Eriochrome Black T (EBT) indicator in the presence of NH_4Cl + NH_4OH buffer to give pH above 10.0. At the end point, whole of Ca^{++} + Mg^{++} forms a complex with EDTA giving colour change from wine red to bluish green or sky blue.

Apparatus:

1. 150ml conical flask or porcelain dish, 2. Burette, 3. 10ml pipette.

Reagents:

1. **0.01 N EDTA solution**: Dissolved 2 gm of EDTA and 0.05 gm of Magnesium chloride hexahydrate in water and dilute to volume of 1 liter. Standardize it by 0.01 N $CaCl_2$ solution (0.5005 gm $CaCO_3$ + 10 ml 0.2 N HCl / litre).
2. **Murexide (Ammonium purpurate) indicator**: Mix 0.02 gm ammonium purpurate with 40 gm K_2SO_4 thoroughly by grinding in mortar and pestle.
3. **4 N NaOH**: Dissolve 160 gmNaOH in 1litre of distilled water.
4. **Buffer solution**: Dissolved 67.5 gm of NH_4Cl in 570 ml of NH_4OH and make it to one liter.
5. **EBT indicator**: Dissolved 0.5 gm EBT and 4.5 gm hydroxylamine hydrochloride in 100 ml of 95% ethanol.

Procedure

(A) Determination of calcium

1. Pipette out 10ml of water sample in conical flask. Add 1 ml of 4N NaOH and about 50 mg of ammonium purpurate powder and shake the contents well.
2. Titrate this against std. 0.01N EDTA solution until the colour changes from red to purple (violet). Note down the burette reading (Xml).

(B) Determination of calcium + magnesium

1. Pipette out 10ml of water sample in a conical flask. Add. 1ml of buffer solution and 3-4 drops of EBT indicator.
2. Titrate this against std. 0.01N EDTA solution until the colour changes form wine red to sky blue. Note down the burette reading (Yml).

(3) Na^+ (meq/l) = $\frac{R \times GF}{23}$

= -------------------------------

Interpretation of water quality

a. pH =__________

b. EC (dS/m) =__________

c. CO_3^{2-} (meq/l) =__________

d. HCO_3^- (meq/l) =__________

e. Cl^- (meq/l) =__________

f. Ca + Mg (meq/l) =__________

g. Na^+ (meq/l) =__________

Calculation :

Total cations (meq/l) (Na+Ca+Mg) = Total anions (meq/l) (CO_3+HCO_3+Cl) = $\frac{\text{Total cations/anions (meq/l)}}{\text{EC (dS/m) x 10}}$

= __________________ = __________________ = ________________________

Total salt content = EC (dS/m) x 640 =__________(mg/l)

EC =__________(dS/m)

pH =__________

SAR =__________

RSC =__________(meq/l)

Cl =__________(meq/l)

Comment :

(C) Determination of Na^+: Small amount of sodium is generally present even in the best quality of irrigation water. Sodium constitutes 50% or more of total cations of saline and sodic waters. The content of sodium may be quite high in saline water with EC greater than 1dS m^{-1}, and containing relatively less amount of Ca^{++} and Mg^{++}, it also exerts a toxic effect on plant growth. Therefore, determination of sodium in irrigation waters is very important for predicting its harmful effects on soil and crops and judging the suitability of water for irrigation. The concentration of potassium is generally low. The determination of Na^+ is carried out directly with the help of flame photometer using appropriate filters and standard curve prepared by taking known concentration of Na^+.

Apparatus

1. Flame Photometer 2. beaker,

Reagents

1. Standards of Na^+ (25, 50 and 100 ppm Na^+)

Procedure

Place the filter in previously standardized Flame photo meter with appropriate standards of Na (25, 50 and 100 ppm Na^+) and note the reading for K and Na in irrigation water.

IRRIGATION WATER QUALITY CRITERIA

1. **Alkali hazard:**

Sodium Adsorption Ratio (SAR) SAR : $\dfrac{Na}{\sqrt{\dfrac{Ca + Mg}{2}}}$

SAR value	Class	Symbol	Inference
0 – 10	Low Na water	S_1	(i) Can be used for all soils with little danger of harmful Na level development (ii) The Na sensitive crops are affected
10 – 18	Medium Na water	S_2	(i) Sodium hazard likely in fine textured soil (ii) Can be used on soils having high permeability
18– 26	High Na water	S_3	(i) May produce harmful level of exchangeable Na in most soils except gypsiferous soils (ii) Requires special management practice like good drainage, high leaching and addition of organic matter and gypsum
> 26	Very high Na water	S_4	(i) Unsatisfactory for irrigation except at low and perhaps medium salinity of irrigation water, special management as above should be made

Adj. SAR = SAR (1 + (8.4 - pH_c)

Where SAR = Sodium Adsorption Ratio

$pH_C = (pK_2 - pK_c) + p(Ca+Mg) + p\ (Alk)$

$pK_2 - pK_c$ = conc. of Ca + Mg + Na in meq/l

p(Ca+Mg) = Ca+Mg in meq/l

pAlk =from conc. of CO_3+ HCO_3 in meq/l**.**

Ion Concentration (me/l)	($pK_2 - pK_c$)	p(Ca+Mg)	pAlk
0.5	2.11	3.60	3.30
1.0	2.13	3.30	3.00
4.0	2.20	2.70	2.40
8.0	2.25	2.40	2.10
10	2.27	2.30	2.00
20	2.35	2.00	1.70
30	2.40	1.82	1.52
40	2.44	1.70	1.40
50	2.47	1.60	1.30

Adjusted SAR:

To predict sodicity hazard more correctly for those water which contain appreciable amounts of HCO3 but no RSC. Ayers and Wescot pointed out that sodicity hazard of these irrigation waters should be determined by Adjusted SAR to be calculated.

The adjusted SAR should be evaluated for such water which have EC higher than 1.5 and less than 3.0 dS m^{-1} because only this group of water are more likely to have twin problem of RSC and SAR.

2. Bicarbonate hazard: $RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$

RSC (meq/lit)	Quality of irrigation water
Less than 1.25	Probably safe for most purpose
1.25 – 2.50	Marginal can be used on light textured soil with adequate leaching and application of gypsum
More than 2.50	Not suitable for irrigation purposes

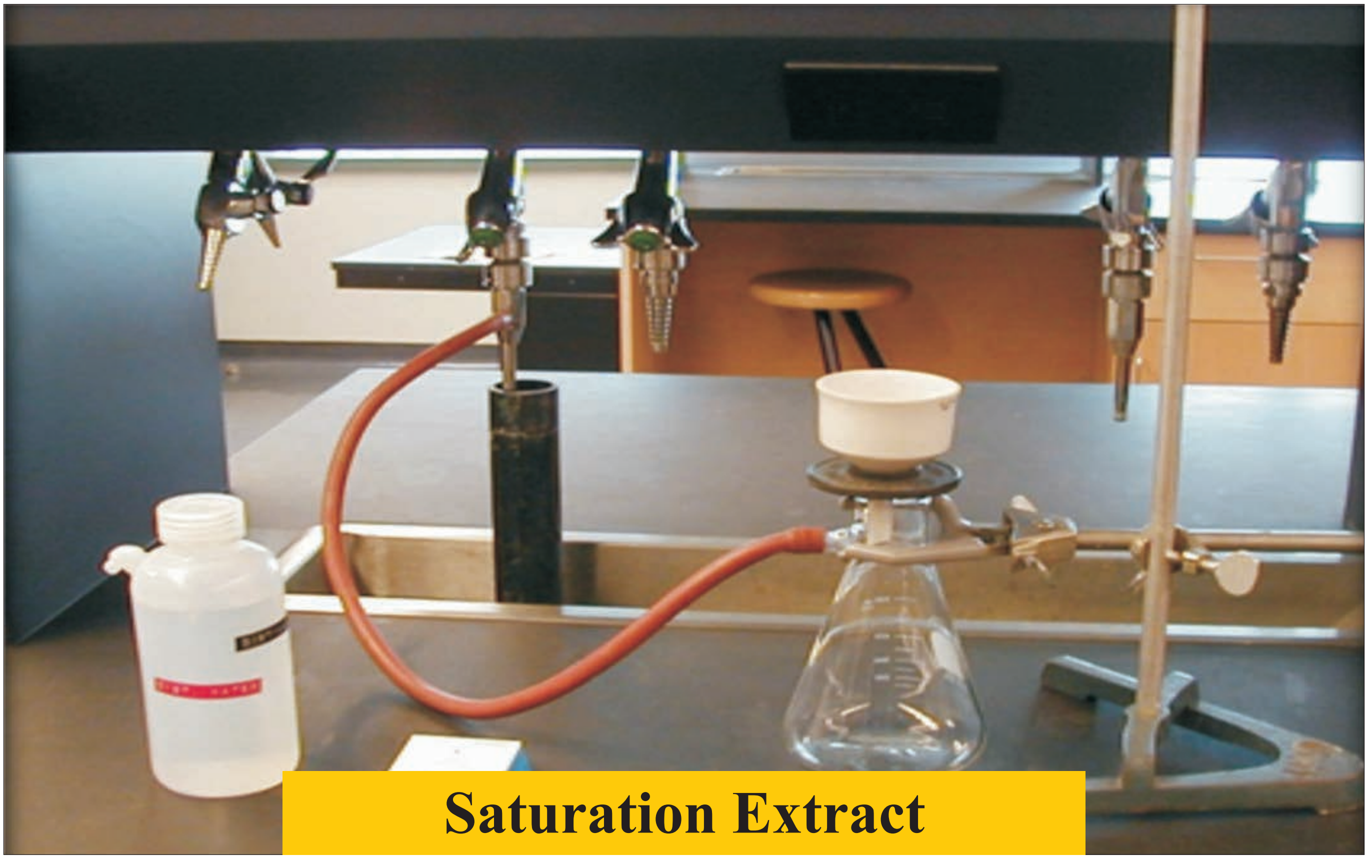
3. Chloride hazards

Chloride (meq/lit)	Class
0 – 4	Excellent
4 – 7	Good
7 – 12	Permissible
12- 20	Doubtful
More than 20	Unsafe

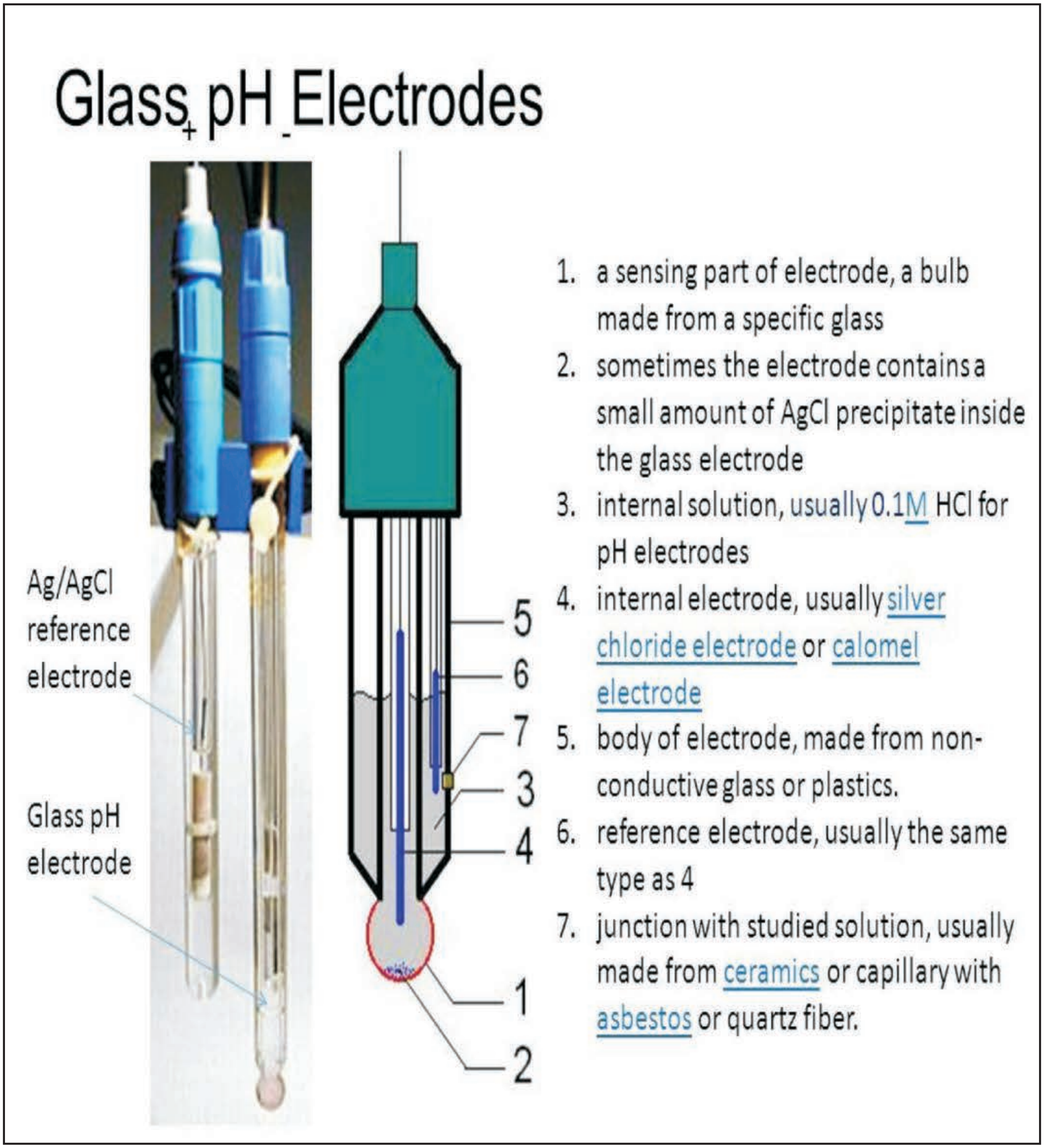
Questions

1. Explain the alkalinity of irrigation water.
2. How can we reduce the adverse effect of high bicarbonate content of irrigation water?
3. Define sodic hazard of irrigation water.
4. How to estimate total dissolved solids (TDS) from electrical conductivity?
5. Can we treat saline or sodic irrigation water?
6. Calculate the adj. SAR for an irrigation water with these ions contents: 7 meq/l of Ca, 2 meq/l of Mg, 5 meq/l of Na, 4 meq/l of HCO_3, and a total ionic concentration of 14 meq/l.

Saturated Pastes



Saturation Extract



pH combination electrode
(Incorporating both glass and reference electrodes in one body)

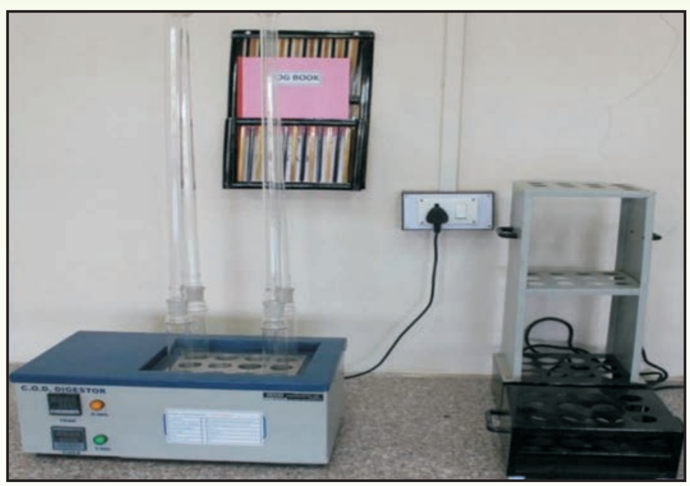
Incubater Cum Shaker

Hot Air Oven

Hot Plate

Centrifuge

Rotary Shaker



COD Digester Meter

ICAR

NAVSARI AGRICULTURAL UNIVERSITY

PRACTICAL MANUAL

Ag. Ento. 3.1 (2 + 1)

FUNDAMENTALS OF ENTOMOLOGY

Third Semester B.Sc. (Hons.) Agri.

Sponsered by ICAR

Prepared and compiled by:

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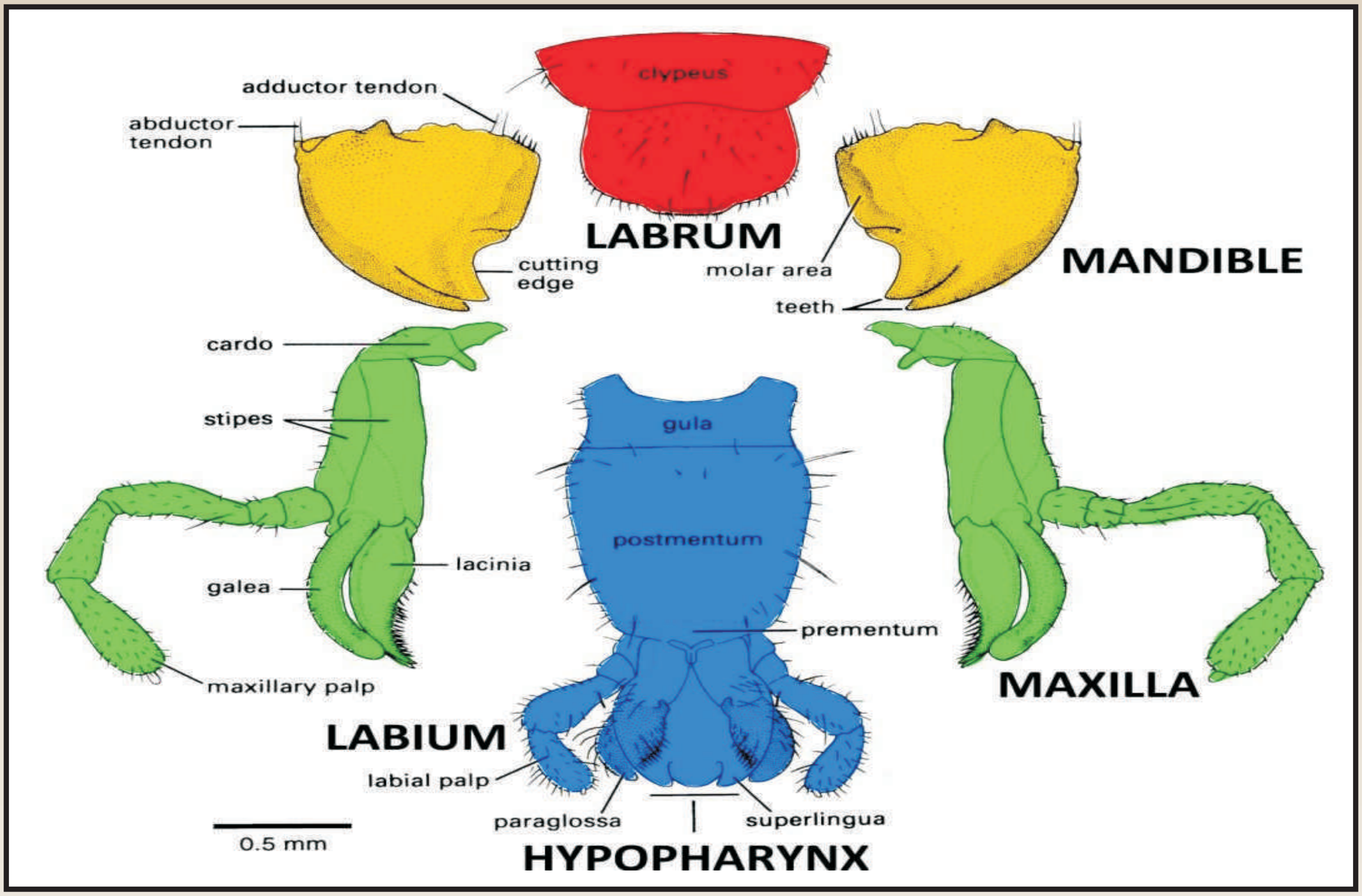
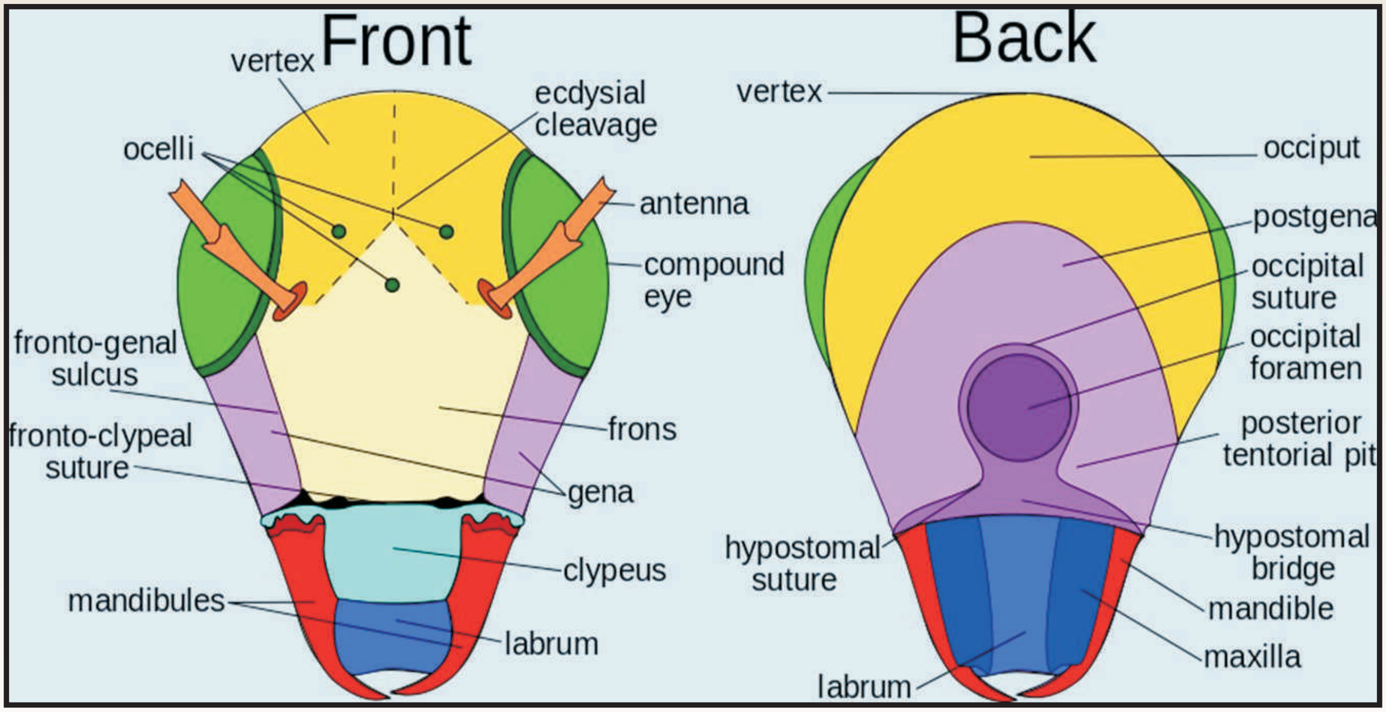
Department of Entomology
College of Agriculture
Navsari Agricultural University,
Waghai (Dangs) – 394730.

Insect Mouthparts





Insect Head

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FOREWORD

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

The manual contains very basic and practically useful information on collection and preservation of arthropods, structure and functions and internal anatomy of insects including step wise procedures of insect dissections as well as order wise description of different agriculturally important insects for proper identification which is prerequisite of pest management tactics.

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. 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 Agricultural Entomology and it will be a useful ready reference material for all the students of third 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. D.M. Damasia, Dr. J.J. Pastagia and Mr. H.R. Kachhela for their commendable efforts in bringing out this practical manual.

(Z. P. Patel)

NAVSARI AGRICULTURAL UNIVERSITY

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
NAVSARI AGRICULTURAL UNIVERSITY
WAGHAI – 394 730

CERTIFICATE

This is to certify that Mr./Ms.____

Reg. No.________________ has performed practicals for **Third semester** B.Sc. (Hons.) Agriculture in the course No. **Ag. Ento. 3.1 Fundamentals of Entomology** Credits: **2+1** during the academic year ___________.

He/She has performed ________ practicals out of **12**.

University Seat No. ___________.

Course teacher **External examiner**

INDEX

EXERCISE – 1
METHODS OF COLLECTION AND PRESERVATION OF INSECTS

The science that deals with the study of insect is known as Entomology. Several types of insects are found on the earth. About 10,00,000 insect species have been recorded. All of these are not harm ful. Some are beneficial to us. *e.g.* pollinating insects, bees, flies *etc.* Some others are useful in controlling other harmful insects that destroys crop plants. So, it is necessary to learn which insects are harmful and which are useful or beneficial. For this purpose, we have to collect insects from various places, field, house, stores *etc.* and pre-serve them. At our conveniences, we can classify and know whether they are useful or harmful. A well-arranged and labeled collection of insects is useful in study of comparative morphology and thus enable us to differentiate between the insects of different orders.

(A) Collection of insects:

Most of the adult insects are active at day time and may be flying in crops, garden or park. These can be collected with insect collecting net *e.g.* butterfly, dragonfly. Some insects are active at night and hovering near light source. *e.g.* moths, ant lions, some beetles, pyrilla, jassids *etc.* many insects like grass hoppers, crickets, walking stick insects, leaf insects, mantids and leaf hoppers may be found on bunds among shrubs and grasses. Silverfish, book lice and cockroaches are found among book shelf. Small grain beetles are found in stored grains. Many crops pests may be present in their respective crop plants and can be collected manually using small specimen tubes.

Equipments for collecting insects:

1. **Insect collecting net: There** are two types of insect collecting nets.

(a) Aerial net: (Butterfly net):

Insect collecting net is made up of a wooden or metallic handle, galvanized iron ring and a cone shaped bag made up of mosquito net or muslin cloth. It is useful to collect small to large sized flying insects like months, butterflies, dragonflies, flies, wasps, etc. Specifications of various parts are as under.

(i) Handle: wooden stick/iron/aluminum pipe about 100 cm long.

(ii) Ring: Galvanized rod of 5 mm thickness and 30 cm diameter.

(iii) Net: cone shaped bag made from mosquito net/muslin cloth measuring 30 cm in diameter and 45 cm in length.

(b) Sweep net:

This is heavier than the aerial net. It consists of a short handle, a large hoop and a muslin cloth bag. This is suitable for collecting leafhoppers, grasshoppers and other small insects. The net is swept over vegetation. The handle is turned by quick turn of the wrist to fold the cloth bag over the hoop in order to prevent the escape of trapped insects.

2. Aspirator or Pooter

Small insects like book louse, thrips, jassids, whitefly *etc.* can be collected with insect collecting net. These can be collected with the help of a simple device known as Aspirator or Pooter.

It is a simple and small but very useful device for collecting small and active insects like jassids, whitefly, psocids *etc.* It can be made by fixing a snugly fitting rubber cork with two holes in the mouth of glass tube. In one of the hole, long suction tube is inserted whose inner end is covered with cotton gauge and second hole accommodates a glass tube with right angle bend which is inlet tube through which insects enter the collecting tube when air is sucked from the suction end.

3. Traps

Traps can be used for collecting different types of insects.

Food lure trap - Flies

Sex lure trap - Moths

Water trap - Brown plant hopper

Light trap - Positively phototropic insects

Sticky trap - White flies

Suction trap - White flies

4. Berlese funnel

Soil dwelling insects can be collected by using Berlese funnel.

(B) Killing the insects:

(a) Cyanide killing bottle**:**

The adult insects collected with the help of an insect collecting net or aspirator are killed by putting them in an insect killing jar. Insects are killed due to poisonous gas emitted from KCN present in the jar. The dead insects should be taken out from the jar as early as possible at least within 30 minutes after keeping them in the jar; otherwise they become brittle and fade.

Insect Killing Jar:

Materials required for preparing the insect killing jar:

(1) Glass jar with tight lid

(2) Potassium cyanide (KCN)

(3) Saw dust

(4) Blotting paper

(5) Plaster of Paris

(6) Tea spoon

(7) Label

(8) String

(9) Wooden butt

How to prepare insect killing jar:

(1) Clean the jar and check the lid for proper fitting *i.e*. air tightness.

(2) Add one tea spoonful of KCN powder and spread it properly on bottom of the jar.

(3) Fill saw dust in the jar and press it with wooden butt to make a 5 cm thick layer over KCN.

(4) Cut a circular disc of blotting paper equal to the inner diameter of the bottom of jar.

(5) Prepare a thin paste of Plaster of Paris in a beaker and pour it on the edge of the blotting paper in the jar by rotating it in slanting position.

(6) Keep bottle undistributed for drying the paste. Cover the lid tightly and paste the label "POSION" DON'T TOUCH: written in red colour.

Precautions to be taken while handling the insect killing jar:

(1) Proper labeling - "POSION" DON'T TOUCH in big, bright red coloured letters.

(2) Keep bottle in lock and key. Never give to an unauthorized person.

(3) Never keep the jar open when not in use.

(4) Take out dead insects within 30-40 minutes; otherwise they become brittle and discoloured.

(b) **Ethyl acetate killing bottle**

The most common killing agent used in killing jars is ethyl acetate (finger nail polish remover). Only a few drops of ethyl acetate are needed in a killing jar because the vapor kills the insects. You may need to add a few drops each day or whenever the insects do not die quickly. As an alternative to killing agents, insects may be killed by placing them in a freezer overnight.

1. Pour 1/2 inch layer of wet plaster of Paris to the bottom of a bottle.
2. Allow it to dry thoroughly (The drying process may be quickened by keeping the bottle inside an oven)
3. Saturate the plaster of Paris layer with ethyl acetate
4. Recharge the bottle with the chemical again as and when it loses its effectiveness

Dos:

1. Tape the bottom of the bottle with a few strips of insulation tape to prevent the shattering of the bottle if it is accidentally dropped.
2. Affix a conspicuous `POISON' label both in English and in vernacular along with the skull and cross bone symbol.

3. Keep the bottle tightly closed to prevent gas leakage.

4. Remove the insects as and when they are dead.

5. Use a separate large killing bottle for moths and butterflies and another for beetles and grasshoppers.

6. Keep the killing bottle in a safe place away from those who are unaware of its deadlines.

7. Dispose the contents of old cyanide bottles preferably by burying it in a pit

Don'ts

1. Do not mix small insects with scaly insects.

2. Do not mix delicate and small insects with large insects like beetles and grasshoppers.

3. Do not allow the bottle to sweat

4. Never overload the bottle

(c) **Killing with alcohol**: Many insects can be killed by dropping them directly into 70 to 90% ethyl or isopropyl alcohol.

(d) **Pinching the thorax**: A butterfly or moth can be immobilised and killed in an emergency by giving a sharp pinch on the thorax.

(C) Preservation of the insects:

Insects may be of various size. Large sized insects are preserved after using relaxing jar, pinning the insect on insect pinning block, setting the insect on setting / spreading board. Small sized insect are preserved using carding. Micropinning and staging. Then these insects are stored in insect storage box after drying in insect drying cabinet. Whereas immature insects are preserved in screw cap bottle using alcohol and KAAD mixture.

a. Relaxing jar:

Sometimes the insects are not removed from insect killing jar within 30 to 40 minutes. Such insects become brittle and fragile due to excess loss of body fluid. It is difficult to pin and set such insects without breaking of some or all of appendages. These insects need to be relaxed. It can be done by keeping them in relaxing jar.

It is a simple device made from a wide mouth jar by filling sand. The sand is moistened with water. A drop of **propionic acid** or **phenyl or carbolic acid** or **formaldehyde** is added to avoid fungus/ mould development. To avoid direct contact of the specimen with moist sand A round piece of blotting paper is kept over sand layer or keep dried specimens in a small open box or in an uncovered Petri dish.It is used to soften dried, hardened insects. Insects are kept for six to eight hours in relaxing jar for relaxing their appendages

b. Insect pinning block:

It is device with the help of which one can pin same type of the insects at uniform height from the bottom level. It may be made from hard P.V.C., aluminum metal or wooden blocks. Bore of different de pth viz., 0.75, 1.5, 2.0 and 2.5 cm are drilled in the vertical manner.

Pinning the insects:

It is necessary to pin and dry insects before storing them in boxes and cabinets. After killing, the insects are pinned properly to facilitate preservation. The pinned insects are arranged on spreading board. Further, the antennae and legs are arranged in natural position. The wings are spread in such a way that the hind wings can be seen very well.

Pinning is the best way to preserve hard bodied insects. Pinned specimens keep well, retain their normal appearance and are easily handled and studied. The colours often fade when the insect dries but this is difficult to avoid. Bright coloured specimens are generally better preserved if they are dried rapidly.

Special type of pin known as **insect pin** or **entomological pin** should be used for pinning the insects. These are made up of steel or brass and varying in thickness and size and do not rust. Insects are pinned vertically through the body on thorax slightly right to the middle line. All specimens should be mounted at uniform height on the pin about 20 mm away from the pointed end.

Sr. No.	Name of the insects	Site of pinning
1	Moths and Butterflies, Bees, Wasps and Flies	Through the thorax between the bases of the front wings.
2	Bugs	Through the scutellum, a little right of the midline if the scutellum is large.
3	Grasshoppers, Cockroaches, Crickets and Mantids	Through the posterior part of the pronotum, just to the right of the midline.
4	Beetles, Weevils, Earwigs and Large hoppers	Through the right forewing (elytra), about halfway between the two ends of the body.
5	Dragonfly and Damselfly	Through the thorax, with the left side uppermost.

Carding:

Small insects like termite soldiers, ants, hymenopterous parasites, thrips, aphids, jassids, whiteflies *etc.* are difficult to pin directly. Therefore, these are pasted on rectangular card (25x10 mm) or triangu lar card (20x10 mm) with the help of gum. The card with insect is pinned and kept in insect box.

Micropinning and staging:

In this method, smaller insects like bugs, flies, hymenopterous parasites *etc.* are pinned with minute pins which are short and very thin. These pins are soft and difficult to insert in hard cork sheet and therefore staged on rectangular piece of soft material like pith of *baru* plant. The piece of *baru* pith is pinned alongwith label kept in insect storing box.

c. Insect setting board/spreading board:

The pinned insects are set or arranged on insect spreading/setting board. The antennae and legs are arranged in natural position. The forewings are stretched and fixed in such a way that hind wings can be seen properly.

Insect setting boards/spreading boards are used to facilitate proper spreading of wings and setting legs, antennae, abdomen *etc*. in correct natural position so as to reveal maximum structures. There are two types of insect setting boards.

(a) Sliding type: one side top is fixed on bottom board while the other top is for sliding adjusting the width of pinning slit.

(b) Fixed type: Both side tops are fixed on bottom board.

Care to taken while spreading the insects on spreading board.

(a) Insert the pin in middle of the slit.

(b) Stretch the front wings so as to make a right angle between anal margin and body line.

(c) Set the antennae in natural position.

(d) Arrange legs in pinning slit in natural position.

(e) Expose hind wings to the maximum extent and provide a card bridge below abdomen when it is stout one. Fix the wings in position using card paper strips and pins.

d. Insect drying cabinet:

The insects after killing, pinning and setting are dried before storing in insect boxes. The setting boards with insects are kept in insect drying cabinet.

It is a wooden air tight cabinet with double door system. **Calcium chloride** or other highly hygroscopic material is kept in an open jar inside the cabinet on the bottom. The chemical absorbs moisture from insect body without causing discolouration. Drying of insects through direct exposure to radiation heat may result in fading of colour of insects so dried.

e. Insect storing box:

The dried insects are stored in an insect storing box in a systematic manner. They may be stored according to orders and family or according to the category of host plants if these are pests. Each insect should carry a small card paper label below it containing name of collector, place, host plant and date of collection. Naphthalene balls should be kept inside insect box containing dead insects to keep away scavenging insects like ants and book louse.

It is useful for storing dead and dried specimens of insects after pinning and setting various appendages. The insects can be stored according to the order and family or they can be stored according to the crop to which they damage. Specimens of antennae and legs glued on card board strips are also stored in boxes. It measures about 45x30x8cm. Inner side of top and bottom are covered with 0.5 cm thick cork sheet. Two slits are provided on the short side of bottom part for filling crystals of naphthalene.

(D) Collecting and preserving immature stages of insects:

Most of the insects cause damage during their larval and nymphal stages. The larvae and nymphs of different insect pests differ in their shape and size. The identification of larvae/nymphs helps in deciding the pest responsible for damage. For collecting and preserving immature stages of insects Specimen tubes with screw cap, Ethyl alcohol - 70 % and Larva killing - stretching solution: KAAD is required. Formalin (4%) can also use for this purpose. But all these preservatives are highly volatile. Screw cap vials are satisfactory if the caps are tight fitting. Sealing the stopper with paraffin wax reduced the evaporation of preservative. Label is written with pencil and placed inside the vial along with the specimen. Careful examination of liquids preserved specimens once in a year is essential to replace the evaporated fluid.

Other materials required for collecting and preserving the insects:

Some of the equipment a collector should have are: forceps or tweezers, dissecting needle, a knife, magnifying glass or hand lens, notepad, camel’s hair brush, vials of preservative, eye dropper and scissors. Other items that come in handy are: shoulder bag for equipment, string, tape, rubber bands, glass slides, cardboard, cotton, and insect pins. Insect pins, Small glass/plastic tubes, Plastic bags, Gum, Card paper, Scissor, Camel hair brush, forceps are required for the purpose.

Answer the following questions

(1) Identify the various equipments required for collection, killing and preservation of the insects in the laboratory and write its use.

(2) Which precautions should be taken while preparing and using the insect killing jar?

(3) Draw proper pinning site of different insects shown in the laboratory.

(4) How will you reactivate killing jar?

(5) What is the utility of insect pinning block?

(6) What is the utility of relaxing jar?

(7) Explain the procedure to prepare insect relaxing jar

EXERCISE – 2
EXTERNAL FEATURES OF THE INSECTS

2.1 Objective

(1) To learn the external morphology of insects this helps to distinguish one kind of insect from another.

(2) To introduce the students with the external structure and functions of insects (grasshopper or cockroach or blister beetle) and classify them on the basis of their morphological characters.

2.2 Materials

(1) Freshly killed Grasshopper or Cockroach or Blister beetle

(2) Dissecting microscope

(3) Dissecting wax tray

(4) Scissors

(5) Forceps

(6) Needles

(7) Pins

2.3 Methodology

(1) Take a grasshopper or cockroach or blister beetle and identify its three body regions -head, thorax and abdomen.

(2) Study and identify various appendages on head, thorax and abdominal regions.

(3) Separate various parts such as antennae, legs, wings with the help of sharp scissors and identify their different parts.

2.4 General body organization of a grasshopper

Insect body is differentiated into three distinct regions called head, thorax and abdomen. Grouping of body segments into distinct regions is known as **tagmosis** and the body regions are called as **tagmata**. Body of a grasshopper is divided into Head, Thorax and Abdomen. The head is a compact front division. It is followed by the middle strong division- the thorax. The last and posterior division is long, tubular and known as abdomen.

2.5 THE HEAD

The head is the first anterior tagma formed by the fusion of six segments namely preantennal, antennal, premandibular, mandibular, maxillary and labial. Head is articulated to the thorax through neck or cervix. Head capsule is sclerotized and the head capsule excluding appendages formed by the fusion of several sclerites is known as **cranium**. Insect head bears various appendages like antennae, eyes, mouthparts etc. They may be paired or single and located on different regions of the head.

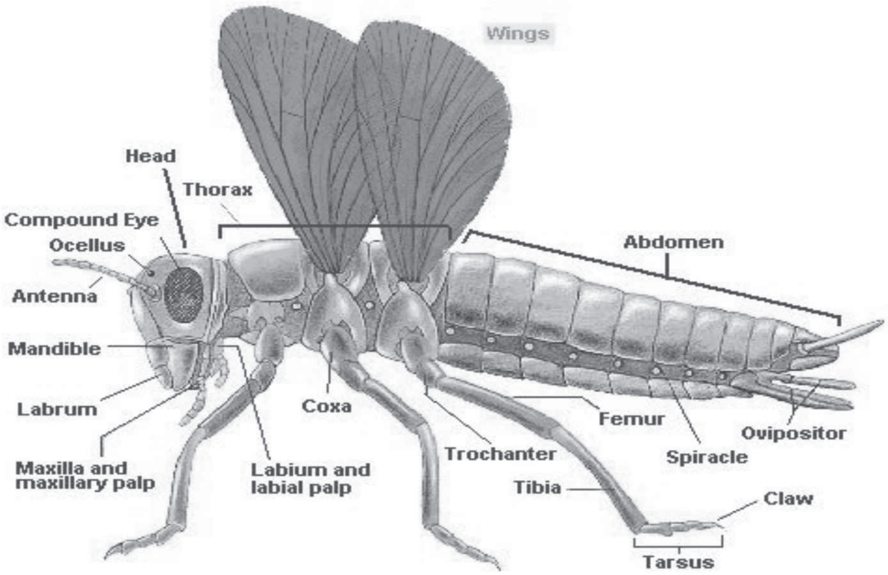
2.5.1 Functions of Head

(1) To ingest the food materials.

(2) Sensory in perception.

(3) To coordinate with various body activities.

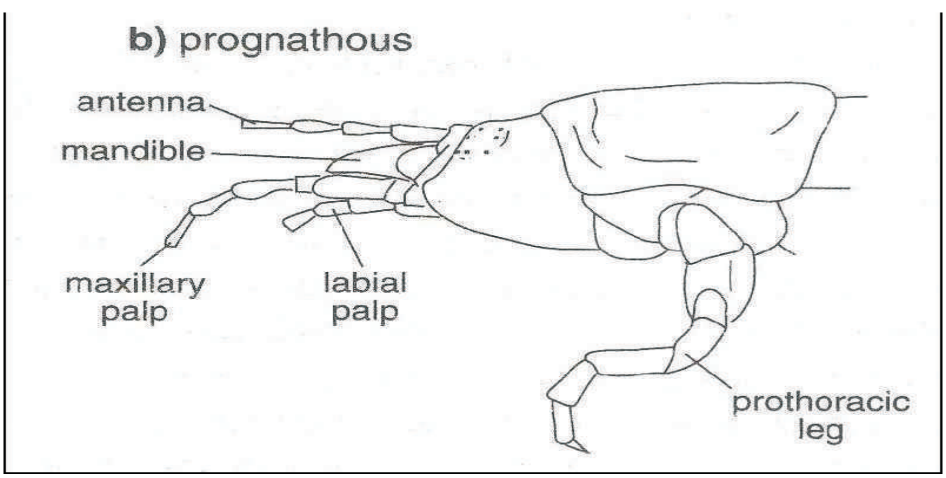
(4) Protection of the coordinating centers.



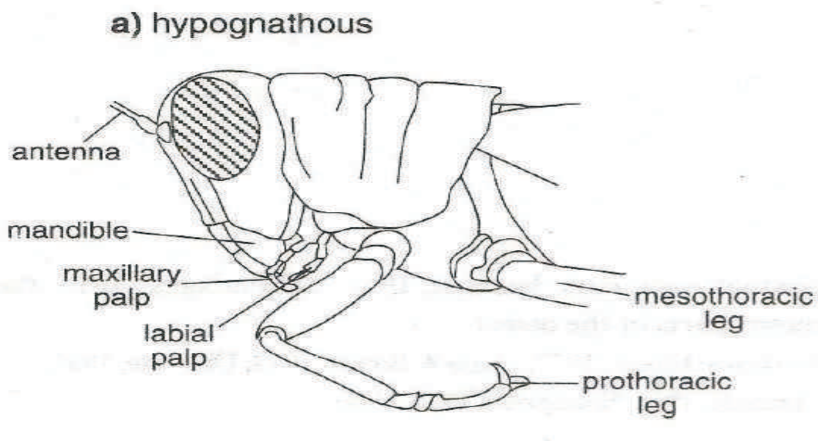
2.5.2 The head inclination

It is defined as the position of insect head and its mouth parts in relation to the rest of the body. There are three type of head inclination found in different insects *viz.,* Prognathous, Hypognathous and Opisthognathous. Grasshopper and cockroach have the hypognathous type of head inclination.

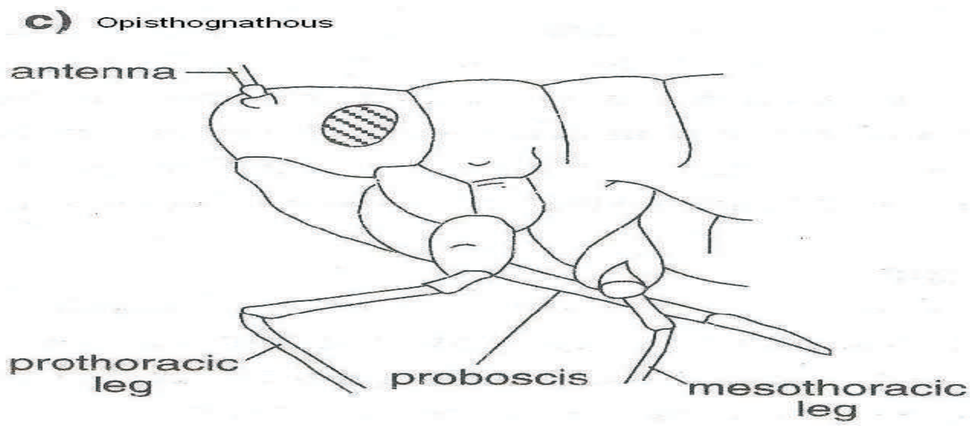
(1) **Prognathous (*Pro*-in front; *gnathus*-jaw):** The long axis of the head is horizontal and in line with the long axis of the insects body. The mouthparts are directed forwards e.g. Stick insect, soldier caste of termites, ground beetle etc.



(2) **Hypognathous (*Hypo*-below; *gnathus*-jaw):** The long axis of the head is vertical i.e. at right angle to the long axis of the body. The mouthparts are projecting downwards e.g. grasshopper, cockroach etc.



(3) **Opisthognathous (*Opistho*-hehind; *gnathus*-jaw):** The head is reflexed ventrally so that the mouth parts are projecting backwards between the coxae of the front legs e.g. Red cotton bug, stink bug etc.



2.6 THE THORAX

The thorax is second and middle region or tagma of the grasshopper body which is three segmented *viz.,* prothorax, mesothorax and metathorax. It bears the organs of locomotion like legs and wings. Each segment bears a pair of legs articulated ventrolaterally while in most adults both meso and metathorax bears the wings articulated dorsolaterally which are collectively known as Pterothorax. Thoracic segments are made up of three sclerites *viz.,* dorsal body plate tergum or notum, ventral body plate sternum and lateral plate pleuron. Two pairs of spiracles are also present on the meso and metapleuron.

2.7 THE ABDOMEN

This is the third and posterior tagma of insect body. It is the large region of body. This tagma is made up of 9-11 highly flexible segments (uromeres). Abdominal segments are telescopic in nature and are interconnected by a membrane called conjunctiva. Abdominal appendages in adult insects are external genital organs and cerci at the distal end. The abdomen function concerned with reproduction and metabolism. It contains majority of internal vital systems like, digestive system, circulatory system, reproductive system, respiratory system and nervous system.

Each abdominal segment is made up of only two sclerites namely dorsal body plate (tergum) and ventral body plate (sternum). In grasshopper eight pairs of spiracles are present on the first eight segments, in addition to a pair of tympanum (auditory organ) is present on either side of first segment. Eight and ninth abdominal segments bears the female genital organ and ninth segment bears male genital organ.

Answer the following questions

(1) Draw the labeled diagram of grass hopper.

(2) Draw the labeled diagram of front and lateral view of grasshopper head.

(3) Which are the appendages of head? Give it's functions.

(4) Draw the diagram of different types of head inclination.

(5) What is the functions thorax?

(6) How many segments do you find in the abdomen? Which term is used for abdominal segments?

(7) The Spiracles are found on which segments of grasshopper body?

(8) What is tympanum?

EXERCISE – 3
INSECT ANTENNAE AND THEIR MODIFICATIONS

3.1 Objectives

(1) To study the insect antennae and their modifications.

(2) To study the various types of antennae based on the distinguishing features of different insects.

(3) To familiarize the students with the different types of insect antennae which can be used in distinguishing their characteristics and helps in their classification.

3.2 Materials

(1) Insects specimens with different types of antennae

(2) Dissecting microscope

(3) Glass slides

(4) Scissors

(5) Forceps

(6) Needle

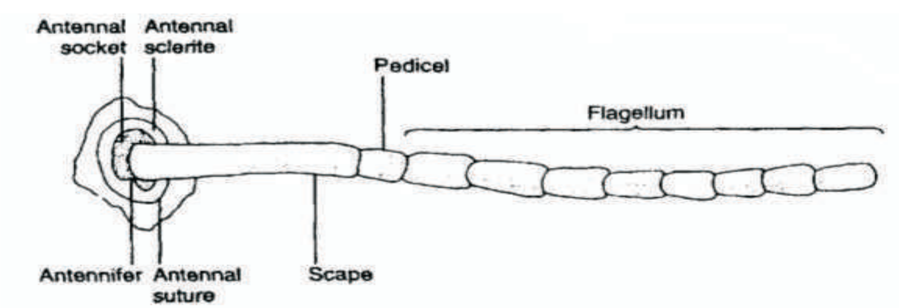
3.3 Methodology

(1) Take an insect, remove its antennae from the base with the help of sharp scissor with extreme care and observe the various parts under the microscope.

(2) Separate antennae from other insects and compare them with characteristics and permanent slides.

3.4 Structure of an insect antenna

Antennae are paired, highly mobile and segmented. They are also called feelers. Antennae are located on either end of upper frons and are in line and between the compound eyes. All insects except protura have a pair of antennae. Antennae are well developed in adults and poorly developed in immature stages. The antenna is set in a socket of the cranium called antennal socket (antennifer). The base of the antenna is connected to the edge of the socket by an articulatory membrane. This permits free movement of antennae. Each antenna consists of a basal segment called the scape followed by the pedicel. A ma ss of sense cells called Johnston's organ is present in the pedicel, which is used as a chordotonal organ in some of the insects like mosquitoes. The remaining segments are collectively known as flagellum. The scape is inserted into a membranous region (antennifer) of the head capsule.



3.4.1 Functions of insect antennae

(1) Antenna is useful to detect chemicals including food, mating partners and pheromones.

(2) It has different receptors to perceive smell, humidity changes, temperature variations, vibration, wind velocity and direction.

(3) It is a tool for communication with other members of same colony in social insects like honey bee, ants, termites etc.

(4) Antenna is useful to perceive the forward environment and detect danger.

(5) It is useful for hearing in mosquitoes and communication in ants.

(6) It is also useful to clasp the mate partner during copulation and grasp the prey.

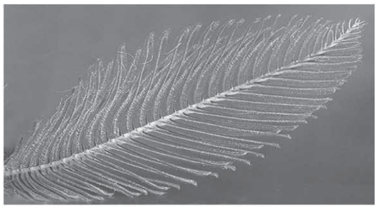
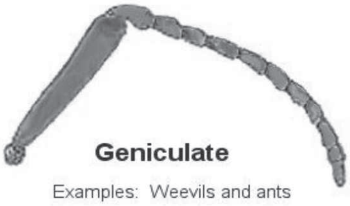
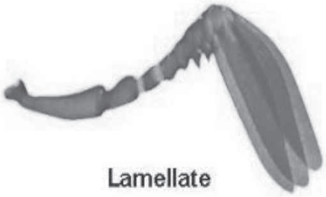
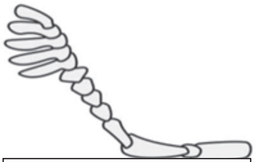
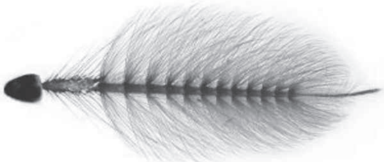
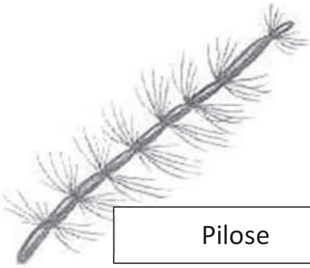
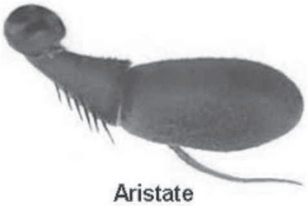
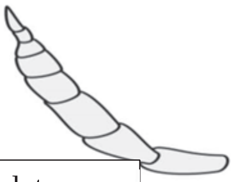
(7) Due to different structures, it is useful in classification of insects and identifying sexual dimorphism.

3.5 Modifications of insect antenna:

The antennae of various insects differ in their shape, size and structure of various segments. Due to this, more than a dozen modifications of antennae are found.

Sr. no.	Type of Antennae	Example	Nature of Modification
1	Filiform (thread like)	Grasshopper	Segments are more or less uniform throughout from base to apex and never ends with bristle
2	Setaceous (Whip Like)	Cockroach	Segments gradually decreases from base to apex presenting a whip or bristle like structure
3	Moniliform (Bead like)	Termites	Segments are round or oval with well developed constrictions between segments, appearing like a string of beads
4	Pectinate (comb like)	Female arctiid moth	Segments possess lateral processes on one side giving comb like appearance.
5	Bipectinate (double comb)	Mulberry silk worm moth, Male lymantriid moth	Segments bear lateral processes on either side
6	Serrate (saw like)	Pulse beetle	Segments are triangular with projecting points on one side giving saw like appearance.
7	Clavate (clubbed)	Butterflies	Segments gradually increase in diameter near the tip ending in a club like apical part.

8	Clavate with hook (clubbed antennae with hook)	Skipper Butterflies	Segments gradually increase in diameter from near the tip and the last one ends with a small hook like structure.
9	Capitate (clubbed with knob)	Red flour beetle	Segments gradually increase in diameter near the apex and the terminal 3 to 5 segments suddenly enlarge to form a knob like structure.
10	Geniculate (elbowed)	Ants, Honey bees.	The first segment (scape) is greatly elongated and flagellum always makes an angle with it.
11	Lamellate (plate like)	Rhinoceros beetle, dung rollers, chaffer beetles	The terminal segments expand to one side into lateral oval lobes.
12	Flabellate (plate like)	Stylopids	The terminal segments expand on one side into lateral lobes. The sides of the lobes are parallel.
13	Plumose (brush like with dense hairs)	Male mosquito	Whorls of hairs arise from each joint of the segment. Each whorl contains a number of hairs.
14	Pilose (brush like with sparse hairs)	Female mosquito	Looks like plumose but each whorl contains less number of hairs.
15	Aristate (antennae with arista)	Housefly	Antennae are small, microscopic, three segmented. Third segment enlarged and bears a bristle called arista on its dorsal side.
16	Stylate (antennae with style)	Robberfly	Antennae small 3 to 4 segmented. Terminal segment elongate into bristle like structure called style.

 Filiform	 Setaceous	 Moniliform
 Pectinate	 **Bipectinate**	 Serrate
 Clavate	 Capitate	 Geniculate Examples: Weevils and ants
 Lamellate	 Flabellate	 Plumose
 Pilose	 Aristate	 Stylate

Answer the following questions

(1) Draw the labeled diagram of typical insect antennae.

(2) Where the antennae are articulated on the insect head?

(3) Which are the different parts of the insect antennae?

(4) What is antennifer?

(5) How antennae are useful to insects?

(6) Differentiate the following types of antennae. (a) filiform and moniliform (b) clavate and capitates (c) aristate and stylet (d) plumose and pilose (e) setaceous and serrate.

EXERCISE – 4
INSECT LEGS AND THEIR MODIFICATIONS

4.1 Objectives

(1) To study the insect legs and their modifications.

(2) To identify various types of insect legs based on the distinguishing features of different insects and characterized them.

4.2 Materials

(1) Insects specimens with different types of legs

(2) Dissecting microscope

(3) Glass slides

(4) Camel hair brush

(5) Scissor

(6) Forceps

(7) Needle

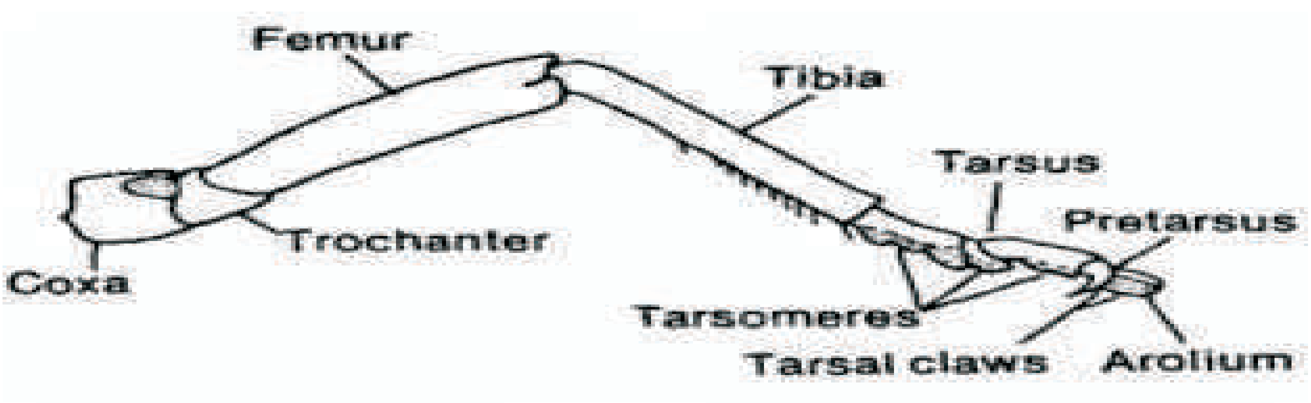
4.3 Methodology

(1) Take an insect, carefully remove its legs from pleural area of the thorax with the help of sharp scissor and observe the various parts under the microscope.

(2) Separate leg from other insects and compare them with characteristics and permanent slides.

4.4 Structure of an insect leg

Every insect have three pairs of legs. Each leg is made up of five parts *viz.,* coxa, trochanter, femur, tibia and tarsus. The tarsus having various structures at the pretarsus. The legs are articulated on ventrolateral region of thorax, one pair on each thoracic segment. It is the main organ for locomotion in terrestrial and aquatic habitat. The hexapod condition facilitates the insects in maintaining balance during locomotion.



4.5 Function of insect leg

(1) Its main function is locomotion in terrestrial and aquatic habitat.

(2) The leg is modified to perform the functions like; walking (ambulatorial), running (cursorial), jumping (saltatorial), digging (fossorial), swimming (natatorial), grasping (raptorial), clinging (scansorial), sound producing (stridulatorial), and pollen collection.

(3) To hold the female during mating.

4.6 Parts of the insect leg

(1) Coxa

- It is the first or proximal leg segment.
- It articulates with the cup like depression on the thoracic pleuron.
- It is generally freely movable.

(2) Trochanter

- It is the second leg segment.
- It is usually small and single segmented.
- Trochanter seems to be two segmented in dragonfly, dameselfy and ichneumonid wasp.
- The apparent second trochanter is in fact a part of femur, which is called trochantellus.

(3) Femur

- It is the largest and stoutest part of the leg and is closely attached to the trochanter.

(4) Tibia

- It is usually long and provided with downward projecting spines which aid in climbing and footing.
- Tibia of many insects is armed with large movable spur near the apex.

(5) Tarsus

- It is further sub-divided. The sub segment of the tarsus is called tarsomere.
- The number of tarsomeres varies from one to five.
- The basal tarsal segment is often larger than others and is named as basitarsus.
- Beyond the tarsus there are several structure collectively known as pretarsus.
- Tarsus terminates in a pair of strongly curved claws with one or two pads of cushions at their base between them.
- A median pad between the claws is usually known as arolium and a pair of pads, at their base is called pulvilli (Pulvillus-singular).

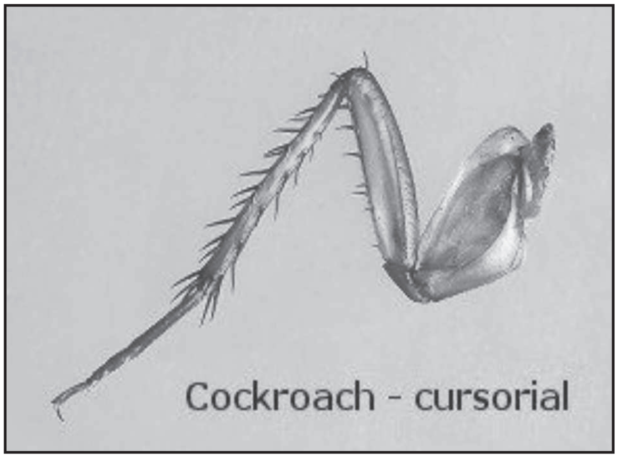
- Leg pads are useful while walking on smooth surface and claws give needed grip while walking on rough surface.
- When one structure is used, the other is bent upwards.

4.7 Modifications of insect legs

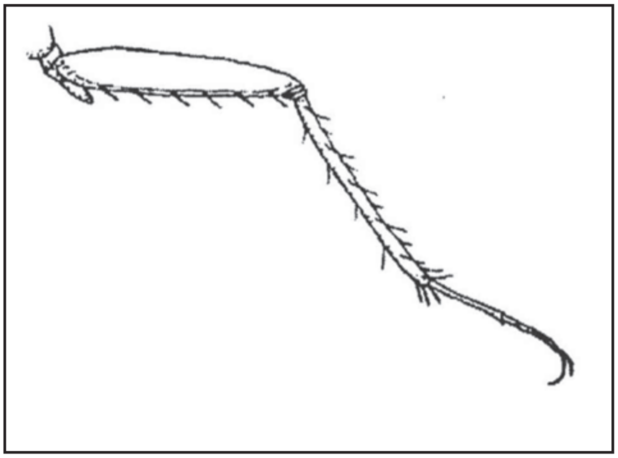
The main function of insect leg is walking. However, legs of various insects are modified for special purposes e.g. running, jumping, swimming, digging, grasping, preying, sound producing, holding hair, collecting pollen etc.

Sr. No.	Type	Leg Modified	Example	Purpose	Nature of Modification
1	Cursorial	All legs	Cockroach	Walking and running	All the legs uniformly well developed without any special modification.
2	Ambulatorial	Fore leg and middle leg	Grasshoppers	Walking	Femur and tibia are long.
3	Saltatorial	Hind legs	Grasshoppers and gryllids	Leaping and Jumping	Femur & tibia elongated
4	Fossorial	Front legs	Mole crickets and dung rollers	Digging	Tibia & tarsus short and broad with teeth like projections.
5	Raptorial	Front legs	Mantids	Preying	Femur spinose & possess a central longitudinal groove. Tibia narrow, blade like spinose & fits into the groove
6	Natatorial	Hind legs	Water beetles	Swimming	Hind legs paddle like. Tibia and tarsus short & broad having dense long marginal hairs.
7	Scansorial	All legs	Head lice	Clinging	Tibia possess tibial thumb. Tarsus single segmented and pretarsus with a single long curved claw.

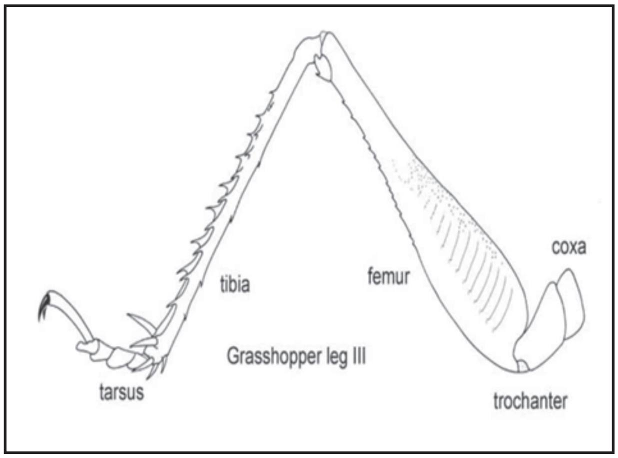
8	Prehensile	All legs together	Dragonflies	Catching prey	Thoracic segments obliquely arranged. Sternal plates pulled forward and tergal plates pushed backward, resulting that all the legs pushed forward and seen below the head, together form a basket like structure useful for catching the prey even in flight
9	Antennal cleaning legs	Front legs	Honey bee	For cleaning antennae	Tibia possesses a process and the first tarsal segment with a semicircular notch.
10	Waxpick type	Middle legs	Honey bee	For picking wax plates	Tibia possesses a spine called wax pick for removing the wax plates from the ventral side of the abdomen.
11	Pollen basket	Hind legs	Honey bee	For collecting pollen & cleaning the body	Inner surface of the tibia has a grove and is used as pollen basket for temporary storage of pollen grains. First tarsal segment enlarged and possess short stiff hairs all over the surface called pollen brush



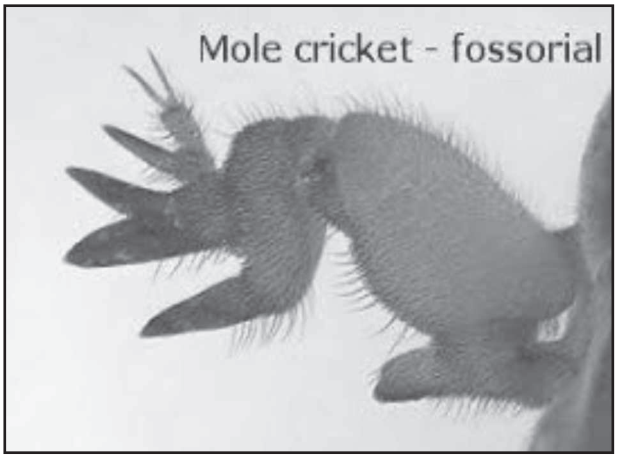
1. Cursorial



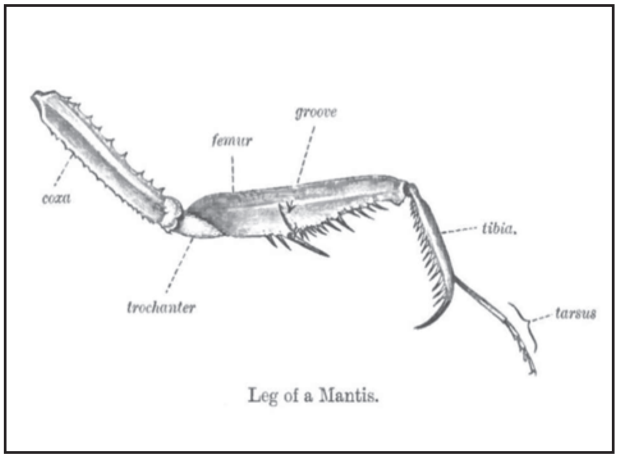
2. Ambulatorial



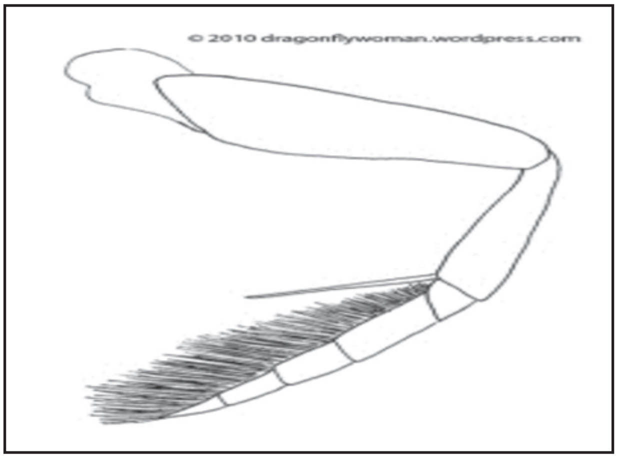
3. Saltatorial



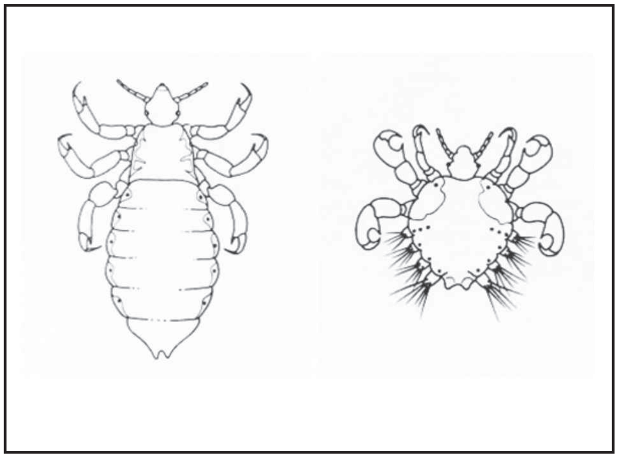
4. Fossorial



5. Rapotorial



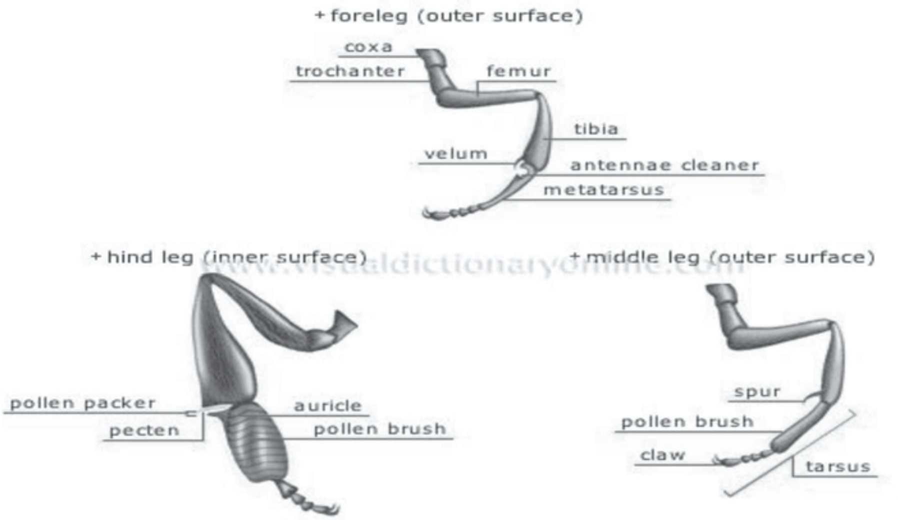
6. Natatorial



7. Scansorial

8. Prehensile

9. Antennal cleaning legs (fore leg)   10. Waxpick type (Middle leg) 11. Pollen basket (hind leg)



Answer the following questions

(1) Draw the labeled diagram of typical insect leg.

(2) What is the significance of three pairs of insect legs?

(3) Which are the different parts of the insect leg?

(4) Where the insect legs are articulated on thorax?

(5) How legs are useful to insects other than walking?

(6) Differentiate the following types of leg. (a) Amulatorial and Cursorial (b) Natatorial and fossorial (c) Ambulatorial and Saltatorial.

(7) How house fly can walk on smooth surface?

(8) What is proleg?

EXERCISE – 5
INSECT WINGS AND THEIR MODIFICATIONS

5.1 Objectives

(1) To study the insect wings and their modifications.

(2) To acquaint students with the insect wing structure and venation as well as various modifications.

5.2 Materials

(1) Insects specimens with different types of wings

(2) Dissecting microscope

(3) Glass slides

(4) Camel hair brush

(5) Scissors

(6) Forceps

(7) Needle

5.3 Methodology

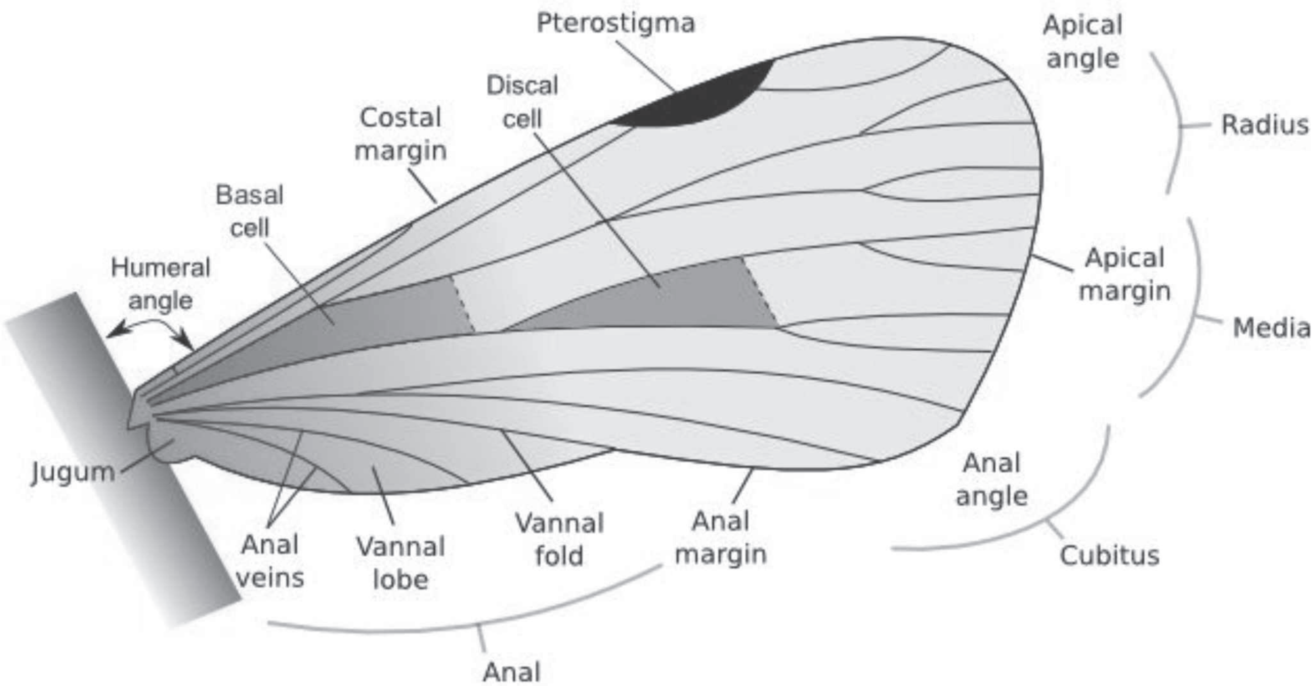
(1) Take an insect, carefully remove its fore and hind pair of wings from dorsolateral area of meso and meta thorax with the help of sharp scissor/forcep and observe the various structures and venation under the microscope.

(2) Separate fore and hind pair of wings from other insects and compare them with characteristics and permanent slides.

5.4 Structure of an insect wing

Among invertebrates, insects are the only winged organisms. Insect wings are somewhat triangular in shape, derived from the integument of thorax. Generally, insects possess two pairs of wings in their adult stage. They are located on dorsolateral region of meso and metathorax. It bears many longitudinal veins and cross veins. It exhibits various shape and colour patterns due to presence of scales. The insect wing is triangular. The anterior margin is known as costal margin while the lateral and hind margins are called apical and anal margin, respectively. The angles formed between costal and apical margins, apical and anal margins and costal and anal margins are known as apex, anal and humeral angle, respectively. The anterior area of the wing supported by veins is usually called remigium. The flexible posterior area is termed vannus. The two regions are separated by vannal fold. The proximal part of vannus is called jugum, when well developed is separated by a jugal fold. The area containing wing articulation sclerites, pteralia is called axilla.

The wings are useful to insects to search habitat, food, mate and escape from attack of natural enemies as well as adverse climatic conditions.



5.5 Functions of insect wings

(1) The main function is locomotion in terrestrial habitat.

(2) To search habitat, food, mate and escape from attack of natural enemies as well as adverse climatic conditions.

(3) It having great taxonomic importance and use in insect classification.

(4) To protect hind wings while resting in coleoptera.

(5) Sound producer in orthoptera while stabilizers in diptera and thermo regulator in honey bee.

5.6 Modifications of insect wing

Wings are modified in different insects. Some insects are primitively wingless e.g. Silverfish, while others are secondarily wingless e.g. bed bug, head louse etc. In some insects, only males are winged. e. g. mealy bugs. In social insects, only reproductive forms are winged for a short period of time. The wings may be hard shield like elytra, partially hard hemelytra, leather like tegmina, fringed- feather like or reduced to a slender knob like structure halter. These may be thin, equal and membranous with dense network of wing venation.

Sr. No.	Name of wing modification	Wing characteristics
1	Elytra	The wing is heavily sclerotised. There is no wing venation. Wing is tough and it is protective in function. It protects hind wings and abdomen. It is not used during flight. But during flight they are kept at an angle allowing free movement of hind wings. e.g. Fore wings of beetles and weevils.
2	Hemelytra	The basal half of the wing is thick and leathery and distal half is membranous. They are not involved in flight and are protective in function. e. g. Fore wing of heteropteran bugs.
3	Tegmina	Wings are leathery. They are protective in function. They are not used for flight. e. g. Forewings of cockroach and grasshopper.
4	Halteres	In true flies the hind wings are modified into small knobbed vibrating organs called halter. They act as balancing organs and provide the needed stability during flight. e.g. House fly
5	Fringed wings	Wings are usually reduced in size. Wing margins are fringed with long setae. These insects swim through the air. e. g. Thrips
6	Scaly wings	Wings of butterfly and moths are covered with small coloured scales. Scales are unicellular flattened outgrowth of body wall. Scales are inclined to the wing surface and overlap each other to form a complete covering. Scales are responsible for colour. They are important in smoothing the air flow over wings and body. e. g. Moth and butterfly
7	Membranous wings	They are thin, transparent wings and supported by many tubular veins. In many insects either forewings or hind wings or both fore wings and hind wings are membranous. They are useful in flight. e. g. Fore wing of house fly, hind wing of beetles and Both wings of dragonfly and damselfly

5.7 Wing venation:

The arrangement of longitudinal and cross veins in wing is called wing venation. Wing venation differs in different insects. It is of great taxonomic importance.

5.7.1 Types of veins

Sr. No.	Name of vein	Characteristics
1	Costa (C)	First anterior marginal vein. Strong and extends to the apex of the wing. It is unbranched and convex. Sometimes it bear stigma on fore and hind wings of Odonata and only on forewings of Hymenoptera, Psocoptera and Mecoptera.
2	Subcosta (Sc)	Second longitudinal vein. It is divided distally into two branches, the outer and inner designated as Sc_1 and Sc_2, respectively. Sc is reduced or fused with R in most Hemiptera. It is concave.
3	Radius (R)	The third vein. The strongest vein on the wing, with branches usually covers the largest area of wing apex. The first branch, outer branch (R_1) runs directly towards outer margin. The second branch is often referred to as radial sector (Rs) which is concave and gives branches as R_2, R_3, R_4 and R_5.
4	Media (M)	The fourth longitudinal vein. It divided into two branches viz., anterior media (MA) which is convex and divided into $MA_1$and MA_2 and posterior media (MP) usually with 4 branches MP_1, MP_2, $MP_3$and MP_4 and are concave.
5	Cubitus (Cu)	The fifth longitudinal vein. It is divided into convex anterior CuAand concave posterior CuP branches. CuAis branched into two branches andCuP is unbranched.
6	Anal (A)	These are veins behind the cubitus,AA and AP are usually separated by the anal fold.
7	Jugal (J)	Small veins in the jugal area, found only in Neoptera.

There are four cross veins found in the insect wing based on their position relative to longitudinal veins.		
1	c-sc	Cross veins run between the costa and subcosta.
2	r	Cross veins run between adjacent branches of the radius.
3	r-m	Cross veins run between the radius and media.
4	m-cu	Cross veins run between the media and cubitus.

5.8 Wing coupling mechanisms:

The two wings of a side usually move together during flight. The two wings are kept together by means of a structure known as wing coupling. Its structure differs in different species and sometimes among two sexes of same species.

Sr. No.	Name of Wing coupling mechanisms	Characteristics
1	Hamuli	A row of small hooks is present on the coastal margin of the hind wing which is known as hamuli. These engage the folded posterior edge of fore wing. e.g. bees.
2	Amplexiform	It is the simplest form of wing coupling. A linking structure is absent. Coupling is achieved by broad overlapping of adjacent margins. e. g. butterflies.
3	Frenate	There are two sub types. e. g. Fruit sucking moth. (1) **Male frenate:** Hind wing bears near the base of the coastal margin a stout bristle called frenulum which is normally held by a curved process, retinaculum arising from the subcostal vein found on the surface of the forewing. (2) **Female frenate:** Hind wing bears near the base of the costal margin a group of stout bristle (frenulum) which lies beneath extended fore wing and engages there in a retinaculum formed by a patch of hairs near cubitus.
4	Jugate	Jugam of the forewings are lobe like and it is locked to the coastal margin of the hind wings. e. g. Hepialid moths.
5	Fold or Hook	It is found in aphids.

Answer the following questions

(1) Draw the labeled diagram of typical insect wing.

(2) What is the significance of insect wings?

(3) Where are the wings articulated on insect body?

(4) Which are the different margins and angles of the insect wing?

(5) Differentiate the Elytra and hemelytra, tagmina and scaly type of wing.

(6) What is halter? What is the utility of halters to a housefly?

(7) Enlist the different longitudinal and cross veins of the insect wing.

(8) What is hamuli?

EXERCISE – 6

INSECT MOUTHPARTS AND THEIR MODIFICATIONS

6.1 Objectives

1) To study the insect mouth parts and their modifications.
2) To identify and categorize the various types of insect mouth parts based on their feeding habit and nature of damage to crop plants.

6.2 Materials

1) Insects specimens with different types of mouth parts
2) Dissecting microscope
3) Glass slides
4) Cover slips
5) Camel hair brush
6) Scissor
7) Forceps
8) Needle
9) Glycerin
10) Water

6.3 Methodology

6.3.1 Biting and chewing type

(1) Take a live cockroach; kill it with the help of detergent water than remove its antennae from the base with the help of sharp scissor.

(2) Hold the cockroach head in between thumb and fore finger to facilitate the dissection of mouth parts.

(3) Take a pointed forceps and first remove the flap like labrum by holding tightly from the base which is upper lip of the cockroach mouth parts. Due to this a pair of mandibles will be clearly seen.

(4) Than hold the mandibles from the base and remove from the head one by one. They are first pair of jaws. Due to this a pair of maxillae will be clearly seen.

(5) Than hold the maxillae from the base and remove from the head one by one. They are second pair of jaws.

(6) The tongue like structure will be seen after removal of the maxillae. Gently remove that part with the help of forcep.

(7) At last remove the labium from the base without damage to the labial palps.

(8) Arrange all dissected parts on the glass slide and observe under the microscope.

6.3.2 Piercing and sucking type

(1) Take a living or liquid preserved red cotton bug.

(2) Put it on the glass slide and separate the head from the thorax.

(3) Dissection should be done under the microscope with glycerin to facilitate the separation of the stylets.

(4) Gently press the labium with help of the needle it will leads to separation of the four stylets from the labial groove.

(5) Extreme care should be taken while pressing the labium to prevent the breaking of labium.

(6) Observe and identify the various mouth parts under the microscope.

(7) For comparison, take a mosquito and complete the process same as above, observe mosquito mouth parts and compare them with that of red cotton bug.

6.3.3 Chewing and lapping type

(1) Take a honeybee, cut the head from the thorax, and gently press it between two slides.

(2) Observe the various parts under the microscope and identify them.

6.3.4 Siphoning type

(1) Take a butterfly or moth, separate head from thorax, press between two slides.

(2) Observe the various parts under the microscope and identify them.

6.3.5 Sponging type

(1) Take a housefly, separate head from thorax.

(2) Observe the various parts under the microscope and identify them.

6.3.6 Rasping and sucking type

(1) Take a thrips, arrange on glass slide.

(2) Observe under microscope.

6.3.7 Mandibulosuctorial type

(1) Take a grub/larvae of ant lion, separate head from thorax.

(2) Observe under microscope.

6.4 Types of insect mouthparts

The insects are causing most of the damage by feeding on various parts of host plants through mouthparts. The type of food differs in different insects. Similarly, method of taking food also differs in various insects and so different types of mouthparts are found in different insects.

The mouthparts are developed as the appendages of various segments of the head as under:

Third segment………Labrum (Upper lip)

Fourth segment…….Mandible (First pair of jaws)

Fifth segment……….Maxillae (Second pair of jaws)

Sixth segment………Labium (Lower lip)

The mouth parts of insects can be classified into two major groups.

6.5 Major types of mouth parts of insects

(1) The biting and chewing type (Mandibulate)

e. g. Cockroach, Beetles, Grass hopper, Lepidopteron larvae etc.

6.5.1 Structure and function of mouthparts of cockroach

a. **Labrum:** It is a thin plate on the front of mouth. It's one side is articulated with the head capsule. It works as a cover for the underlying mouthparts. It forms a roof of the preoral cavity and mouth.

b. **Epiharynx:** it is swollen area of the ventral surface of the labrum which is an organ of taste.

c. **Mandibles:** It is the hardest part of all the mouthparts. It is articulated on either side, below gena. The inner margins are dark and chitinous, while the rest of the part is brown coloured. The function of mandibles is to cut and chew food material. To carry the thing. In honey bees and wasps, they are used to mould wax or mud. It may be used for defense.

d. **Maxillae:** It is the second pair of jaws. It lies behind the mandible in side view. Each maxilla consists of a cardo, stipes, inner lacinea and outer galea. A maxillary palp arises from the base of the stipes. The function of maxillae is to hold the food while mastication and it also helps in selection of food through tactile sensory hairs.

e. **Labium:** It is the lower most part made-up of several structures viz., glossae, paraglossae and labial palps. It closes the buccal cavity from lower side and helps in selecting the food by testing through sensory hairs present on it.

f. **Hypopharynx:** The flap like part which is seen in the mouth after removing the mandibles is known as hypopharynx. It is articulated with inner wall of labium. Salivary duct opens at its base. It is known as tounge of an insect.

(2) The piercing sucking type (Haustellate)

e. g. Bugs, louse, mosquito, whitefly, aphids, jassids etc.

Labium projects downwards from the anterior part of the head like a beak. Beak is four segmented and grooved throughout its entire length. At the base of the labium there is a triangular flap like structure called labrum. Labium is neither involved in piercing nor sucking. It functions as a protective covering for the four stylets (fascicle) found within the groove. Both mandibles and maxillae are modified into long slender sclerotized hair like structure called stylets. They are lying close together and suited for piercing and sucking. The tips of the stylets may have minute teeth for piercing the plant tissue. The inner maxillary stylets are doubly grooved on their inner faces. When these are closely opposed they form two canals viz., food canal and salivary canal through sap and saliva are conducted respectively. Saliva contains enzymes or toxins that can distort plant cell wall to permit the stylets to penetrate down and reach phloem for sucking the sap. Both palps are absent.

(3) Piercing and sucking / mosquito type: e.g. Female mosquito

Mouthparts of female mosquito consists of an elongate labium which is grooved forming a gutter which encloses six stylets. The stylets are composed of labrum - epipharynx (enclosing the food canal), the hyphopharynx (containing the salivary canal), two maxillae and two mandibles. Both the ends of maxillary stylets and mandibular stylets are saw like and suited piercing flesh. The stylets are inserted into host's skin by a strong downward and forward thrust of body. Both mandibles and maxillae are reduced in male and they feed on plant nectar and juices of decaying fruits. Female pierces the skin of human beings into which it injects saliva containing an anticoagulant (to keep the blood flowing without clotting) and an anesthetic (to keep the victim unaware of the bite) and sucks up the blood. Labium does not pierce but folds up or back as stylets pierce. Maxillary palpi are present.

(4) Chewing and lapping type: e.g. Honey bee

Labrum and mandibles are as in biting and chewing type of mouth parts. But mandibles are blunt and not toothed. They are useful to crush and shape wax for comb building; ingest pollen grains and other manipulative functions. Maxillolabial structures are modified to form the lapping tongue. The tongue unit consists of two galea of maxillae, two labial palpi and elongated flexible hairy glossa of labium. The glossa terminates into a small circular spoon shaped lobe called spoon or bouton or flabellum which is useful to lick the nectar.

(5) Rasping and sucking: e.g. Thrips

Mouth cone consists of labrum, labium and maxillae. There are three stylets derived from two maxillae and left mandible. Right mandible is absent. Stylets are useful to lacerate the plant tissue and the oozing sap is sucked up by the mouth cone. Both maxillary palpi and labial palpi are present.

(6) Mandibulosuctorial type: e.g. Grub of antlion

Mandibles are elongate sickle shaped and grooved on the inner surface. Each maxilla is elongated and fits against the mandibular groove to from a closed food canal. The body of the insect victim is pierced by the opposing mandibles and fluids are extracted.

(7) Sponging type: e.g. House fly

The proboscis is fleshy, elbowed, retractile and projected downwards from head. The proboscis can be differentiated into basal rostrum and distal haustellum. The proboscis consists of labium which is grooved on its anterior surface. Within this groove lie the labrum-epiphraynx (enclosing the food canal) and slender hypopharynx (containing the salivary canal). Mandibles are absent. Maxillae are represented by single segmented maxillary palpi. The end of the proboscis is enlarged, sponge like and two lobed which acts as suction pads. They are called oral discs or labella. The surfaces of labella are transvered by capillary canals called pseudotracheae which collect the liquid food and convey it to the canal. Labella function as sponging organs and are capable of taking exposed fluids. These insects often spit enzyme containing saliva onto solid foods to liquify them.

(8) Siphoning type: e.g. Moths and butterflies

Mouth parts consist of elongate sucking tube or proboscis. It is formed by two greatly elongated galeae of maxillae which are zippered together by interlocking spines and hooks. Galeae are grooved on their inner surface and when they are fitting together closely they form a suctorial food canal through which the nectar is sucked up. The proboscis is coiled up like watch spring and kept beneath the head when it is not in use. By pumping of blood into galeae, the proboscis is extended. The other mouth parts are reduced or absent except the labial palpi and smaller maxillary palpi.

Answer the following questions

(1) List out the names of the insects having biting and chewing type of mouth parts.

(2) Name the insects of agricultural importance possessing siphoning type of mouth parts.

(3) Write the function of labrum, mandible, maxillae, labium and hypopharynx.

(4) Enlist the names of the insects having piercing and sucking type of mouth parts.

(5) How the study of mouth parts of insects useful in plant protection.

EXERCISE – 7

METAMORPHOSIS AND DIAPAUSE IN INSECTS

7.1 Objective

(1) To study the life stages of an insect.

(2) To familiarize the students with the different developmental stages of an insect.

7.2 Materials

Preserved specimens including various stages of Silverfish, Grasshopper, dragonfly, Butterfly, Red cotton bug etc.

7.3 Methodology

(1) Observe the different growth stages of different insects in the laboratory and insect museum as well as in the field.

(2) Note the external characteristics of adults and immatures (young, nymph, naiads, larvae and pupae)

7.4 What is metamorphosis?

Metamorphosis is the change in growth and development an insect undergoes during its life cycle from birth to maturity. There are four basic types of metamorphosis found in insects as given below.

Sr. No.	Type of Metamorphosis	Description of Metamorphosis
1	**Ametabola** (No metamorphosis)	These insects have only three stages in their life namely egg, young ones and adult. It is most primitive type of metamorphosis. The hatching insect resembles the adult in all respects except for the size and called as juveniles. Moulting continues throughout the life. e.g. Silverfish
2	**Hemimetabola** (Incomplete metamorphosis)	These insects also have three stages in their life namely egg, young one and adult. The young ones are aquatic and are called as **naiads**. They are different from adults in habit and habitat. They breathe by means of tracheal gills. In dragonfly naiad the lower lip (labium) is called mask which is hinged and provided with hooks for capturing prey. After final moult, the insects have fully developed wings suited for aerial life. e.g. Dragonfly, damselfly and mayfly
3	**Paurometabola** (Gradual metamorphosis)	The young ones are called **nymphs**. They are terrestrial and resemble the adults in general body form except the wings and external genitalia. Their compound eyes and mouth parts are similar

		to that of adults. Both nymphs and adults share the same habitat. Wing buds externally appear in later instars. The genitalia development is gradual. Later instar nymphs closely resemble the adult with successive moults. e.g. Cockroach, grasshopper, bugs
4	**Holometabola** (Complete metamorphosis)	These insects have four life stages namely egg, larva, pupa and adult. Majority of insects undergo complete metamorphosis. Larvae of butterflies are called caterpillar. Larva differs greatly in form from adult. Compound eyes are absent in larva. Lateral ocelli or stemmata are the visual organs. Their mouth parts and food habit differ from adults. Wing development is internal. When the larval growth is completed, it transforms into pupa. During the non-feeding pupal stage, the larval tissues disintegrate and adult organs are built up. e.g. Butterfly, moth, fly and bees
5	**Hypermetamorphosis**	This is a peculiar type of development which consists of two or more types or forms of larvae in the life cycle of insects. In majority of the cases the first larval instar is **campodeiform** and the subsequent larval forms depends on type and mode of life of the larva. E.g.: In blister beetle (Meloidae; Coleoptera), the first larval instar is **campodeiform** followed by **scarabeiform** larval type.

7.5 Diapause in insects

Diapause is a period of suspended or arrested development during an insect's life cycle. Diapause may occur in any life cycle stage – embryonic, larval, pupal, or adult – depending on the insect species.

Diapause is a predetermined period of dormancy, meaning it's genetically programmed and involves adaptive physiological changes. Environmental cues aren't the cause of diapause, but they may control when diapause begins and ends. Quiescence, in contrast, is a period of slowed development that is triggered directly by environmental conditions, and that ends when favorable conditions return.

7.5.1 Types of Diapause

Diapause can be either obligatory or facultative:

(1) **Obligatory diapause:** Insects undergo this period of arrested development at the predetermined point in their life cycle, regardless of the environmental conditions. Diapause occurs in every generation. Obligatory diapause is most often associated with univoltine insects means insects that have one generation per year.

(2) **Facultative diapause:** Insects undergo a period of suspended development only when conditions require it for survival. Facultative diapause is found in most insects and is associated with bivoltine (two generations per year) or multivoltine insects (more than two generations per year).

Answer the following questions

(1) What is metamorphosis?

(2) Name the various stages of development in a moth and write their characteristics.

(3) Differentiate the following. Complete and incomplete metamorphosis, nymph and larvae, larvae and pupae.

(4) What is diapause?

(5) Difference between obligatory or facultative diapause.

EXERCISE – 8
INSECT LARVAE AND PUPAE

8.1 Objectives

(1) To learn the type of immature stages like larvae and pupae of an insect.

(2) To understand the insect development.

8.2 Materials

Preserved specimens of different larvae and pupa.

8.3 Methodology

(1) Observe the different larvae and pupa of different insects in the laboratory and insect museum.

(2) Note the external characteristics of larvae and pupa.

8.4 Insect larvae

Larval stage is the active growing stage. It is the immature stage between the egg and pupal stage of an insect having complete metamorphosis. This stage differs from the adult.

8.4.1 Types of larvae

Sr. No.	Type of larvae	Characteristics
1	Protopod	Found in some parasitic Hymenopteran insects, Egg contains small quantity of yolk and hence larva hatches from the egg before completing its embryonic development (Degenerate larva), Segmentation in abdomen absent, Appendages of head and thorax small or rudimentary, Nervous and respiratory systems undeveloped Cannot live free life; always internally parasitic on other insects.
2	Polypod or Eruciform	**a) Caterpillar:** It has three pair of thoracic legs and five pairs of prolegs and are situated on 3, 4, 5. 6 & 10th abdominal segments. e.g. Lepidopteron larvae **b) Platyform larva:** Larva is thick, short, stout and fleshy. Laval head is small and retractile. Thoracic legs are minute. Abdominal legs are absent. Abdominal segmentation is indistinct. Larva has poisonous spines called scoli distributed all over the body. e.g. Slug caterpillar **c) Semilooper:** Either three or four pairs of prolegs are present. Prolegs are either wanting or rudimentary in either third or third and fourth abdominal segments. e.g. castor semilooper.

		d) Looper: They are also called measuring worm or earth measurer or inch worm. In this type, only two pairs of prolegs are present in sixth and tenth abdominal segments. e.g. Daincha looper, Cabbage looper
3	Oligopod	Thoracic legs are well developed and abdominal legs are absent. **a) Campodeiform:** Body is elongate, depressed dorsoventrally and well sclerotised. Head is prognathous. Thoracic legs are long. A pair of abdominal cerci or caudal processes is usually present. Larvae are generally predators and are very active. e.g. grub of crysopa and lady bird beetle. **b) Scarabaeiform:** Body is `C' shaped, stout and subcylindrical. Head is well developed. Thoracic legs are short. Caudal processes are absent. Larva is sluggish, burrowing into wood or soil. e.g. grub of rhinoceros beetle and white grub. **c) Carabeiform:** Body is dorsoventrally flat and bears three pairs of thorac legs which are short. e. g. ground beetle and carabeidae family of coleoptera order.
4	Apodous	larvae without appendages **a) Eucepalous:** Larva with well developed head capsule with functional mandibles, maxillae, stemmata and antennae. Mandibles act transversely. e.g. Wriggler and grub of red palm weevil. **b) Hemicephalous:** Head capsule is reduced and can be withdrawn into thorax. Mandibles act vertically. e.g. Larva of robber fly. **c) Acephalous:** Head capsule is absent. Mouthparts consist of a pair of protrusible curved mouth hooks and associated internal sclerites. They are also called vermiform larvae. e.g. Maggot (larva of house fly).

8.5 Insect Pupae

It is the resting and inactive stage in all holometabolous insects. During this stage, the insect is incapable of feeding and is quiescent. During the transitional stage, the larval characters are destroyed and new adult characters are created. There are three main types of pupae.

8.5.1 Types of pupae

Sr. No.	Type of pupae	Characteristics
1	Obtect	Appendages are glued to the body **a) Chrysalis:** It is the naked obtect pupa of butterfly. It is angular and attractively coloured. The pupa is attached to the substratum by hooks present at the terminal end of the abdomen called cremaster. The middle part of the chrysalis is attached to the substratum by two strong silken threads called gridle. **b) Tumbler:** Pupa of mosquito is called tumbler. It is an obtect type of pupa. It is comma shaped with rudimentary appendages. Breathing trumpets are present in the cephalic end and anal paddles are present at the end of the abdomen. Abdomen is capable of jerky movements which are produced by the anal paddles. The pupa is very active.
2	Exarate	Various appendages viz., antennae, legs and wing pads are not glued to the body. They are free. All oligopod larvae will turn into exarate pupae. The pupa is soft and pale e.g. Pupa of rhinoceros beetle.
3	Coarctate	The pupal case is barrel shaped, smooth with no apparent appendages. The last larval skin is changed into case containing the exarate pupa. The hardened dark brown pupal case is called puparium. e.g. Housefly and some other Dipteran flies.

8.5.2 Protection to the pupae

In general pupal stage lacks mobility. Hence it is the most vulnerable stage. To get protection against adverse conditions and natural enemies, the pupa is enclosed in a protective cover called cocoon. Based on the nature and materials used for preparation of cocoons, there are several types.

Types of cocoon	Materials used	Example
Silken cocoon	Silk	Silk worm
Earthen cocoon	Soil + saliva	Gram pod borer
Frassy cocoon	Frass + saliva	Coconut black headed caterpillar
Fibrous cocoon	Fibres	Red palm weevil

Answer the following questions

(1) What is tumbler?

(2) What is chrysalis?

(3) What is puparium?

(4) What is wriggler?

(5) Difference between campodeiform and scarabaeiform larvae

(6) Difference between caterpillar and semilooper

(7) Difference between grub and maggot

(8) Difference between oligopod and polypod larvae

(9) Difference between obtect and exarate pupae

EXERCISE – 9

DISSECTION OF DIGESTIVE SYSTEM OF INSECTS

9.1 Objective

To acquaint the students with the internal structures particularly the digestive system of cockroach or grasshopper to help them to know the internal anatomy of insects.

9.2 Materials

(1) Freshly killed grasshopper or cockroach

(2) Dissecting microscope

(3) Dissecting wax tray

(4) Wash bottle with water

(5) Scissors

(6) Camel hair brush

(7) Forceps

(8) Needle

(9) Pins

9.3 Methodology

(1) Take a freshly killed cockroach.

(2) Carefully remove its antennae, legs and wings from the base to facilitate dissection.

(3) Make a lateral cut on both sides of the abdomen starting from posterior end with the help of a sharp scissor/blade.

(4) Place the cockroach in a wax tray in dorsal-ventral position (exposing dorsal side towards you).

(5) Insert a pin through the head and fix at 45 degree angle on wax tray.

(6) Pour the fresh water in wax tray to facilitate dissection process.

(7) Remove the tergum from posterior end to anterior end up to thorax with extreme care with the help of a forceps and needle. Care should be taken while removing the pronotum.

(8) Pin the lateral margins placing them at an angle of 45 degree without damaging alimentary canal

(9) Remove all fatty tissues, air sacs, tracheae and muscles surrounded from mouth to anus with the help of camel hair brush.

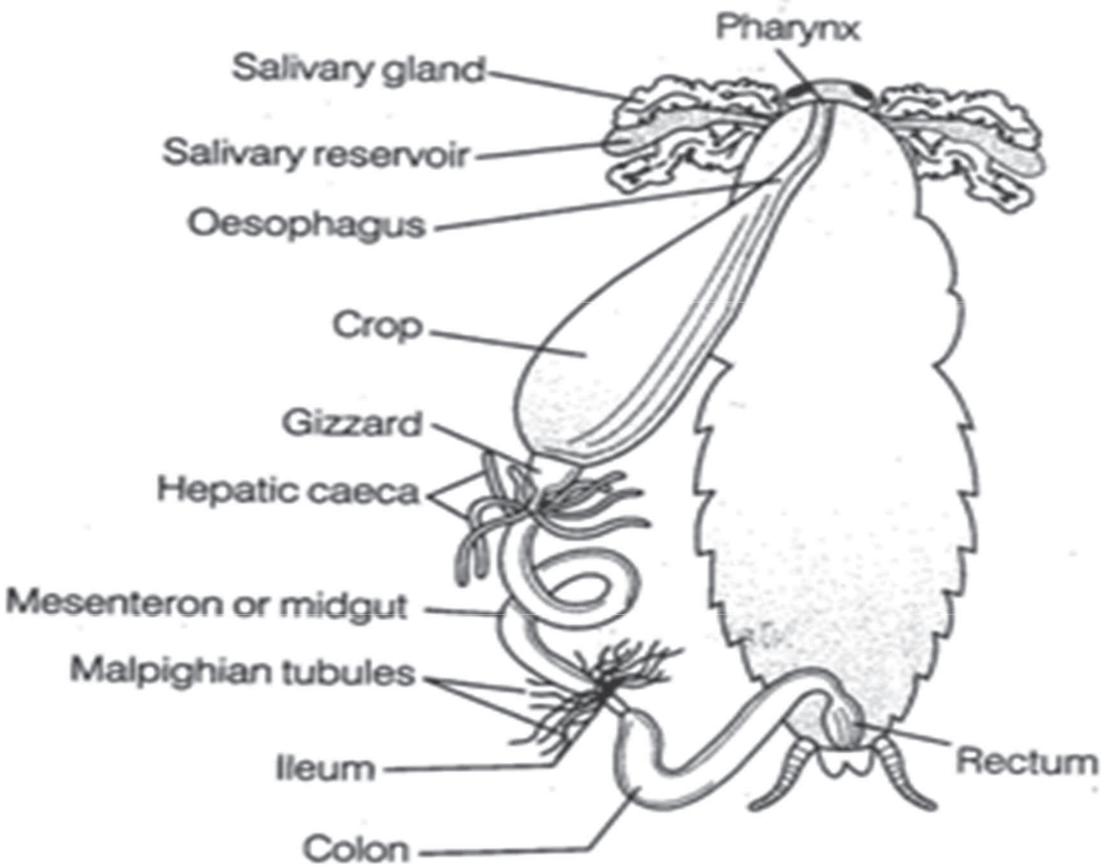
(10) Finally discard the dirty water and pour fresh water again to display the system.

(11) Observe and identify the various parts of alimentary canal.

9.4 Digestive system of cockroach

The organs primarily concerned with the intake of food are mouth parts which are variously modified to suit the type of food required to be taken by insects. The food that has been taken pass through the digestive tract which extends from mouth to anus is known as alimentary canal.

The digestive system of cockroach is divided into foregut, midgut and hindgut. It begins near the buccal cavity in the head and ends into anus. A pair of salivary glands lies on the side of oesophagus and produces saliva. The foregut consists of tubular oesophagus, sac like crop and conical gizzard. At the junction of foregut and midgut one finds finger like structures known as gastric caeca or enteric caeca which developed from midgut which increase surface area for the absorption of food material. The mid intestine secretes digestive enzymes which digest the ingested food material and absorb digested food. Very fine thin hair like yellow colored numerous tubules are present at the junction of midgut and hindgut which are known as Malpighian tubules. They are associated with excretion. The hindgut is made up of ileum, colon and rectum and help in conserving salt and moisture through rectal papillae. The digestive tract ends with anus.



Alimentary canal of cockroach

Answer the following questions

(1) Draw the labeled colour diagram of digestive system of cockroach.

(2) Describe the structure and function of Oesophagous, crop, gizzard, gastric caeca, midgut, malpighian tubules, ileum, colon and rectum of digestive system of cockroach.

(3) Write the difference between foregut and midgut?

(4) Enlist the parts of alimentary canal in a sequence starting from mouth to anus.

(5) Collect the adult cockroach/grasshopper and dissect the digestive system in the laboratory.

EXERCISE – 10

DISSECTION OF MALE AND FEMALE REPRODUCTIVE SYSTEMS OF INSECTS

10.1 Objective

To acquaint the students with the reproductive structures particularly male and female reproductive systems of cockroach or grasshopper to help them to understand functions and mechanism of reproduction in insects.

10.2 Materials

(1) Freshly killed grasshopper or cockroach
(2) Dissecting microscope
(3) Dissecting wax tray
(4) Wash bottle with water
(5) Scissors
(6) Camel hair brush
(7) Forceps
(8) Needle
(9) Pins

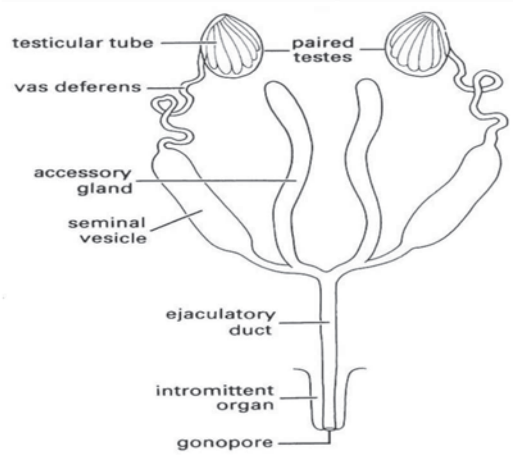
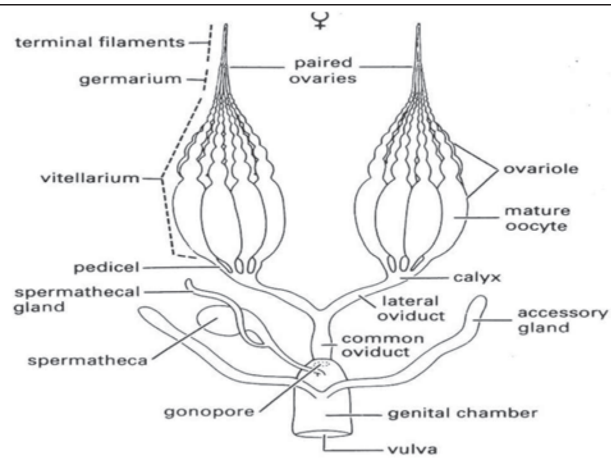
10.3 Methodology

(1) Take a freshly killed cockroach.
(2) Carefully remove its antennae, legs and wings from the base with the help of sharp scissor to facilitate dissection.
(3) Make a lateral cut on both sides of the abdomen starting from posterior end with the help of a sharp scissor/blade.
(4) Place the cockroach in a wax tray in dorsal-ventral position (exposing dorsal side towards you).
(5) Carefully insert a pin through the thorax and at the end of anus fix at 45 degree angle on wax tray.
(6) Pour the fresh water in wax tray to facilitate dissection process.
(7) Remove the tergum from posterior end to anterior end up to metathorax with extreme care with the help of a forceps and needle.
(8) Remove all fatty tissues, air sacs, tracheae and muscles surrounded to reproductive system with the help of camel hair brush.
(9) Finally discard the dirty water and pour fresh water again to display the system.
(10) Observe and identify the various parts of male and female reproductive parts, remove alimentary canal separating it from rectum, pin the rectum stretching posteriorly. Separate ovaries, testes and observe their various parts.

10.4 Reproductive systems

Cockroach is a unisexual organism. Either male or female reproductive system is present in a cockroach. The male is externally distinguished from female mainly by the presence of anal styles in addition to anal cerci.

10.5 Difference between male and female reproductive systems.

Sr. No.	Male reproductive system	Female reproductive system
		
1	Male having paired testes composed of follicles and developed from mesoderm. They produce spermatozoa (sperms).	Female having paired ovaries composed of ovarioles and develop from Mesoderm. They produce ova (eggs).
2	Male having paired vasa differentia develop from mesoderm.	Female having paired oviducts develop from mesoderm.
3	Male having seminal vesicles.	Female having egg calyces.
4	Male having median ejaculatory duct	Female having common oviduct and vagina.
5	In male accessory glands are Mesadenia and Ectadenia.	In female accessory gland is Collateral glands.
6	Male external genitalia called as aedaegus.	Female external genitalia called as Ovipositor.

Answer the following questions

(1) Draw the labeled diagram of male and female reproductive system of cockroach.

(2) Write the functions of male and female reproductive parts of cockroach.

(3) How will you distinguish a male and female cockroach on the basis of external characters?

EXERCISE – 11
STUDY THE CHARACTERS OF ORDERS ORTHOPTERA, DICTYOPTERA, ODONATA, ISOPTERA, THYSANOPTERA, HEMIPTERA AND THEIR FAMILIES OF AGRICULTURAL IMPORTANCE

11.1 Objective

1) To learn the distinguishing features of insect orders and their families of agricultural importance.
2) To collect the insects of commonly found families of various orders.
3) To familiarize the students with different orders of insects and their characters to identify them up to family level.

11.2 Materials

Preserved specimens of different orders *viz.,* orthoptera, dictyoptera, odonata, isoptera, thysanoptera and hemiptera in the laboratory as well as insect museum.

11.3 Methodology

Carefully observed the different specimens of various insects under different order as shown in the laboratory as well as insect museum and note the different distinguishing characters.

11.4 Order: ORTHOPTERA (Orthos = Straight; Ptera = Wing) e. g. Grass hopper, cricket and locust

This is a large order with more than 18000 described species. The insects of this order are found more in the tropics but some species do occur in the coldest zone.

Generally, they are terrestrial and usually capable of jumping. Some members of this order are strong fliers, all belonging to the family Acrididae. Some of the grass hoppers are important pests of field crops, e.g. paddy grass hopper, surface grass hopper, crickets etc. The locusts which fly gregarious in large numbers invade distant areas causing depletion of green biomass resulting in famine and starvation.

11.4.1 General characters of Orthoptera

- Medium to large sized insects with well developed exoskeleton.
- Head is hypognathous.
- They are winged.
- Fore wings modified into tegmina.
- Hind legs often enlarged for jumping purpose (saltatorial leg).
- Special sound producing and auditory organs often present (Stridulatorial legs in cricket).
- Cerci short and one segmented.
- They have chewing and biting type of mouthparts.
- Female has well developed ovipositor; male genitalia symmetrical.
- They have incomplete metamorphosis.

11.4.2 Sub order: Ensifera e. g. Crickets and long horned grasshoppers

- Antenna longer than their body.
- Tympanum organs present on their fore tibia, tarsi 3 to 4 segmented.
- Ovipositor less elongated.

Sr. No.	Name of Family	Characters
1	Tettigonidae	• e. g. Katydid (Long horn grasshopper) *tettigonia* sp. • Antennae are very long. • Tegmina modified asymmetrically for stridulation. • Predominantly green colour. • They have long ovipositor.
2	Gryllidae	• e. g. House cricket *Gryllus domesticus* • Head large and antennae very long. • Eye large. • Hind legs modified for jumping type. • Cerci long and unjointed. • Ovipositor long, slender and needle like. • Stridulate by friction of modified tegmina.
3	Gryllotalpidae	• e. g. Mole cricket, *Gryllotalpa africana* • Antennae short. • Tarsi 2 to 3 segmented. • Forelegs modified for digging type (Fossorial). • Typanum on fore tibia. • Eyes reduced. • Ovipositor small.

11.4.3 Sub order: Caelifera e. g. Short horned grasshoppers and locusts

- Antennae shorter than body.
- Hind legs adapted for leaping.
- Tarsi not more than three segmented.
- Ovipositor short and stout.

x Tympanum organ present at the base of abdomen.

Sr. No.	Name of Family	Characters
1	Acrididae	• e. g. Ak grasshopper (*Poecilocerus pictus*), Surface grasshopper (*Chrotogonous* sp.), Rice grasshopper (*Hieroglyphus banian*) and Locusts (*Scitocera gragaria*) • Forewings invariably leathery called tegmina. • Pronotum is collar shaped. • Ovipositor well developed, short and curved. • Hind legs modified as jumping. • Many small peg like projections near the base of tegmen and hind femur bears a simple longitudinal ridge which are rubbed against tegmina for producing the buzzing sound Mouth parts chewing type, eyes and antennae well developed. • Auditory organs located on each side of the basal segment of abdomen.

11.5 Order: DICTYOPTERA (Dictyon = Net; Ptera = Wing) e. g. Cockroach and Mantids

They are medium or large sized insects. They are terrestrial and occurring in tropical and subtropical region. They are not good flier. The order includes two distinct sub orders.

11.5.1 General characters of Dictyoptera

- Long filiform antennae, pronotum large as in praying mantis and shield shaped as in cockroaches.
- Ovipositor reduced.
- Tarsi 5 segmented.
- Stridulatory and auditory organs absent.

11.5.2 Sub order: Blattoidea e. g. Cockroaches

- Head nearly or completely cover.
- Pronotum shield shaped.
- Cerci prominent.
- Swift runners with ambulatorial and curssorial type of legs.
- Antennae long filiform.
- Mouthparts are typically mendibulate.
- Compound eyes present.

- They are nocturnal but also seen venturing during day time.
- They are omnivorous.
- They are household pests and spoil kitchen articles and food.

11.5.3 Sub order: Mantoidea e. g. Mantid

- Pronotum large elongated.
- Forelegs raptorial, helps in seizing the prey.
- Antennae long filiform.
- Head triangular with vertical face and movable on slender neck hence can see at 360^{O}.
- Eggs are deposited in ootheca or capsule formed of frothy quick drying material.
- They are largely arboreal and occur in all warmer parts of the world.
- They are carnivorous and live predaceous life both as young and adult.
- They feed on grasshoppers, flies, caterpillars etc.
- The female usually devours the male after mating.

11.6 Order: ODONATA (Odoun = Tooth) e. g. Dragonfly and damselfly

These conspicuous insects comprise a largely tropical order containing about 5500 described species. These are predatory insects. They catch and devour small flying insects. These are found in large numbers flying nearby stream, river etc. It can fly at a speed of 100 km/hr. They are fastest flying insects. The nymphs are aquatic in habit. Wide range of coloration is found in the adult.

11.6.1 Sub order: Anisoptera e. g. Dragonfly

- Predacious insect with biting mouthparts..
- Large insects with two pairs of unequal membranous wings, each with a large number of veins and cross veins and a prominent stigma known as Pterostigma**.**
- Unequal wings. Hind pair broadened basally.
- Wings held horizontally at rest.
- Antennae setaceous very small and the eyes are very long.
- Abdomen extremely long and slender.
- Metamorphosis hemimetabolous.
- Nymph is aquatic; respiration by means of caudal or rectal gills.
- They are diurnal in habit found in proximity of water.

11.6.2 Sub order: Zygoptera e. g. Damselflies

- Fore and hind wings similar and petiolated basally.
- Wings held vertically above the abdomen.

- Eyes projected laterally and separated by a space more than their dorsal diameter.
- Nymphs are slender, elongated abdomen and three caudal gills.
- They are diurnal in habit, found in proximity of water and predaceous in nature.

11.7 Order: ISOPTERA (Iso = Equal; Pteron = Wings) e.g. Termites

The isoptera is a small order of some 2600 described species of hemimetabolous neopterans. Termites are found throughout the tropics. Termites live in a nest called **termitaria** which are subterranean and which sometimes rise above the soil surface as large mounds. A termite colony has usually royal pair – the king and the queen which are primary reproductive castes; sterile castes consist of soldiers and workers, both are apterous. They feed on wood and are able to digest cellulose with the help of protozoa in their gut. They exhibit symbiosis with intestinal protozoans.

11.7.1 Different castes in a termite colony

1) **Queen**: It is reproductive caste that is responsible for maintaining the population of workers and soldiers in the termitaria.
2) **King**: It has a function of copulation with queen and accompany the queen for rest life
3) **Soldier**: They perform the function of patrolling the termitaria and defend the colony from the enemies.
4) **Workers**: They are actual workers, who find and collect foods and nourish young one, queen, king and maintain cleanliness of termitaria.

11.7.2 General characters of Isoptera

- Termites are soft bodied social and polymorphic (Queen, king, soldiers and workers) insects.
- Two pairs of similar wings present in sexually mature males and females.
- The wings are deciduous.
- The wings are membranous with restricted venation.
- Mouthparts biting and chewing type.
- Termites feed predominantly on cellulose rich material; wood, rotting timber, paper, books, furniture, many harvest grasses, many crops etc.
- Antennae short moniliform.
- External genitalia are absent.

Sr. No.	Name of Family	Characters
1	Termitidae	• e. g. *Odontoterms obesus* and *Microterms obesi.* • Ground dwelling with wide range of food habits and colony structure. • Worker castes well developed. • Pest of sandy soils and wood. • Wings very slightly reticulate. • Pronotum of workers and soldiers narrow with raised anterior lobe.

11.8 Order: THYSANOPTERA (Thysanos = Fringed; ptera = wings) e.g. Thrips

This is a worldwide order of minute to small insects commonly known as thrips, comprising about 5000 species. They are mostly yellow, yellowish brown or black and may found among all kinds of vegetation, both on reproductive and vegetative parts. When disturbed, some species crawl in a leisurely fashion, other run quickly or leap and large number is flying but do not readily do so. Member of this order cause damage to cotton, onion, castor, groundnut, pulses, rose, tomato, chilly, tobacco etc.

11.8.1 General characters of Thysanoptera

- Their development is intermediate between hemi- and holometabolous; metamorphosis accompanied by two or three inactive pupa-like instars.
- The body is slender and elongate.
- Head hypognathus.
- Short antennae with 6 to 10 segment.
- Mouthparts are asymmetrical stylet like for rasping and sucking type.
- Right mandible is reduced in size.
- Fore and hind wings are similar and narrow with a long fringe.
- In female the cerci are absent.
- Many species curving the abdominal tip upward and movement.

Sr. No.	Name of Family	Characters
1	Thripidae	• e. g. *Thrips tabaci* • Mouthparts not bilaterally symmetrical. • Tarsus has claw like appendages. • Antennae 4-9 segmented with slender, simple or forked sense cones. • At rest the wings are parallel. • In female the cerci are absent.

11.9 Order: HEMIPTERA (Hemi = Half; Ptera = Wing) e.g. Aphids, Jassids, Whiteflies, Mealy bugs, Scale insects, Red cotton bug

The hemiptera distributed worldwide and is most diverse of the non endopterygote orders, with more than 90000 described species. The hemiptera or "true bugs" are easily recognized by the form of their mouthparts. Some of them are blood suckers and transmits diseases in vertebrate animals. Several bugs are natural enemies that help to destroy insect pest.

11.9.1 General characters of Hemiptera

- Usually small to large insects.
- Bugs have somewhat flattened body.
- Forewings are hemelytra (i.e. leathery at the base and membranous at the tip) in Heteroptera and uniform wings in Homoptera.
- Mouthparts piercing and sucking type, mandibles and maxillae are modified into needle like stylets.
- Metamorphosis usually gradual (incomplete), rarely complete.

19.9.2 Economic importance of Hemiptera

- Aphid, jassid and whitefly act as vectors of plant viruses.
- They transmit many diseases in plant.
- They suck the cell sap from the plant parts and cause economic damage.
- They attack a wide variety of crops, vegetables crops, fruit crops, garden crops etc and cause heavy loss farmers.

11.9.3 Sub-order: Homoptera

- Forewing either leathery or membranous folded roof like.
- Abundant discharge of a sugary waste product of honey dew especially in aphids.
- Pronotum small.
- Eggs lay singly mostly in plant tissues.
- Hemimetabolous.
- No scutellum.
- Body shape is either wedged or oval, slender and elongated.

Sr. No.	Name of Family	Characters
1	Delphacidae	• e.g. Sugarcane leafhopper • Mediun ocellus absent. • Hind tibia large. • Large aedeagus. • Movable spur.
2	Fulgoridae	• e.g. Sugarcane Pyrilla (*Pyrilla perpusilla*) • Ocelli 2 or 3 or absent. • Antennae 3 segmented. • Rostrum elongated. • Tarsi 3 segmented. • Aedeagus with a clear thecae surrounding penis. • Incomplete ovipositor.
3	Cicadidae	• e.g. Cicadas (*Magicicada septemdecim*) • Sound producing insects. • Tympanal and auditory organs present. • Empodia absent. • Femur and tibia of fore legs greatly enlarged and modified.
4	Memracidae	• e.g. Tree hoppers • Vertical crown on head. • Pronotum large having spine like structure on both sides.
5	Cicadellidae	• e.g. Leaf hopper (*Amrasca bigutella bigutella*), Green leaf hopper (*Nephotettix virescens*), Brown plant hopper (*Nilaparvata lugens*) and Mango planthopper (*Ideocerus atkinsoni*) • Wedge shaped or slender in form. • Ocelli absent. • Antenna 8 segmented when disturbed they often leap several feet and always ready for flight. • An adult walks diagonally.

6	Aleyrodidae	• e.g. Cotton whitefly (*Bemisia tabaci*), Citrus whitefly (*Dialeurodes citri*) and Sugarcane whitefly (A*leurolobus barodensis*) • Wings powdery with white waxy material. • Wing venation reduced. • Excrete honeydews. • Incomplete metamorphosis.
7	Aphididae	• e.g. Mustard aphid (*Lipaphis erysimi*), Cotton aphid (*Aphis gossypii*), Peach aphid (*Myzus persicae*) and Black bean aphid (*Aphis craccivora*) • Winged or wingless adults. • Ocelli absent and cornicles present on abdomen. • Antennae 2-3 segmented. • Tarsi 2 segmented having pair of claws. • Parthenogenetic reproduction.
8	Lacciferidae	• e.g. Lack insects (*Laccifer lacca*) • Female apterous and male winged. • Antennal vestigial. • Body globose type enclosed in dense resinous cells. • Legs reduced of absent. • Body covered with lac glands and open in epidermis.
9	Coccidae	• e.g. Sugarcane scale insects (*Melanspis glomerata*), Cottony scale insect (*Icerya puchasi*) and Mango mealy bug (*Drosicha mangiferae*) • Males harmless without mouthparts. • Females smooth with smooth integument. • Body small inconspicuous, soft covered with wax, scale like or gall like structures or powdery exudates. • Antennae much reduced or absent. • They secrete honeydew. • Rostrum small and double segmented.

11.9.4 Sub-order: Heteroptera

- Two pairs of wing present which are different to each other folded flat over the abdomen.
- Mouthparts typically piercing and sucking type.
- Flat body.
- Antennae 4-5 segmented.
- Large pronotum.
- Formation of shield like scutellum.
- Forewings basally sclerotized and apically membranous called hemelytra and hind wings are transparent and membranous.

Sr. No.	Name of Family	Characters
1	Tingidae	• e. g. Brinjal Lace wing bug (*Urntius hystricellus*) • Ocelli absent. • Scutellum concealed by the pronotum. • Body and hemelytra densely reticulated.
2	Reduviidae	• e. g. Assasin bug (*Reduvius personatus*) • It includes predatory bugs, pests of crops, vector of human diseases. • Head prolonged and narrowed behind the eyes. • Rostrum pointed. • Labium stout and robust with 3 segments. • Generally wings don’t cover the lateral part of abdomen fore legs with fossula spongiosa for adhesion. • Antennae long with intercalary segments.
3	Cimicidae	• e. g. Bed bug (*Cimex lectularius*) • Ectoparasites of man and other animals • Ocelli absent
4	Anthocoridae	• e. g. *Anthocoris* sp. • Predaceous on small insects. • Body small, elongated and flat. • Ocelli absent. • Scent glands present on metathorax. • Legs with empodium.

5	Miridae	• e. g. Tea bug (*Helopeltis* sp.), Lygus plant bug (*Lygus pabulinus*) • Delicate small to medium insects. • Ocelli absent. • Empodium instinct.
6	Lygaeidae	• e. g. Dusky cotton bug (*Oxycarenus hyalinipennis*) • Ocelli present. • Small, dark or brightly coloured insects. • Antennae inserted below the head. • Veins in the hemelytra never more than five.
7	Pyrrhocoridae	• e. g. Red cotton bug (*Dysdercus koenigii*). • Insect contrasting red and black colouration. • Polyphagous insects and gregarious in habit. • Both antennae and rostrum 4 segmented. • Ocelli absent.
8	Coridae	• e.g. Rice gundhi bug (*Leptocorisa acuta*). • Medium to large sized, elongated or oval polyphagous insects. • Both antennae and rostrum 4 segmented. • Ocelli present. • Scutellum small. • Legs strong with pulvelli. • Scent glands opening conspicuous that produce disagreeable odour.
9	Pentatomidae	• e. g. Painted bug (*Bagrada hilaris*), Stink bugs. • Moderate to large insects often brightly coloured. • Scutellum large that cover half abdomen. • Rostrum 4 segmented. Tarsi 2-3 segmented. • Ocelli always present. • Well developed hemelytra. • Triangular bugs with five segmented antennae.

Answer the following questions

(1) Write two important characters of Orthoptera, Dictyoptera, Odonata, Isoptera, Thysanoptera and Hemiptera orders and their families of agricultural important.

(2) Differentiate the following. (a) Caelifera and Ensifera (b) Dragonflies and Damselflies (c) (d) Antlion and Dragonfly (e) Anisoptera and Zygoptera (f) Homoptera and Heteroptera.

(3) Visit to the nearby field and collect as well as preserve the different insects and arrange according to order in the insect storage box.

EXERCISE – 12

STUDY THE CHARACTERS OF ORDERS LEPIDOPTERA, COLEOPTERA, NEUROPTERA, HYMENOPTERA, DIPTERA AND THEIR FAMILIES OF AGRICULTURAL IMPORTANCE

12.1 Objective:

(1) To learn the distinguishing features of insect orders and their families of agricultural importance.

(2) To collect the insects of commonly found families of various orders.

(3) To familiarize the students with different orders of insects and their characters to identify them up to family level.

12.2 Materials:

Preserved specimens of different orders *viz.,* Lepidoptera, Coleoptera, Neuroptera, Hymenoptera and Diptera in the laboratory as well as insect museum.

12.3 Methodology:

Carefully observed the different specimens of various insects under different order as shown in the laboratory as well as insect museum and note the different characters.

12.4 Order: LEPIDOPTERA (*Lepidos* = Scale; *Pteron* = Wings) e. g. Butterfly and moth

The Lepidoptera is one of the major insect orders, both in terms of size with some 160000 described species and popularity. Both moth and butterfly live on nectar of flowers; over ripen fruits, honey dew and other substances.

12.4.1 General characters of lepidoptera

- Small to large insects with two pairs of membranous wings covered with overlapping flat scales.
- Forewings are always larger than hind wings.
- Antennae pectinate, bipectinate or club shaped.
- Mouthparts siphoning type spirally coiled suctorial proboscis.
- Larvae phytophagous, polypod and having biting type of mouthparts.
- Pupae adecticous and obtect type usually form the cocoon or earthen cell.
- Head hypognathus.
- Butterflies are diurnal and moths are nocturnal.
- Holometabolus insects.

12.4.2 Economic importance of lepidoptera

- The larvae cause damage to the commodities of human interest.
- Some of the Lepidopteran acts as parasites of crop insect pest e. g. *Epericanea melanoleuca* on sugarcane pyrilla.

- Many of them play important role in pollination of flowers.
- Silkworm moth yields silk which is of high commercial value.
- It increases the aesthetic values of nature.

Sr. No.	Name of Family	Characters
A. Families of moth		
1	Gelechiidae	• e. g. Pink bollworm (*Pectinophora gossypiella*), Angoumois grain moth (*Sitotroga cereallela*) and Potato tuber moth (*Gnorimoschema operculella*). • Usually small and delicate moth. • The hind tibia possesses hard hairs. • Maxilary palp either absent or very small. • Fore wings trapezoidal and stalk at the base narrower than hind wings.
2	Pyralididae	• e. g. Sugarcane shoot borer (*Chilo infuscetellus*), Sugarcane top borer (*Scirpophaga* sp.), Rice moth (*Corcyra cephalonica*), Almond moth (*Ephestia cautella*), Brinjal fruit and shoot borer (*Leucinodes orbonalis*), Cotton leaf roller (*Sylepta derogeta*), Sorghum stem borer (*Chilo partellus*). • Large family varying greatly in shape and size. • Maxillary palp always present. • Legs long and slender. • Forewings usually narrow and hind wings broad. • Moths have abdominal tympanal organs.
4	Noctuidae	• e. g. Gram cutworm (*Agrotis ypsilon*), Gram pod borer (*Helicoverpa armigera*), Tobacco leaf eating caterpillar (*Spodoptera litura*), Spoted boll worm, (*Earias vittella*) and Green semilooper (*Plusia ni*, *Chrysodexis* spp.). • Eminently nocturnal moths attracted to light. • Frenulum present as wing coupling apparatus. • Maxillary palp vestigial. • Proboscis stout or flexible. • Forewings coloured and cryptic or dull. • Larvae have setae and prolegs.
5	Arctiidae	• e. g. Bihar hairy caterpillar (*Spilosoma obliqua*), Gujarat hairy caterpillar (*Amsacta moorei*) and Sunhemp caterpillar (*Utethesa pulchella*).

		• Moths with stout body. • Broad brightly coloured wings with spots or bands on them. • Generally nocturnal. • Larvae densely clothed with long hairs and fed on herbaceous plants.
6	Sphingidae	• e. g. Spinx moth (*Acherontia styx*) and hawk moth (*Agrius convolvuli*). • Moderate to large sized moth. • Antennae gradually thickened and in male they are ciliated with partial whorls. • Apex of antennae are pointed or hooked. • Tympanal organs absent. • Moths have exceptionally powerful flight, crepuscular or nocturnal of diurnal in habit.
7	Pterophoridae	• e. g.Tur plume moth (*Exelastis atomosa*). • Both pairs of wing split into feather like structure (plumes). • Haustellum naked. • Legs usually long and slender. • Small sized moth.
8	Bombycidae	• e. g. Silk worm (*Bombyx mori*). • Generally white moth with several faint brownish lines across the front wings. • Antennae pectinate in both sexes. • Maxillary palpi and tympanal organs absent. • Proboscis rarely developed. • Adults don’t feed and they rarely fly. • Larvae glabrous elongated and form dense silken cocoons before pupation.
9	Saturniidae	• e. g. Atlas moth (*Attacus atlas*). • Large moths (Biggest moth in insect world in terms of total wing surface area). • Antennae bipectinate in both sexes. • Frenulum absent. • Labial palpi very small. • Wings broad with transparent eye spot near center.

B. **Families of butterfly**		
1	Lycaenidae	• e. g. Blue butterfly and Anar butterfly. • Moderate sized butterfly. • Upper surface of wings metallic blue or coppery, dark or orange. • Underside of the wing is more dull with dark centered eye spots. • Hind wings with delicate tail like prolongations. • Tarsi more or less abbreviated with claw. • Antenna ringed white. • Rim of white around each eye.
2	Pieridae	• e. g. Cabbage butterfly (*Pieris brassicae*). • Medium sized butterflies usually white, yellow or orange marked with black colour. • Legs well developed and claw toothed. • Larvae green and covered with fine short hairs. • Pupae with single median projection or spine.
3	Papilionidae	• e. g. Lemon butterfly (*Papilio demoleus*). • Large and conspicuously coloured butterflies with tail like prolongations on hind wings. • Wings generally glossy black with shades of green, red, blue, orange or yellow. • Setae usually absent on the body. • Pupa with two lateral projections.
4	Hesperidae	• e. g. Rice skipper (*Parnara mithias, P. Colaca*). • Antennae gradually clavate or club shaped which often last in hook. • Forewings without cubitous 2 (Cu_2). • Hind wings without frenulum. • Erratic darting flight.
5	Nymphalidae	• e. g. Rice horn caterpillar (*Melanitis* spp.). • Anterior legs of adults unfit for walking. • Tibia short and clothed with long hairs. • Antennae club shaped and without scales. • Tuft of hairs produces peculiar odours.

12.5 Order: COLEOPTERA (*Coleos* = Sheath; *Ptera* = Wing) e.g. Beetles and Weevils

The coleoptera is the **largest order** in the animal kingdom, with about **350000** described species of holometabolous.

12.5.1 General characters of Coleoptera

- Minute to large insects with hard exoskeleton.
- Forewings are modified into horny shell like elytra (vein less sheath).
- Elytra covering the folded hind wing at rest.
- Mouthparts biting and chewing type.
- Prothorax large.
- Antenna lamellate, serrate or clubbed type.
- In weevil, antennae carried forward; the frons and vertex prolonged anteriorly to form rostrum or snout.
- Ocelli are usually absent.
- Metamorphosis complete.
- Larvae types are apodous, campodeiform, euriciform or scarabaeiform.
- Pupation in a specially constructed cell or chamber.
- Most of the beetles are ground-dwellers, some are aquatic.

12.5.2 Sub-order: Adephaga

- Grub has a single tarsus and one or two claws.
- No molar area in mandibles. Four malpighian tubules.

Sr. No.	Name of Family	Characters
1	Carabidae	• e. g. Ground beetle and Tiger beetle • Grubs and beetles are predatory in nature. • They are occurring in soils. • Legs slender adapted for running or digging. • Body brightly coloured. • Prominent eyes and large mandibles.
2	Dyticidae	• e. g. Water beetle • Grubs and adults are aquatic but adults can live on land also. • Carnivorous in habit. • Natatorial types of legs and fringed with long hairs.

		• Capable of prolonged flight. • Antennae filiform. • The fore tarsi dilated to form adhesive pad or cup like structure. • Elytra elevated to enter the air.

12.5.3 Sub-order: Polyphaga

- Elytra shorter than abdomen hence not fully covered with elytra.
- Fore tibia toothed or with spines.
- Antennae filiform or club shaped or serrate type.

Sr. No.	Name of Family	Characters
1	Scarabaeidae	• e. g. White grub (*Holotrichia consanguinea*) and chaffer beetle (*Melolontha* sp.) • Forelegs with spines or toothed. • Hind tibias with a single terminal spur. • Antennae 10 segmented. • The larvae live in decomposing organic matter, the larvae attacks roots of plants. • Hypognathous mouthparts. • Grubs scarabaeiform living in soil. • Pupation in earthen cocoons.
2	Buprestidae	• e. g. Jewel beetle (*Sphenoptera indica*) • Serrated antennae 11 segmented. • Thorax and abdomen firmly united. • Adults love bright sunshine, inhabit wooded areas. • Grub with free labrum and bore into the stem. • Eyes absent. • Elytra strongly sclerotized and hard and most brilliantly coloured.
3	Elateridae	• e. g. Firefly • Elongated insects dull or metallic coloured. • Emit bright light from round yellow area on either sides of the thorax. • Flat head with a transverse ridge above the antennal sockets

		• Largest prothorax. • Body reddish brown. • Antennae short.
4	Lampyridae	• e. g. Glowworms (*Lamprophorous tardus*) • Antennal socket facing dorsally. • Luminous organs present on hind segments of the abdomen which emit bright light. • Nocturnal in nature.
5	Dermestidae	• e. g. Khapra beetle (*Trogoderma granarium*) • Small and hemispherical oval beetle. • Body cover with fine scales or hairs. • Antennae small clavate type 11 segmented. • Tarsi 5 segmented. • Well developed compound eyes.
6	Anobiidae	• e. g. Drug beetle (*Stegobium paniceum*) and Cigarette beetle (*Lasioderma serricorne*) • Antennae very short. • No anal processes or cerci. • The terminal abdominal segments are large. • Pests of spices, cigarette, drugs, bakery and furniture.
7	Bostrychidae	• e.g. Lesser grain borer (*Rhizopertha dominica*) • Pronotum hood like. • Antennae with less than 11 segments and last three segments form club. • Only thorax and abdomen visible dorsally because head deflected downwards.
8	Coccinellidae	• e.g. Ladybird beetle (*Coccinella septumpunctata*): beneficial and Hadda beetles (*Epilachna vigintioctopunctata*): harmful • Small or medium sized oval or round convex brightly coloured and black spotted adults. • Predaceous or phytophagous insects. • Head almost concealed under the pronotum. • Antennae small, clavae type with 11 segmented.

		• Tarsi 4 segmented.
9	Tenebrionidae	• e. g. Red rust flour beetle (*Tribolium castaneum*) • Small, narrow elongated body. • Head, thorax and abdomen distinctly visible. • Antenna capitates type.
10	Meloidae	• e. g. Blister beetle (*Mylabris pustulata*) • Hypognathous head. • Prothorax narrow and elongated. • Grubs predator and adults pests of crops; generally feeds on flower. • Faeces frequently coming out and most of time attached with anus. • The adult produce pharmaceutical product cantharidin.
11	Cerambycidae	• e. g. Mango stem borer (*Batocera rufomaculata*) and Long horned beetles (*Saperia populanea*) • Big beetles, very long antennae like dried twigs usually 2/3rd as long as body and fixed backwardly. • Cryptic colouration of the body. • Tibia has two spurs. • Six malpighian tubules.
12	Bruchidae	• e. g. Pulse beetle (*Callosobruchus chinensis*) • Small, short, stout, dull grayish to brownish body covered setae or scales. • Antennae clavate, serrate or pectinate type. • Head prolonged, prognathous type. • Femora swollen and tarsi 5 segmented ending into claws. • Wings short keeping the abdominal tip exposed.
13	Chrysomelidae	• e. g. Red pumpkin beetle (*Rhapidopalpa foveicollis*) and Rice hispa (*Dicladispa armigera*) • Orange or bright or elongated metallic colour or leathery or shield like or flattened tortoise adults. • Elongated body. • Sunken needle spots on elytra. • Hispa usually covered with long stout upright spines.

14	Curculionidae	• e. g. Rice weevil (*Sitophilus oryzae*), Coconut palm weevil (*Rhynchophorus ferrugineus*) • Head produced into pronounced rostrum or snout or beak like • Geniculate or clubbed antennae. • Trochantur elongated. • Reduced rigid palps.
15	Staphylinidae	• e. g. Rove beetle • Beetles, primarily distinguished by their short elytra that leave more than half of their abdomens exposed. • Second largest family of beetles after the Curculionidae (the true weevils).

12.6 Order: NEUROPTERA (Neuron = Nerve; Ptera = Wing) e.g. Green lacewing (*Chrysoperla carnea*) and Antlions (*Myrmeleon*)

Approximately 5000-6000 species are described.

12.6.1 General characters of Neuroptera

- Two pairs of wing are similar membranous and folded roof like over the body at rest.
- Mandibulosuctorial type mouthparts.
- Prothorax often larger than meso- and metathorax.
- Cerci absent.
- Antennae long well developed and filiform.
- Larvae campodeiform with prognathous head and predaceous in nature.
- Pupae exarate decticous.
- Both larvae and the adults are predaceous on other insects.
- Ant lions are often attracted to light at night. During the day it hides amidst the vegetation.

12.6.2 Economic importance of Neuroptera

- Chrysopa feeds on aphids thus act as biological control agent of aphids.
- The larvae of ant lions feed on ants. The ant lion prepare a tunnel like pits in the soil when the runway ants slips into the pit, the larvae capture the victim and sucks out the body fluids.

Sr. No.	Name of Family	Characters
1	Chrysopidae	• e. g. Green lacewing (*Chrysopa* sp.) • Antennae longer than forewings. • Mandibles long and strong. • Wings and body green with golden eyes. • Eggs stalked. • Larvae with hooked hair on the body for supporting the dead host. • Chrysopa feeds on aphids.
2	Myrmeleontidae	• e. g. Antlion • Antennae longer than forewings. • The adult has two pairs of long, narrow, multi-veined wings in which the apical veins enclose regular oblong spaces. • It has long, slender abdomen. • It has prominent, apical clubbed antennae. • They are highly active in desert regions and are a nuisance. • They will deliver a small, mildly painful bite if given the chance to land on someone.

12.7 Order: HYMENOPTERA (Hymen = Membrane; Ptera = Wing) e.g. Wasps, Ants, Sawflies and Honey bees

The hymenoptera is an order of about 100000 described species of holometabolous neopterans. Most of the species of the sub order symphyta are phytophagous, while most of the insects of the sub order apocrita are useful in one of the other way in agriculture.

12.7.1 General characters of hymenoptera

- Small to medium sized insects.
- Head extremely mobile hypognathous or prognathous.
- Mouthparts biting, lapping or sucking type.
- Antennae geniculate or variable.
- Compound eyes are usually large.
- Wings membranous, hind wings are smaller than the fore wings, hind and fore wings interlocked with hooklets, the 'hamuli'.

- Abdomen basally constricted.
- Ovipositor modified for sawing or piercing or stinging.
- Larvae generally apodous or may be polypod, rarely eruciform with locomotory appendages.
- Tracheal system holopneustic or peripneustic.
- Pupae adecticous and exarate (rarely obtect) generally in cocoon.
- Metamorphosis usually complete.
- They are diurnal who love sunshine and warmth.
- They are free living or phytophagous or entomophagous parasitic or social insects

12.7.2 Economic importance of hymenoptera

- They are act as biological control agents of many crop pests.
- Many are crop pests.
- They are helpful in pollination of various crop plants.
- Honey bees are very beneficial as it provide honey and bees wax.

12.7.3 Sub-order: Symphyta

- Slender waist or petiole absent.
- Abdomen broadly attached with thorax.
- No constriction between 1st and 2nd abdominal segment.
- Legs with 2 segmented trochanter.
- Ovipositor used for sawing and boring.
- Prolegs without crochets.

Sr. No.	Name of Family	Characters
1	Tenthridinidae	• e. g. Mustard sawfly (*Athalia proxima lugens*). • Medium sized brightly coloured insects. • Antennae serrate and clubbed type. • Scutellum with defined post scutellum. • Ovipositor is modified into saw like structure. • Prolegs without crochets. • Tarsi 5 segmented.

2	Cephidae	• e. g. Stem sawfly (*Cephus cinctus*). • Slender narrow bodied insects with thin integument. • Mostly black or dark coloured insects with or without yellow band. • Prothorax large with hind margin straight.

12.7.4 Sub-order: Apocrita

- Abdomen deeply constricted or petiolated between 1^{st} and 2^{nd} segments.
- No constriction between 1^{st} and 2^{nd} abdominal segment.
- Trochanter with 1 or 2 segments.
- Ovipositor well developed.
- Prolegs without crochets.

Sr. No.	Name of Family	Characters
1	Ichneuminidae	• e. g. Ichneumon wasp. • Forewings with cross veins (2m-Cu) present. • Propodium elongated. • Parasites of many Lepidoptera and Coleoptera etc.
2	Braconidae	• e. g. Parasitic wasps *Bracon chinensis*, *Apanteles* spp., *Chelonus* spp., *Microplitis* spp. • Body small and stout. • Abdomen sessile and petiolated. • Thick hind femur. • Forewings with cross veins (2m-Cu) absent.
3	Chalcididae	• e. g. Chalcid fly • Parasites of Lepidoptera and Coleopteran etc. • Hind femur with short teeth. • Wings not folded while resting, wing venation reduced. • Ovipositor short and straight.
4	Eulophidae	• e. g. *Tetrastichus pyrillae.* • Very small insects. • Parasites of aphids, coccids and pyrilla. • Forewings not broad. • Pubescence not in rows. • Tarsi 4-5 segmented.
5	Trichogrammatidae	• e. g. *Trichogramma chilonis.* • Very small insects. • Egg parasites of lepidopterous insects. • Forewings broad.

		• Pubescence in line. • Tarsi 3 segmented. • Marginal and stigma veins in curve.
6	Formicidae	• e. g. Ants (*Formica indica*). • Polymorphic ants. • Demarcation between head, thorax and abdomen very well differentiated. • Scape in antennae very large. • Pedicel (Propodium) well develop. • Wings long in sexually matured insects. • Social insects includes three castes – King, Queen and Workers.
7	Vespidae	• e. g. Yellow wasp (*Vespa orientalis*). • Solitary and social wasps. • Wasp often yellow or red with black markings. • Legs moderate size. • Hind wings lack anal lobes. • Abdomen with well developed stings. Sting very painful for animals and human beings.
8	Apidae	• e. g. Honey bees (*Apis dorsata, A. Indica, A. Florea and A. mellifera*). • Social insect living in colony – Queen, king (Drone), Soldiers and workers. • Mouthparts chewing and lapping type. • Solitary, parasitic honey bees. • Antennae geniculate. • Hind legs pollen collecting. • Ovipositor modified for stinging.

12.8 Order: DIPTERA (Di = Two; Ptera= Wings) e.g. House fly, Mosquitoes, Fruit fly, Tachinid fly, Tsetse fly, Syrphid fly, Robber fly, Tur pod fly etc.

The diptera is one of the large insect orders, includes over 125000 described species. The adults of most species are diurnal in habit but many mosquito species are nocturnal. Majority are either flower lovers which feed upon nectar or frequently decaying organic matter of various kinds. Some are predacious and live on various insects. Some suck blood of vertebrate animals including men. A few are phytophagous. The pathogens of most virulent diseases such as malaria, sleeping sickness, elephantiasis and yellow fever are transmitted to man through blood sucking diptera.

12.8.1 General characters of Diptera

- Small to medium sized insects.
- Forewings are membranous and hind wings modified into halters or balancers.
- Antennae aristate or plumose.
- Mouthparts sponging type forming proboscis or sucking and piercing type.
- Larvae apodous (maggot).
- Pupae adecticous, obtect or exarate type.
- Prothorax and metathorax are reduced and fused with the well developed mesothorax.
- Holometabolus insects. Metamophosis complete.

12.8.2 Economic importance of Diptera

- Blood sucking insects are capable of transmitting disease causing microorganisms from one host to other.
- They cause great annoyance.

12.8.3 Sub-order: Nematocera

- Antenna many segmented, elongated and generally plumose type.
- Larvae have well developed head.

Sr. No.	Name of Family	Characters
1	Culicidae	• e.g. Mosquitoes • They are slender, long-legged insects. • Larvae are distinguished from other aquatic insects by the absence of legs, the presence of a distinct head bearing mouth brushes and antennae.
2	Cecidomyidae	• e.g. Gall midges, Sorghum midge (*Contarinia sorghicola*) • Minute and delicate fly • Antennae moniliform with whorl of hairs • Wings with few longitudinal veins • Larvae peripneustic with reduced head responsible for producing galls on leaves, stem and other plants.

12.8.4 Sub-order: Brachycera

- Tracheal system amphineustic.
- Prothoracic respiratory organs sessile.
- Abdominal segments with girdles of spines.
- Terminal segment armed with pointed process.
- Larva with incomplete head with vertically biting mandibles.
- Simple obtect pupa.

Sr. No.	Name of Family	Characters
1	Asilidae	• e. g. Robber flies (*Laphria* spp.) • Proboscis adapted for piercing • Pulvilli large and empodium bristle like • Long and powerful legs • Body elongated with numerous bristle.
2	Bombylidae	• e. g. Bee flies (*Bombylius major*) • Proboscis very long • Empodium rudimentary • Body stout and densely covered with hairs

12.8.5 Sub-order: Cyclorrhapha

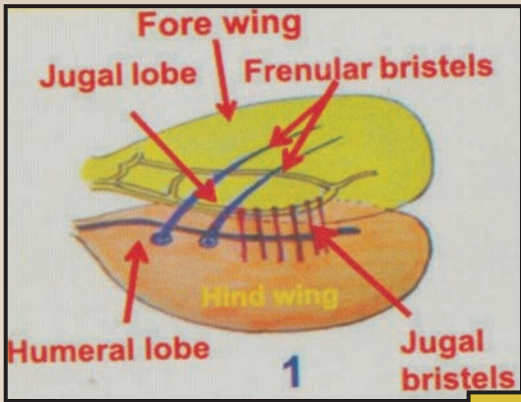
- Antenna three segmented, flagellum bears spiny projection (arista).
- Larva has vestigial head.
- A pupa enclosed in a hardened puparium.
- Circular-seamed flies.

Sr. No.	Name of Family	Characters
1	Phoridae	• e. g. Phorid fly (*Aneurina* sp.), Mashroom fly • Antenna long apical or sub dorsal arista. • Wings vestigial or absent.
2	Syrphidae	• e. g. Syrphid fly • Moderate to large bristle. • Brightly coloured markings. • Arista dorsal.

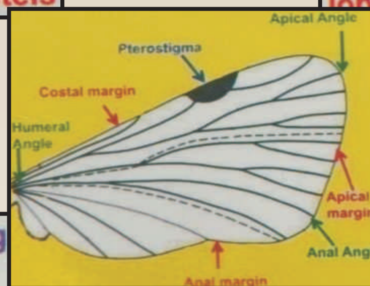
3	Drosophilidae	• e. g. Drosophilla (Drosophilla melanogastor)
4	Psilidae	• e. g. Carrot fly (*Psila rosae*) • Cubitus well developed.
5	Anthomyiidae	• e. g. Leaf miner (*Pegomyia* spp.) • Vein Cu1+ 1A reach the vein margin but faint distal .
6	Tachinidae	• e.g. Tachinid fly (*Sturmiopsis inferens*) • Parasites of the lepidopterous larvae. • Arista bare. • Abdomen elongated with numerous bristles. • Postscutellum little developed.
7	Agromyzidae	• e. g. Tur pod fly (*Melanagromyza obtusa*), Pea leaf miner (*Phytomyza horticola*) and *Liriomyza* spp. • Small sized black with bluish, shiny coloured insects. • Larvae mine in leaves, stem or developing pods.
8	Tephritidae	• e. g. Cucurbits fruit fly (*Bactrocera cucurbitae*), Ber fruit fly (*Carpomyia vesuviana, Dacus dorsalis*) • Fore wings either with brownish spots or strips. • Abdomen oval in shape. • Inner orbit sclerotized. • Male with long, flexible, coiled aedeagus.

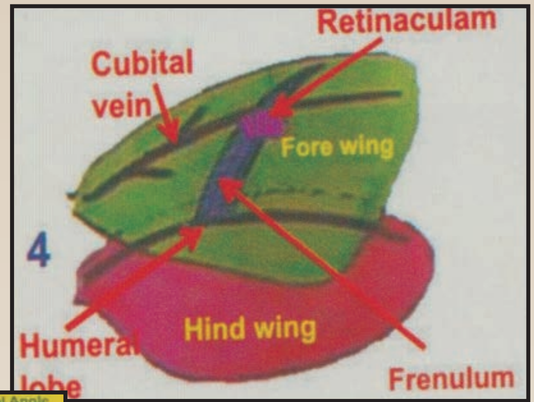
Answer the following questions

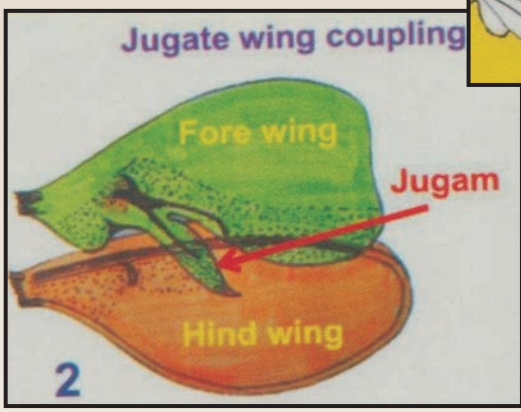
1) Write two important characters of Lepidoptera, Coleoptera, Neuroptera, Hymenoptera and Diptera orders and their families of agricultural important.
2) Difference between the following (a) Butterfly and Moth (b) Beetle and Weevil Nematocera and Brachycera (c) Symphyta and Apocrita.
3) Visit to the nearby field and collect as well as preserve the different insects and arrange according to order in the insect collection box.

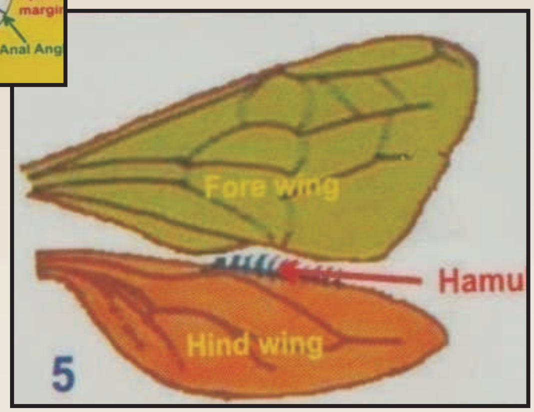


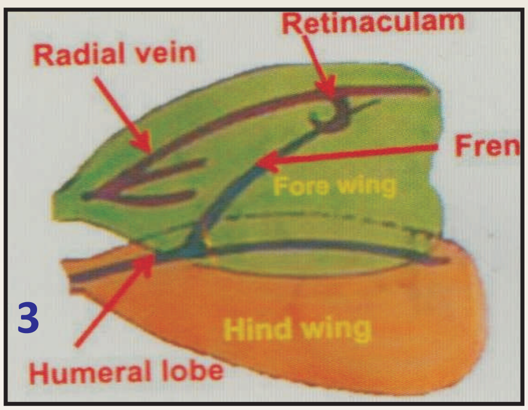
TYPICAL WING

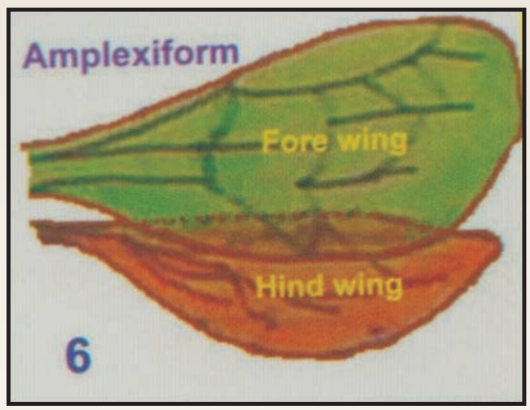






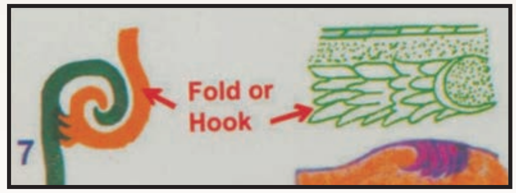


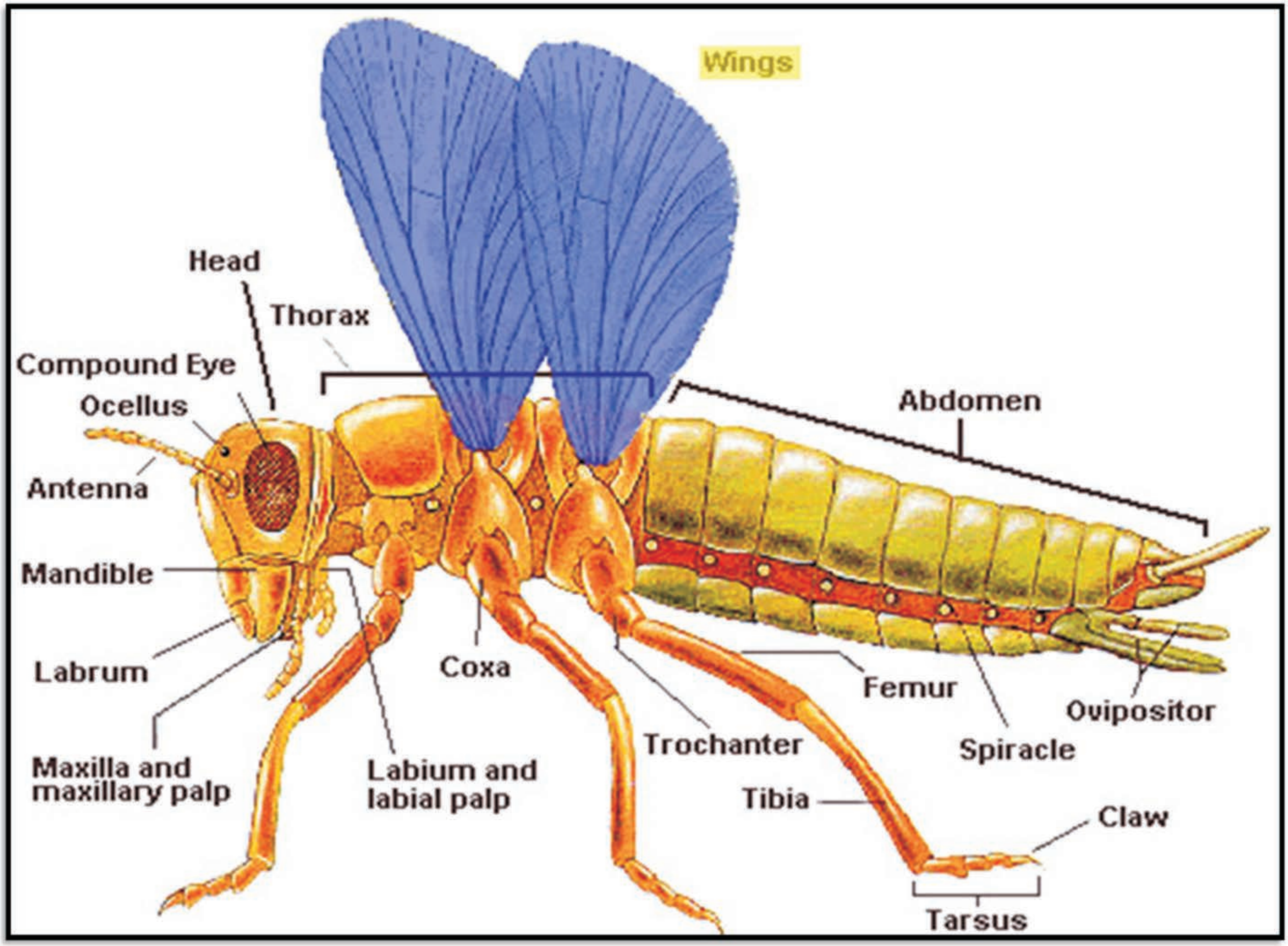




WING COUPLING APPARATUS

1. Primitive mecopteran
2. Jugate
3. Frenate (Male)
4. Frenate (Female)
5. Hamuli
6. Amplexiform
7. Fold or Hook




Wings
Head
Thorax
Compound Eye
Ocellus
Antenna
Abdomen
Mandible
Labrum
Maxilla and
maxillary palp
Labium and
labial palp
Coxa
Trochanter
Femur
Spiracle
Ovipositor
Tibia
Claw
Tarsus

NAVSARI AGRICULTURAL UNIVERSITY

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

ICAR

PRACTICAL MANUAL

"FUNDAMENTALS OF AGRICULTURAL EXTENSION EDUCATION"

AG. EXTN. 3.1 (2+1)

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CERTIFICATE

This is to certify that Mr./Ms.____

Reg. No.___________ has performed practicals for third semester B. Sc. (Hons.) in Agriculture in the course No. **Ag. Extn. 3.1: Fundamentals of Agricultural Extension Education** during the academic year_______.

He/She has performed ______ practicals out of __________

University Seat No.____________

Course Teacher **Head of Department**

Examiner

INDEX

Practical: 01

A VISIT TO UNDERSTAND THE PROBLEMS BEING ENCOUNTERED BY THE FARMERS

Introduction:

In order to inculcate the qualities and skills of good extension worker, a special learning situations which provide practical experience of doing field extension work is necessary. These situations can never be created in class room. Students, during their practical classes in various extension courses, might have gained some insight into the techniques of doing field work. However, the most effective imparting practical in extension can only be done if, the students go and stay in village for some time and grab opportunities to practice the use of various extension teaching methods in order to create learning situations and understand the constraint and problem in the benefit of farmers.

There are several methods available to identify and understand the problem of farmers but, before that the students have to develop understanding the meaning of different words are being used by farming community in their day to day life.

What is constraint?

- It can be said as limitation or restriction.
- Something that controls what you do by keeping you within particular limits.

The synonyms of word constraint: restriction, limitation, curb, check, restraint, control, curtailment, damper, rein, hindrance, impediment, hampering, obstruction, handicap, inhibition, uneasiness, embarrassment, restraint, reticence, guardedness, formality, self-consciousness, awkwardness, forcedness, unnaturalness, woodenness, stiltedness.

Given examples can help to understand the word 'constraint'.

- The non-availability of water is the main constraint on food production.
- They would be able to talk without constraint.
- Individual stiffness creates inhibition in relations between people.
- Time constraints make it impossible to do everything.

What is problem?

It is a perceived gap between the existing and a desired state, or a deviation from a norm, standard or status quo.

A thing that is difficult to achieve.

A matter or situation regarded as unwelcome or harmful and needing to be dealt with and overcome.

It is an inquiry starting from given conditions to investigate or demonstrate a fact or result due to certain causes.

A problem is also a question to be answered or solved by reasoning.

The synonyms of word problem: *noun* **difficulty; bad situation,** complication, dilemma, drawback, difficult situation, dispute, headache, issue, obstacle, question, trouble, botheration, count, crunch, disagreement, doubt, hitch, mess, pickle, predicament, quandary, scrape, squeeze, stumbling block, worriment, can of worms, disputed point

Given examples can help to understand the word 'problem'.

- He's been under increasing stress due to farming and personal problems.
- A thing that is difficult to achieve higher production.
- Motivation to farm labour can also be a problem"
- Practitioners help families to develop strategies for managing problem behaviour.
- Farmer's main problem is lack of cash.
- I'm having problems with my computer.
- No one has solved the problem of what to do with market mediators.

What does it mean to identify the problem?

It is directly or indirectly related to a desired outcome or standard of behavior. Identifying a very clearly defined and specific problem is the first critical step to successfully implementing the problem-solving process. One has to identify the Problem before the Solution.

Being an agriculture student one has to develop understanding regarding the problems of farmers. This can be done by conducting a visit of village and organize a group meeting with the farmers by following steps.

Step-1 : Contact farmers' Leader of the village and discuss about the purpose of your visit. Fix the date, time, place and topic of meeting with farmers.

Step-2 : At backstage, prepare questionnaire on decided topic for collecting necessary information as well as for the success of meeting. Convert questionnaire into require copies.

Step-3 : Before actual date of meeting, you should do curtsy call to the Leader and remind about meeting. This is necessary activity for developing the meeting environment and for success.

Step-4 : Reach at place well in time with necessary questionnaire and convey your presence to the Leader.

Step-5 : On the arrival of Leader at meeting place, once again brief the purpose of meeting to the leader.

Step-6 : According to available space for meeting, organize the seating arrangement for farmers. Several type of seating arrangements is being followed to organize a group meeting. However, in context to present practical the round seating arrangement is advisable so, you can easily make eye contact and verbal or symbolic opinion during the meeting from each and every farmer.

Step-7 : Introduce yourself to develop rapport among them. Start meeting with cordial welcome to the farmers. Request the Leader to brief the purpose of meeting.

Step-8 : After the address of Leader, once again welcome to all. Explain the reason of meeting and its importance. Circulate the copy of questionnaire and pen/pencil to all farmers. Provide understanding / meaning of each point to eliminate the doubts.

Step-9 : Collect the filled questionnaires from every farmer and convey thanks for cooperation.

Step-10 : Prepare a master sheet and compile the information according to points narrated in questionnaire. Separate them according to problem and issues of control.

General problems and their issues of control in agricultural extension:

Sr.	The problem and issues of control	
A	**Bringing control to agricultural extension system**	
	Issues	
1	Who should control	Outsider / Insider
2	How to control	Centralization / Decentralization
3	Where to control	Programme level / People level
B	**Determining the goal and nature of extension programme**	
	Issues	
1	Whom will be the beneficiary	Urban people/ Rural people Small farmers/ Big farmers
2	How to consider	Specialized efforts/ Generalized efforts
3	What to consider	Production/ Human resource development
C	**Emphasis on agricultural programme**	
	Issues	
1	Whom to give emphasis	Weaker section/ Equally to all
2	What to give emphasis	Specific messages/ General Messages
3	Where to give emphasis	Individual level/ Group level
4	How to give emphasis	Narrow focus/ Broad focus
D	**Selecting and managing staff in extension activity**	
	Issues	
1	Whom to recruit	Technical hand/ Practical hand
2	Where to post	Near one’s house/ Far from one’s house
3	How to reward	Achievement based/ Fixed salary
4	How to train	Lectures’/ Hand-on-exercises
E	**Establish harmonious relationship in all activities**	
	Issues	
1	How to achieve	Keep all functions in one separate institution
F	**Spending of resources and money to carry agricultural extension function**	
	Issues	
1	Who should spend	Public/ Private
2	How much to spend	Total/ Partial
3	How to spend	Through mass/ Individual contact methods
G	**Making the resources and activities accountable**	
	Issues	
1	What to account	Capabilities acquired / Production achieved Inputs / Outputs Effectiveness of staff/ Program
H	**Responsive to real need of the farmers**	
	Issues	
1	Which approach will be better	Subjective area/ Geographic area Individual/Group

Asking a series of clear questions leads to precision. When questions are developed with this result in mind, they will generate a natural sorting and sifting during the discovery process. Focus on the aspects to gather only the specific evidence you require, only those facts that illuminate the main question at hand. This focus makes it harder to get lost in the process or mistake the peripheral for what is central.

When you ask smart questions, you will:

1. Connect with people in a more meaningful way
2. Understand the aspect with greater depth
3. Defuse volatile situations
4. Get cooperation
5. Seed your own ideas
6. Persuade people to work with you because you've gained their confidence

Powerful questions are the path to clarify about problems. Here are some examples of questions you can use during the inquiry phase to enhance your understanding of the situation:

Ask to the farmer:

What seems to be the trouble in receiving extension services (private/public)?

……………………………………………………………………………………………..……………
……………………….……..

What concerns you the most about crop (inputs/information)?

……………………………………………………………………………………………..……………
……………………….……..

What is holding you back from higher production?

……………………………………………………………………………………………..……………
……………………….……..

What seems to be your main obstacle?

……………………………………………………………………………………………..……………
……………………….……..

To probe deeper, ask these follow -up questions:

What do you mean by? Tell me more about

……………………………………………………………………………………………..……………
……………………….……..

What else?

……………………………………………………………………………………………..……………
……………………….……..

What other ways did you try so far to overcome?
(Answer differentiate the constrain and problem)

……………………………………………………………………………………………..……………
……………………….……..

……………………………………………………………………………………………..……………
……………………….……..

Engage farmer to solve the problem. And always, no matter what, ask them how they would solve the problem.

How do you want to turn out?

……………………………………………………………………………………………..……………
……………………….……..

What is your desired outcome?

……………………………………………………………………………………………..……………
……………………….……..

What benefits would you like to get out of problem?

……………………………………………………………………………………………..……………
……………………….……..

If you do this, how will it affect?

……………………………………………………………………………………………..……………
……………………….……..

Exercise:

Village visit to identify problems in public extension approach

(1) Prepare a semi-structured interview schedule incorporating the problems and issues discussed above on the major crop of your area.

(2) Visit to a village to identify the important problems and issues in the public extension approach as perceived by the farmers using semi-structured interview method.

(3) Write down your findings below:

Practical: 02

PREPARATION OF INTERVIEW SCHEDULE, QUESTIONNAIRE AND DATA ANALYSIS FOR FARMERS

Introduction:

Schedule

A schedule is a structure of a set of questions on a given topic which are asked by the interviewer or investigator personally. The order of questions, the language of the questions and the arrangement of parts of the schedule are not changed. However, the investigator can explain the questions if the respondent faces any difficulty. It contains direct questions as well as questions in tabular form.

Following are the different types of schedules used by social scientists and anthropologists.

- **Village or community schedule:** It is used by census researchers who collect general information on populations, occupations, etc.
- **Family or Household schedule:** It gives full demographic details of households, the status of individuals, data on education, age, family relations, etc.
- **Opinion or attitude schedule:** To schedule the views of the population regarding an issue.

Questionnaire

A questionnaire refers to a device for securing answers to questions by using a form which the respondent fills in by himself. It consists of some questions printed or typed in a definite order. These forms are actually mailed to the respondent who was expected to read and understand the questions and reply to them by writing the relevant answers in the spaces provided. Ideally, speaking respondent must answer to a verbal stimulus and give a written or verbal response. It is totally devoid of any table. Its purpose is to collect information from the respondents who are scattered over a vast area.

Following are the different types of Questionnaire used by social scientists and anthropologists.

- **Structured questionnaire:** It includes definite, concrete and pre-obtained questions which were prepared in advance.
- **Closed-form questionnaire:** It is used when categorized data is required.
- **Pictorial questionnaire:** It is used to promote interest in answering after seeing the pictures on a particular theme.
- **Unstructured questionnaire:** Designed to obtained viewpoints, opinions, and attitudes and to show relationships and interconnections between data which might escape notice under more mechanical types of interrogations.

Schedule and Questionnaires include open-ended questions and close-ended questions. Open-ended questions allow the respondent considerable freedom in answering. However, questions are answered in details. Close-ended questions have to be answered by the respondent by choosing an answer from the set of answers given under a question just by ticking.

Difference between Schedule and Questionnaires

Particulars	Questionnaire	Schedule
Meaning	Questionnaire refers to a technique of data collection which consists of a series of written questions along with alternative answers	Schedule is a formalized set of questions, statements and spaces for answers, provided to the enumerators who ask questions to the respondents and note down the answers
Delivery system	Questionnaire are delivered to the informants by post or mail and answered as specified in the cover letter	schedules are filled by the research workers, who interpret the questions to the respondents if necessary
Filled by	Respondents	Enumerators
Response Rate	Low	High
Coverage	Large	Comparatively small
Cost	Economical	Expensive
Respondent's Identity	Not known	Known
Success relies on	Quality of the questionnaire	Honesty and competence of the enumerator
Usage	Only when the people are literate and cooperative	Used on both literate and illiterate people
Mode of response taken	A questionnaire takes for itself and is self-explanatory	schedule has to be explained by the investigator

Similarities between Schedule and Questionnaire

- Both are set of related items having questions relating to central problems.
- Both use mainly structured questions and these questions are so phased and interlocked that they have a built in mechanism for testing the reliability and validity of the response.
- In both the same set of questions is administered to all the respondents and comparable results are obtained.
- Both these instruments have to be used with the same general principles of designs and have to take into account the same problems and basic difficulties they have to be limited in lend.
- In both, the central problem has to be concentrated upon the following considerations involved in the problem of evolving the questionnaire and a schedule as a unit.
    1. Drawing the responding into a situation through awake and interest.
    2. Proceeding from simple to complex questions.
    3. No early and sudden request for information of a personal and embracing intimate nature.
    4. Not asking embarrassing questions without giving the respondent an opportunity to explain himself.
    5. Moving smoothly from one item to another.

- In both certain types of questions have to be eliminated such as vague and ambiguous questions, emotionally changed questions, loaded and leading questions, questions eliciting no response and questions having structured response to the queries, violence to the existing facts.
- In both pilot studies and pre-tests are necessary for formulating the instrument and for bringing them to the final form. They have to go through the same stages of development.

How to Develop a Schedule and Questionnaire

Schedule and questionnaire are techniques for collecting data in which a respondent provides answers to a series of questions. To develop schedule and questionnaire that will collect the data you want takes effort and time. However, by taking a step-by-step approach to schedule and questionnaire development, you can come up with an effective means to collect data that will answer your unique research question.

1. Identify the goal of your questionnaire

- What kind of information do you want to gather with your questionnaire? What is your main objective? Is a questionnaire the best way to go about collecting this information?
- Come up with a research question. It can be one question or several, but this should be the focal point of your questionnaire.
- Develop one or several hypotheses that you want to test. The questions that you include on your questionnaire should be aimed at systematically testing these hypotheses.

2. Write a short questionnaire

Above all, your questionnaire should be as short as possible. When drafting your questionnaire, make a mental distinction between what is essential to know, what would be useful to know and what would be unnecessary. Retain the former, keep the useful to a minimum and discard the rest. If the question is not important enough to include in your report, it probably should be eliminated.

3. Use simple words

Survey recipients may have a variety of backgrounds so use simple language. For example, what is the frequency of your automotive travel to your parents' residents in the last 30 days?" is better understood as, "About how many times in the last 30 days have you driven to your parent's home?"

4. Relax your grammar

Relax your grammatical standards if the questions sound too formal. For example, the word "who" is appropriate in many instances when "whom" is technical correct.

5. Assure a common understanding

Write questions that everyone will understand in the same way. Don't assume that everyone has the same understanding of the facts or a common basis of knowledge. Identify even commonly used abbreviations to be certain that everyone understands.

6. Start with interesting questions

Start the survey with questions that are likely to sound interesting and attract the respondents' attention. Save the questions that might be difficult or threatening for later. Voicing questions in the third person can be less threatening than questions voiced in the second question. For example, ask: "How do your colleagues feel about management?" rather than "How do you feel about management?"

7. Don't write leading questions

Leading questions demand a specific response. For example: the question "Which day of the month is best for the newly established company-wide monthly meeting?" leads respondents to pick a date without first determining if they even want another meeting.

8. Avoid double negatives

Respondents can easily be confused deciphering the meaning of a question that uses two negative words.

9. Balance rating scales

When the question requires respondents to use a rating scale, mediate the scale so that there is room for both extremes.

10. Don't make the list of choices too long

If the list of answer categories is long and unfamiliar, it is difficult for respondents to evaluate all of them. Keep the list of choices short.

11. Avoid difficult concepts

Some questions involve concepts that are difficult for many people to understand.

12. Avoid difficult recall questions

People's memories are increasingly unreliable as you ask them to recall events farther and farther back in time. You will get far more accura te information from people if you ask, "About how many times in the last month have you gone out and seen a movie in a movie theater or drive-in?" rather than, "About how many times last year did you go out and see a movie in a movie theater or drive-in?"

13. Use Closed-ended questions rather than Open-ended ones

Most questionnaires rely on questions with a fixed number of response categories from which respondents select their answers. These are useful because the respondents know clearly the purpose of the question and are limited to a set of choices where one answer is right for them. An open-ended question is a written response. For example: "If you do not want a company picnic, please explain why". If there are an excessive number of written response questions, it reduces the quality and attention the respondents give to the answers. However, Info Poll allows you to use a wide variety of other types of questions.

14. Put your questions in a logic order

The issues raised in one question can influence how people think about subsequent questions. It is good to ask a general question and then ask more specific questions. For example, you should avoid asking a series of questions about a free banking serviceand then question about the most important factors in selecting a bank.

15. Pre-test your survey

It is better to identify a problem during the pretest than after you have published the survey. Before sending a survey to a target audience, send it out as a test to a small number of people.

After they have completed the survey, brainstorm with them to see if they had problems answering any questions. It would help if they explained what the question meant to them and whetherit was valid to the questionnaire or not.

16. Cover memo or introduction

Once a recipient opens your survey, you may still need to motivate him or her to complete it. The cover memo or introduction offers an excellent place to provide the motivation. A good cover memo or introduction should be short and includes:

- Purpose of the survey
- Why it is important to hear from the correspondent
- What may be done with the results and what possible impacts may occur with the results
- Address identification
- Person to contact for questions about the survey
- Due date for response

The research process is incomplete without collection of data, which starts after identification of research problem and chalking out research design. The researcher should keep in mind that there are two types of data, i.e. primary and secondary data. There are several methods involved in the collection of primary data, like observation, interview, questionnaires, schedules, etc. People quite commonly use questionnaire and schedule interchangeably, due to much resemblance in theirnature; however, there are many differences between these two.While a questionnaire is filled by the informants, enumeratorsfill schedule on behalf of the respondent.The questionnaire is usually employed only when therespondents literate and cooperative. Unlike schedule whichcan be used for data collection from all classes of people

Types of questions: Depending on the information you wish to gather, there are several possible types of questions to include on your questionnaire, each with unique pros and cons. Here arethe types of commonly used questions on a questionnaire.

1. Dichotomous question: this is a question that will generally be a “yes/no” question, but may also be an “agree/disagree” question. It is the quickest and simplest question to analyze, but is not a highly sensitive measure.

2. Open-ended questions: these questions allow the respondent to respond in their own words. They can be useful for gaining insight into the feelings of the respondent, but can be a challenge when it comes to analysis of data. It is recommended to use open-ended questions to address the issue of “why.”

3. Multiple choice questions: these questions consist of three or more mutually-exclusive categories and ask for a single answer or several answers. Multiple choice questions allow for easy analysis of results, but may not give the respondent the answer they want.

4. Rank-order (or ordinal) scale questions: this type of question asks your respondent to rank items or choose items in a particular order from a set. For example, it might ask your respondents to order five things from least two most important. These types of questions forces discrimination among alternatives, but does notaddress the issue of why the respondent made thesediscriminations.

5. Rating scale questions: these questions allow the respondent to assess a particular issue based on a given dimension. You can provide a scale that gives an equal number of positive and negative choices , for example, ranging from "strongly agree" to "strongly disagree." These questions are very flexible, but also do not answer the question "why."

INTERVIEW SCHEDULE FOR FARMERS DATA COLLECTION

PART -A

Respondent No.: …………………….. Date:……………………..
District: ……………………… Taluka: ……………………
Village: ……………………….

General information

a. **Name of the respondent**: ___________________________

b. **Father name**: ___________________________

1. Age (in completed years): ___________________________

2. Education ______________________________

3.Farming experience

From how many years you are engaged in farming.------------------

4.Family details

4.1 Family size

Sex	**Adult**	**Children below 15 years**
Male		
Female		
Total		

4.2 Family type: Nuclear/ Joint family

5. Occupation i) Main : ___________________________

ii) Subsidiary : ___________________________

6. Extension contact:

No	Media	Frequency of Exposure						
		Daily	Weekly	Once in 5 Days	Monthly	Once in 3 Month	Once in 6 Month	Never
1	Progressive farmer/ Opinion Leader							
2	Village level worker							
3	Scientist of SAU							
4	Scientist of KVK							
5	Agril. Extension officer							
6	Agri. Officer							
7	Veterinary Officer							
8	Agro service centre							
9	Input dealers							
10	NGO							
	Any other							

7. Social Participation

Sr. No.	Name of institution	Members hip	Position held	Weekly	Once in 5 Days	Monthly	Never
1	Gram panchayat						
2	Taluka panchayat						
3	District panchayat						
4	Service Cooperative Society						
5	Milk Cooperative society						
6	Youth Club						
7	Farmer's Club						
8	Other						

8. Exposure of Agricultural mass media

Sr. No.	Mass media	Yes/No	Regular	Irregular	Never
1	**Print media** **a**. Newspaper (Agril. Colum)				
	b. Agriculture publications **i. KrushiJivan**				
	ii. KrushiGovidya				
	c. Extension literature (leaf let, pamphlet, etc.)				
2	**Electronic media** **a.** Radio (Agril. Programme)				

	b. Television (DD Kisan& (Agril. Prog.)				
2	**Social media**				
	i. ikhedut				
	ii. mKisan				
	iv. IFFCO-Kisan				
	Any other				

9. Land Holding

Sl. No.	**Type**	**Owned**	**Leased in**
		Bigha	**Bigha**
1	**Irrigated**		
	a. Cultivated		
	b. Uncultivated		
2	**Un-Irrigated**		
	a. Cultivated		
	b. Uncultivated		

Part- B

1. Land Utilization: Crop production- Year 2016

Sr.No.	Name of crop	Name of the variety used		
		Variety	Variety	Variety
1				
2				
3				
4				
Total				

2. Insect Management

Sr. no.	Name of the Crop	Name of Insect observed	Control Measures
1.			
2.			
3.			

3. Disease management

Sr. no.	Name of the Crop	Name of Disease observed	Control Measures
1.			
2.			
3.			

4. Agriculture implements owned

Sl. No.	Implements	Number	Sl. No.	Implements	Number
1.	Iron plough		2.	Seed drill	
3.	Wooden plough		4.	Sprayer	
5.	Harrow		6.	Duster	
7.	Hoe		8.	Power tiller	
9.	Roller		10.	Pumpset	
11.	Spade		12.	Tractor	
13.	Bullock cart		14.	Any other specify	

5. Livestock possession

Sl. No.	Type	Number
1.	Buffaloa. Milch	
	b. Dry	
2.	Cows a. Milch	
	b. Dry	
	Any other specify	

5.1 Average milk production : ________________________

Do you sell milk to milk cooperatives? yes / No _____ If yes, than how much? In liters: ___________

6. Irrigation facility

Number of acres of irrigated land: ----------------- Bigha

Sl. No.	Type	Response
1.	Surface System	
2.	Drip System	
3.	Sprinkler system	
4.	Bore-well system	
5.	Open-well	

7. Annual Income of family from all sources _______________ Income(Rupees)

8. Do you know about soil health card? Yes / No _____________
If yes, do you apply fertilizer using SHC? **Yes / No**

9. ICT skills: Do you know operating of the following ICT components

A	**Smart Phone Related**	B	**Computer Related**
	Photo Taking		Word
	Photo Posting on WhatsApp		Excel
	Photo Editing		PowerPoint
	Sending Voice message on WhatsApp		Internet
	Forwarding message to others on WhatsApp		E mail
	Creating Group on WhatsApp		E- Banking
	Save Photos		Railway Ticket Booking
	Delete Message/Photos		On line Purchase

10. Do you know about Kisan credit card? Yes / No
If yes, Issued bank name:________________________ Amount eligibility of card:_______________________
11. Have you taken crop loan from any bank? Yes / No
if Yes, Name of Bank: __________________________ Amount of loan: __________________________

Part- C

1. Problems related to crop production

i) ____ii) ____

iii) ____

2. Problems related to Horticulture production

i) ____

ii) ____

iii) ____

3. Problems related to marketing

i) ____

ii) ____

iii) ____

4. Problems related to Animal Husbandry

i) ______________________________

ii) ______________________________

iii) ______________________________

5. Problems related to Technology

i) ______________________________

ii) ______________________________

iii) ______________________________

6. Expectation from agricultural universities

i) ______________________________

ii) ______________________________

iii) ______________________________

Practical: 03

STUDY OF GRAM PANCHAYAT

Introduction:

Panchayat means a body of five *(panch)* members of the Gram. These members are elected by the people in the Gram. They are expected to lead and guide all Socio-economic activities in the Gram. The Panchayat also settles the dispute among the members of the community. It, in fact, act as a self-governing institution. It normally consists of the learned and experienced members of the society and is able to guide the society and competent to regulate and guide all matters related to social life. It is expected to protest and promote social norms and social values in society. Panchayat is thus, an executive body of five members to regulate the life of the community living in a Gram.

Gram Panchayat

- Gram Panchayat is statutory body of elected members of the Gram.
- For every Gram or a group of Grams there is a Gram Panchayat having duration of five years from the date of its first meeting.
- Each Gram Panchayat area is divided in different wards as determined by the District Collector.
- A Gram Panchayat consists of Sarpanch, Up-Sarpanch and elected members.
- Gram Panchayat is subordinate to Taluka Panchayat and District Panchayat.

Constitution of Gram Panchayat:

A Gram Panchayat shall consist of such number of member elected by qualified voters from different wards of the Gram Panchayat area.

Gram Panchayat shall consist of Gram having the population 3000 to 15000. If there is a less than 3000 population or 250 qualified voters there will be a group Panchayat.

A Gram Panchayat of Gram having population not exceeding 3000 shall consist of seven (7) members and where population exceeds 1000, then for every 1000 and part there of the said number of seven shall be increased by 2 and exceeds to 21 members at population of 10000. For population of the Gram from 11000 -15000 its remains same as 21 members. A Gram Panch ayat shall consist of members not less than 7 and not more than 21.

Constitution:

A Gram Panchayat shall have a Sarpanch and Up- Sarpanch. The Sarpanch shall be elected by ballot (direct election) by qualified voters of the Grams from amongst themselves. The Up- Sarpanch shall be elected by the members of the Gram Panchayat from amongst them. Two seats in every Gram Panchayat are reserved for the scheduled castes and scheduled tribes. Such seats shall be allotted by rotation to different wards. One tenth of the total number of seats in Gram Panchayat shall be reserved for socially and educationally backward classes such seats shall be allotted by rotation to different wards. One-third of total number of seats shall be reserved for women belonging to SCs/ STs or OBCs.

Qualification required for membership in Gram Panchayat

1. He should be a citizen of India.
2. His name should be included in the voters list of the Gram.
3. Having 21 years old for membership and 18 years for voting.
4. He should be mentally sound.
5. He should not be a government servant.
6. He should not be a government debtor.
7. He should not be a proved as a guilty man by the court.

Meeting of Gram Panchayat

In the constitution of Gram Panchayat or its reconstitution, the first meeting shall be held within four weeks for election of Up-Sarpanch from amongst the elected members.

Taluka Development Officer (TDO) is competent authority for fixing the date of first meeting of Gram Panchayat.

Meeting of Gram Panchayat shall be presiding over by Sarpanch. In case of Gram Panchayat, where fails to elect a Sarpanch or where an elected Sarpanch is not willing to take office, the first meeting shall be presiding over by TDO / Secretary of Gram Panchayat. He shall have power and follows such proceeding of meeting but shall not have the right to vote.

At the first meeting of Gram Panchayat no business other than election of Up-Sarpanch shall be carried out.

One-tenth of the total number of seats in Gram Panchayat shall be reserved for socially and educationally backward classes such seats shall be allotted by rotation to different wards.

One-third of total number of seats shall be reserved for women belonging to SCs/ STs or OBCs.

Gram Sabha

The Gram Sabha is a statutory body and integral part of the Panchayati Raj System (PRS). The general body of the adult people of the Gram is called Gram Sabha. Every person may be a member of Gram Sabha whose name is registered in the electoral rolls pertaining to the Gram Sabha area and is above eighteen years. Gram Sabha serves an assembly of the Gram, act as watch dog of the working of Gram Panchayat and provide facilities to the peoples for participation in the decision making process.

A Gram Sabha should meet compulsory for as many times in a year as provided in the Panchayati Raj Act of the respective states. According to Gujarat Panchayat Act 1993, in our state at least two ordinary meeting of Gram Sabha shall meet every year. The secretary of Gram Panchayat conveys the time and place of meeting of Gram Sabha. Here Sarpanch act as a chairman and preside over the meeting of Gram Sabha. In absence of Sarpanch, up-Sarpanch holds the meeting. The secretary of gram panchayat acts as a secretary of Gram Sabha. He prepares the agendas, resolutions and places it before the Gram Sabha. He prepares schedule for follow up action.

The quorum for a meeting of the Gram Sabha shall be one-tenth of the total number of members out of which presence or members belonging to the Scheduled Castes, Scheduled Tribes, and Backward Classes and Women members shall be in proportion to their population.

In the meeting of the Gram Sabha, Gram Panchayat has to place following matter on which Gram Sabha makes recommendations and suggestions to the Gram Panchayat.

1. Annual statement of account of the Gram Panchayat.
2. The report of administration of the preceding financial year.
3. The last audit report and replies if any.
4. The report in respect of development programmes of the Gram Panchayat relating to the preceding year.
5. The development programmes proposed to be undertaken during the current financial year.
6. Proposal of new taxation or enhancement of existing taxes.
7. Programmes of adult education and family welfare.

Functions of Gram Sabha

The Gram Sabha is to perform the following functions:

1. Identification of beneficiaries for poverty alleviation programmes.
2. Mobilization of public contribution in cash, kind or labour for implementation of community welfare schemes.
3. Promotion of social harmony among all sections of the people in the Gram.
4. Rendering assistance in the implementation of development schemes in the area.

Committees of Gram Panchayat

Basically, the Gram Panchayat has two types of committee.

1. **Executive committee**

The executive committee shall consist of five members, to be elected by the Panchayat from among its members. Out of these five members one shall belong to scheduled caste or scheduled tribe and one shall be a woman. The term of executive committee shall be two years and on the expiry of its term, it may be reconstituted. The executive committee has to perform such of its functions as the Panchayat may assign to it.

2. **Social Justice Committee**

A Gram Panchayat shall constitute the social Justice committee tiling suchfunctions, which are essential for securing social justice to the weaker sections of thc society including personsbelonging to scheduled castes and scheduled tribes. The tern, of the social justice committee shall be co-exists with the duration of Panchayat.

Functions of Gram Panchayat

A. Specific function:

1. To identify and to give priorities to development schemes within its jurisdiction.
2. To identify beneficiaries of poverty alleviation and other beneficiary oriented programmes with the help of Gram Sabha.
3. To decide location of projects.
4. To implement or supervise the implementation of schemes for economic and social justice entrusted to Gram Panchayat.
5. To render the assistance in the implementation of schemes for economic development schemes assigned by Taluka Panchayat or District Panchayat.

6. To maintain assets and properties of the Gram Panchayat.
7. To create awareness among the public about different development schemes.

B. Financial Powers and Functions:

1. To improve taxes and levy (user's charges) and develop endowments for income generation.
2. To prepare and finalise annual budget estimates of the Gram Panchayat.
3. To constitute Gram Panchayat fund and operate it for authorized purposes.
4. To take loan from banks, financial institutions etc. for authorized purposes

C. Obligatory Functions:

1. Lighting of the Grams.
2. Supply of pure drinking water for domestic use and for cattle.
3. Construction, repair and maintenance of Gram roads, drains and bridges.
4. Watering public streets.
5. Reclamation of unhealthy localities.
6. Establishment and maintenance of markets.
7. Planting of trees in market places and other public places, their maintenance and preservation.
8. Cleaning of public roads, drains, tanks and wells.
9. Removal of obstructions and projections in public streets or places and in sites not being private property.
10. Promotion and development of economic conditions with special reference to agriculture and animal husbandry.

Sources of Income of Gram Panchayat:

1. House tax
2. Water tax
3. A duty on transfer of property
4. Tax on agricultural land (land revenue)
5. Local funds
6. Grant allotted by government under different development projects

Practical work

Students shall visit the best Gram Panchayat in their area and shall study the activities of Gram Panchayat.

A Visit and study of the Gram Panchayat

1. Name of the village panchayat: ______________________________
2. Taluka: ____________________ District: ____________________
3. Date of establishment of Gram Panchayat: ______________________
4. Total population of Gram: ______________________________
5. Total voters in Gram: ______________________________
6. Type of Gram Panchayat: ______________________________
7. Total number of members in Gram Panchayat:______________________
8. Information about members of executive body of Gram Panchayat:____________

Sr. No	Name of Members	Position Held	Age	Qualification	Occupation
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

9. Information about meeting of executive committee held in Gram Panchayatin current year

Sr. No	Gram Panchayat	Chaired by	No. attended	Purpose/Decision
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

10. Information regarding Gram Sabha meeting in current year

Sr. No	Gram Sabha Meet	Chaired by	No. voters attended	Purpose/Decision
1				
2				
3				
4				

11. Whether the Gram Panchayat Sub-Committee had conveyed meeting during current year? Yes/No If Yes, give the information as under

Sr. No	Gram Sabha Meet	Chaired by	No. voters attended	Purpose/Decision
1				
2				
3				
4				
5				

12. **Information regarding Panchayat Secretary/Talati-cum-Mantri:**
   a. Name: ______________________________
   b. Age: ____________ Years: ____________
   c. Educational Qualification: ______________________

13. **State whether any villager has been co-opted any man or women for development activities?**

Sr. No	Name of Members	Reason	Note about his/her outstanding act
1			
2			
3			

14. **Is there any reward/award received by the Gram Panchayat?**

Sr. No	Name of Award/Reward	Reason/Mode of Work/Performance
1		
2		
3		
4		
5		

15. **Detail of Position in Gram Panchayat Committee and its functions**

Sr. No	Name of Committee formed	Number of members in committee	Functions of the committee
1			
2			
3			
4			
5			

16. **State whether which ICT facilities/services available in Village Panchayat**

Sr. No	Name of the Facilities	Year	Funded by Gov./ Cooperative/ Private/ Sponsored
1			
2			
3			
4			

17. State whether which are the basic facilities available in the village created by panchayat

Sr. No	Name of the basic Facilities	Year	Funded by Gov./ Cooperative/ Private/ Sponsored
1	Drinking water		
2	Education 1) Anganwadi 2) Primary School 3) High School		
3	Lighting		
4	Health		
5	Sanitation		
6	Village Road		
7	Cooperative		

18. State whether which are the agricultural development activities carried out by VillagePanchayat

Sr. No	Name of the activities	Year	Funded by Gov./ Cooperative/ Private/ Sponsored
1	Check-Dam		
2	Drainage & Drainage Cleaning		
3	Digging of Pond		
4	Afforestation		
5	Pasture development		
6			
7			

19. List of development activities done in village during the last year

Sr. No	Name of Yojana	Chairman of Committee	Type of work done	Amount spent
1				
2				
3				
4				
5				
6				
7				
			Total	

20. **Give information regarding scheme operated by Village Panchayat:**

Sr. No	Name of Yojana	Year
1	Pradhan Mantri Jan Dhan Yojana	
2	Mission Indra-Dhanush	
3	Unnat Jyoti	
4	Pradhan Mantri Jeevan Jyoti Bima Yojana	
5	Pradhan Mantri Suraksha Bima Yojana	
6	Pradhan Mantri Ujjawala Yojana	
7	Saubhagya Yojana	
8	Pradhan Mantri Fasal Bima Yojana	
9	Pradhan Mantri Rojgar Protsahan Yojana	

21. **The constraints experienced by Village Panchayat in development of Village**

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Stamp of Village

SIGNATURE
Sarpanch/Talati-cum-Mantri

Observation of students about visit:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Name of the Student: ______________________________
Date of Visit: ____________________
Roll No: ____________________

Signature: __________________

Practical: 04

STUDY OF COOPERATIVE SOCIETY

Introduction:

Back ground:

The idea of using co-operative in India as a means of combating rural indebtedness and supplying credit was first suggested by Fedric Nicholson. He published a report and pleased powerfully for the introduction of co-operative credit societies in India. These societies were finally established in India under Cooperative Credit Society Act : 1904, while Government of Gujarat has considered its importance and passed the act in 1962.

Why Cooperatives?

The cooperative will be responsible for the economic development of the village. It shall have to be molded in such as way as to provide the organizational, financial and technical guidance for the development of rural economy.

What are the functions?

The primary functions of the village co-operative society will be…

a) To provide the short and medium term credit.
b) Supply the agricultural and production oriented requirements.
c) Marketing and formulation of their produce.
d) To fulfill the infrastructure requirements.

What are the objectives?

The fundamental objective of cooperatives is promotion of self interest by mutual help and its, motto is; "Each for all and all for each", it is new form of our old adage thought as "United we stand, divided we fall", Thus, co-operatives is the act of persons voluntarily untied for utilizing their forces and resources or both under their mutual management to the common benefit to all. The specific objectives are as unclear:

a) To supply agricultural inputs like fertilizer, seed, pest control chemicals and cattle feeds etc.
b) To advance short, medium term and in such case long term loans to the members especially to small and marginal farmers.
c) To undertake the supply of consumer goods.
d) To arrange for sale of member's produced.
e) To promote own/hire agricultural processing units.
f) To organize agro-based services by providing agricultural machines on hire basis like sprayers, tractors, bulldozers etc.
g) To render the service for improvement and development of cattle breed and milk production.
h) To own or hire go-down facilities for storage or produce of members.
i) To create irrigation facilities.
j) To provide agricultural extension services to educate the villages.
k) To raise the funds needs by society in terms of share, deposits of money, borrowing etc.
l) To undertake such other activities which is most helpful to the members of the society.

Principles of Cooperative Society

1. Voluntary Membership: - Any person can become the member of the society and can leave it any time.

2. Equal Rights: - Each member of the society has an equal right to vote and ownership. Each shareholder has one vote.

3. Democracy: - The principle of democracy is adopted while making the decisions. The decision of the majority is honored.

4. Honesty: - It is the basic principle of this society. Its members should be honest. Selfish people cannot run the business of cooperative society.

5. Mutual Confidence: - Cooperative society foundation it is laid down on mutual confidence. Members of the society should trust each other and work like a team.

6. Welfare Main Objective:- Its main objective is to provide goods and services to its members at lower price.

7. Cash Payment:- Credit team is prohibited and goods are supplied to its members on cash payment.

8. Economy:- The member of the society should act upon the principle of economy. They should not misuse capital of the society and always keep in view best interest of the society.

9. Distribution of Profit:- The profit can be distributed among the members according the cooperative act. One fourth (1/4) of the profit can be kept in reserve. Then (10%) of the profit can be used for providing facilities to the members.

10. Self Service:- All the business activities are conducted by the members themselves. All are the owner and all are the consumers. So self service rule is employed in the organization.

11. Spirit of Love and Cooperation:- There should be spirit of love, sacrifice and cooperation among the members to achieve the objectives.

How to organize the cooperative society?

A cooperative society was to registered with the Registrar, Cooperative society through the extension officer (co-op.) working at block / taluka level.

Membership and nomination:

a) Any villager who is living under it working area of the society.

b) Having 18 years of age.

c) He should apply through executive committee of the society.

d) He must have purchased one share and nomination fees.

e) He shall not be a government debater.

f) He shall not be a licensed as money leader.

g) He shall be abiding to behave as per rules.

Ceasing the membership:

When the member becomes mentally invalid withdraws his share money or become bankrupt or expelled by the society.

The member who do not pay the loans, disobey by laws or shows undesirable behaviour towards the society.

General meeting:

For general meeting following points should be fulfilling:

- Above 18 years of age.
- Proposed society has 500 depositors. Order of district central co-operative bank.
- Duties and rights of the members should be described.
- Benefits / objectives should be determined and described.
- Assistant District Registrar should be there.
- If it is first meeting, name, type of member, their works, share, profits… should be decided.
- Complete appraisal should be finalized and submitted to Registrar's office.

The existing co-operative societies may be classified as under:

Types of Cooperative Societies

The main types of cooperative societies are given below:

1. Consumers cooperative societies:

Consumers' cooperatives are formed by the consumers to obtain their daily requirements at reasonable prices. Such a society buys goods directly from manufactures and wholesalers to eliminate the profits of middlemen.

These societies protect lower and middle class people from the exploitation of profit hungry businessman. The profits of the society are distributed among members in the ratio of purchases made by them during the year.

Consumer's cooperative or cooperative stores are working mainly in urban areas in India. Super Bazaar working under the control of Government is an example of consumers' cooperative society.

2. Producers cooperatives:

Producers or industrial cooperatives are voluntary associations of small producers and artisans who join hands to face competition and increase production. These societies are of two types.

(a) Industrial service cooperatives:

In this type, the producers work independently and sell their industrial output to the cooperative society. The society undertakes to supply raw materials, tools and machinery to the members. The output of members is marketed by the society.

(b) Manufacturing cooperatives:

In this type, producer members are treated as employees of the society and are paid wages for their work. The society provides raw material and equipment to every member.

The members produce goods at a common place or in their houses. The society sells the output in the market and its profits are distributed among the members.

3. Marketing cooperatives:

These are voluntary associations of independent producers who want to sell their output at remunerative prices. The output of different members is pooled and sold through a centralized agency to eliminate middlemen. The sale proceeds are distributed among the members in the ratio of their outputs.

As a central sales agency, the society may also perform important marketing functions such as processing, grading and packaging the output, advertising and exporting products, warehousing and transportation, etc.

Marketing societies are set up generally by farmers, artisans and small producers who find it difficult to face competition in the market and to perform necessary marketing functions individually. The National Agricultural Cooperative Marketing Federation (NAFED) is an example of marketing cooperative in India.

4. Cooperative Farming Societies:

These are voluntary associations of small farmers who join together to obtain the economies of large scale farming. In India farmers are economically weak and their land-holdings are small.

In their individual capacity, they are unable to use modern tools, seeds, fertilizers, etc. They pool their lands and do farming collectively with the help of modern technology to maximum agricultural output.

5. Housing Cooperatives:

These societies are formed by low and middle income group people in urban areas to have a house of their own. Housing cooperatives are of different types. Some societies acquire land and give the plots to the members for constructing their own houses.

They also arrange loans form financial institutions and Government agencies. Other societies themselves construct houses and allot them to the members who make payment in installments.

6. Credit Cooperatives:

These societies are formed by poor people to provide financial help and to develop the habit of savings among members. They help to protect members from exploitation of money lenders who charge exorbitant interest from borrowers.

Credit cooperatives are found in both urban and rural areas. In rural areas, agricultural credit societies provide loans to members mainly for agricultural activities. In urban areas, non-agricultural societies or urban banks offer credit facilities to the members for household needs.

In India, several national federations of cooperative societies have been formed. National Cooperative Consumers Federation, National Federation of Cooperative Sugar Factories, National Agricultural Cooperative Marketing Federation, National Cooperatives Dairy Federation, National Cooperative Housing Federation. All India State Cooperatives Banks Federation is some examples.

Difference between Primary and Secondary Co-operative Societies:

Primary Co-operative Society	**Secondary Co-operative Society**
• Directly deal with their members	• Deal through primary co-operative society.
• Mainly responsible for fulfilling the credit need of their members and non-members	• Mainly responsible for administrative and inspecting work of primary co-operatives.

Co-operative Societies

- Primary co-op. society
  - Credit Society
    - Agril. Credit Society
      - * Farming Society
    - Non Agril. Credit Society
      - * Housing Society
      - * Milk co-op.
  - Non credit Society
    - Agril. Non Credit Society
      - * Sugar factory
    - Non Agril. Non-Credit Societies
      - * Public Health Societies
- Secondary co-op. society
  - Co-op. Unions
    - * Supervising unions
    - * Banking unions
  - Central Co-op. banks
  - State Co-op. banks

A Visit and study of the Cooperative Society

1. Name of the Cooperative Society:
2. Taluka: ______________________________ District: ____________________________
3. Date of establishment of Cooperative Society: __________________________________
4. Registration Number of Cooperative Society: __________________________________
5. Type of Cooperative Society: _____________________________________
6. Total number of members in Cooperative Society:______________________
7. Sanction Amount of Share/Capital : __________________________________
8. Information about members of executive body of Cooperative Society :-

Sr. No	Name of Members	Position Held	Age	Qualification	Occupation
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

(A) Whether board of directors are elected by the rule? Yes /No

(B) Whether board of directors are elected by election / unanimously? Election/Unanimously

(C) Whether female and backward reservation is observed in the body of Director? Yes/No

(D) Whether board of Director meeting called as per rule by giving notice? Yes /No

(E) Whether Director Bodies make decision with majority of votes? Yes /No

9. **Information about meeting of executive committee held in Cooperative Society in current year**

Sr. No	Executive Committee	Chaired by	No. attended	Purpose/Decision
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

10. **Whether the Cooperative Society Sub-Committee had conveyed meeting during current year? Yes/No If Yes, give the information as under**

Sr. No	Sub-Committee Meet	Chaired by	No. members attended	Purpose/Decision
1				
2				
3				
4				
5				

11. **Information regarding Cooperative Society Secretary/Manager:**
    a. Name: ______________________________
    b. Age: ____________ Years: ____________
    c. Educational Qualification: ______________________

12. Is there any reward/award received by the Cooperative Society?

Sr. No	Name of Award/Reward	Reason/Mode of Work/Performance
1		
2		
3		
4		
5		

13. List of activities carried out by Cooperative Society for their members development during the last year:

Sr. No	Name of Activity	Type of work done	Amount spent
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
		Total	

14. Audit

Particular	2013-14	2014-15	2015-16	2016-17	2017-18
Audit class					

(1) Whether internal auditor is appointed by the Cooperative Society? Yes /No

(2) Whether annual audit is done by every year? Yes /No

(3) Common mistakes had shown by the auditor.

15. The constraints experienced by Cooperative Society in development of their members.

1. ____
2. ____
3. ____
4. ____
5. ____

Stamp
of
Cooperative
Society

SIGNATURE
Secretary/Manager

Observation of students during visit:

1. ____
2. ____
3. ____
4. ____
5. ____

Name of the Student: ______________________________

Date of Visit: ____________________

Roll No: ________________________

Signature: __________________

Practical: 05

STUDY ABOUT THE NON GOVERMENT ORGANIZATION

Introduction:

The term 'Voluntarism' is derived from the Latin word 'Voluntas' meaning 'Will'. Thus, voluntary organization may be regarded as associations, which are formed to fulfill the wishes and aspirations of its members. People motivated different ways to be volutes like religion, humanity or any mutual aid. Voluntary organization is an organization where its workers are paid or unpaid, governed by its own members without external control. Moreover, it is the product of the blood, sweat and toil of a few individuals, which are known for their persistent efforts for achievement of their sincere aspirations.

Concept of NGO

In its broadest sense, the term "nongovernmental organization" refers to organizations (i) not based on government; and (ii) not created to earn profit.

The terminology of an NGO varies itself: for example, in the United States they may be called "private voluntary organizations," and most African NGOs prefer to be called "voluntary development organizations.

Duggal (1988) defines NGOs in the following manner: (i) they are registered as public trusts or societies; (ii) the different programmes adopted by the NGOs are welfare ones and sometimes government funded too; (iii) NGOs as a rule do not generate their own funds completely but rely on external financial assistances from government agencies-both national and international; (iv) they are private organisations, but their nature makes them somewhat different from what one generally expects from a private sector. Thus, they are not supposed to make any profit.

According to the World Bank, lla Non-governmental Organisation (NGO) is a private organization that pursues activities to relieve suffering, promote the interest of the poor, protect the environment, provide basic social services, or undertake community development".

Rajasekhar (2000) defines the term NGO that undertakes voluntary action, social action and social movements. He further argues that the following characteristics of NGOs make them distinct organisations: (i) Voluntary formation, (ii) Working towards development and amelioration of suffering, (iii) Working with non-self-serving aims, (iv) Relative independence.

Origin of Non Government Organization

India has a long history of civil society based on the concepts of daana (giving) and seva (service). A voluntary organization is organizations that are voluntary in spirit and without profit-making objectives were active in cultural promotion, education, health, and natural disaster relief as early as the medieval era. They proliferated during British rule, working to improve social welfare and literacy and pursuing relief projects.

During the second half of the 19th century, nationalist consciousness spread across India and self-help emerged as the primary focus of sociopolitical movements. Numerous organizations were established during this period, including the Friend-in-Need Society (1858), Prathana Samaj (1864), Satya Shodhan Samaj (1873), Arya Samaj (1875), the National Council for Women in India (1875), and the Indian National Conference (1887).

The Societies Registration Act (SRA) was approved in 1860 to confirm the legal status of the growing body of nongovernment organizations (NGOs). The SRA continues to be relevant legislation for NGOs in India, although most state governments have enacted amendments to the original version.

In early 20th Century, several voluntary efforts were started in the fields of education, health etc. The NGOs became prominent after independence especially after 1970s.

Development practitioners' government officials and foreign donors consider that Non-Government organization by the virtue of being small scale; flexible, innovative and participatory are more successful in reaching the poor and in poverty alleviating. This consideration has resulted in the rapid growth of NGOs involved in initiating and implementing rural development programmes. The concept of NGOs and social welfare are not new India has a glorious tradition of voluntary organizations. In the pre-Independence days, Rabindranath Tagore in his Shantiniketan experiments showed how rural development could be brought about by integration of education and culture. Gandhi in his **Wardha experiment** showed how village industries could bring about the development of the poorest sections of the people in his country. After independence too, there was a lot of talk planning process in the early 50s, the British Government in India Spent minimum resources on social welfare programmes and so voluntary agencies played an important role in developing programmes for the poor, the destitute women and children.

NGOs provide value in promoting sustainable development in country through

- ❖ Innovation : Identifying new approaches and models for specific development activities and drawing upon their close knowledge of local communities;
- ❖ Accountability: Helping ensure that project components are implemented as envisaged and planned;
- ❖ Responsiveness: Encouraging the implementation of projects to respond to local needs;
- ❖ Participation: Serving as bridges between project authorities and affected communities, and providing structures for citizen participation; and
- ❖ Sustainability: Nurturing continuity in project work, especially when the implementing agencies lack capacity or when staffing changes.

STEP TO START AN NGO

- ❖ **Conceptualization:** NGO wants to address, and identify the mission and vision.
- ❖ **Forming the Governing: I**ncluding strategic planning, financial management, human resources and networking.
- ❖ **Formulation of Byelaws:** Every NGO in India is legally required to document a trust deed/ Memorandum of Understanding/ byelaws that contain the name and address of the NGO, mission and objectives.

- **Registration:**
  - a) Indian Trusts Act, 1860
  - b) Societies Registration Act 1882
  - c) Companies Act, 1956
- **Fund raising:** Funds can be raised through internal sources (membership fees, sales, subscription charges, donations, etc.) or grants-in-aid from the Government, private organizations or foreign sources.

NGO Coordinating and Support Bodies

Association for Voluntary Agencies for Rural Development AVARD is an association of more than 650 NGOs engaged in rural development in India. Since 1958, it has promoted voluntary action, planned rural reconstruction with local participation and panchayati raj (a decentralized form of government where each village is responsible for its own affairs, as the foundation of India's political system), thereby addressing issues of poverty reduction, food security, rural technology, and environmental sustainability. Excellent microplanning and strong networking are its strengths.

AVARD has worked as a consultant for projects financed by th e Asian Development Bank (ADB) and the Food and Agriculture Organization. It has established links with most national organizations connected with voluntary action and rural development in India. It is a member of the Asian NGO Coalition for Agrarian Reform and Rural Development.

Council for Advancement of People's Action and Rural Technology (**CAPART**) was formed by mandate of the 7th Five-Year Plan in 1986 as a nodal agency for catalyzing and coordinating the emerging partnership between voluntary organizations and the government for sustainable development of rural areas. CAPART was formed by the amalgamation of two agencies, the Council for Advancement of Rural Technology and People's Action for Development India. CAPART is an autonomous body registered under the Societies Registration Act 1860, and functions under the aegis of the Ministry of Rural Development. Today, this agency is a major promoter of rural development in India, assisting more th an 12,000 volunteer organizations across the country in implementing a wide range of development initiatives.

Voluntary Action Network India Voluntary Action Network India (VANI) is a national apex body of NGOs in India. It is a network that comprises 237 organizations, 2500 NGOs (in 25 states), 19 network federations, 42 individuals. VANI is a platform for national advocacy on issues and policies confronting the development sector, and for coordination and action to promote and support volunteer involvement. VANI has been working as a catalyst between cent ral and state governments, on the one hand, and NGOs in India, on the other. It represents NGO concerns through advocacy, networking, and sensitization of the government and other stakeholders.

NGO IN AGRICULTURAL DEVELOPMENT

1. To assist and guide the members in obtaining financial and technical assistance for agricultural and rural development programmes.
2. To undertake integrated programmes for the upliftment and economic development of rural India.
3. To assist in the development of Self Help Groups (SHGs) of farmers.
4. To organize and conduct such promotional and training programmess.
5. To undertake identification, development, adaptation and promotion of appropriate technologies.

****

Collect the information from assigned NGO

Village – **Serial No……………….**

Taluka – **Date of interview: ………………..**

District –

1) Name of NGO :

…………..………………………………………………………………………………………….

2) Who are the trusty / Head of the NGO?...

3) Is there any Body from where decisions are taken democratically? Yes/No

………

……………………………………………………………………………………………

4) Which types of projects are run under NGO?

………

………

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……………………………………………………………

5) Is there monitory helps are taken from the state / central government? Yes/No

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……………………………………………………………………………………………

6) Purpose of formation of NGO:

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7) Major activity of NGO :

……………………………...…………………………………………………………………...

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8) What are your constraints to run the NGO?

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……………………………………………………………………………………………………

9) What are your suggestions to run the NGO effectively?

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……………………………………………………………………………………………………

Practical : 06

KRISHI VIGYAN KENDRA

Introduction:

Krishi Vigyan Kendra, an Institutional Innovation inspiring the World in 21 st Century also known as Farm Science Centre, a grass root level scheme has been designed and nurtured by the ICAR for the past four decades. Since 1974 when the first KVK was established at Pondicherry, so far, ICAR has established 694 KVKs across the country under different host organization like State Agricultural Universities, ICAR Institutes, Central Institutes/Deemed Universities, State Governments, Public Undertakings and Governmental Organization.

History of KVK

The Education Commission (1964-66) recommended that a vigorous effort be made to establish specialized institutions to provide vocational education in agriculture and allied fields at the pre and post matriculate levels to cater the training needs of a large number of boys and girls coming from rural areas. The Commission, further, suggested that such institutions be named as 'Agricultural Polytechnics'. The recommendation of the Commission was thoroughly discussed: during 1966-72 by the Ministry of Education, Ministry of Agriculture, Planning Commission, Indian Council of Agricultural Research (ICAR) and other allied institutions. Finally, the ICAR mooted the idea of establishing Krishi Vigyan Kendras (Agricultural Science Centres) as innovative institutions for imparting vocational training to the practicing farmers, school dropouts and field level extension functionaries.The ICAR Standing Committee on Agricultural Education, in its meeting held in August, 1973, observed that since the establishment of Krishi Vigyan Kendras (KVKs) was of national importance which would help in accelerating the agricultural production as also in improving the socio-economic conditions of the farming community, the assistance of all related institutions should be taken in implementing this scheme. The ICAR, therefore, constituted a committee in 1973 headed by Dr. Mohan Singh Mehta of Seva Mandir, Udaipur (Rajasthan), for working out a detailed plan for implementing this scheme. The Committee submitted its report in 1974.

The first KVK, on a pilot basis, was established in 1974 at Puducherry (Pondicherry) under the administrative control of the Tamil Nadu Agricultural University, Coimbatore.

Vision

Science and technology-led growth leading to enhanced productivity, profitability and sustainability of agriculture.

Mission

Farmer centric growth in agriculture and allied sectors through application of appropriate technologies in specific agro-ecosystem perspective.

Mandate

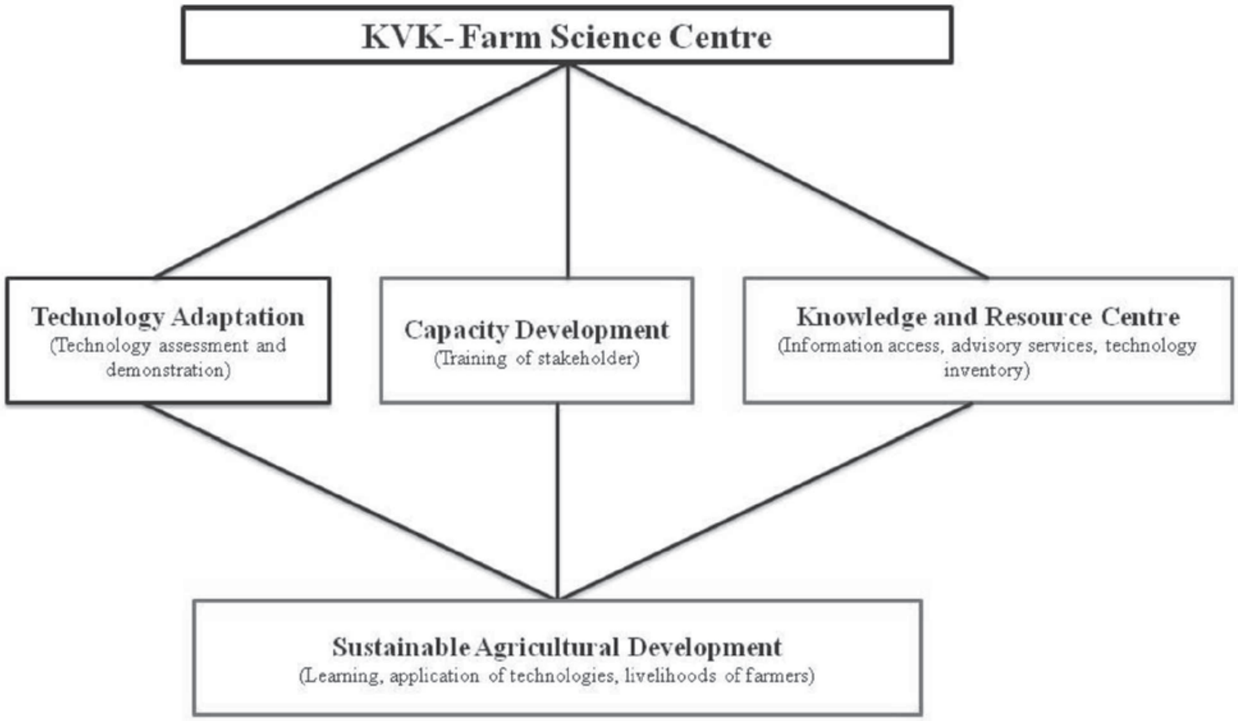
The mandate of KVK is Technology Assessment and Demonstration for its Application and Capacity Development (TADA-CD).

To implement the mandate effectively, the following activities are envisaged for each KVK:

a) On-farm testing to assess the location specificity of agricultural technologies under various farming systems.
b) Frontline demonstrations to establish production potential of technologies on the farmers' fields.
c) Capacity development of farmers and extension personnel to update their knowledge and skills on modern agricultural technologies.
d) To work as Knowledge and Resource Centre of agricultural technologies for supporting initiatives of public, private and voluntary sector in improving the agricultural economy of the district.
e) To provide farm advisories using ICT and other media means on varied subjects of interest to farmers.

Objectives:

1. To demonstrate the latest agricultural technologies to the farmers as well as the extension workers of the State Department of Agriculture / Non-Government organizations with a view to reducing the time-leg between the technology generation and its adoption.
2. To test and verify the technologies in the socio-economic condition of the farmers and identifying the production constraints.
3. To get first-hand scientific feedback from the fields and passing it to the research system in order to keep the scientists abreast with the performance of the technologies and the farming problems, so that they re-orient their research, education and training programme accordingly.
4. To import training to the farmers, farmwomen, rural youth and field level extension functionaries by following the principles of "Teaching by doing" and "Learning by doing".
5. To provide training and communication support to the line departure of the State / NGOs.
6. To develop extension models to be adopted by general extension system for large scale multiplications.
7. Organizing farm science clubs in rural areas for young farmers.
8. Developing and maintaining the campus farm demonstration unit on scientific lines.



Functional structure of KVK

Feature in Krishi Vigyan Kendra:

1. Powerful technical support
2. Real experience as training
3. Need based training courses
4. Flexibility with farmers
5. Concept of integrated training
6. Real field oriented course content
7. Specific area of operation
8. Informal training without certificate or diploma
9. Powerful institutional linkage
10. Practical training
11. Frequent follow up measures
12. Training interaction and reporting system
13. Impact study of the trainings, demonstrations and all extension activities

Activities of Krishi Vigyan Kendra:

Based on mandate, the following activities are performed by the KVKs.

1. On farm testing.
2. In service training of extension functionaries.
3. Vocational training of practicing farmers, farm women and rural youths.

The above said activities are performed every year by the Krishi Vigyan Kendra, through specialist of six disciplines viz. Extension Education, Agronomy, Horticulture, Plant Protection, Animal Scienc e, Agriculture Engineering (the specialist can be changed as per location specific need), which are most relevant taking in consideration national resources and infrastructure facilities of the district.

Manpower in KVK

At present, there are six SMSs (recommended to be re-designated as Scientists), each one taking care of one subject matter area. The KVKs have to provide multidisciplinary and broad based technological interventions to enable farmers to manage their farm in a sustainable and integrated manner, which demands enhanced manpower not only in terms of number but also covering the most important subject matter areas relevant to the district. With ever-growing nature and quantum of workload of each KVK, the existing six SMSs are finding it difficult to cope up with their responsibilities. Therefore, as per new KVK guideline of ICAR recommended that four additional posts of SMSs (Scientists) should be created in each KVK, thus, increasing the number of SMSs to 10 and also recommended that the total staff strength for each KVK should be 22 as against 16 at present.

Krishi Vigyan Kendras	**No.of KVKs**
ATARI, Zone I, Ludhiana	69 KVKs
ATARI, Zone II, Jodhpur	63 KVKs
ATARI, Zone III, Kanpur	75 KVKs
ATARI, Zone IV, Patna	63 KVKs
ATARI, Zone V, Kolkata	59 KVKs
ATARI, Zone VI, Guwahati	45 KVKs
ATARI, Zone VII, Barapani	43 KVKs
ATARI, Zone VIII, Pune	79 KVKs
ATARI, Zone IX, Jabalpur	77 KVKs
ATARI, Zone X, Hyderabad	73 KVKs
ATARI, Zone XI, Bengaluru	48 KVKs
Total	**694**

KVKs of Gujarat come under ATARI, Zone VIII, Pune

S. No.	**Address of Krishi Vigyan Kendras**	**Host Organization**	**Year of Sanction**
Gujarat (30)			
1.	Krishi Vigyan Kendra, Village Sansora, Distt. Bhavnagar-	Director, Lokbharati Gramvidyapith, PO. Sansora, Taluka Sihor, Distt. Bhavnagar	2009 NGO
2.	Krishi Vigyan Kendra, Kodinar Taluka, Distt. Junagadh-	Director, Ambuja Cement Foundation, 248, Okhla Industrial Estate, Phase-III, New Delhi-110020	2007 NGO
3.	Krishi Vigyan Kendra, Navsari NAU Campus, Distt. Navsari-396 450	Vice-Chancellor, Navsari Agricultural University, Navsari- 396450, Gujarat	2006 SAU

4.	Krishi Vigyan Kendra, Seed Multiplication Farm, Dedidyapada, Distt. Narmada-	Vice-Chancellor, Navsari Agricultural University, Navsari-396450, Gujarat	2006 SAU
5.	Krishi Vigyan Kendra, Nanakanthasar, Ta.-Chotila, Distt. Surendranagar-363520	Vice-Chanmcellor, Junagadh Agricultural Universtiy, Junagadh-362 001 (Gujarat)	2005 SAU
6.	Krishi Vigyan Kendra, Dethali, Distt. Kheda-378210	Vice-Chancellor, Gujrat Vidyapeeth, Ahmedabad-382 620	2005 DU
7.	Krishi Vigyan Kendra, Panchmahal (CIAH) Vejalpur (Godhra) Distt. Panchmahal-389340	Central Institute for Arid Horticulture, Bikaner, Rajasthan	2005 ICAR
8.	Krishi Vigyan Kendra, Kherva, Distt. Mehsana-382711	Mehsana District Education Foundation, Khera , Mehsana	2005 NGO
9.	Krishi Vigyan Kendra, Khedbrahma, Distt. Sabarkantha-383255	Vice-Chancellor, Sardarkrushinagar Dantiwara Agricultural Univesity, S.K.Nagar Distt. Banaskantha, Gujarat	2004 SAU
10.	Krishi Vigyan Kendra, Arnej.Ta-Dholka, Distt. Ahemedabad-382 230	Vice Chancellor Anand Agricultural University, Anand	2004 SAU
11.	Krishi Vigyan Kendra, Regional Rice Research Station, Vyara, Distt. Tapi .394650	Vice-Chancellor, Navsari Agricultural University, Navsari, Gujarat	2004 SAU
12.	Krishi Vigyan Kendra, Agril. Research Farm, Keria Road, Distt. Amreli-365601	Vice-Chanmcellor, Junagadh Agricultural Universtiy, Junagadh-362 001 (Gujarat)	2004 SAU
13.	Krishi Vigyan Kendra, Main Dry Farming Research Station, Targhadia, Distt. Rajkot-60003	Vice-Chanmcellor, Junagadh Agricultural Universtiy, Junagadh-362 001 (Gujarat)	2004 SAU
14.	Krishi Vigyan Kendra, Air Force Road, Distt. Jamnagar-361006	Vice-Chanmcellor, Junagadh Agricultural Universtiy, Junagadh-362 001 (Gujarat)	2004 SAU
15.	Krishi Vigyan Kendra, Khapat, Distt. Porbandar-360579	Vice-Chanmcellor, Junagadh Agricultural Universtiy, Junagadh-362 001 (Gujarat)	2004 SAU
16.	Krishi Vigyan Kendra, Po-Chaswad, Ta.Valiya, Distt. Bharuch-393130	Chairman, Bhartiya Agro Industries Foundation, Baroda	1994 NGO

17.	Krishi Vigyan Kendra, Gola Gamdi, PO-Bahadarpur, Distt. Vadodara -391125	Chairman, Mangal Bharti Bahadurpur, Baroda-391125	1994 NGO
18.	Krishi Vigyan Kendra, Ta. Kaparada, Distt. Valsad -396191	Vice-Chancellor, Gujrat Vidyapeeth, Ahmedabad-382 620	1992 DU
19.	Krishi Vigyan Kendra, Samoda, Ganwada Tal. Sidhpur, Distt. Patan-384130	Director, Sarswati Gram Vidyapeeth Samoda	1992 NGO
20.	Krishi Vigyan Kendra, Ta. Mundra, PO. Sadau, Distt. Kuchchh-370 421	Chairman, Rural Agro. Research & Development Society, Juhu, Bombay	1992 NGO
21.	Krishi Vigyan Kendra, Anand Devataj Sojitra Distt. Anand-387240	ViceChancellor Anand Agricultural University, Anand	1985 SAU
22.	Krishji Vigyan Kendra Waghai, Distt. Dang-390470	Vice-Chancellor, Navsari Agricultural University, Navsari, Gujarat	1985 SAU
23.	Krishi Vigyan Kendra, Randheja, Distt. Gandhinagar-382620	Vice-Chancellor, Gujrat Vidyapeeth, Ahmedabad-382 620	1977 DU
24.	Krishi Vigyan Kendra, Deesa, Distt. Banaskantha-385535	Vice-Chancellor, Sardarkrushinagar Dantiwara Agricultural Univesity, S.K.Nagar Distt. Banaskantha, Gujarat.	1976 SAU
25.	Krishi Vigyan Kendra, Devgarh Baria, Distt. Dahod-389380	ViceChancellor Anand Agricultural University, Anand	1976 SAU
26.	Krishi Vigyan Kendra RRS Kukma, Bhuj Distt.- Kutch (Gujarat)	Director Central Arid Zone Reserch Insttitute(ICAR) Jodhpur-342005(Rajasthan)	ICAR 16/11/2010
27.	Krishi Vigyan Kendra, Cotton Research Station, Athwaline Distt. Surat	The Vice Chancellor Navsari Agricultural University, Navsari – 396 450 (Gujarat)	13/10/2011 SAU
28.	Krishi Vigyan Kendra TDS Farm, Pipalia, Ta. - Dhoraji, Distt. – Rajkot (Gujarat)	The Vice Chancellor, Junagadh Agricultural University, Junagadh-362 001 (Gujarat)	ICAR 16/03/2012
29.	Krishi Vigyan Kendra Distt. – Banaskantha (Gujarat)	The Vice Chancellor, Sardarkrushinagar Dantiwara Agricultural Univesity, S.K.Nagar Distt. Banaskantha, Gujarat.	ICAR 12/03/2015
30.	Krishi Vigyan Kendra Distt. – Morbi (Gujarat)	The Vice Chancellor, JAU, Junagarh, Gujarat	ICAR 18/10/2016

Collect the information about KVK

1. Name of the Programme Coordinator of KVK?..
2. Educational qualification of PC?...
3. From how many year the charge of KVK is held?..
4. How much amount allotted for the activities of KVK this year?............................
5. What is the present financial status of KVK?...................................
6. Which activities are carried out since last three years? Give the numbers.

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7. How many projects run in KVK?

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   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………….
8. This year how many feedbacks are received form the farmers?

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   ……………………………………………………………………………………………………
   ……………………………………………………………
9. Which constraints confined the activities of KVK?

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   ……………………………………………………………………………………………………
   ……………………………………………………………
10. What are your suggestions to make KVK more effective?

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Practical: 07

STUDY ABOUT THE ACTIVITIES OF SARDAR SMRUTI KENDRA

Introduction:

Sardar Vallbhbhai Patel, who defined the role and importance of Indian farmers and conceived the dream to be a part of the country's prosperity. Considering the fearlessness and loyalty towards the country and particularly the efforts made for the upliftment of farming community throughout the life, Gujarat Agriculture University has decided to establish Sardar Smruti Kendra in the year 1975, on the occasion of his centenary celebration. At present at Navsari, Anand, Junagadh and Sardarkrushinagar universities has SSK.

Motto

To empower the rural farmers and form women through improved farming resulting in better economic condition.

Objectives

1) Promotion of agricultural services.
2) Diffusion of technical know-how and motivate the farmers to adopt new innovations.
3) Development of prod oriented activities of agriculture and allied fields.
4) Improvement of agro-economic status of farmers.
5) To establish direct contact blow farmers and agricultural scientists.
6) To transmit the value addition techniques of agricultural products.

With above cited objectives the SSK carries out its mission through well competent information training and exhibition wings.

Training Methods

1) Participatory approach
2) Do it yourself
3) Lectures, role plays, case studies, field visit, film / video shows and other suitable audio visual aids.

Activities

1) Organize the need based training programme at on and off campus.
2) Up to date information about agriculture and allied fields for farmers.
3) Publish literature on agriculture and allied enterprises.
4) Arrange agriculture exhibition, fairs and farmers meetings.
5) Organize farmers-scientist meet.

Facilities

1) Lodging and boarding
2) Modern agricultural advancements through exhibition

****

Collect the information about SSK

1. Name of the Programme Organiser of SSK?..
2. Educational qualification of PO?..
3. From how many year the charge of SSK is held?..
4. How much amount allotted for the activities of SSK this year?............................
5. What is the present financial status of SSK?....................................
6. Which activities are carried out since last three years? Give the numbers.

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8. How SSK is considered as farmers' information and training centre?

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8. This year how many feedbacks are received form the farmers?

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11. Which constraints confined the activities of SSK?

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12. What are your suggestions to make SSK more effective?

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Practical: 08

Study of Agriculture Technology Information Centre (ATIC)

Introduction:

The significance of suitable information package and its spreading as one input has understood additional emphasis in thepresent age of information and technology. The kind of information andthe way it is to be used are key factors for the development of agriculture.It is also worth noting that it is no longer enough for research to generate information alone. The required information is also to be delivered to the end users at one place. This information must be direct clear and easily understandable and without providing any scope for distortion.

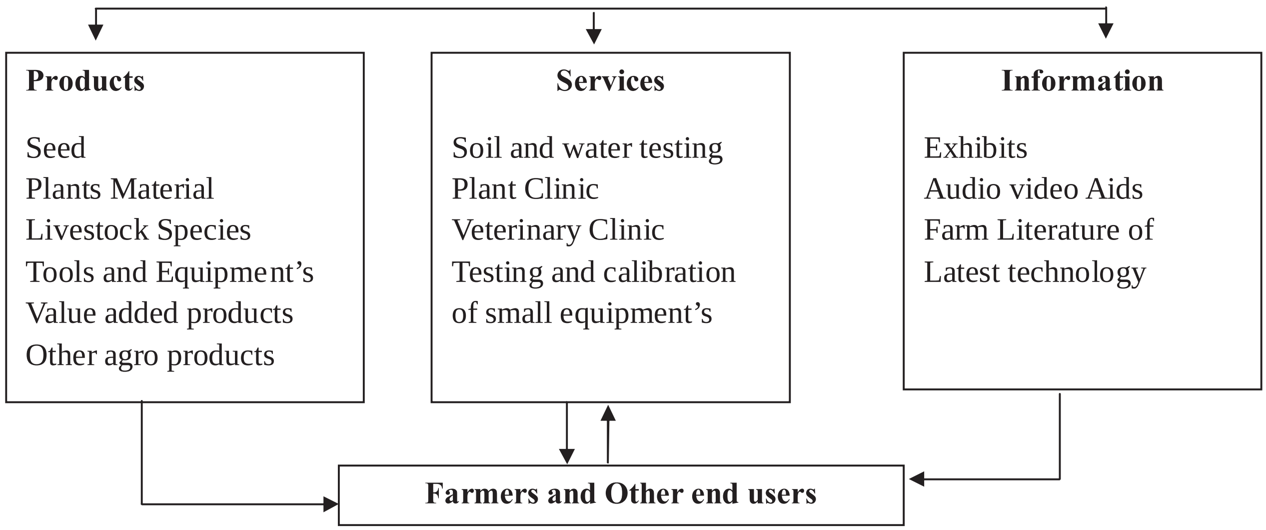
The foundation stone of agricultural revolution has been the accessibility of improved varieties of crops, breeds of livestock includingpoultry and fisheries, horticultural plant materials and improvedmanagement practices for improved productivity, sustainability and stability of various crop and livestock enterprises. This has raised the hunt by farmers for future availability of seed, planting materials and other materials, trouble-free accessibility to diagnostic services for soil fertility and plant protection, availability of appropriate information through leaflets and pamphlets and increased scope in sale of consultancy services.

Habitually the farmers are not aware as to whom and where to approach for field problems. It is felt that the facilities of a single window approach will unable farmers to have the required information for the solution to their problems related to the areas in which the concerned institute is involved. With these views, the ICAR has taken decision to set up ATICs as a part of World Bank Funded Nati onal Agricultural Technology Project in the year 1990-91. In Gujarat, S. D. Agricultural University, Anand Agricultural University, Navsari Agricultural University, and Junagadh Agricultural University has s uch center.

What is ATIC?

The Agricultural Techn ology and Information Centre is a single window support system linked with units of research institutions with intermediaries and end users in decision making and problem solving exercise.

Functional structure of ATIC: ATIC



ATIC is partly funded by the World Bank. Initially ICAR had decided to setup 40 ATIC throughout India, from amongst one is started at SDAU, Sardarkrushinagar.

Objectives of ATIC:

1. Provide a single window delivery system for the products and species available from an institution to the farmers and other interested group as a process of innovativeness in technology dissemination at the institute level.
2. Facilitate the direct farmer's access to the institutional resources available in terms of technology advice and technology products etc. for reducing technology dissemination losses.
3. Provide mechanism for feedback from the users to the institute. In addition to supporting individual farmers, groups, public and private agencies in supplying quality materials, technology and technical knowledge.

Activities of ATIC

The major activities of this system is to supply all the information on technologies, techniques and knowledge and necessary input and materials including planting materials, seeds advisory services, diagnostic services from the one place.

The activities are as follows:

? Soil and water sample testing facilities
? Plant clinic and diagnostic centre
? Rhizobium culture
? Organic and bio-pesticide, NPV
? Seed and planting material, small implements
? Fertilizer quality testing
? Insecticide quality testing
? Tissue culture and plant material

? Farm literature: leaflets, pamphlets, journals and magazines
? Booklets and manuals
? Audio and video cassettes on crops and other enterprise
? Process products: Cereals, milk, meat, fish, vegetable, fruits, mushroom etc.
? Cafeteria (Tea/Coffee/Lassi/Cold drinks/Snakes, etc.)
? Technology Park (Display *I* Exhibition)
? Veterinary: Animal clinical service for small as well as large a nimals
? Poultry hybrids livestock breeds, fish seed, etc.

Assignment

Visit the ATIC of the university and prepare the visit report on prescribed proforma

The information proforma about ATIC

1. Name of the Manager of ATIC? ____________________________________
2. Educational qualification? ____
3. From how many years the charge of ATIC is held? ______________________
4. How much amount was allotted under revolving fund for ATIC? _________
5. In which year? ____
6. What is the present status of revolving fund under ATIC? _______________
7. Which activities are carried out since last three years? Give the numbers.

Sr no	Name of activity	Number/Participants

8. Services provided by the ATIC to the farmers

Sr no	Name of Service	Number of farmers availed

1. Why ATIC is considered as single window system?

2. Which feedbacks are received form the famers?

3. Which constraints confined the activities of ATIC?

4. What are your suggestions to make ATIC more effective?

Practical: 09

PRA techniques and its application in planning of village development activities

Introduction:

Participatory rural appraisal (PRA) is an approach used by non-governmental organizations (NGOs) and other agencies involved in international development. The approach aims to incorporate the knowledge and opinions of rural people in the planning and management of development projects and programmes.

PRA can be described as a family of approaches, methods and behaviours that enable people to express and analyse the realities of their lives and conditions, to plan themselves what action to take, and to monitor and evaluate the results. Its methods have evolved from Rapid Rural Appraisal (RRA). The difference is that PRA emphasises processes which empower local people, whereas RRA is mainly seen as a means for outsiders to gather information.

Origins of participatory rural appraisal:

The roots of PRA techniques can be traced to the activist adult education methods of Paulo Freire and the study clubs of the Antigonish Movement. In this view, an actively involved and empowered local population is essential to successful rural community development. Robert Chambers, a key exponent of PRA, argues that the approach owes much to "the Freirian theme that poor and exploited people can and should be enabled to analyze their own reality."

By the early 1980's, there was growing dissatisfaction among development experts with both the reductionism of formal surveys, and the biases of typical field visits. In 1983, Robert Chambers, a Fellow at the Institute of Development Studies (UK), used the term Rapid Rural Appraisal to describe techniques that could bring about a 'reversal of learning'. Two years later, the first international conference to share experiences relating to RRA was held in Thailand [. This was followed by a rapid growth in the development of methods that involved rural people in examining their own problems, setting their own goals, and monitoring their own achievements. By the mid 1990's, the term RRA had been replaced by a number of other terms including 'Participatory Rural Appraisal (PRA)' and 'Participatory Learning and Action' (PLA).

PRA provides a structure and many practical ideas to help stimulate local participation in the creation and sharing of new insights. The emphasis on ensuring community feedback broadens the group of people involved. It is increasingly linked to participatory planning processes (e.g. using adapted forms of logical framework analysis). Although PRA was not intended to collect statistically significant information, it is increasingly used in combination with other methodologies to fulfil more scientific information needs and is easily made complementary.

There is no single way to 'do' PRA, although there are core principles and over 30 methods available to guide teamwork, do sampling, structure discussions and visualise analysis. The combination and sequence of methods will emerge from the context. Optimal ignorance and triangulation of findings guide the fieldwork in recognition of the need to know enough without knowing it all and to ensure that the qualitative insights are cross-checked by different sources using different methods.

What is Participatory Rural Appraisal (PRA):

PRA, an approach towards empowering the poor and marginalized communities, offers a basket of techniques. It helps to learn from as well as with the community or villagers. A set of principles, a process of communicating and interacting with the participants (villagers/ community people) using a set of menu of methods for seeking their participation. In PRA, the use of local graphic representations created by the community that legitimize local knowledge and promote participants' empowerment.

"An approach (and family of methodologies) for shared learning between local people and outsiders to enable development practitioners, government officials, and local people to plan together appropriate interventions (1998)."

Principles of PRA

Different practitioners would find different principles but most would agree to include the following

1. Using optimal ignorance: this refers to the importance of knowing what it is not worth knowing. It avoids unnecessary details and irrelevant data. It does not measure more precisely than is needed. It optimizes tradeoff between quality, relevance, accuracy and timeliness.

2. Offsetting biases: especially those of rural development tourism, by being relaxed and not rushing, listening not lecturing, probing instead of passing on to the next topic, being unimposing instead of important , and seeking out the poorer people and their concerns.

3. Triangulation: using more than one, and often three, sources of information to cross-check answers.

4. Learning from and with rural people: directly, on the site, and face-to-face, gaining from indigenous physical, technical and social knowledge.

5. Learning rapidly and progressively: with conscious exploration, flexible use of methods, opportunism, improvisation, iteration, and cross-checking, not following a blueprint program but adapting through a learning process.

Key Features of PRA

1. Participatory process, Provides vast scope and space for the community/participants
2. No preset questionnaires; rather semi structured/open-ended interview technique followed
3. Interactive process: exchange of ideas
4. Enables people and outsiders to learn through sharing of information
5. Flexibility in using methods , Innovate adaptable methods to suit local conditions

Dos

1. Stay in the village along with the villagers
2. Learn to unlearn by staying with the people, by more of listening and less of talking
3. Establish a rapport with the people
4. Organize do-it-yourself to start the field work. This will involve the team in trying their hands at everyday local activities
5. Choose a place in consultation with the people where men, women and people from different sections of the community can gather and participate
6. Create an open and enabling atmosphere to encourage participation
7. Start and build up interaction and dialogue gradually
8. Meet the people at their convenience. Ensure that the team from outside is multidisciplinary in nature
9. Decide the role of each member of the team from outside
10. Cultivate the attitude of letting people to set agenda
11. Ask open-ended questions in an informal way. Resort to the six helpers of PRA: What? When? Where? Who? How? Why?
12. Use locally available materials in all PRA exercises.
13. Be humble in your approach, respect the local people, their culture, their customs and their way of life.
14. Be flexible in your approach.
15. Be an active participation in all the PRA deliberation.
16. Be aware of the conflicts, if any; deal with them in a positive way.
17. Be conscious of the silent and invisible people in the village.
18. Be sensitive to the feelings of the people.
19. Be careful about your body language.
20. Think about the possible sequences of methods that can be used before leaving for the field.
21. Share your knowledge with the people.
22. Hand over the stick.

Don’ts

1. Don’t fail to listen closely.
2. Don’t ask leading questions
3. Don’t ask intensive questions.
4. Don’t fail to probe into issues.
5. Don’t fail to judge the responses.
6. Don’t interrupt.
7. Don’t dominate.
8. Don’t lecture.
9. Don’t personalize issues.
10. Don’t make false promises.
11. Don’t be arrogant and obsessive.
12. Don’t be judgmental.
13. Don’t use tricky language.
14. Don’t decide; rather facilitate the people to decide.

Methods

PRA employs a wide range of methods to enable people to express and share information, and to stimulate discussion and analysis. Many are visually based, involving local people in creating.

For example: maps showing who lives where and the location of important local features and resources such as water, forests, schools and other services; flow diagrams to indicate linkages, sequences, causes, effects, problems and solutions; seasonal calendars showing how food availability, workloads, family health, prices, wages and other factors vary during the year; matrices or grids, scored with seeds, pebbles or other counters, to compare things - such as the merits of different crop varieties or tree species, or how conditions have changed over time.

PRA activities usually take place in groups, working on the ground or on paper. The ground is more participatory, and helps empower those who are not literate. Visual techniques provide scope for creativity and encourage a frank exchange of views. They also allow crosschecking. Using combinations of PRA methods a very detailed picture can be built up, one that expresses the complexity and diversity of local people's realities far better than conventional survey techniques such as questionnaires.

A selection of participatory methods and their uses

Participatory method	Brief description	Examples of particular use
Timelines	Historical profiles of longer-term events or trends	Fish catch over time, productivity changes, policy changes
Seasonal calendars	Graphical representation of seasonal events or trends	Labor availability, hydrographic changes
Transect walks and through particular areas	Land- and water-use maps based on walking capital, local knowledge of microhabitat, current use of aquatic resources	Quality and quantity of natural resource maps
Social maps	Maps locating key social features	Access to services and infrastructure
Wealth ranking	Socio-economic categorization of households	Assets, income
Preference ranking	Ordinal ranking, e.g. based on pairwise comparisons, based on defined criteria with scoring	Livelihood strategies, assets and matrix ranking access to services (e.g., fish for conservation)

Practical applications

Since the early 1990s, PRA approaches and methods have evolved and spread with astonishing speed. Originating mainly among Non-Government Organisations (NGOs) in East Africa and South Asia, they have since been adopted by government departments, training institutes, aid agencies, and universities all over the world. They are now being used in at least 100 countries, with PRA networks existing in over 30. PRA has been applied in almost every domain of development and community action, both urban and rural.

Examples include: Natural resources management, establishing land rights of indigenous people, slum development, HIV/aids awareness and action, anti-poverty programmes, disaster management, negotiation and conflict resolution and adult literacy.

PRA as a new approach and method in which rural people themselves do much of the investigation, presentation, analysis, planning and dissemination than has been normal past.

Types of PRA Methods

PRA Methods		
Space Related	**Time Related**	**Relation Method**
• Social and Resource Map • Participatory Modeling Method • Mobility Map • Services and Opportunities Map • Transect • Participatory Census Method	• Timeline • Trend Analysis • Historical transect • Seasonal diagram	• Cause effect • Network Diagram • Process Map • Well-being Ranking • Venn Diagram • Pair-wise ranking • Matrix ranking • FF Analysis • Pie • Livelihood analysis • Spider Diagram • body Mapping

Stages of participation

Generally the following five stages are followed for PRA in qualitative method.

1st stage: outside experts tells and manipulation the villagers
2nd stage: the outside experts inform participants
3rd stage: the outside experts and participants consult each other to make decision together
4th stage: they act together
5th stage: the outside experts delegate authority and support to the participants

SOCIAL MAPPING

It is used to present information on: village layout, infrastructure, population, social stratifications, chronic health cases, disability, malnourished children, family planning, vaccination, widows, destitute and so on

Procedures

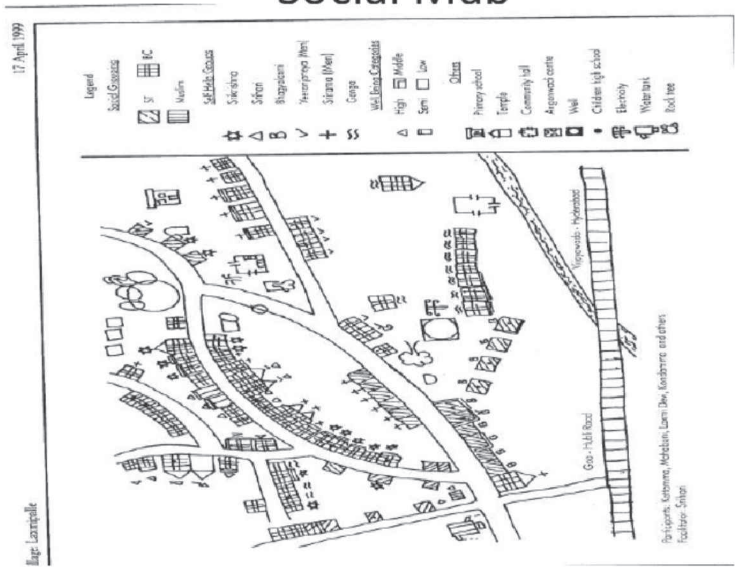
1. Find the members of the community who know and who are willing to be a part of it
2. Take a walk with the participants and establish compass direction at the boundaries on the village areas

3. Explain the purpose of the exercise to the participants and request them to start off. Leave them to use whatever the materials they choose
4. Watch the process alertly. Listen the discussions carefully
5. Take notes in as much detail as possible
6. Do not rush things. Avoid chipping in. Try to hand over the stick to them
7. Observe who are actively involved. Encourage and facilitate others who are not able to say anything
8. Once mapping is over ask them to identify their houses in the map
9. Number the households and mark different households according to the need
10. Triangulate the information generated with others in the locality

Applications

1. Developing a comprehensive understanding of the physical and social aspects of community
2. Collecting demographic and other required information household wise
3. Providing a forum of discussion in which to unravel the various aspects of social life
4. Serving as a guiding instrument during the process of planning intervention
5. Serving as a monitoring and evaluation tool

Social Map



Resource Map

A resource map is mainly drawn to present information on:

- Land, water and tree resources
- Land used, land and soil types
- Cropping pattern
- Land and water management, etc.

Procedures

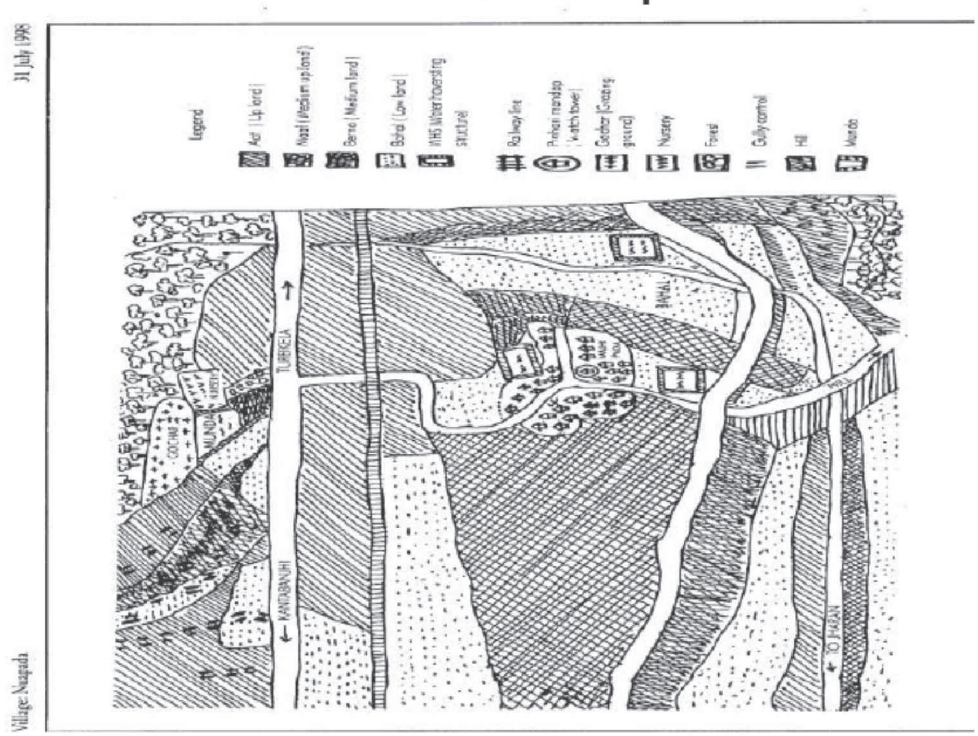
1. Establish rapport
2. Find out key informants
3. Explain the purpose
4. Select a place
5. Hand over the stick
6. Observe the discussion
7. Do not make objection
8. Observe if any of the member is excluded from discussion

Applications

Resource maps are used for depicting of various aspects related to the natural resource management of a locality including.

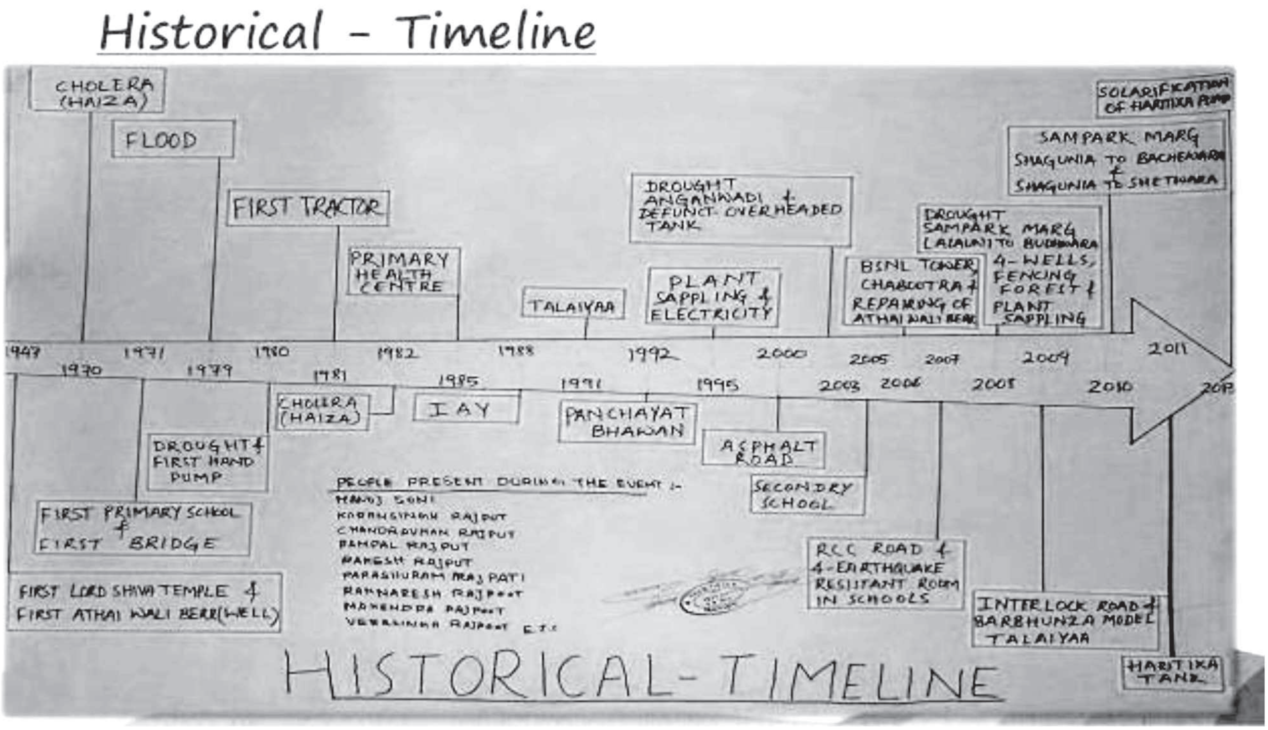
- Topography and slopes
- Forest vegetations and tree species
- Soil type, fertility, erosion
- Land and forest use
- Water and water bodies
- Agriculture cropping pattern, etc.

Resource Map

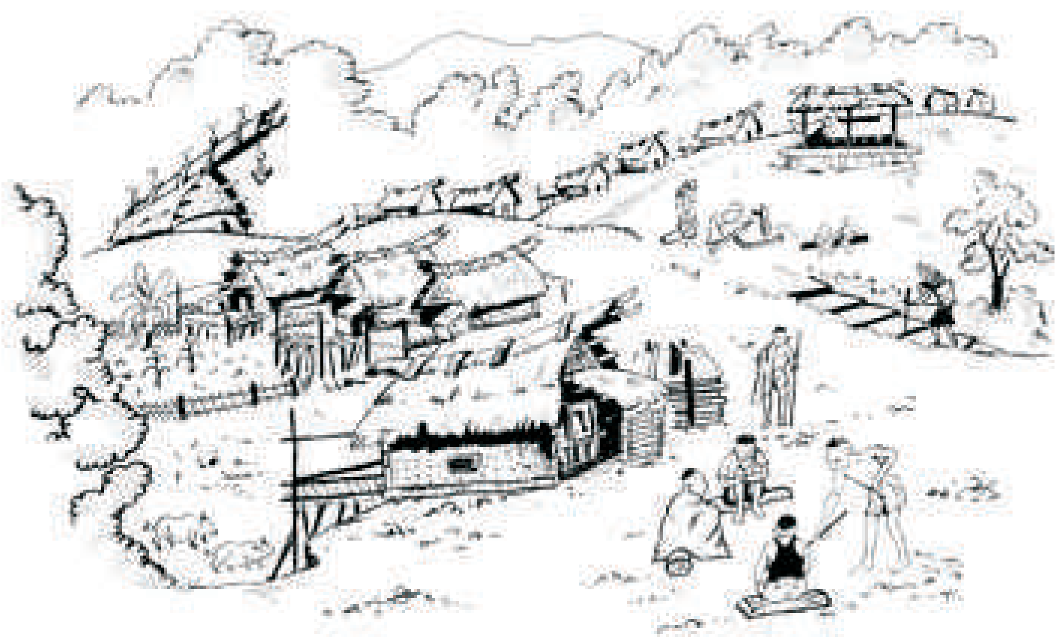


Other PRA Tools that have different uses and applications

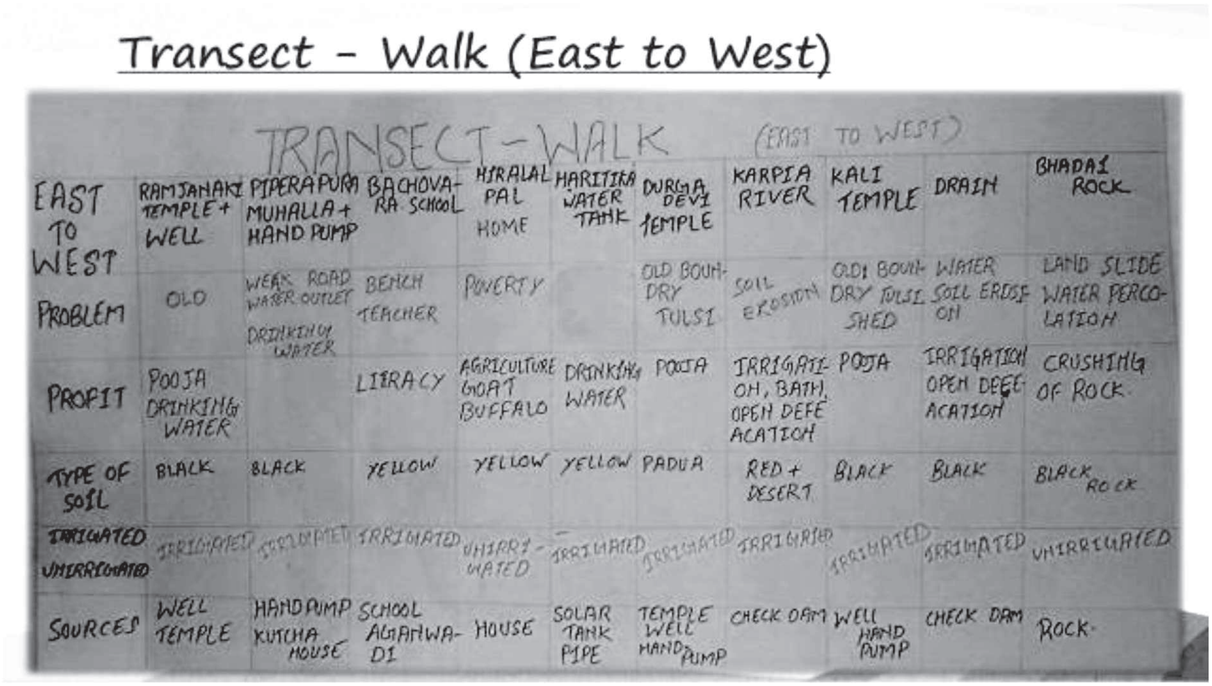
1. **Historical Calendars:** Historical timeline exercises are conducted to highlight trends and key points in the history of the Commune or Village that households considered had an impact on their livelihoods – either positively or negatively.



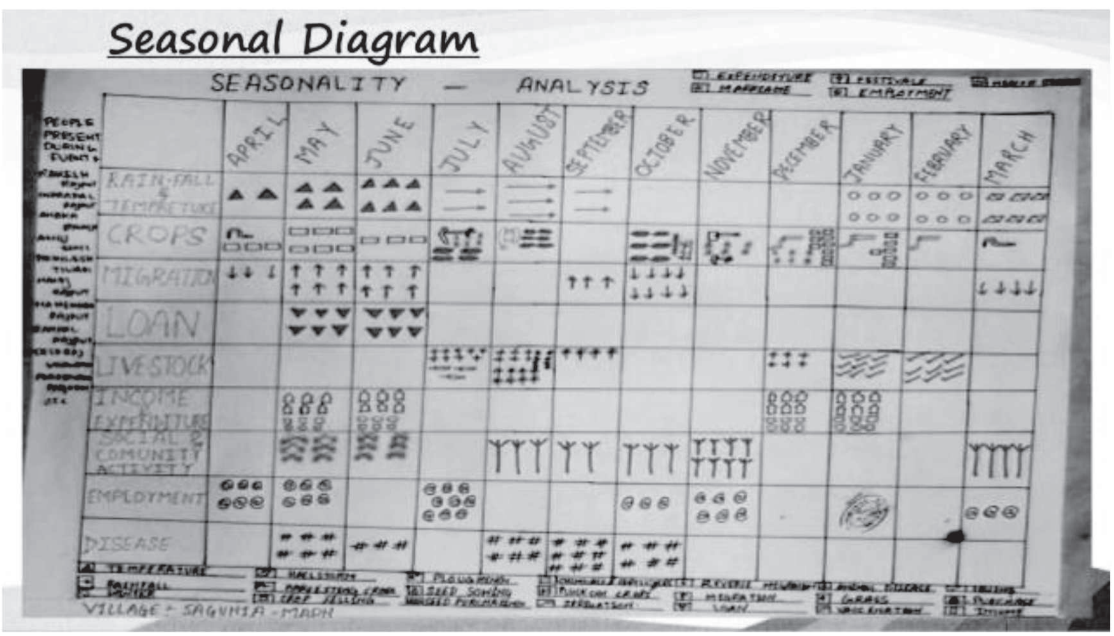
2. **Village Mapping**: Village mapping is a PRA tool used to facilitate understanding and discussion on local farming systems, physical resources/features and infrastructure considered important by households.



3. **Transect Walks:** Transect walks are a PRA tool used to develop familiarity with local farming systems, local geography, natural resources, production problems and opportunities to overcome such problems. Transect walks facilitate the opportunity and households to view, discuss and compare local resources between areas and between the past, present and different seasons.

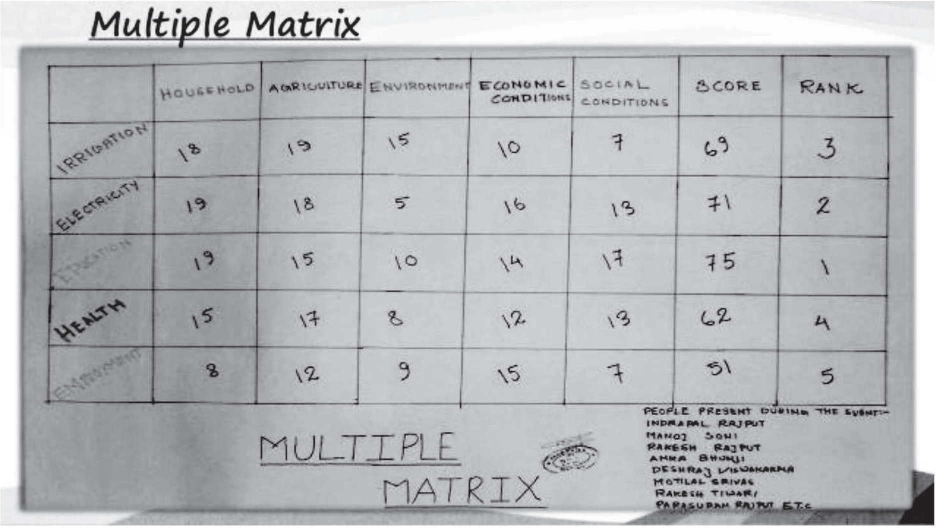


4. **Seasonal Calendars:** Seasonal calendars are developed to illustrate important activities, problems or resource changes throughout a calendar year or production cycle. They can investigate community based activities, livestock production, cropping and cultivation, weather and climatic conditions, and expenditure and borrowing.



5. **Linkage Diagrams**: Linkage diagrams are used to investigate local farming systems. They determine the main crop and livestock varieties cultivated and raised, sources of inputs, sale of products and the uses of by-products. Linkage diagrams can identify under-utilised resources and assist farmers to propose solutions to improve local farming systems.

6. **Matrix Scoring and Ranking Matrix:** scoring and ranking is a PRA tool that allows households to identify activities most preferred by households and why particular activities are preferred. This particular exercise is also used as a planning tool (e.g. to identify crops or livestock that households wish to cultivate and why). In addition, matrix scoring and ranking is also used effectively to evaluate household perceptions on a technology or activity.

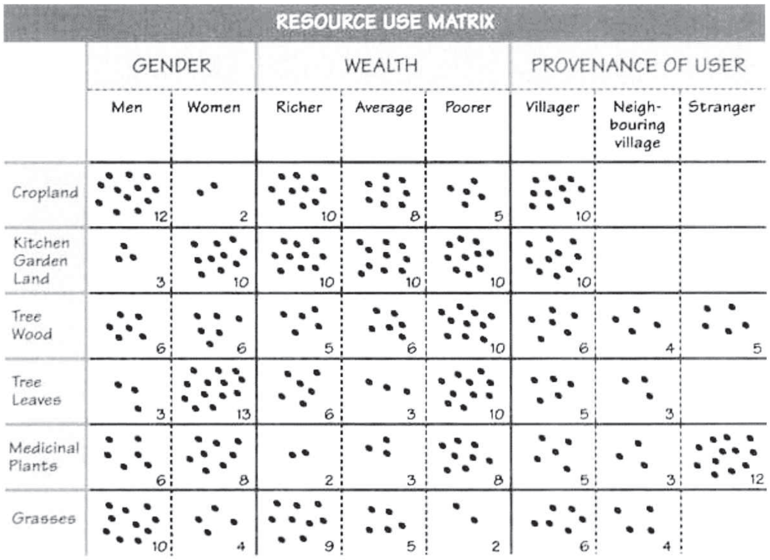

Multiple Matrix

	HOUSEHOLD	AGRICULTURE	ENVIRONMENT	ECONOMIC CONDITIONS	SOCIAL CONDITIONS	SCORE	RANK
IRRIGATION	18	19	15	10	7	69	3
ELECTRICITY	19	18	5	16	13	71	2
[illegible]	19	15	10	14	17	75	1
HEALTH	15	17	8	12	13	62	4
[illegible]	8	12	9	15	7	51	5

MULTIPLE MATRIX

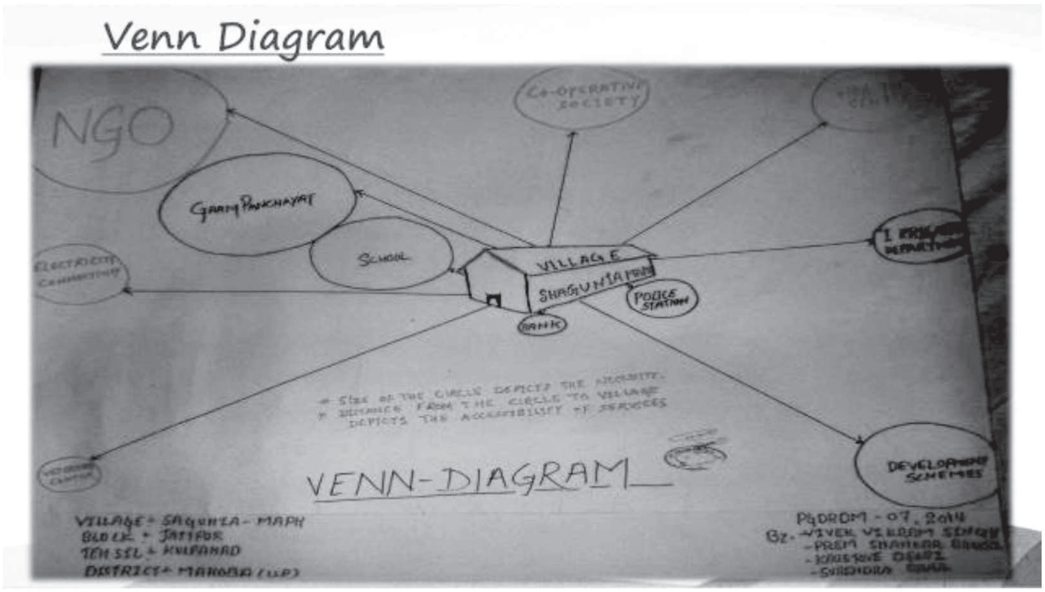
PEOPLE PRESENT DURING THE EVENT:-

7. **Wealth Ranking**: Wealth ranking is conducted to allow households to define differing levels of wealth in a Commune and the households that belong to a particular class of wealth. The characteristics of each class of wealth are defined. The results of wealth ranking exercises facilitate an understanding of the characteristics and resources of households of a particular wealth class, particularly the poor.


RESOURCE USE MATRIX

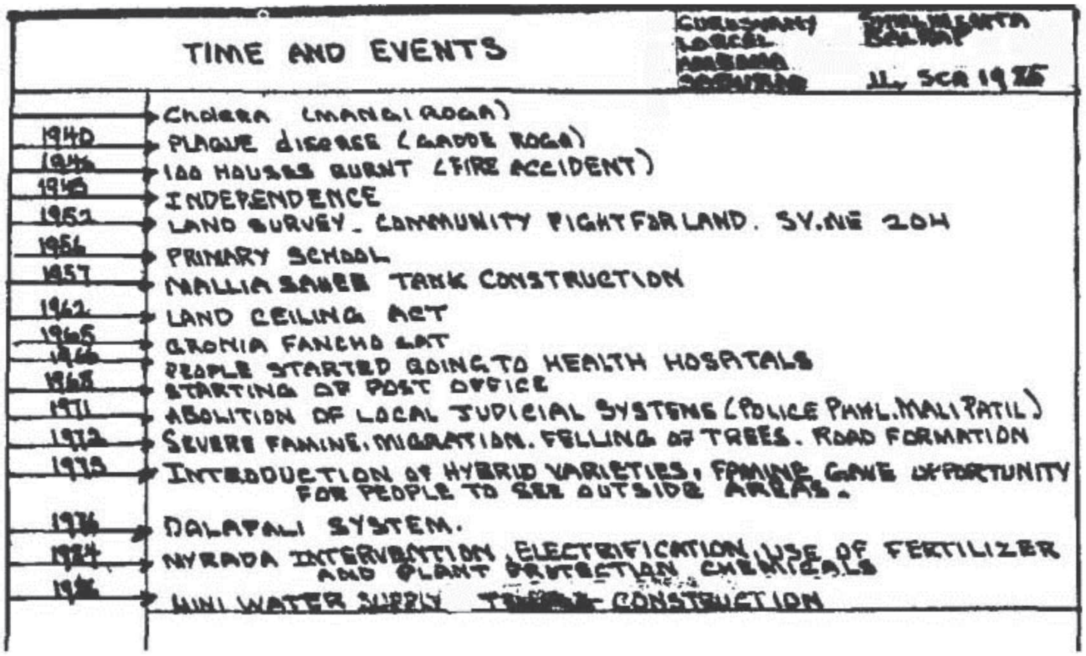
	GENDER		WEALTH			PROVENANCE OF USER		
	Men	Women	Richer	Average	Poorer	Villager	Neigh-bouring village	Stranger
Cropland	12	2	10	8	5	10		
Kitchen Garden Land	3	10	10	10	10	10		
Tree Wood	6	6	5	6	10	6	4	5
Tree Leaves	3	13	6	3	10	5	3	
Medicinal Plants	6	8	2	3	8	5	3	12
Grasses	10	4	9	5	2	6	4	

8. **Venn Diagrams**: Venn diagrams are a tool used to investigate linkages, relationships and interactions between differing groups of households, institutions or community groups. The Venn Diagram exercise allows participants to raise any conflicts, their causes and discuss options on how to resolve these issues.

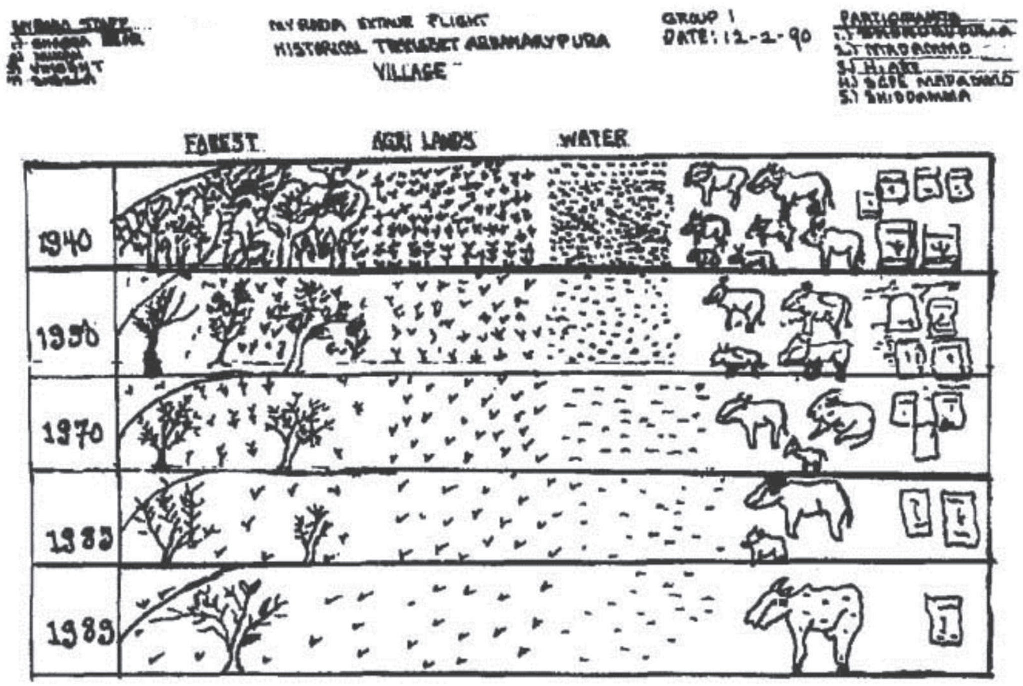


9. **Focus Group Discussions**: Focus group discussions facilitate discussion on a particular problem or development topic. The discussions ultimately encourage households to propose solutions to these issues.

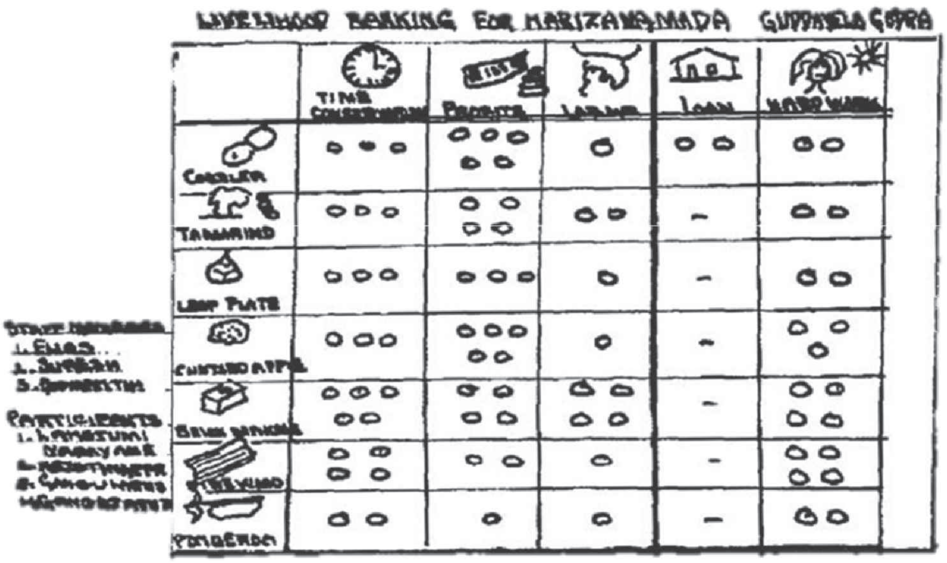
10. **Time Line:** A chronological description of important events which occurred in the community's past and how such has influenced its development.



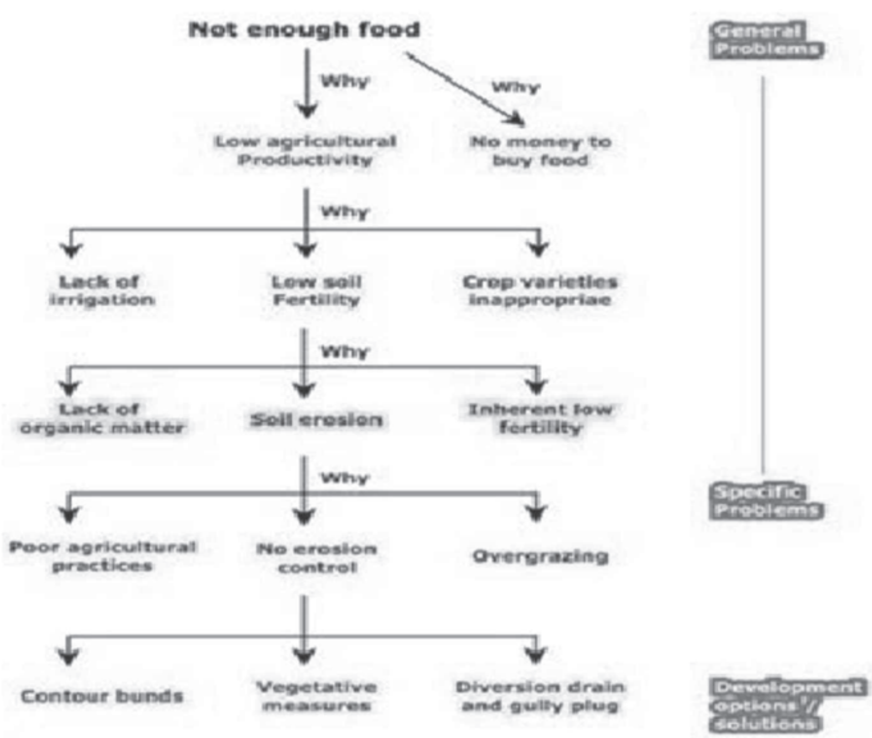
11. **Trend Analysis:** A visual documentation of the past, present and future directions or patterns of changes in the community's life. It examines the implications and causes of such changes.



12. **Problem Ranking**: A matrix that identifies compares and prioritizes main problems of villagers. It serves as basis for focusing recommendations, alternative options or possible solutions.



13. **Problem Cause Diagram**: A diagram which traces and diagnoses the root causes of certain problems in the community or household.



ADVANTAGES OF PRA

1. Identification of genuine priorities for target group
2. Devolution of management responsibilities
3. Motivation and mobilisation of local development workers
4. Forming better linkages between communities and development institutions
5. Use of local resources
6. Mobilisation of community resources
7. More sustainable development activities

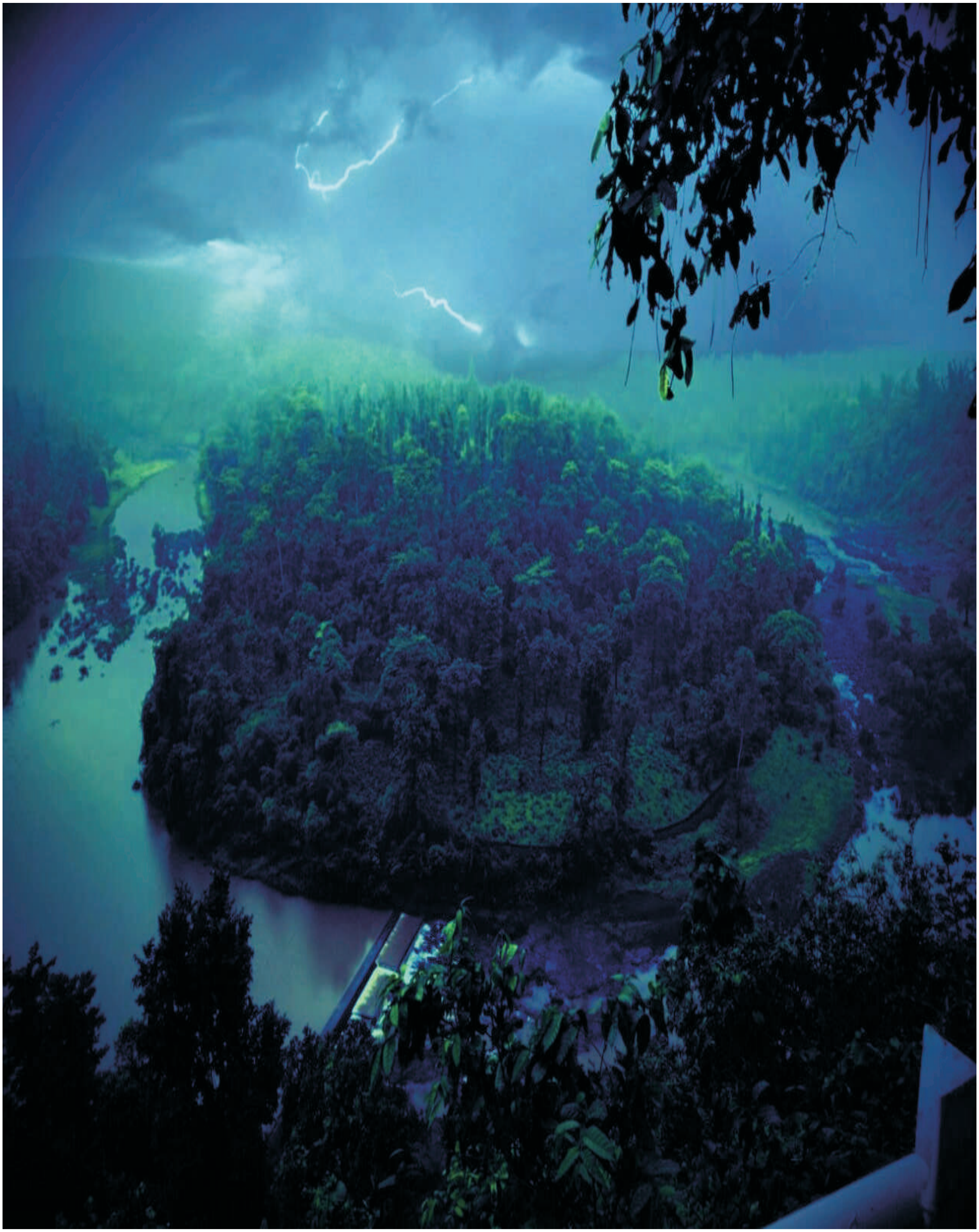
DISADVANTAGES OF PRA

1. Raising expectations which cannot be realized
2. Proposal of development plans which participating agencies cannot respond to
3. Risk of “capture” of activities by local interests
4. Failure to take account of stratification in communities

NOTES

NOTES

NOTES



NAVSARI AGRICULTURAL UNIVERSITY

ICAR

PRACTICAL MANUAL

Agron. 3.3

Crop Production Technology-I : (*Kharif* crops) (1+1=2)

SPONSERED BY ICAR

For

B.Sc. (Hons.) Agriculture

Prepared & Complied by

Dr. R. R. Pisal, Dr. A. P. Patel, Dr. V. R. Naik, Prof. S. S. Sonawane

College of Agriculture

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Waghai - 394730

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FOREWORD

A new course on Crop Production Technology-I : (Kharif crops) 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.

In this Practical Manual information is provided on raising of field crops. It is hoped that an understanding the cultural as well as practical requirements for crop cultivation on farm. 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 Natural Resource Management, 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 crop production 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. Dr. R. R. Pisal, Dr. A. P. Patel, Dr. V. R. Naik, Prof. S. S. Sonawane for their commendable efforts in bringing out this practical manual.

January, 2019

(Z. P. Patel)

CERTIFICATE

Reg. No.   : ____________

Uni. Seat No.: ____________

This is to certify that Mr./Miss____studying in Second semester B. Sc. (Hons.) Agriculture has satisfactorily carried out ________ practical exercises in the subject of **Agron. 3.3 Crop Production Technology-I : (*Kharif* crops) (1+1=2)** on the College Agronomy Farm, College of Agriculture, NAU., Waghaiduring the _________________.

Course Teacher
Asstt. Prof. of Agronomy

Professor and Head
Dept. of Agronomy

External Examiner

I N D E X

Exercise: 1

Identification of *kharif* crops and seeds

Introduction

Crops and seeds are too often confuses a student, particularly different varieties of a crop, if he/she does not have proper acquaintance previously. Similarities in morphological characters like plant stature, size of the ear head, colour and size of the seed leads to lot of confusion especially for those not having farming back ground or lack of exposure to such crops and seeds. Therefore maintenance of the crop cafeteria (crop museum) is a mandatory for each college farm.

In crop cafeteria different crops are sown. In each instructional farm (college farm/ students farm) a piece of land is meant for raising crop cafeteria which includes different crops with recommended package of practices for student instructional purpose (identification).

Different types of field crops like cereals, pulses, oil seeds, commercial crops, fibers etc. are grown in limited area considering the season of growing at a time with the purpose of studying detail characteristics and demonstration is called crop cafeteria. This crop cafeteria serves as an important guide to the students and farmers to know the important characteristics of different *kharif* crops and offering an opportunity to choose suitable crop or crops.

Objectives:

(1) To know the crop growth stages of different crops viz. germination stage, tillering stage, flowering stage, maturity stage etc.

(2) To know the life period of different crops.

(3) To know the periodical growth habit of the crops viz. height and width of crop plants.

(4) To know the different stages at which the crops are affected by insects, pests, and diseases and nature of damage.

(5) To know the climatic effect on different *kharif* crops.

(6) To know the method of the sowing, seed rate, fertilizer and irrigation requirement, maturity and time of harvesting.

(7) To identify two similar crops at initial stage of the crop growth e.g. sorghum and pearlmillet.

Material required

Crop museum (crop cafeteria), seed museum

Procedure

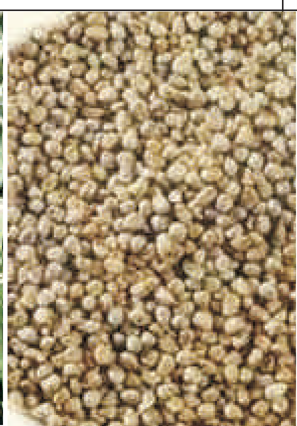
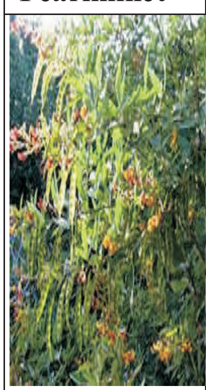
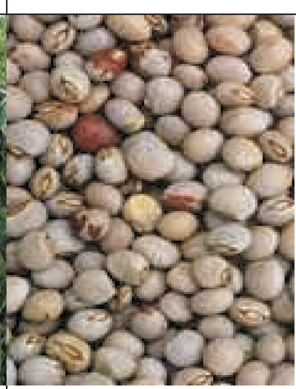
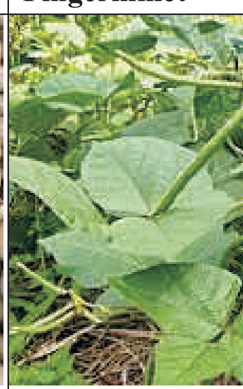
Visit the students' farm/college farm; observe the existing crops, their morphological characters for easy identification.

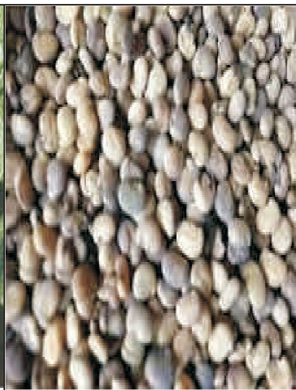
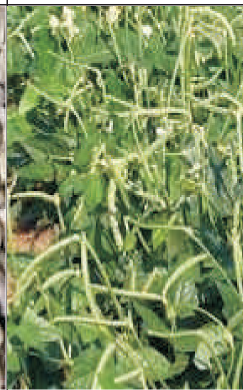
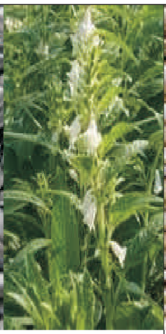
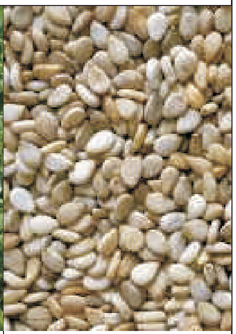
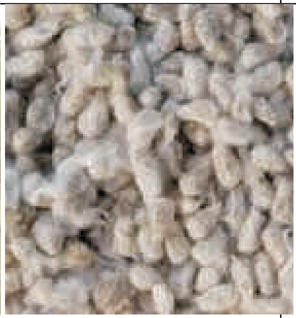
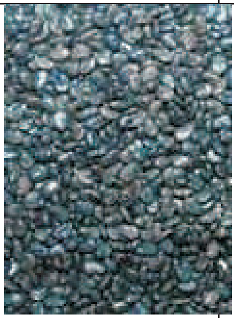
Sr.No.	Name of crops	Botanical Name	Family	Varieties
(A)	**Cereals and Millets**			
1	**Rice**	*Oryza sativa*	Gramineae (Poaceae)	Jaya, Gurjari, GR 3,GR 4, GR 7,GR 11, GR 103, IR 22, IR 28,Gujarat Anand Rice 13 (GAR 13),NAU R 1,GNR 2,GNR 3,GNR 4(Bio fortified for high iron and dietary fiber content), GNR 5 (Salt resistant),GNR 6
2	**Maize**	*Zea mays*	Gramineae (Poaceae)	Gujarat Maize 2,GM 4,GM 6,Narmada moti,Madhuri (Sweet corn),Vin orange (Sweet corn), Amber (Popcorn),GAYMH 1,GAWMH 2 , HQPM 1(For quality protein)
3	**Sorghum**	*Sorghum bicolor*	Gramineae (Poaceae)	CSH1, CSH5, CSH6, CSH 8, CSH 13, GJ 8, GJ 9, GJ 35, GJ 36, GJ37, GJ38, GJ39, GJ40, GJ41,GJ 42, BC 9 (Striga resistant), Gundari,Solapuri,C-10-2
4	**Pearl millet**	*Pennisetum glaucum*	Gramineae (Poaceae)	GHB 558,GHB 538, GHB 719, GHB 732, GHB 744, GHB 757,GHB 905 For summer: GHB 526, GHB 538,GHB 558
5	**Vari**	*Penicum miliare*	Gramineae (Poaceae)	Gujarat Vari.1, Gujarat Vari.2, Gujarat Navsari Vari.3
6	**Kodomillet**	*Paspalum scrobicalatum*	Gramineae (Poaceae)	Gujarat kodra 1, Gujarat kodra 2, GPUK 3
7	**Finger millet**	*Eleusine coracana*	Gramineae (Poaceae)	Guj.Nagli 1, Guj.Nagli 2, Guj.Nagli 3, Guj.Nagli 4, Guj.Nagli 5, Guj.NavsariNagli 6, GNN 7,GNN 8

(B)	**Pulses**			
1	**Pigeonpea**	*Cajanus cajan*	Leguminosae	BDN 2, GT 100, GT 101,GT 103, ICPL 87, ICPH 8, GT 1, C 11, Manak,SVT 1,Banas
2	**Greengram**	*Phaseolus aureus*	Leguminosae	Gujarat moong 3and 4, K 851, GAM 5, GAN 6,Guj.Black Moong 1 (NAU)
3	**Blackgram**	*Phaseolus mungo*	Leguminosae	T 9, TPU 4, Pusa 1,Guj.Urd 1
4	**Clusterbean**	*Cyamopsis tetragonoloba*	Leguminosae	GG 1, GG 2
5	**Cowpea**	Vigna unguiculata	Leguminosae	Pusa falguni, Gujarat Cowpea 3,4,5and 6 , Pusa 152, AVCP 1
(C)	**Oilseeds**			
1	**Groundnut**	*Arachis hypogaea*	Leguminosae	GG 2, GG 5,GG11, GG12, GG20, GG13, GJG-HPS 1,GJG 9,GJG 22,TAG 24, TG 26,TG 37 A,TPG 41
2	**Castor**	*Ricinuscommunis*	Euphorbiaceae	GC3, GAUCH1, GCH 2, GCH 4, GCH 5, GCH 6,GCH 8,GNCH 1,GC 101
3	**Sesame**	*Sesamum indium*	Pedaliaceae	Gujarat Til 1,Gujarat Til 2,Purvatil1
4	**Soybean**	*Glycine max*	Leguminosae or Fabaceae	Gujarat Soybean 1,2,3, Shilajeet,ClarkJS 335, NRC 37, NRC 47
5	**Sunflower**	*Helianthus annus*	Asteraceae	Co.1, Modern, EC68413, EC68414, EC 68415, APSH11, KSFH1, TNAU SUF 7, Gujarat Sunflower 1,
(D)	**Fiber crops**			
1	**Cotton**	*Gossypium hirsutum*	Malvaceae	Bt. Cotton **:** G. Cot. Hy.6 ,8,10,12 and GTHH 49 Desi cotton **:**V797, G.Cot. 13, G.cot. 21, Anand Desi Cotton 1

2	**Jute**	*Corchorus olitorius* (Native Africa)*Corchorus capsularia* (Native Indo Burma)	Tiliaceae	-
(E)	**Forage crops**			
1	**Sorghum**	*Sorghum vulgare*	Gramineae (Poaceae)	For single cut : S 1049, C 10 -2, GFS 3 (IA 5026), GFS 4,GFS 5, GAFS 11&12 For multi cuts : M.P.Chari, SSG 59-3, Pioneer hybrid,GFSH 1(AS 16),Harasona, Safed moti, COFS 29
2	**Cowpea**	*Vigna sinensis*	Leguminosae	GFC 1,GFC 2,GFC 3,GFC 4,EC4216
3	**Napier hybrid**	*Pennisetum purpureum*	Gramineae (Poaceae)	APBN 1, BNH 10, CO 3
4	**Fodder maize**	*Zea mays*	Gramineae (Poaceae)	Ganga 5, Ganga Safed 2, Farm Sameri,African tall, Guj.Maize 1, Guj.Maize 2, Guj.Maize 3, Guj.Maize 4, Guj.Maize 6
(F)	**Cash crop**			
1	**Bidi tobacco**	*Nicotianatabacum*	Solanaceae	A 2, A 119, GT 5, GT 9, MRGTH 1, ABT 10 (Nematodes resistance) GAB T 11, For unirrigated areas **:** GT 4,GT 7 Rustica tobacco**:** GC 1, GC 2, GC 3, DCT 4
(G)	**Green manure crops**			
1	**Sunnhemp**	*Crotolaria juncea*	Leguminosae	K 12,M19,M35, ST 35, Nalandasanni
2	**Dhaincha**	*Sesbania aculeata* *Sesbania rostrata*	-	-

Identification of *Kharif* season crop plants and seeds

					
Plants	Seed	Plants	Seed	Plants	Seed
Rice		**Maize**		**Sorghum**	
					
Plants	Seed	Plants	Seed	Plants	Seed
Pearlmillet		**Fingermillet**		**Kodomillet**	
					
Plants	Seed	Plants	Seed	Plants	Seed

Pigeonpea/Redgram		Mungbean/Greengram		Urdbean/ Blackgram	
					
Plants	Seed	Plants	Seed	Plants	Seed
Clusterbean		**Cowpea**		**Groundnut**	
					
Plants	Seed	Plants	Seed	Plants	Seed
Castor		**Sunflower**		**Sesamum**	
					
Plants	Seed	Plants	Seed		
Cotton		**Sunnhemp**			

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Exercise: 2

Field lay-out of different methods of rice nursery including SRI

Objectives:

1. To know different methods of raising nurseries for rice crop planted through transplanting.
2. To obtain healthy and robust seedlings to transplant in time for better yield.

Rice has small sized seeds and soft seeds, if sown directly in the field, it will not give uniform and satisfactory germination. To avoid such difficulty, the seeds are not directly sown in the field but seedlings are raised in the nursery with special care and later on they are transplanted in the field. A nursery of succeeding crop is prepared to avoid its delay sowing in case of late harvesting of preceding crop. For example, seedlings of rice are raised in nursery for summer cultivation. In cases of hybrid seeds require in large quantity, where seed material is costly or in limited quantity, crop is grown in raised nursery.

Selection of Nursery site:

- It is desirable that the nursery site is changed every year to minimise the incidence of diseases, pests and weeds.
- Soils of nursery area having good water retention capacity with good amount clay and O.M., well drained, on high elevation to drain excess water.
- It should be near to source of irrigation
- Away from shade of tree.

Wet nursery:

Seed and seed treatment:

- Select the certified seed for sowing
- For fine grain varieties, 20-25 kg seed and for coarse varieties, 25-30 kg seed would be required to raise seedlingsin 10 Gunthaarea, which is enough for one hectare.
- **Dry seed treatment:**Seeds should be treated with thiram or carbendazim 25 S.D. @ 3 g/kg seed.
- **Wet seed treatment:**Soak the seeds (25 kg) in streptocycline@ 6g/24 lit water for 10 hours.After soaking the seeds, they should be dried for sowing.

Nursery

- Select the well-drained and levelled field having better irrigation facilities
- Usually nursery area for rice is about one tenth of the main field area. About 1000 sq. m. area of nursery is sufficient to transplant one hectare.

- Flats type of beds are prepared easily in sandy loam type of soils. Whereas, raised type of beds are mostly preferred in heavy black soils which have poor drainagecapacity.The basal measurement of beds should be 10 m x 1m. Length of beds should be kept according to the slope of nursery.

  In between the raised beds, a drainage channel of about 30 cm width is provided.The surface of the bed is smoothened with gradual inclination towards both sides to facilitate easy drainage of water.

↑
1.0 m **Flat bed for**
↓ Sandy loam soil (Goradu)

←10.0 m→

	←10.0 m→	
1.0 m→	**Raised bed for blacl soil**	**←Channel→**
	0.3m channel	

- Apply the manures and fertilizers as below

Sr. No.	Fertilizer application	For 10 sq.m.of bed	For 1000 sq. m. (10 Guntha) of nursery area
1	Basal **:** Well decomposed F.Y.M. castor cake Ammonium Sulphate Single Super Phosphate	 20.000 kg 1.000 kg 0.250 kg 0.500 kg	 2000 kg 100 kg 25 kg 50 kg
2	**Top dressing : (15 DAS)** Ammonium Sulphate	 0.250 kg	 25 kg

- Keep the nursery wet by sprinkling water with water cane or give light irrigation till the germination of seeds.
- Weeding in time is the important operation. Spray pendimethalin @ 1.0 kg/ha or oxadiazon o.5 kg/ha or pretilachlor@1kg/ha with sand after 3 days of sowing for control of weeds.
- Application of Carbofuran 3G @ 10 kg / 10 Guntha 15 DAS
- After care should be taken for plant protection measures.

Time of seeding in nursery and T.P. in field

Sr. No.	Seasons	Time of seeding in nursery	T.P. time in field	Age of seedlings
1	***Kharif***	First fortnight of June	First fortnight of July	25-30 days
2	**Summer**	Last week of November to First week of December	First fortnight of February	50-55 days

Dapog Nursery:

- This method of raising nurseries has been introduced in India from Philipines.
- This involves growing seedlings on a concrete floor or on a raised bed of soil covered with polyhtene sheets or banana leaves.
- The polyhtene sheets prevent entry of roots into the soil.
- The dapog beds should be about 1- 1.5 m wide and its length depends on the area to be planted.
- Pre-germinated seeds are sown on the top of the sheets @ 2.0 kg/sq.m.ofnursery.
- Water is sprinkled and the seeds are pressed gently with hand or with a wooden flat board twice a day for the first 3-6 days.
- This helps the roots to remain in contact with water retained on the surface and prevents drying.
- After 6 days, the seed beds are watered upto a depth of 1-2 cm.
- In about 14 days,seedlings are readyfor transplanting. Besides, the seedlings are thin, slender and short in height.
- The main merit of this method is that less area (30-40 sq.m.) is needed to raise seedlings sufficient for planting one hectare.
- By this time,the roots are well developed and interwine with one another so that the nursery can be cut into stripes, rolled and transported easily to the planting site.
- Loosen the interlocked roots carefully before transplanting.

Details of SRI Technology

System of Rice Intensification (SRI) was first developed in MEDAGASKAR in 1980's.

1. Land preparation	:	Apply 5 t FYM ha^{-1} and plough the field
2. Suitable varieties 3. Seed rate 4. Nursery raising 5. Age of seedling	: : : : :	Any variety / hybrid 5 kg seed /ha 5 Apply layer of fine manure on seed bed. Distribute pre-sprouted se seeds and cover with them with layer of fine manure.Seed bed 1 should be mulched with paddy straw. About 100 sq. m. area of rs nursery is sufficient to transplant one hectare 1 12 -14 days old seedling (Two leaves stage)
6. Transplanting	:	Transplant one seedling per hill (25 cm x 25 cm). The root of the seedling should not be disturbed. Transplanting should be done a day after puddling the field having no standing water. Transplanting should be done from last fortnight of June to First fortnight of July.
6.Nutrient Management Fertilizer dose	:	25 % RDN through chemical fertilizer and remain 75 % through organic manure
Bio-fertilizer	:	Liquid biofertilizer @ 1 lit/ ha each of *Azotobactor* and PBS after mixing with 50 kg well decomposed & sieved FYM, broadcast it equally at the time of transplanting.
7. Weed Control	:	Use cono-weeder/ rotary weeder 4 times at an interval of 10 DATP for weed control.
8. Water Management	:	A light irrigation should be given after transplanting when hair like crack of soil has been seen. Keep standing water (5 cm) from 50 % flowering to maturity stage.Water should be drained 10-15 days before harvesting.

Healthy plants in SRI is because of ………..

- Large root volume
- Profuse and strong tillers
- Non loding
- More and well filled spikelets with higher grain weight

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Exercise: 3

Seed treatment and sowing of major crops

Objectives:

1. To know the different methods of seed treatment.
2. To study about different seed treatment to different field crops.
3. To know the importance of seed treatment.
4. To acquire skill in seed treatment.

The improved seeds play an important role in increasing the crop production. Similarly, the seed treatment is also equally important to boost up the crop yield. Seed treatment is low cost input and the monetary returns realized due to seed treatment are comparatively higher as compared to other inputs in crop production.

Seed treatment refers to the application of fungicide, insecticide, or a combination of both, to seeds before sowing for various purposes to control insects, pests, diseases, improving germination, atmospheric nitrogen fixation and inducing the initial root growth of crop.

Purposes of seed treatment:

1. **Easy sowing:**

When the seed contain fuzzes and cannot be separated from each other at the time of sowing, the physical or chemical method of seed treatment is used for easy sowing. e g. Cotton seed

2. **Uniform distribution of seeds during sowing:**

When the seeds are small in size and light in weight, it is difficult to sow the seeds and maintaining uniform plant population. Therefore, the seeds are mixed either with sand or powder of oil seed cake or FYM. e.g. Sesame and Rajgira seeds.

3. **Seed treatment for improving germination:**

Some crops have hard seed coat or hard layer over the seeds and ultimately, it takes more time for germination. Soaking the seeds in water before sowing will improve the germination percentage. Duration of soaking depends on the nature of the seed coat. e.g. soaking of paddy seeds for 12 hours in water and drying of seed under shade for 4-5 hrs.

4. **To prevent the effect of pests:**

Some of the seed material carries eggs of insects and pests in dormant condition or the pest itself is in the dormant condition in the soil. After sowing of the crop, the pests become active and start to damage the seed and seedling, hence the seed treatment is necessary against the pests e.g. termites.

5. To prevent the seed borne and soil borne diseases:

In case of seed borne diseases, the pathogens are carried either on surface of the seed within it. When pathogen externally present, may be destroyed by treating the seeds with chemical viz, captan, thirum and agrosan etc. If pathogens are present internally in the seed, the hot water treatment is effective.

6. Microbial culture treatment to maximize the yield:

Pulses crop have ability to fix the atmospheric nitrogen through root nodules which used by crop plant. Similarly, in cereal crops free living bacteria fix the N_2 in soil. The seeds of legumes/ cereals are inoculated with effective bacterial culture for better N_2 fixation the in soil. e.g. *rhizobium* cultural used in pulses and *Azatobecter* and *Azospirillum* culture for cereals.

7. To reduced the seed rate:

To reduce the seed rate coriander seeds are rubbed and spited in two halves and these two halves should be sown for easy germination and optimum plant population.

8. To induce the genetic variation:

By genetic variation plant breeder can obtain disease resistant variety through the seed treatment create fundamental change in colour, taste, quality *etc*, By mutation, inducing variation in the progeny by X- rays and *gama* rays.

9. To break the seed dormancy:

Dormancy is a resting period of crop seeds during that time plant completes its physiological process. If temperature and moisture are appropriate for seed germination even though seeds cannot be germinate. For that, seeds should treat with chemical. e.g ethanol is used in spreading variety of groundnuttobreak the seed dormancy.

10. To safe seed storage:

Sun drying reduce the moisture content of seeds. For safe storage of seeds the moisture per cent should be 8-10 %. If the moisture content is more than 8-10 %, there is a chance of diseases and pests for spoiling the seeds. So, seeds should be treated with some pesticides or Neem leaves for safe storage.

11. Seed hardening:

The seed hardening may be done for inducing tolerance to adverse weather and soil condition such as drought, frost, cold, salt etc. By dipping in to a solution of chemical, such as potassium chloride, potassium nitrate and calcium chloride.

Equipments used for seed treatment :

1) Slurry Treater 2) Direct Treater 3) Grain auger 4) Home- made drum mixer 5) Shovel

Methods of seed treatment:

1. **Rotary seed dressing drum:**

   The fungicide may be applied to small lot of seeds with rotary seed dresser. Sometimes it may be applied in large quantity of seeds also. In this method, the rotary seed dresser is filled up to 2/3 part with seeds and with required quantity of fungicide. The rotary seed dresser is rotated 10-15 minutes with jack in slow motion. Generally, the seeds of cereals, legumes and oil seeds are treated by this method.

2. **Planter or Hopper box method:**

   The required quantity of fungicide is mixed with the seed planter or hopper box of seed drill at the time of sowing. The advantages of this method are that only required quantity of seed is used and rest of the seeds may be used for other purposes.

3. **Earthen pot method:**

   This is a local method used, where rotary seed dresser is not available and seed is in small quantity. In this method, pot is filled up to 2/3 part with seeds and with required quantity of fungicide, shakes it well for 10 minutes to make seeds ready for sowing.

4. **Seed treatment by plastic or paper bag:**

   When the seeds are costly and in small quantity, seed treatment may be applied by plastic or paper bag. The required quantity of fungicide is mixed with seed in plastic or paper bag and treated seeds are then used for sowing.

5. **Slurry methods:**

   The required quantity of wettable power is mixed with water and make in to slurry. When the treatment is to be made on larger scale, the slurry method is applied with automatic machinery generally by private- seed growers, government seed farms and Seed Corporation. But when the seeds are to be mixed in small quantity, it is done manually, such as legume seed treatment with *rhizobium* culture.

6. **Soaking seeds/ Dipping roots of seedling:**

   This method is generally adopted vegetatively propagated seed material e.g. sugarcane, potato etc. Some times seeds are also soaked e.g legumes seeds. In some cases, roots of crop seedling are dipped in the fungicidal solution. In this method, required quantity of fungicide is dissolved in water to make the solution of desired concentration. The seed material is soaked in the solution for specific time and dried in shade and used for sowing/ planting.

Seed treatment for different field crops:

Sugarcane:

For the control of Mealy bug and scale insects: Setts should be dipped in the 0.1 % solution of Melathion for five minutes before use.

For seed borne and soil borne diseases : After giving the above treatment, sugarcane settsare dipped into 0.5 % solution (500 gm in 100 litres of water) of Aretan or Amisan or Agallol or Seresan for 5 minutes before planting.If these chemicals are not available, the seed setts are treated with Thiram or Captan.

For better germination: **a**. Setts should be dipped in 0.5 kg of quick lime in 200 liters of water for 12 hours for softening of the eyes.This treatment ensures better germination and also kills eggs of insects.

Hormones treatment : To obtain good germination and vigorous seedlings treat the setts with 10 ppm solution of Naphthalene Acetic Acid (NAA) or Indole Acetic Acid (IAA) or Gibberellic Acid (GA).

Tobacco :

For uniform distribution of seeds at sowing seed should be mixed with fine sand or oilseed cake or FYM.

Cotton:

Physical method: due to fuze seeds should be rubbed in cow dung slurry/ earth soil for easy sowing.

Chemical Method: Acid delinting of cotton seed @ 1 kg of commercial sulphuric acid with 10 kg of seeds, kept 2-3 minute in 10 liters of water, wash the seeds with fresh water for 2-3 times. Treat the seeds with Thiram /Carbendazim @ 2-3 gm kg seeds.

Ground nut:

For white grub: Treat the seeds with Chlorpyriphos @ 25 ml /kg seeds

For collar rot and root rot: Treat the seeds with fungicide like Thiram/ Captan/ Mencozeb @ 3 gm/ kg of seeds

Sesame:

For uniform distribution at sowing: Seed should be mixed with fine sand or oilseed cake or FYM

For leaf spot and bacterial blight: Applied hot water treatment at 52 ^{0}c for 10 minutes or Treat the seed with *Thirum /Captan* @ 3 gm/kg of seed

Castor:

For hastening the germination: Soaking the seeds in water for 12-14 hrs before sowing

For root rot and alternaria blight: Treat the seed with Thiram or Ceresan@ 3 gm/ kg of seeds.

Paddy:

For the selection of bold seed: Soak the seeds in to 3.0 % salt solution and remove the unfilled seeds by draining the water, after that wash out the seeds with fresh water and dry it under shade.

For dormancy: Give heat treatment. For that, exposure of seeds which has 11-12 % moisture to a temperature of 47-50 ^{0}cfor 4-7 days.

For Stem rot, Foot rot and Brown spot: Treat the seeds with Agrosan @ 2-3 g/ kg of seeds.

For bacterial leaf blight: Soaking in 0.1 % streptocyclin (100 ppm) + wet dressing of Agrosan or Ceresan& Azotobacter or Azospirillum culture treatment.

Pearl millet:

For the selection of bold seeds: Soaking of seed in to salt solution and after that, wash the seeds with fresh water for 2-3 times, dry in the shade and use for sowing.

For ergot and smut: Treat the seeds with organo - mercurial fungicide like Agrosan / Cerasan @ 3 gm /kg of seeds.

For downey mildew, Apron @ 6 gm/kg of seeds.

Sorghum:

For False smut: 4-6 gm Sulphur or organo- mercurial fungicide like Agrosan / Cerasan @ 3 gm /kg of seeds.

For stem borer : Carbofuran 3 G @ 100 gm/ 1 kg of seeds.

Maize:

For seedling blight: Agrosan / Cerasan @ 3 gm /kg of seeds.

Pulses: (Gram, Pigeon pea, Green gram, Black gram, Cluster bean, Kidney bean Indian bean, Pea and Rajmashetc)

Seed borne and fungal diseases: Agrosan / Cerasan/ Captan @ 3 gm / kg of seeds.

For atmospheric nitrogen fixation: Seeds inoculation with *Rhizobium* and PSB @ one packet (250 gm) / 8-10 kg seeds of each culture.

Objectives of methods of sowing :

- To achieve uniformity in distribution of seeds.
- To sow the seeds at desired seed rate and inter-row and intra-row spacing
- To maintain the depth of seed placement.
- To provide proper compaction over the seed.

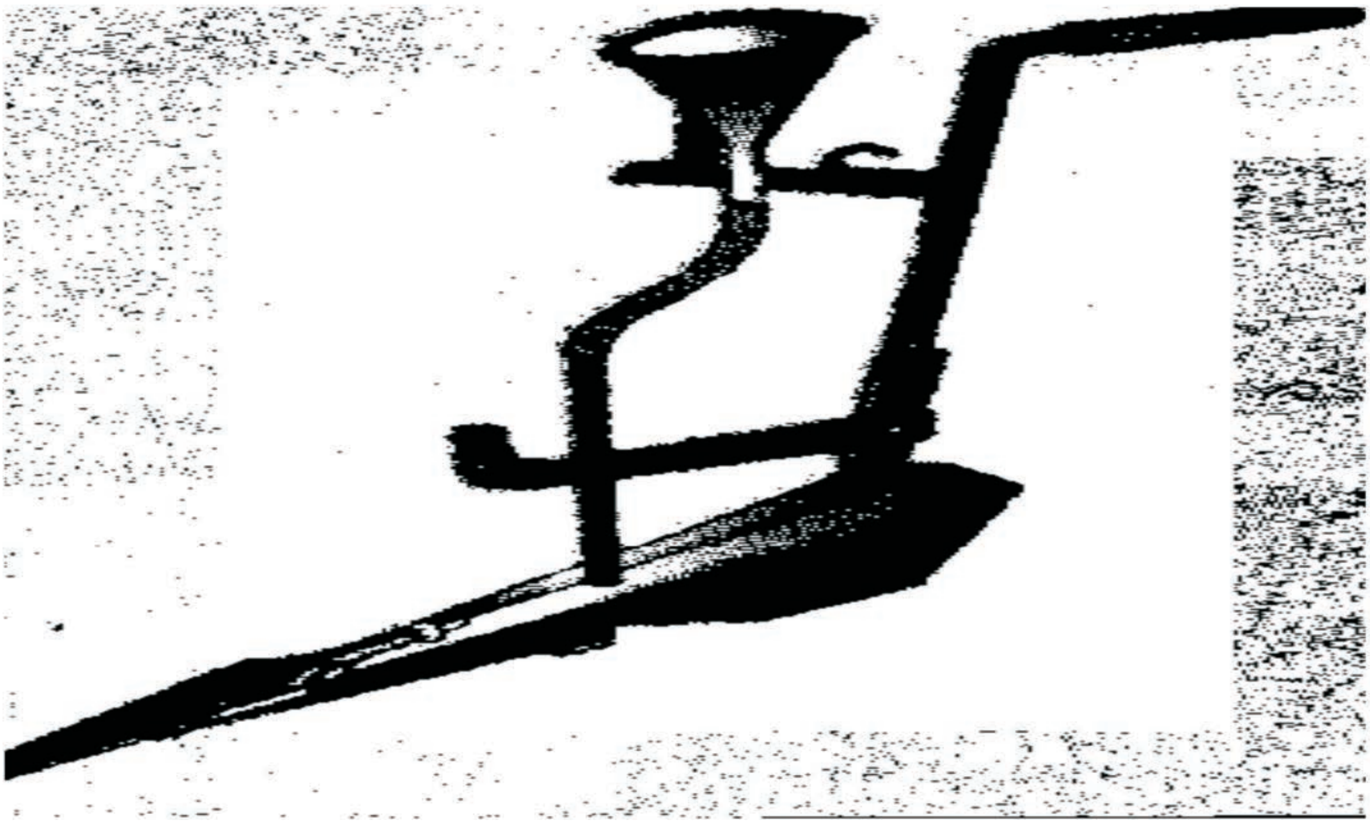
The methods include broadcasting manually, opening furrows by a country plough and dropping seeds by hand i.e. behind the plough, drilling, dibbling. zero tillage technique and transplanting of seedlings.

1.Broadcasting:

In this method the seeds are broadcast and then covered with the help of harrowing. However, the seeds are not uniformly distributed in the field. This method of sowing is very insufficient and should not be encouraged. Germination of broadcast seeds is relatively poor and the plant stand is often irregular. Wastage of seeds because, most of the seeds are left on the surface which can not germinate and may picked up and eaten by birds.

2. Behind Local Plough:

A majority of farmers uses this method. This method consists of dropping the seeds by hand into the furrows opened with local plough at a depth of 5-6 centimeters. When seeds are dropped in furrows by hand, it is called **'kera'** method and when it is dropped through a *Pora* or *Nai*or *Hazara*a special attachment with local plough it is called '**Pora**' method. Germination is satisfactory in this method.



3.Drilling:

In this method seeds are sown by seed drill or seed cum fertilizer drill. With the help of this implement seeds drop at proper depth, placement of fertilizers and results in uniform germination with regular plant stand. Seed bed should be fine and well leveled, free from clods and weeds for the use of this implement. Seed drills are easily available in the market. They may be either bullock driven or tractor driven.

4.Zero tillage technique:

This new method is used in Rice-Wheat cropping system where showing of wheat is delayed due to preparation of field, uncertain rainfall and rice harvesting with traditional method. Puddling in transplanted rice creates a hard pan in the field. After harvesting of rice crop, field requires at least 6-8 tillage operations in ploughing and harrowing for sowing of wheat, in which generally 10-15 days are required for proper field preparation. A Zero-till-fertizer-seed-drill has been developed at **G.B.Pant** University of Agriculture and Technology, Pantnagar by which direct sowing of wheat is done in Rice field without ploughing. This helps advancing the sowing of wheat as the time required for field preparation is saved. At the time of sowing there should be proper moisture in the field.

5. Diblling:

This method is used when quantity of seed is limited. Sowing is done with the help of dibble. This method cannot be commercialized because it is time consuming and labour intensive.

6. FIRB:

The Furrow Irrigated Raised Bed (FIRB) system has been developed and is being promoted by the by the Rice- Wheat Consortium of GIAR Institute. In this method wheat is sown on raised beds accommodating 2-3 rows of wheat. Between the beds are furrows that are used for irrigation.

Machine making raised bed – furrow system

The benefit of overlapping technology under FIRB is that sugarcane is planted at the optimum time i.e. in the month of February.

Tobacco

- Tobacco seedlings are transplanted. The field is line marked with the help of iron or wooden marker at 90 cm apart.

- The furrows are opened with the help of plough as per the line marked in field.
- There after cross marking at 60 cm distance is done at the right angle to the opened furrows.
- Seedlings are transplanted at cross mark at the hedge of the furrow to avoid seeding rot and uprooting of the seedlings due to heavy flow of rainwater.
- If there is no rain, the line-marked field is irrigated in furrows in the morning and cross marking is done for transplanting of the seedlings in the late evening time.
- Healthy disease free seedlings of 8-10 cm height should be used for transplanting.
- If rain is not occur after transplanting, light irrigation at 5-6 days may conveniently be given in furrows for good establishment of the seedlings.

Sugarcane

Sugarcane planting is done by two methods.

1) Dry method

The sugarcane setts are placed in furrow in dry soil and setts are covered with 4-5 cm of soil and then irrigation is given.

2) Wet method

In this method, the pre-planting irrigation is given and then the sugarcane setts are placed in furrows and inserted into soil by pressing them under foot. Wet planting method is found more convenient in our state.

- In India sugarcane is planted by adopting two systems viz., (i) Ridges and furrows system (ii) Flat system.
- There are some special systems also such as Trench system, Deep Trench system, paired - row system, Ring or pit system etc.

A. Ridges and furrows system

- In the finely prepared field, ridges and furrows are formed at 60-135 cm between the rows using tractor - drawn or bullock - drawn ridgers. some small farmers open furrows manually also.
- Depth of furrow should be around 25 cm. and length of 10-15 meter is ideal when guided irrigation is followed.
- Irrigation and drainage channels should be provided appropriately. Drainage channels which are deeper than the furrows and the irrigation channel, should be opened along with field borders as well as within the field at regular intervals.
- The ridge - furrow system is the most ideal system of planting under highly irrigated sugarcane cultivation.

Paired row system of planting

- In the paired row system, two cane rows are brought together followed by a wide gap before the next set of two rows (60 cm with 120 cm gap) in which the number of rows per hectare remains same. The paired rows which can be utilized for growing profitable inter crops, also good earthing up is possible and permits better light interception. Thus can give higher yield

B. Flat system

It involves repeated ploughing using a country plough and compacting by planking to conserve soil moisture. For planting, shallow furrows are opened with a wooden country plough and the setts are dropped and again covered by planking. Irrigation does not follow immediately.

C. Trench system

- In this system U-shaped furrows or trenches of 25-30 cm. deep are made mostly using spade and heaping clods maually. The system is useful to prevent lodging which is quite common. A specially fabricated implement "Ridgemax" can be used for formation of trenches

D. Deep trench method

- In this system deep trenches of depth 30-45 cm. and width 60 cm. are dugout manually at a spacing of 120 cm. between the centres of two adjacent trenches. That is the gap between the trenches is 60 cm. Sugarcane setts are planted on either side of the trench bottom and covered with soil slightly.
- As the canes grow, the trench is filled with the soil with each manuring. Finally a small trench is formed in between two setts of paired rows which serves as a drainage channel to remove excess water during the N-E monsoon period

E. Modified trench system

- In the modified trench system ridges and furrows are opened at 120 cm. spacing using a tractor drawn ridger. The furrow bottom is dug and widened and the soil is removed to the ridges.
- Thus trenches are formed, basal manures are applied and then setts are planted. As the crop grows while each manuring, only slight earthing up is done so that a trough is maintained through out the crop growth. Here irrigation is given in the cane row itself.

F. Single bud direct planting

- In this system single bud setts are planted directly in the field in the furrow at 30-45 cm. spacing between the setts. This method is highly economical and sowing of seed material. The buds should be healthy.

Planting techniques

1) End to end technique

Three budded setts are put in furrow in such a way that end of the other setttouch to the end of the former sett. Eye to eye distance is maintained.

2) Over lapping technique

Three budded setts are put in furrow so that eye of the one sett touch to theeye of another set. This technique requires more seed rate.

3) Slant Technique

Three budded setts are planted slanting with one bud in the soil and two budsabove the ground. When the above the ground buds sprout up into shoots of 20- 25 cm length the setts are horizontally pressed down inside and the leaves of the shoots covered with soil.

4) Transplanting technique

Seedbeds of 8.0 x 1.5 m are generally prepared to raise seedlings. The germination of bud is complete within a fortnight and seedlings become ready for transplanting after one week of germination. The sprouted setts are taken out from seedbed and are cut into two pieces making one-budded setts. The sprouted setts are thus planted in the field.

IISR Disc Type Cutter Planter

IISR Sugarcane Cutter Planter cum Wheat seeder

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Exercise:4

Effect of seed size on germination and seedling vigour of *kharif* crops

Plants reproduce sexually by seeds and asexually by vegetative parts. Most crop plants produce viable seed which is used for sowing.Those used for multiplication are called seeds while those used for human or animal consumption are called grains.Those plants which do not produce seeds are multiplied with vegetative parts. Sugarcane is planted with stem cuttings known as setts. Forage grasses like napier grass, guinea grass, paragras etc. are mainly propagated by stem cuttings or rooted slips.Rooted slips are basal two to three internodes of the stem with a few roots. Tubers are used as seed material in potato.The crop sown with vegetative parts need larger quantities of seed material.Grafting, budding and layering methods are used for the propagation of horticultural crops.

Characteristics of good seed material

Establishing a vigorous crop starts with selecting good quality seeds. Quality seed ensures uniform crop stand establishment with uniform vigour and population per unit area.Selection of good seed is,therefore, of prime importance for remunerative crop production. Major seed quality characteristics include **:**

(1) Improved variety: It should be superior to existing ones. It should realise its yield potential in the region where it is grown.

(2) Genetic purity: It referes to the trueness to type. It has direct effect on ultimate yield.

(3) Physical purity : It should be free from other varieties of the crop, other crop seeds,weed seeds, broken seeds and inert material.

(4) Maturity : The seed must be from harvested maturity crop.

(5) Free from storage pests and seed born diseases : The seed free from pest and disease pathogens for optimum stand establishment.

(6) Free from dormancy : It should germinate within stipulate time when sown under optimum soil conditions.

(7) Uniformity: Seed must be uniform in size, shape and colour.

(8) High percentage of germination: High percentage of germination (98-99%) for adequate stand establishment.

Qualityofseed

Viability and vigour are the two important characters of seed quality. Viability can be expressed by the germination percentage, which indicates the number of seedlings produced by a given number of seeds.Vigour of seed and seedlings is difficult to measure. Low germination percentage, low germination rate and low vigour are often associated. Seeds with low vigour may not be able to withstand unfavourable conditions in the seedbed. The seedlings may lack the strength to emerge if the seeds are planted too deep or if the soil surface is crusted.

Germination is measured with two parameters- the germination percentage and the germination rate.Vigour is indicated by the higher germination percentage, high germination rate and quicker seedlings growth. Germination percentage is the numbers of seeds germinated to numbers of seeds planted and is expressed as percentage. Germination rate is expressed in two ways: (1) the number of days required to produce a given germination percentage and (2) the average number of days required for radicle or plumule to emerge.

Traditionally, seeds used to be sown at a specified weight of seed per unit area irrespective of seed size. Depending on the seed size, the number of seeds per unit area varies considerably. Hence, number of seeds per unit area is more important than the weight per unit area. This requires knowledge of test weight of crop seeds for adjustments in seed rate to obtain required population density. Several conditions viz.; (1) Late seeding (2) Poorly drained soils (3) Rough seedbed (4) Partly undecomposed plant residues (5) Seeds with low test weight than normal (6) Low germination percantage (7) High pest and disease problems (8) Inadequate soil moisture for germination may demand higher seed rate than recommended.

Relationship between vigour, field performance and yield

- The germination ability and vigour of a seed lot is directly related to performance in the field.
- Seeds low in vigour generally produces weak seedlings that are susceptible to environmental stresses.
- High level of vigour in seeds can be expected to provide an early and uniform stands which give the growing seedlings the competitive advantage against various environmental stresses.
- Provides a very good estimate of potential field performance and subsequently, the field planting value.
- The ability of the germinating seed to continue to grow and survive then determines crop establishment.
- Low seed vigour contributes to the development of smaller and uneven seedlings which leads to poor plant stand and growth (weaker seedlings) and uneven time of maturity, resulting in the possibility of yield loss.

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Exercise: 5

Effect of sowing depth and methods on germination of crops

Establishment of a good stand is the essential pre-requisite for attaining high yields. It depends on time, depth and method of sowing and seed treatment.Plantingdepth of seeds vary according to seed size and available soil moisture.Uneven depth of sowing results in uneven crop stand. Plants will be of different sizes and ages and finally harvesting is a problem as there is no uniformity in maturity. Shallow or deep sowing results in low plant population because all seeds do not germinate.The crops appear with uneven spread of plants with large number of gaps.Weed problem becomes serious under these conditions.Itis,therefore, essential to sow the crop at optimum depth for obtaining good stand of the crop.

Crops with bigger sized seeds like groundnut, castor, sunflower etc. can be sown even upto the depth of 6 cm. Whereas, small sized seeds like tobacco, sesamum, bajra, mustard have to be sown as shallow as possible.

If the seeds are sown too shallow, the surface soil dries up quickly and germination may not occur due to lack of moisture. Therefore, small sized seeds which are sown shallow should be watered frequently to ensure good emergence of the crop.

If the small seeds are sown deep in the soil, the seed reserve food may be inadequate to put forth long coleoptiles for emergence. Even if the seedling emerges, it is too weak to survive as an autotrophic.

The thumb rule is to sow seeds to a depth approximately 3 to 4 times theirdiameter. The optimum depth of sowing for most of the field crops ranges between 3 cm to 5 cm.Shallow depth of planting of 2 cm to 3 cm is follow for small seeds like bajra, sesamum, mustard.Whereas,seeds of tobacco are very small in size (0.08-0.09 mg) and the emerging seedlings are tiny and delicate.Hence, the seeds are unsuitable for sowing directly in the field and are sown in nursery at a depth of 1 cm and tended carefully till the seedlings attain a particular size before transplanting in the main field.

For achieving good results from transplanting,the seedlings are transplanted at optimum age and at proper depth. The thumb rule for the optimum age of seedlings is one week for every month of total duration of the crop.the depth of planting should be as shallow as possible for getting more number of tillers in tillering crops. Transplanting of rice seedlings more than 2 cm deep results in poor tillering.

Because of randomness of seed dispersal in broadcasting method, the spacing available for individual plant varies considerably. It results in excess competition at certain areas and no competition at all in some other areas of the field. However, this methods is still used for sowing fodder crops or crops where seeds are cheap or crops which can easily establish and supress weeds. Rice is also sown by broadcasting on puddled soil.

In broadcasting method, seeds cannot be placed in desired depth. Desired depth ensures perfect anchorage. Lodging (falling down) of crops are common in broadcasting.Whereas, drilling or line sowing method facilitates uniform depth of sowing resulting in uniform crop stand. Crops may not be lodged under drilling method.

In the same crop,coleoptile length may differ due to varieties.Traditional tall varieties of wheat have long coleoptile.Generally,they are sown deep in the soil with seed drill. Mexican varieties with short coleoptile do not emerge when they are sown deep.Thesemexicanwheats give higher yields compared to tall varieties only when they are sown at a depth of 4 cm.

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Exercise : 6

Study of various methods of fertilizer application

Objectives:

1. To decide right stage of the crop for fertilizer application.
2. To decide right place of fertilizer application.
3. To adopt right method for maximizing fertilizer use efficiency.

   It is most essential to apply fertilizer at proper time, place and with proper methods for its efficient use.

Time of fertilizer application:

Time of fertilizer application depends on the type of crop cultivated, its growth stage, nutrient requirement, soil conditions, and nature of fertilizer. The fertilizers are applied (1) prior to sowing (2) at sowing and (3) after sowing the crop.

1. **Application of before sowing**:

   Amendments should be applied well in advance to sowing. Some of the water insoluble **P** fertilizers such as rock phosphate and basic slugs should be applied about 2- 4 weeks before sowing. This enables conversion of water insoluble form of **P** to soluble form for efficient crop utilization.

2. **Application at sowing:**

   Application of fertilizer at the time of sowing or just before sowing is called basal application. Mostly phosphatic and potassic fertilizers are basally applied. A part of recommended N is also applied as basal dose. Micronutrient fertilizers should be applied at the time of sowing on the soil and should not be incorporated in to soil.

3. **Application after sowing (Top dressing):**

   Application of fertilizers after the crop establishment is called top dressing. Usually a portion of **N** is applied as top dressing depending on the stage of crop. In light textured soil, potash is also recommended for top dressing.

4. **Spilt application of N:**

   Spilt application increases the nitrogen use efficiency by supplying **N** at the critical stages of crop when the crop requirement is high. This also avoids large amounts of basally applied **N** being subjected to various losses. It is the most convenient and easily adaptable technique. Factors such as total amount of **N** to be applied, soil texture, crop duration, critical stages of growth, crop season and water management practices largely govern the number of splits. In irrigated crops **N** is generally applied in 2-3 splits. In dry land condition, all the N is applied at sowing as it is difficult to apply N at later stages in the absence of adequate soil moisture. Nitrogen application is recommended at tillering and panicle initiation stages for rice. Basal application of N is sufficient for pulses.

Principles governing selection of proper time of application of fertilizer

1. Nitrogen is taken up by the crop plant slowly in the initial growth stages, rapidly during the grand growth period and slowly at its maturity stage. Thus nitrogen requirement of a crop is less in the early stages, maximum during its peak growth period and very slow at the subsequent stage up to the harvest. But the nitrogen required by the crop through out its growth stages.
2. Nitrogenous fertilizers are highly soluble in water. They are mobile and move rapidly in all direction within the soil. The nitrogen is easily lost through leaching, volatilization and other means. Therefore, it should be applied in split dose at critical growth period.
3. Phosphorus is required during the early root development and early growth of plant. As such crop plant utilizes 2/3 of the total requirement of phosphorus and accumulates 1/3 of their dry weight. Entire quantity of phosphorus should be applied as basal dose before sowing or planting.
4. Potash behaves partly like nitrogen and partly like phosphorus. From the rate of absorption point of view it is like nitrogen being absorbed up to harvest, but available slowly like phosphate fertilizers.
5. In sandy soil nitrogenous fertilizers should be applied after irrigation in to splits, in medium black soil it should be applied before irrigation.

Methods of fertilizer application:

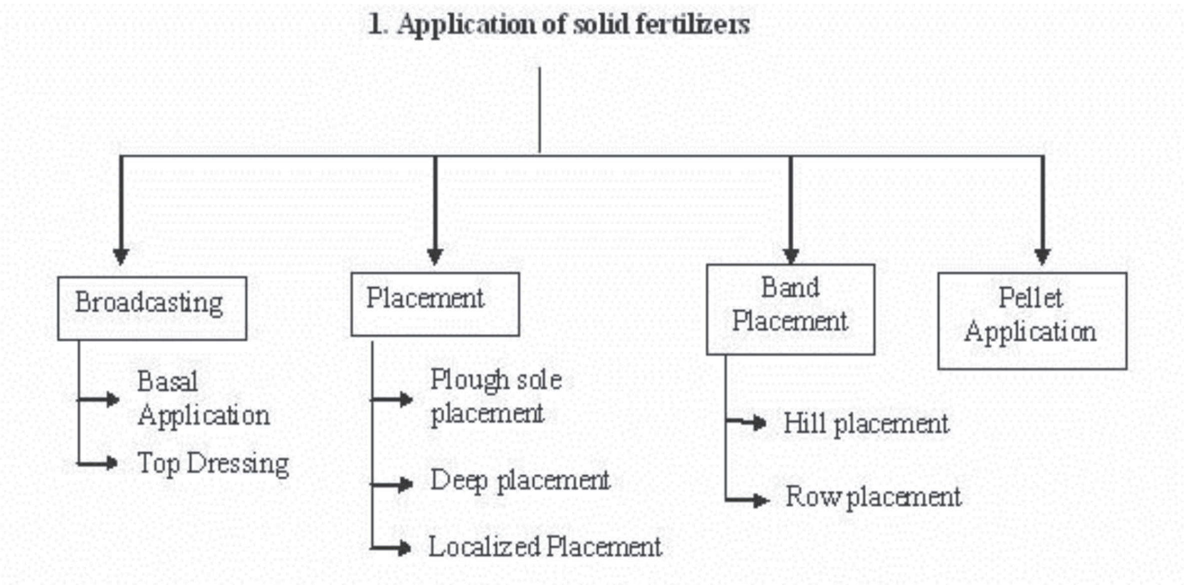
It will vary in relation to

1. The nature of fertilizer
2. The soil type
3. The deferential nutrient requirement
4. Nature of field crops

Fertilizers applied to different crops are of two types

1. Fertilizer in solid form
2. Fertilizer in liquid form

1. Methods of application of fertilizer in solid form



A) Broadcasting

1. It refers to spreading fertilizers uniformly all over the field.
2. Suitable for crops with dense stand, the plant roots permeate the whole volume of the soil, large doses of fertilizers are applied and insoluble phosphatic fertilizers such as rock phosphate are used.

Broadcasting of fertilizers is of two types.

i) Broadcasting at sowing or planting (Basal application)

The main objectives of broadcasting the fertilizers at sowing time are to uniformly distribute the fertilizer over the entire field and to mix it with soil.

ii) Top dressing

It is the broadcasting of fertilizers particularly nitrogenous fertilizers in closely sown crops like paddy and wheat, with the objective of supplying nitrogen in readily available form to growing plants.

- **Disadvantages of broadcasting**
  - The main disadvantages of application of fertilizers through broadcasting are:
  - Nutrients cannot be fully utilized by plant roots as they move laterally over long distances.
  - The weed growth is stimulated all over the field.
  - Nutrients are fixed in the soil as they come in contact with a large mass of soil.

B) Placement

1. It refers to the placement of fertilizers in soil at a specific place with or without reference to the position of the seed.

2. Placement of fertilizers is normally recommended when the quantity of fertilizers to apply is small, development of the root system is poor, soil have a low level of fertility and to apply phosphatic and potassic fertilizer.

The most common methods of placement are as follows:

i) Plough sole placement

1. In this method, fertilizer is placed at the bottom of the plough furrow in a continuous band during the process of ploughing.
2. Every band is covered as the next furrow is turned.
3. This method is suitable for areas where soil becomes quite dry upto few cm below the soil surface and soils having a heavy clay pan just below the plough sole layer.

ii) Deep placement

It is the placement of ammonical nitrogenous fertilizers in the reduction zone of soil particularly in paddy fields, where ammonical nitrogen remains available to the crop. This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off.

iii) Localized placement

It refers to the application of fertilizers into the soil close to the seed or plant in order to supply the nutrients in adequate amounts to the roots of growing plants. The common methods to place fertilizers close to the seed or plant are as follows:

a) Drilling

In this method, the fertilizer is applied at the time of sowing by means of a seed-cum-fertilizer drill. This places fertilizer and the seed in the same row but at different depths. Although this method has been found suitable for the application of phosphatic and potassic fertilizers in cereal crops, but sometimes germination of seeds and young plants may get damaged due to higher concentration of soluble salts.

b) Side dressing

It refers to the spread of fertilizer in between the rows and around the plants. The common methods of side-dressing are

1. Placement of nitrogenous fertilizers by hand in between the rows of crops like maize, sugarcane, cotton etc., to apply additional doses of nitrogen to the growing crops and
2. Placement of fertilizers around the trees like mango, apple, grapes, papaya etc.

C) Band placement

If refers to the placement of fertilizer in bands.

Band placement is of two types.

i) Hill placement

It is practiced for the application of fertilizers in orchards. In this method, fertilizers are placed close to the plant in bands on one or both sides of the plant. The length and depth of the band varies with the nature of the crop.

ii) Row placement

When the crops like sugarcane, potato, maize, cereals etc., are sown close together in rows, the fertilizer is applied in continuous bands on one or both sides of the row, which is known as row placement.

D) Pellet application

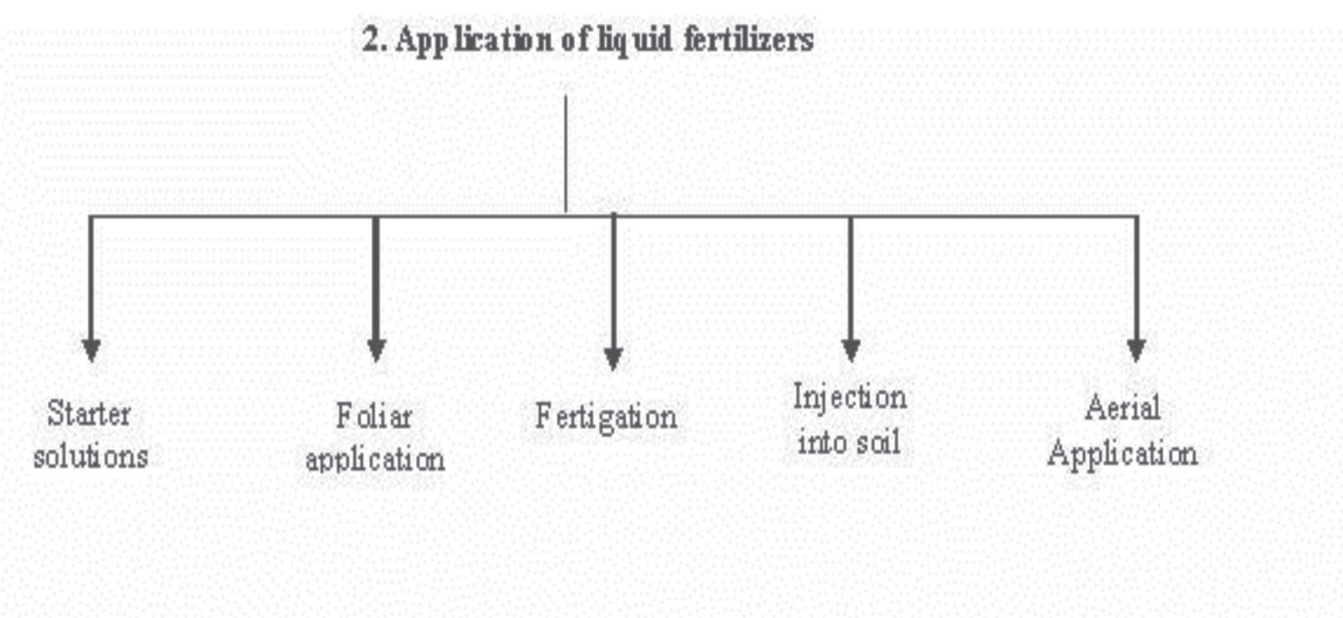
1. It refers to the placement of nitrogenous fertilizer in the form of pellets 2.5 to 5 cm deep between the rows of the paddy crop.
2. The fertilizer is mixed with the soil in the ratio of 1:10 and made small pellets of convenient size to deposit in the mud of paddy fields.

➢ **Advantages of placement of fertilizers**

The main advantages are as follows:

- When the fertilizer is placed, there is minimum contact between the soil and the fertilizer, and thus fixation of nutrients is greatly reduced.
- The weeds all over the field can not make use of the fertilizers.
- Residual response of fertilizers is usually higher.
- Utilization of fertilizers by the plants is higher.
- Loss of nitrogen by leaching is reduced.
- Being immobile, phosphates are better utilized when placed.

2. Methods of application of fertilizer in liquid form:



a) Starter solutions

It refers to the application of solution of N, *P_2O_5 and* K_2O in the ratio of 1:2:1 and 1:1:2 to young plants at the time of transplanting, particularly for vegetables. Starter solution helps in rapid establishment and quick growth of seedlings.

The disadvantages of starter solutions are

- Extra labour is required, and
- The fixation of phosphate is higher.

b) Foliar application

1. It refers to the spraying of fertilizer solutions containing one or more nutrients on the foliage of growing plants.
2. Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them.
3. The concentration of the spray solution has to be controlled, otherwise serious damage may result due to scorching of the leaves.
4. Foliar application is effective for the application of minor nutrients like iron, copper, boron, zinc and manganese. Sometimes insecticides are also applied along with fertilizers.

c) Application through irrigation water (Fertigation)

1. It refers to the application of water soluble fertilizers through irrigation water.
2. The nutrients are thus carried into the soil in solution.
3. Generally nitrogenous fertilizers are applied through irrigation water.

d) Injection into soil

1. Liquid fertilizers for injection into the soil may be of either pressure or non-pressure types.
2. Non-pressure solutions may be applied either on the surface or in furrows without appreciable loss of plant nutrients under most conditions.
3. Anhydrous ammonia must be placed in narrow furrows at a depth of 12-15 cm and covered immediately to prevent loss of ammonia.

e) Aerial application

In areas where ground application is not practicable, the fertilizer solutions are applied by aircraft particularly in hilly areas, in forest lands, in grass lands or in sugarcane fields etc.

Exercise : 7

Study of growth and yield attributing characters

Objectives :

1. To know the different growth and development stages of crops
2. To manage the various resources according to crop growth stage requirement.

Crop plants are differ in respect to ontology (development of organism), morphology, anatomy, physiology and requirement of particular type of ecology.

Growth: It is an irreversible increase in mass or weight. Growth is attained mainly by photosynthesis loss, what is goes through respiration that is weight, height, length, diameter.

Development: It is defined as change means development of a plant from germination to maturity. It can be considered as the series of discrete periods such as weight, size, and structure of specific organs.

Development Stages:

1. Germination and emergence
2. Seedling growth
3. Vegetative growth
4. Flowering
5. Fruit growth
6. Fruit maturity
7. Physiological maturity
8. Harvest maturity

Factor affecting growth and development of plant:

1. Solar radiation(Light)
2. Temperature
3. Soil moisture
4. Soil aeration

The dry matter production from a crop growth, many factors such as type of soil, fertilizer, water, growing season and variety of crop attribute great variation in crop production.

Yield attribute: Any factor responsible for attributing increase the yield called yield attribute.

❖ Growth analysis

Growth analysis is a mathematical expression of environmental effects on growth and development of crop plants. This is a useful tool in studying the complex interactions between the plant growth and the environment.The basic principle that underlie in growth analysis depends on two values (1) total dry weight of whole plant material per unit area of ground (w) and (2) the total leaf area of the plant per unit area of ground (A).

The total dry weight (w) is usually measured as the dry weight of various plant parts viz, leaves, stems and reproductive structures. The measure of leaf area (A) includes the area of other organs viz, stem petioles, flower bracts, awns and pods that contain chlorophyll and contribute substantially to the overall photosynthesis of the plants

According to the purpose of the data, leaf area and dry weights of component plant parts have to be collected at weekly, fortnightly or monthly intervals. This data are to be used to calculate various indices and characteristics that describe the growth of plants and of their parts grown in different environments and the relationship between assimilatory apparatus and dry matter production.These indices and characteristics are together called as growth parameters. Some of the parameters that are usually calculated in growth analysis are crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), Leaf area ratio (LAR), Leaf weight ratio (LWR). Specific Leaf Area (SLA), Leaf area index (LAI) and Leaf area duration (LAD). Accuracy in calculations of these parameters and their correct interpretation are essential aspect in growth analysis.

Advantages of growth analysis

a) We can study the growth of the population or plant community in a precise way with the availability of raw data on different growth parameters.

b) These studies involve an assessment of the primary production of vegetation in the field i.e. at the ecosystem level (at crop level) of organization.

c) The primary production plays an important role in the energetic of the whole ecosystem.

d) The studies also provide precise information on the nature of the plant and environment interaction in a particular habitat.

e) It provides accurate measurements of whole plant growth performance in an integrated manner at different intervals of time.

Drawbacks of Growth Analysis

In classical growth analysis sampling for primary values consist of harvesting (destructively) representative sets of plants or plots and it is impossible to follow the same plants or plots throughout whole experiment.

❖ **Growth Characteristics - Definition and Mathematical Formula**

The following data are required to calculate different growth parameters in order to express the instantaneous values and mean values over a time interval. In the following discussion W, WL, WS and WR are used to represent the dry weights of total plant (w), dry leaves (wL), stem (WS) and roots (WR) respectively. Whereas A is the leaf area and P is the land area.

1. Crop Growth Rate (CGR):

D.J. Watson coined the term Crop growth rate. It is defined as the increase of dry matter in grams per unit area per unit time. The mean CGR over an interval of time T_1 and T_2 is usually calculated as show in the following formula

$$CGR = \frac{W_2 - W_1}{P\,(T_2 - T_1)}$$

Where, CGR is the mean crop growth rate, P= ground area, W_1 and W_2 are the dry weights at two sampling times T_1 and T_2, respectively and it is expressed in $g/m^{-2}/day^{-1}$.

2. Relative Growth Rate (RGR):

The term RGR was coined by Blackman. It is defined as the rate of increase in dry matter per unit of dry matter already present. This is also referred as Efficiency index since the rate of growth is expressed as the rate of interest on the capital. It provides a valuable overall index of plant growth. The mean relative growth rate over a time interval is given below.

$$RGR = \frac{Log_e\, W_2 - Log_e\, W_1}{T_2 - T_1} \quad (g\ g^{-1}\ day^{-1})$$

Where, Log is natural logarithm, T_1= time one (days), T_2= time two (days), W_1= dry weight of plant at time one (days), W_2= dry weight of plant at time two (days) and it is expressed as g/g/day.

3. Net Assimilation Rate (NAR):

The NAR is a measure of the amount of photosynthetic product going into plant material i.e. it is the estimate of net photosynthetic carbon assimilated by photosynthesis minus the carbon lost by respiration. The NAR can be determined by measuring plant dry weight and leaf area periodically during growth and is commonly reported as grams of dry weight increase per square centimeter of leaf surface per week. This is also called as Unit leaf rate because the assimilatory area includes only the active leaf area in measuring the rate of dry matter production.

The mean NAR over a time interval from T_1 to T_2 is given by

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\text{Log e } L_2 - \text{Log e } L_1}{L_2 - L_1}$$

Where L_1 and L_2 are total leaf are at time t_1 and t_2 respectively. W_1 and W_2 are total dry wt. time t_1 and t_2 respectively. Log e is Logarithum to base 'e' (Log e = 2.3026)
and it is expressed as (g cm^{-2} wk^{-1}).

4. Leaf Area Ratio (LAR)

The LAR is a measure of the proportion of the plant which is engaged in photosynthetic process. It gives the relative size of the assimilatory apparatus. It is also called as capacity factor. It is defined as the ratio between leaf area in square centimeters and total plant dry weight. It represents leafiness character of crop plants on area basis.

$$LAR = \frac{A}{W} \; (cm^2 g^{-1})$$

Where, A= leaf area in square centimeters, W= total plant dry weight

5. Leaf Weight Ratio (LWR)

It is one of the components of LAR and is defined as the ratio between grams of dry matter in leaves and total dry matter in plants (g). Since the numerator and denominator are on dry weight basis LWR is dimensionless. It is the index of leafiness of the plant on weight basis.

$$LWR = \frac{W_L}{W}$$

Where, WL= Dry matter in leaves, W= Total dry matter in plants

6. Specific Leaf Area (SLA)

It is another component of LAR and defined as the ratio between leaf area in cm2 and total leaf dry weight in grams. This is used as a measure of leaf density. The mean SLA can be calculated as

$$SLA = \frac{A}{W_L}$$

Where, A= leaf weight plant^{-1} and WL= leaf area plant^{-1} and it is expressed as cm^{-2} g^{-1}.

7. Specific Leaf Weight (SLW)

The reversal of SLA is called as SLW. It is defined as the ratio between total leaf dry weight in gm s and leaf area in cm^2. It indicates the relative thickness of the leaf of different genotypes.

$$SLW = \frac{W_L}{A}$$

Where, WL= leaf weight plant^{-1} and A= leaf area plant^{-1} and it is expressed as g cm^{-2}.

8. Leaf area index (LAI):

D.J. Watson coined this term. It is defined as the functional leaf area over unit land area. It represents the leafiness in relation to land area. At an instant time (T) the LAI can be calculated as

LAI = Leaf area / ground area

It is expressed as m^2/m^2

For maximum production of dry matter of most crops, LAI of 4-6 is usually necessary. The leaf area index at which the maximum CGR is recorded is called as 'optimum leaf area index'.

Growth indices in summary :

Few key indices are commonly derived as an aid to understanding growth responses. Mathematical and functional definitions of those terms are summarised below.

Growth index	Functional definition
Relative growth rate (RGR)	Rate of mass increase per unit mass present (efficiency of growth with respect to biomass)
Net assimilation rate (NAR)	Rate of mass increase per unit leaf area (efficiency of leaves in generating biomass)
Leaf area ratio (LAR)	Ratio of leaf area to total plant mass (a measure of 'leafiness' or photosynthetic area relative to respiratory mass)
Specific leaf area (SLA)	Ratio of leaf area to leaf mass (a measure of thickness of leaves relative to area)
Leaf weight ratio (LWR)	Ratio of leaf mass to total plant mass (a measure of biomass allocation to leaves)

Growth and yield attributing characters and Quality Parameter

Sr. No.	Growth and Yield attribute characters	Sr. No.	Quality Parameter
1	Number of branches	1	Oil content (%)
2	Number of tiller per plant	2	Protein content(%)
3	Number of leaves	3	Nicotine in tobacco(%)
4	Number of internodes per plant	4	linoleic acid content inSafflower / Sunflower/ cotton(%)
5	Length of internodes	5	Crude protein (In fiber/ forage crops)
6	Length of earhead / fruit/ pod size	6	Starch content (%) (Sugar and sucrose content)
7	No. of seed in earhead / pod	7	Fiber content in cotton
8	Test weight(g)		
9	Seed/grain yield (kg/ha)		
10	Straw yield (kg/ha)		
11	Harvest index (%)		

Periodical growth and yield attributing characters of different crops:

Sr. No.	Sugarcane	Sr. No.	Cotton
1 2	Germination percentage Tillering percentage	1	Germination percentage/Plant population /ha
3	Periodical and total plant height(cm)	2	Plant height at harvest(cm)
		3	No. of monopodical branches/plant
4	Number of internode /plant		
5	Girth of middle internode/plant	4	No. of ball/plant
6	No. of milliable cane/unit area	5	Germinating percentage
7	Wt of miliable cane/unit area	6	Seed cotton yield/plant
8	Cane yield/ha	7	Lint seed ratio
9	Sugar percentage in juice	8	Fibre length
10	Sugar percentage in cane	9	Oil content
11	Sugar yield/ha	10	Harvest Index
12	Harvest index (%)		

Tobacco

1 Plant stand/ha
2 No of leaves/plant
3 Leaf length and Width (cm)
4 Leaf area(sq. cm)
5 Leaf thickness(mm)
6 Dry leaf yield(kg/ha)
7 Nicotine content(%)
8 Harvest Index(%)

Ground nut

1 Plant population
2 No. of branches/plant (%)
3 Periodical plant height
4 No. of peg/plant
5 No. of effective peg/plant
6 No. of pod/plant
7 No. of seed /pod
8 Pod/ grain/ seed yield(kg/ha)
9 Oil percentage
10 Shelling percentage
11 Protein content (%)
12 Harvest Index

Sesame

1 Final plant height plant
2 No. of capsules/plant
3 No. seed /capsules
4 Length of capsules(cm)
5 Test weight(g)

Chicory

1 Germination percentage
2 Plant population
3 Plant height
4 Root length
5 Root weight
6 Root girth
7 Fresh and Dry root yield/ha
8 Fresh green leaves/ha
9 Crude fibre (%)
10 Harvest index (%)

Castor

1 Initial and after plant population
2 Plant height up to main spike(cm)
3 No. of branching
a. Primary branching /plant
b. Secondary branching plant
c. Tertiary branching /plant
4 Length of main spike
5 No. of capsules/ spike
6 No. of spike /plant
7 Yield (kg/ha)
8 Seed and stalk yield.
9 Oil percentage
10 Test weight (g)
11 Harvest Index (%)

6 Grain and straw yield (kg/ha)

7 Oil percentage & **8.** HI (%)

Sunflower

1 Germination percentage

2 Periodical Plant height.

3 Diameter of Head

4 No. of mature seed/head

5 Wt of seed /head

6 Wt. of seed yield/plant

7 Test weight(g)

8 Oil Yield

9 Seed and straw yield (kg/ha)

10 Oil content and Oil yield

11 Straw to seed ratio

12 No. of immature seed/head

13 Harvest index

Mustard and Rape seed

1 Germination percentage

2 Periodical Plant height and at harvest (cm)

3 No. of branching

a. Primary branching /plant

b. Secondary branching plant

c. Tertiary branching /plant

4 Length of siliqua

5 No. of seed/ siliqua.

6 Seed yield /plant

7 Oil percentage

8 Test weight (g)

9 Seed and straw yields (kg/ ha)

10 Harvest Index

Wheat

1. Initial plant population
2. No of tiller /plant or in1 mt row length
3. No of effective tiller/1 mt row length
4. Plant height(cm)
5. Date of flowering
6. Length of spike(cm)
7. No. of grains/ spike
8. No of spikelets/ spike
9. Date of Maturity
10. Seed and Straw yield kg/ha
11. Grain to straw ration
12. Test weight(1000- gm)
13. Harvest Index(%)

Fennel

1. Date of seeing
2. Age of seedling
3. Date of transplanting
4. Periodical plant height
5. No. of Branches/plant
6. Date of 50 % flowering
7. No of umbel per plant
8. No of umblets / umbel
9. Date of maturity
10. Seed and stalk yield
11. Test we(g)
12. Protein %
13. Oil content(%)

Chickpea

1. Initial plant population
2. Periodical Plant height(cm)
3. Date of 50 % flowering
4. No of branches/ plant
5. No of pods /branch
6. No. of grains/ pod
7. Date of Maturity
8. Seed and Straw yield kg/ha
9. Test weight(1000 - gm)
10. Harvest Index (%)
11. Protein content %
12. No. of root nodules/plant
13. No. of active nodule/plant

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Exercise : 8

Visit to the agronomic and forage experiments

Agronomy experiments are mainly field oriented. Choice of appropriate design and conduct of the experiments in a proper manner may help to get valid information.Field selection and layout of the experiments also play a vital role.It is always necessary to collect data on ancillary characteristics so as to have better interpretation of the results. Use of appropriate software package makes the job of the scientists/ workers to analyze the data scientifically and interpret the results.

An experiment is designed based on the objectives, availability of experimental material and cost of the experiment. It is important to design the experiment carefully to test the hypothesis with acceptable degree of precision. The choice of treatments, method of assigning treatments to experimental units and arrangement of experimental units in various patterns to suit the requirement of a particular problem are combinedly known as the design of experiment. In an agricultural field experimentation, it is normally aimed to assess the performance of varieties of a crop, effect of manures, irrigation methods, new herbicides,etc. in different crops.All these objects of comparison are known as teatments.

Experiment is to be laid out in the field, keeping view of land slope and fertility status to make homogeneous plots within the replication.

Layout : The layout is done before deciding base line of the experimental area. Then right angle is to be taken on the base line by 3 m x 4 m x 5 m triangle to draw straight line on the both sides of base line with the of measuring tape, pegs and rope to obtain uniform plot size. Thereafter plotting is done as per the predecided size of the plot, keeping border between plots, between replications, space required for irrigation and drainage channels.After plot demarcation, randomization of the treatment is done and experimental field is prepared for sowing and treatments are then imposed as per experimental requirement to fulfill the objectives of the experiment.

Replication : The repetition of the same treatment so that it appears two or more times in an experiment.

Treatments : Asingle state of some factor being varied and to evaluate the effect in an experiment such as rate of fertilizer, varieties, herbicides etc.

Randomization : The allocation of treatment to the different plots by a random process.In this method each treatment has an equal chances to be allocated to an experimental unit.

Experimental design : Various experimental designs are available for different type of experiments i.e. CRD, RBD, LSD and split plot design etc.

Analysis of variance : Analysis of variance is splitting of the total variation into various factors responsible for variation in a given population.

Critical difference : Value which indicate the significance of the treatment in the experimentation.

Exercise :

Q.1 : Enlist the name of titles of agronomic and forage experiments conducted during current season.

Q.2 : Draw the field layout of any one experiment with no. of treatments, no. of replications, spacing and gross plot size.

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Exercise 9 :

Numerical exercises on fertilizer, seed requirement and plant population

Objectives:

To calculate correct quantity of fertilizer required for sowing per unit area.

Manures and fertilizers are the substances containing fair amount of plant food, which are used for supplementing the nutrients in the soil. On the other hand, indiscreet or excess use of fertilizers not only increase cost of cultivation, but also deteriorates soil quality: leading to poor productivity. Therefore, use of proper quantity of fertilizer is prime importance for sustainable agriculture.

Fertilizers: are the organic and inorganic materials or natural or synthetic origin which are added to the soil to supply certain elements essential to the growth of plants. The term " fertilizer" is now commonly restricted to commercial products. eg. Urea, DAP, AS etc.

Manures: Manure is a organic substance containing plant nutrients. Therefore manures are defined as the sources of plant nutrients. eg. cattle manure and other bulky natural substance that were applied to land or soil with the objective of increasing the production of crops. On the basis of concentration of nutrient manures can be grouped in to two

1. Bulky organic manures. eg. FYM, Vermicompost, compost and Green manure
2. Concentrated organic manures. eg. Fish manure, Poultry manure, Cakes,blood meal , borne meal and human excreta.

Amendments: are the substances other than manures and fertilizers which are added to soils for the improvement of soil. eg. Gypsum and lime.

Classification of fertilizers:

1. <u>Straight fertilizers:</u> Such fertilizer contains only one major nutrient e.g. Urea
2. <u>Binary fertilizer:</u> Such fertilizer contains two major nutrients. e.g. Potassium Nitrate.
3. <u>Ternary fertilizer:</u> Such fertilizer contains three major nutrients eg. Ammonium Potassium Phosphate.
4. <u>Compound / Complex fertilizer:</u> Such fertilizer content of at least two of the major nutrients obtained chemically and generally granular in form. eg. Nitro- Phosphate, DAP, Ammonium –phosphate.
5. <u>Mix fertilizer:</u> Individual or straight fertilizer materials are blended to gather physically to permit application in the field in one operation such fertilizers supply two or three major nutrients in a definite proportion or grade eg. NPK -15-15-15.

6. Complete fertilizer: Having all three primary major nutrients, viz, N,P,K called complete fertilizer.
7. In complete fertilizer: Containing any two primary major nutrients.
8. Bio- fertilizers:Biofertilizer is a substance which contains living microorganisms, when applied to seed, plant surfaces, or soil it willpromotes the growth by increasing the supply or availability of primary nutrients to the host plant. They are cost effective, eco-friendly and renewable source of plant nutrients. eg*Rhizobium, Azatobecter, Azospirillum* and PSB
9. Green manure: Green undecomposed plant materials grown primarily to add nutrients and organic matter to the soil is called green manure. By growing green manure crops in the field and in corporating it in its green stage in the same field is called green maturing. egsannhemp and dhaincha.

Factors determining quantity of fertilizers:

1. The N-P-K content of the fertilizer
2. Soil type
3. Cropping system
4. Rainfall and its distribution
5. Availability of irrigation
6. Initial fertility status of the soil
7. Use of organic manures
8. Planting density
9. Recommended dose of nutrient for the crop.
10. The total area you will be applying the fertilizer (ha)

Percent nutrient content of chemical fertilizers:

Sr. No	**Name of fertilizer**	**Nutrient content (%)**				
		N	**P_2O_5**	**K_2O**	**Ca**	**S**
A	**Nitrogenous fertilizers**					
1	Ammonium Sulphate	20	--	--	--	24
2	Ammonium Chloride	25	--	--	--	-
3	Ammonium Nitrate	33-34	--	--	--	--
4	Ammonium Sulphate Nitrate	26	--	--	--	15
5	Calcium Ammonium Nitrate(CAN)	25	--	--	8.1	--
6	Liquid Ammonia	82	--	--	--	--
7	Urea	46	--	--	--	--
B	**Phosphatic fertilizers**					
8	Single Super Phosphate	--	16	--	21	12
9	Double Super Phosphate	--	32	--	--	--
10	Triple Super Phosphate	--	48	--	--	--

11	Rock Phosphate	--	18-20	--	--	--
12	Di calcium phosphate	--	34-39	--	--	--
13	Calcium Meta sulphate	--	64	--	--	--
14	Bone meal	--	20-25	--	23	--
15	Basic slug	--	14-18	--	34	--
C	**Potassic fertilizers**					
15	Muriate of Potash (Potassium chloride)	--	--	60	--	--
16	Sulphate of Potash (Potassiun Sulphate)	--	--	48	--	18
17	Potassium Nitrate	--	--	44	--	--
D	**Complex fertilizers**					
18	DAP	18	46	--	--	--
19	Poli Phosphate	15	57	--	--	--
20	Ammonium Sulphate	20		--	--	24
21	Ammonium Phoshate (Amophos)	20	20	--	--	--
22	Ammonium Nitrate Phosphate	20	20	--	--	--
E	**Mixed fertilizers**					
23	IFFCO grade(12:32:16)	12	32	16	--	--
24	IFFCO grade(10:26:26)	10	26	26	--	--
25	Suphala (Nitro phosphate) (20:20: 00)	20	20	00	--	--
26	Suphala (Nitro phosphate) (18:18: 09)	18	18	09	--	--
27	Suphala (Nitro phosphate) (15:15: 15)	15	15	15	--	--

Example:1

Recommended dose of fertilizer for wheat crop is 120: 60: 00 NPK kg/ha and nitrogen is applied in two equal split. The source of fertilizer are Urea and DAP. Calculate the fertilizer requirement in kg for wheat crop.

Solution:

Now , Urea contain 46% N and DAP contain 18% N and 46 % P

So, First we should calculate the quantity of DAP

Therefore, required quantity of DAP

For 46 kg P_2O_5, we required 100 kg of DAP

Therefore, for 60 kg P_2O_5, How much quantity of DAP is required ?

$$= \frac{100 \times 60}{46} = \textbf{130 kg DAP/ha.}$$

Now, DAP also contain 18 % N,

Therefore,

$$\text{From 130 kg DAP} = \frac{130 \times 18}{100} = \text{24 kg N is suppled}$$

Now, The basal N require. is 60 kg /ha, but 24 kg N is received from DAP,

Therefore remaining 36 kg (60 -24) N should be apply from the urea

To fulfill the remaining quantity of nitrogen:

For 46 kg N, 100 kg urea is required

Therefore, $\frac{100 \times 36}{46}$ = **78 kg urea** is required for N application

Now, remaining 60 kg N as second spilt, which required

$= \frac{100 \times 60}{46}$ = **130 kg urea** is required.

Therefore, at the time of sowing the quantity required for basal application

= 78 kg Urea + 130kg DAP

and for 2nd split application 130 kg Urea is required.

Example: 2.

Calculate the quantity of urea, SSP, and muriate of potash required for one hectare of rice with the N, P_2O_5 and K_2O, The recommended dose of rice is 100-50-50 kg/ha.

Solution:

As mention in above example, we can calculate the fertilizer quantity directly,

For, Urea = 100 / 46 **x** 100 = 217.4 kg

For, Single Super Phosphate = 100 / 16 **x** 50 = 312.5 kg

And for, Muriate of Potash = 1 **x** 60 = 83.3 kg

NB. Requirement of fertilizer can be calculated using the conversion factor.

(The conversion factor of Urea is **2.2,** Single super phoshphate is **6.3,** Muriate of Potash is **1.67**)

Therefore, total Urea required= 100 **x** 2.2 = 220 kg

Single super phosphate= 50 **x** 6.3 = 315 kg

Muriate of Potash = 50 **x** 1.7 = 85 kg

Example: 3

Calculate the quantity of DAP, Urea and muriate of potash required for one ha of rice to meet the nutrient requirement of N, P_2O_5 and K_2O at 100- 50-50 kg recommended dose of fertilizer.

Solution:

DAP to meet 50 kg P_2O_5 = 100 / 46 **x** 50 = 108.7 kg

Now, quantity of N is present in 108.7 kg of DAP = 18 / 100 **x** 108.7 = 19.6, ie.20 kg

Therefore, the quantity of N to be supplemented with urea

= 100-20 = 80 kg

So, requirement of Urea = 100 **x** 46 **x** 80 = 173.9 kg

and Muriate of Potash = 100 / 60 **x** 50 = 83.3 kg.

(Note: Where complex fertilizer is involved, calculate first for the contribution of that fertilizer for the nutrient that is **present in higher quantity**. For example, in the case of DAP, first calculate for **P** as DAP contains higher quantity of P. Then calculate the quantity of the **next highest quantity** of nutrient (in case N) contributed by that quantity of the fertilizer.

Example: 4

Work out the quantity of complex (17:17: 17) and urea required to meet the nutrient requirement of 100: 50: 50 kg N, P_2O_5 and K_2O, /ha.

Solution:

Quantity of complex fertilizer = 100 / 17 **x** 50 = 294 kg

This will supply 50 kg each of N, P_2O_5 and K_2O.

Remaining 50 kg **N** is to be supplemented with urea.

Therefore, quantity of Urea = 100 /46 **x** 50 = 108.7 kg.

Example. 5

Progressive farmer of Gandhinagar district wishes to apply 100-50-50 kg/ha NPK to one ha crop. The fertilizers available with him are 12-32-16 grade complex fertilizer Urea and MOP. The nitrogen will be applied in two splits. i.e. 50 % basal, 50 % at tillering. Calculate the quantity of fertilizers to be required for basal and for split application.

Solution:

First we should calculate the quantity of fertilizer for P_2O_5:

For 32 kg P_2O_5, 100 kg Complex fertilizer is required

Therefore, for 50 kg P_2O_5, how much complex fertilizer is required ?

= 100 **x** 50 / 32= 156 kg complex fertilizer is required.

Now for Nitrogen requirement:

From 100 kg complex fertilizer, 12 kg Nitrogen is supplied

Therefore, from 156 kg complex fertilizer, how much **N** is supplied ?

= 156 **x** 12 / 100 = 18.7 kg **N** from complex fertilizer.

Now Basal N requirement is 50 kg and 18.7 kg N is supplied from complex fertilizer

Therefore, remaining **N** (50.0- 18.7 = 31.3 kg) should applied from Urea

So, for that Urea requirement is 100 **x** 31.3 / 46

= 68 kg **urea** is needed.

and for split application of N requirement is 50 kg

For that 100 **x** 50 / 46 = 109 kg **Urea** is required.

Now for Potash:

From the complex fertilizer

16 **x** 156 /100 = 25 kg **K** will be supplied from the complex fertilizer

While our requirement is 50 kg K_2O

Therefore, remaining **K** (50.0- 25.0 =25.0 kg) should be applied from MOP

Therefore, 100 **x** 25 / 59 = 42.4 kg MOP is required

Total fertilizer requirement:

156 kg complex fertilizer (12-32-16)

68 kg Urea for basal + 109 Kg Urea for split application

and 42.4 kg MOP for one hectare.

Self study:

Ex. 1. A progressive farmer desired to grow a Rajmah crop. The recommended dose of Rajmah crop is 90-60-30 kg NPK/ha, Nitrogen is applied in to two split. The fertilizers with him are Urea, DAP and Muriate of Potash. Calculate the total quantity of fertilizers for **1.5** ha of land.

Ex. 2.A progressive farmer desired to grow Irrigatedhybrid Gujarat cotton -10. The recommended dose of crop is 150-00-00 kg NPK/ha. Nitrogen is applied in to three equal split. The fertilizer with him is Ammonium sulphate. Calculate the total quantity of fertilizer for 2.5 ha of land.

Exercise 10 :

Calculation of seed requirement and plant population

Objectives: To estimate correct quantity of seeds required for sowing of crop per unit area.

Introduction:

The 1,000 seeds weight is a measure of seed size. It is the weight in grams of 1,000 seeds. Seed size and the weight can vary from one crop to another, between varieties of the same crop and even from year to year or from field to field of the same variety losses.Seeding rate is an important factor when considering all the decisions that need to be made at planting time. For instance, a high seeding rate can result in higher crop yields, better weed competition, earlier maturity, less tillers, smaller seed size and shorter plant height.

To calculate the seeding rate in kg per ha, we need the following information: It is a good, if we have a value for the 1000 seed weight (in grams). Otherwise, we will need to count out 1,000 seeds and weigh them (grams).

1. Spacing or Plant density or plants per square mt

2. Germination percentage and Emergence mortality (%)

3. 1000 seeds weight in grams

4. Purity of seed

1.Spacing or Plant density or plants per square mt

Spacing is very important for plant growth. There are many variation in spacing for different crops. It is depend upon type of crop varieties, soil type and purpose of crop. If any crop grown for fodder purpose, close spacing is to be required, but when these crops are grown for grain purpose wider spacing should be maintained. Plant population also depends on seed size.

2. Test weight of seeds or grain:

Test weight means 1000 or 100 seeds weight in gram or on volume base. It varies from one variety to another and from one crop type to another. Bold seeded varieties has higher test weight, which required higher seed rate, while fine or small seeds has low test weight as compared to bold seeds of same crop, which required less quantity of seed/ ha for sowing.

3. Germination & Mortality percentage:

To properly calculate seeding rates, germination tests should be done on all seed lots. Higher germination percentage of seed required less quantity of seeds for sowing, while seeds has low germination percentage, more quantity of seeds is required for sowing.

An estimate is also needed of seedling mortality, that is all those seeds that germinate but fail to develop into a plant. The reasons for plant death include disease, insects, rocks and drought. A common value used for mortality is 3%. Unfortunately, seedling mortality can vary greatly from year to year, and field to field. Mortality in cereals typically ranges from 5 to 20 per cent.

4. Purity percentage:

Seed quality is important when using the 1,000 seed weight. Poor seed produces weak plants. To properly calculate seeding rates, purity percentage play vital role. It is decided from different component of purity, such as pure seeds, other crop seeds, weed seeds and inert matter. The seeds having more purity percentage required less quantity of seeds for sowing as compared to less purity percentage of seeds. With the above values, we can use the calculator to get the desired seeding rate.

Test weight of some important field crops:

Sr. No.	Name of Crops	Test weight (g) (Approximate)
1	Sunflower	38-40
2	Mustard	4-5
3	Cow pea	70 -75
4	Wheat	40-45
5	Oat	35-40
6	Barley	30-45
7	French bean(100 seeds)	40- 42
8	Fenugreek	15-18
9	Gram	130- 140
10	Castor (100 seeds)	30-35
11	Bajara	7-10
12	Groundnut	40-45
13	Maize	220-240
14	Pigeon pea (100 seeds)	10-12
15	Field pea (100 seeds)	25-30

16	Sesame	4-5
17	Soybean(100 seeds)	8-10
18	Black gram	40-45
19	Green gram	30-40
20	Sorghum	15-20
21	Cluster bean	30-45
22	Cumin	3-5
23	Fennel	7-8
24	Dill seed	7-8
25	Isabgol	2-3
26	Lucerne	1-2
27	Amaranth(rajgira)	1.0
28	Lentil	30-80
29	Rice	30

❖ **Plant population**

Number of plants in a particular area depends on the canopy coverage of the individual plants. If vigour of the plant is less, canopy coverage is less and requirement of plants per unit area will be more. Thus, spacing is maintained in such a way that its canopy mathematically covers the entire area to intercept maximum sunshine without interfering the neighbouring crop plants.

$$\textbf{Plant population} = \frac{\textbf{10,000}}{\textbf{Row to row distance (m) x Plant to plant distance (m)}}$$

Example 1: Calculate the plant population/ha, if the spacing is 20 cm x 20 cm.

Spacing = 20 cm x 20 cm = 0.2 m x 0.2 m =0.04 m^2

i.e. 0.04 m^2 is covered by = 1 plant

10000 m^2 is covered by $= \frac{10000}{0.04}$

= 2,50,000 plants

Example 1: Find out the seed rate of wheat in kg/ha from the following details;

1. Spacing- 23 cm x 1 cm,   3.. Test weight: 25. 0 gm
2. Germination % = 90   4. Purity % = 95

Solution:

$$\text{Seed rate(kg/ha)} = \frac{\text{Area to be sown in sq.m. x test wt (g) x 100 x100}}{\text{1000 x 1000 x germination \% x purity \% X spacing (m)}}$$

$$= \frac{10000 \times 25 \times 100 \times 100}{1000 \times 1000 \times 90 \times 95 \times 0.23 \times 0.01}$$

$$= \frac{10 \times 25}{9 \times 95 \times 0.23 \times 0.01}$$

$$= \frac{250}{1.9665}$$

$$= 127.12$$

$$= 130 \text{ kg/ha}$$

Example 2: Find out the seed rate of maize in kg/ha from the following

details:

1. Spacing- 60 cm x 20 cm,   4 t weight: 350 gm
2. Germination % = 90   5. Purity % = 95
3. Gap filling : 5 % of required seed

Solution:

$$\text{Seed rate(kg/ha)} = \frac{\text{Area to be sown in sq.m. x test wt(g) x 100 x100}}{\text{1000 x 1000 x germination \% x purity \% X spacing (m)}}$$

$$= \frac{10000 \times 350 \times 100 \times 100}{1000 \times 1000 \times 90 \times 95 \times 0.60 \times 0.20}$$

$$= \frac{10 \times 350}{9 \times 95 \times 0.60 \times 0.20}$$

$$= \frac{3500}{102.6}$$

$$= 34.11 \qquad = 35 \text{ kg/ha.}$$

Now, seed required for gap filling $= \frac{35 \times 5}{100}$

$= 1.75$ kg

Therefore, total quantity required = 35 + 1.75 = 36.75 = **37 kg/ ha.**

Example 3. Work out the seed requirement of transplanted crop in kg/ha

1. Spacing : 60 x 30 cm, 2. No. of seedling / hill : two,
3. Germination: 80 % 4. Purity: 90 %, 5. Test wt: 30 gm,
6. No. of damaged seedling at the time of uprooting: 20 %,
7. No. seedling required for gap filling: 5 per 5 sq. m.

Solution:

Total No. of seedling required for T.P + No. seedling damaged during uprooting + No. of seedling required for gap filling

The No. seedling required for T.P. /ha $= \frac{10000 \times \text{no. of seedling/ hill}}{\text{spacing}}$

$$= \frac{10000 \times 2}{0.60 \times 0.30}$$

$$= \frac{10000}{0.18} \qquad = \mathbf{1,11,110} \text{ plants}$$

No. of seedling damaged

while uprooting $= \frac{\text{No. seedling required for T.P.} \times 20}{100}$

$$= \frac{111110 \times 20}{100} = \mathbf{22222} \text{plants}$$

Now, No. of seedling required for gap filling $= \frac{10000 \times 5}{5}$

= **10000** plants

Therefore, total seedling required = 111110 + 22220 +10000

= 143330 seedling /ha

Now for seed rate calculation= $\frac{\text{No .of seedling /ha x test wt(g) x 100 x100}}{\text{1000 x1000 x GP \% x Purity \%}}$

$= \frac{143330 \times 30 \times 10000}{1000 \times 1000 \times 80 \times 90}$

$= \frac{4299900}{80 \times 90 \times 10}$

= 59.72 kg/ha **= 60 kg/ha**

Self study:

Ex.1 Work out the seed requirement of transplanted rice crop in kg/ha

1. Spacing : 20 x 10 cm 2. No. of seedling / hill : two
3. Germination: 80 % 4. Purity: 90 %, 5. Test wt: 30 gm
6. No of damaged seedling at the time of uprooting: 25 %
7. No. seedling required for gap filling: 5 per 5 sq. m.

Solution:

Ex.2 Calculate the seed rate of mustard crop in kg/ha and total seed required for 10.5 hectare from the following detail.

1. Test wt.(g) : 5.20 2. Spacing (cm) : 45 x 15
3. Germination % : 80 4. Purity % : 95

Solution:

****

Exercise : 11

Work out cost of cultivation for different field crops

Sr. No.	Name of operation	Average labour unit required per hectare		
		Man	Woman	Bullock pair
1	Ploughing	2.5	-	2.5
2	Harrowing	2	-	2
3	Harrowing and planking	2.5	-	2.5
4	Planking	1	-	1
5	opening ridges and furrows	2.5	-	2.5
6	Drilling with seed-drill and planking	5	-	2.5
7	Interculturing with harrow	2.5	-	2.5
8	Earthing up - with ridger	5	-	2.5
9	-with plough	2.5	-	2.5
10	Threshing	4	-	5
11	Winnowing	6	10	-
12	Spreading of FYM	-	5	-
13	Dibbling and Marking-Maize	2	20	-
14	- Castor	1	10	-
15	Planting- Ginger and Turmeric	20	50	-
16	Preparing of beds	30	-	-
17	Marking of beds	2	-	-
18	Transplanting-Paddy	20	30	-
19	- Tobacco	-	40	-
20	- Fennel	-	25	-
21	-Guinea Grass	10	16	-
22	Broadcasting Sun hemp	1	-	-
23	Desuckering and Topping in Tobacco	-	60	-
24	Gap filling and thinning	-	5	-
25	Harvesting - Turmeric	50	10	-

26	- Ginger	40	20	-
27	- Bajra	-	20	-
28	Harvesting - Hill millets	-	30	-
29	- Gram	-	15	-
30	- Pigeon pea	10	-	-
	Harvesting and picking	**for kg of produce**		
31	Groundnut	-	1(75)	-
32	Tur pod	-		-
33	Turmeric	-		-
34	Ginger	-		-
35	Maize green cobs	-		-
36	Maize dry cobs	-		-
37	Fennel	-		-
	Tying bundles	**Bundles / man**		
38	Jowar-Bajra	1	600	-
39	Paddy	1	700	-
40	Hill millets	1	600	-
	Nipping	**kg/man**		
41	Bajra	1	60	-
42	Jowar	1	120	-
43	Hill millets	1	80	-
	Tractor cost	**Hours/ha**	**Rs./Hour**	
44	Ploughing	8	350	
45	Cultivator	4	300	
46	Disking	4	300	
47	Threshing	-	300	
48	Planking	-	200	
49	Seed drilling	-	300	
50	Bund former	-	200	
51	Ditcher (Ridge)	-	200	
52	Leveling	-	200	
53	Puddling (cage wheel)	-	500/ha	

A model of prices or rates calculated for the purpose of cost of cultivation as under:

(Only the prevailing rates to be used)

1	Man, Woman (except spraying or dusting pesticides)	: Rs. 260/day (8 hours)
2.	Pairs of bullocks for sowing purpose	: Rs. 520/day
3.	Pairs of bullocks for interculturing purpose	: Rs. 520/day
4.	Ploughing by country plough per hectare require 3 days	: Rs. 780/day
5.	Harrowing by bullocks pairs - 1 day / ha	: Rs. 520/day
6.	Planking: 1 day / ha	: Rs. 260/day
7.	Tractor discing requires 3.5 hrs/ha @ Rs.600 /hr.	: Rs. 2100/ha
8.	Tractor tines cultivation cross wise requires2.5 hrs/ha Rs. 500/hr.	: Rs. 1250/ha
9.	Tractor ploughing requires 8 hours i.e. Rs. 500 × 8 =	: Rs. 4000/day
10.	Cost of cultivation for irrigation - Rs. 100/hour	8-10hrs require for one ha Rs.1000/ha
11.	Lay-out for irrigation (land preparation) – 15 labours/ha	: Rs. 3900/day
12.	Cost of drilling of fertilizers – One bullock pair/day/ha	: Rs. 520/day
13.	Cost of manuring 5 labours/ha	: Rs. 1300/day
14.	Cost of weeding require 20 labours/ha	: Rs. 5200/day
15.	Top dressing - 5 labours/ha i.e.	: Rs. 1300/day
16.	Cost of spraying or dusting (Labour charges): 5 labours/ha @ Rs. 308/labours /day	: Rs. 1540/day
17.	Cost of seeds depends upon crop and its prevailing market rate	
18.	Cost of one kg nitrogen	
	- From Urea (kg N)	: Rs. 13.87
	- From Ammonium sulphate(kg N)	: Rs. 60.00
19.	Cost of one kg P_2O_5	
	- From single super phosphate (SSP) (kg P_2O_5)	: Rs. 46.63
	- From Diammonium phosphate (DAP) (kg N) - From Diammonium phosphate (DAP) (kg P_2O_5)	: Rs. 21.10 : Rs. 53.91
20.	Cost of one kg K_2O	
	- From Muriate of potash (kg K_2O)	: Rs.19.80

21	Cost of F.Y.M. Rs. 600/tone	
	- Spreading of F.Y.M. 5 laboures/ha	: Rs. 1300/ha
22	Cost of gap filling 5 laboures/ha	: Rs. 1300/ha
23.	Cost of thinning 5 laboures / ha	: Rs. 1300/ha
24.	Cost of dibbling	
	(i) For Maize 22 laboures / ha	: Rs. 5720/ha
	(ii) For castor 11 laboures / ha	: Rs. 2860/day
25.	Cost of broadcasting : 2 laboures / ha	: Rs. 520/day
26.	Cost of preparation of blinds	
	one bullock pair, Rs. 200/day/ha	: Rs. 520/day
27.	Cost of trans[planting	
	(i) Tobacco: 40 laboures / ha	: Rs. 10400/day
	(ii) Tobacco: 25 laboures / ha	: Rs. 6500/day
	(iii) Tobacco: 50 laboures / ha	: Rs.13000/day
28.	Cost of planting: crop Ginger. Average labour unit required/ha (Man - 20 + Woman - 50 = 70)	: Rs. 18200/day
29.	Cost of harvesting	
(i)	Turmeric and Ginger : 60 laboures/ha	: Rs. 15600/ha
(ii)	Bajra : 20 laboures/ha	: Rs. 5200/ha
(iii)	Tur (1 labour picking 125 kg of Tur pod / day)	:Rs.260/125 kg
(iv)	Fennel (1 labour picking 40 kg of Fennel)	:Rs. 260/ 40 kg fennel
(v)	Paddy : 20 labours / ha	: Rs. 5200/ha
(vi)	Maize and Castor : 30 labours / ha	: Rs. 7800/ha
(vii)	Sesamum : 15 labours / ha	: Rs. 3900/ha
(viii)	Ground nut uprooting	
	(Tractor harrowing 4 hours @ Rs 500/hr. + 2 labours)	: Rs. 2520/ha
	(1 labour picking 75 kg of ground nut pods from soil)	: Rs.260/ 75 kg pod of G'nut
30.	Tying bundles:	
1.	Paddy : 20 labours / ha	: Rs. 5200/ha
2.	Bajra : 15 labours / ha	: Rs. 3900/ha

31.	Threshing and winnowing :	
(i)	Paddy : 50 labours / ha	: Rs. 13000/ha
(ii)	Bajra : 25 labours / ha	: Rs. 6500/ha
(iii)	Maize : 40 labours / ha	: Rs. 10400/ha
(iv)	Sesamum : 25 labours / ha	: Rs. 6500/ha
(v)	Castor : 60 labours / ha	: Rs. 15600/ha
32.	Interest on working capital : 12 % per annum for the duration of the crop.	
33.	Depreciation of farm building : @ 5 % on Kachha and 2 % on Pakka building.	
34.	Interest on owned fixed capital.	: @ 6 % per annum
35.	Rental value of owned land income.	: @ 16 % of gross income.
36.	Supervision charges: 10 % of gross income.	: 10 % of gross income.
37.	Charges of repairing & depreciation of farm implements	: @ 5 % per annum.
38.	Price / rate of fertilizers:	
1.	Urea : Rs. 319 / 50 kg bag	
2.	A.S. : Rs. 600 / 50 kg bag	
3.	S.S.P. : Rs. 373 / 50 kg bag	
4.	M.o.P. : Rs. 594 / 50 kg bag	
5.	D.A.P. : Rs. 1240 / 50 kg bag	

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NAVSARI AGRICULTURAL UNIVERSITY

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

NAVSARI AGRICULTURAL UNIVERSITY

PRACTICAL MANUAL

ICAR

Production Technology for Vegetables and Spices (1+1)

HORT. 3.3

Department of Horticulture
College of Agriculture
Navsari Agricultural University
Waghai-394 730 (Dangs), Gujarat

Prepared and Compiled By:
Dr. M. Sarkar, Dr. B. Chakraborty
Dr. S.A. Aklade and Prof. H.A. Prajapati

Practical Manual

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FOREWORD

It is a matter of great pleasure to write and forward the **Practical Manual** of the course entitled **"Production Technology for Vegetables and Spices"** prepared by **Dr. Mangaldeep Sarkar, Assistant Professor (Horticulture), Hill Millet Research station, NAU, Waghai**. Indian agriculture is witnessing a gradual change particularly in the cropping system, land use system, input utilization, marketing and above all the monetary returns. The horticulture has gained importance in recent years as a significant component of agriculture in India as it has emerged as one of the potential enterprises in accelerating economic growth and alleviating the poverty of country. Besides providing wide range for crop diversification to the farmers, it also plays very important role for sustaining large number of Agro-industries creating a huge employment opportunity for the people.

This practical manual would certainly provide complete information regarding botanical aspects, planting material and propagation method, field management as well as post harvest technology for vegetables and spices. This manual has been prepared following the latest syllabus and knowledge; so probably fulfils the requirements of B.Sc. (Hons.) Agriculture students for the above mentioned course. However, it is equally useful for the post graduate students, scholars, teachers and scientists working on the applied aspects of these dollar earning crops.

Place : Waghai
January, 2019

Dr. Z. P. Patel
Principal & Dean
College of Agriculture, Waghai
Navsari Agricultural University

CERTIFICATE

Uni. Seat No._______

Registration Number______________

This is to certify that Mr./Miss. ____ of third semester B.Sc. (Hons.) in Agriculture has satisfactorily carried out ________________ exercises as shown in the practical manual of **Hort. 3.3 (Production Technology for Vegetables and Spices)** at Horticulture Department during the year 20______.

(Course Teacher)

Head of Department

Signature of External Examiner

INDEX

Experiment No.: 1 **Date:**

Identification of vegetables and their seeds

Objective: Study and acquire knowledge about botanical description of different vegetable crops grown in India.

Common Name	Botanical Name	Family	Edible part	Propagation
1. Tomato	*Solanum lycopersicum*	Solanaceae	Fruit	Seed
2. Brinjal	*Solanum melongena*	Solanaceae	Fruit	Seed
3. Chilli	*Capsicum annuum*	Solanaceae	Fruit	Seed
4. Potato	*Solanum tuberosum*	Solanaceae	Stem tuber	Tuber, Seed
5. Okra	*Abelmoschus esculentus*	Malvaceae	Fruit	Seed
6. Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae	Fruit	Seed
7. Watermelon	*Citrullus lanatus*	Cucurbitaceae	Fruit	Seed
8. Cucumber	*Cucumis sativus*	Cucurbitaceae	Fruit	Seed
9. Ridge gourd	*Luffa acutangula*	Cucurbitaceae	Fruit	Seed
10. Sponge gourd	*Luffa cylindrica*	Cucurbitaceae	Fruit	Seed
11. Bitter gourd	*Momordica charantia*	Cucurbitaceae	Fruit	Seed
12. Pointed gourd	*Trichosanthes dioica*	Cucurbitaceae	Fruit	Vine cutting
13. Muskmelon	*Cucumis melo*	Cucurbitaceae	Fruit	Seed
14. Cabbage	*Brassica oleracea var. capitata*	Brassicaceae	Head	Seed
15. Cauliflower	*Brassica oleracea var. botrytis*	Brassicaceae	Curd	Seed
16. Pea	*Pisum sativum*	Leguminaceae	Pod and seed	Seed
17. Cluster bean	*Cyamopsis tetragonoloba*	Leguminaceae	Pod	Seed
18. Cowpea	*Vigna unguiculata*	Leguminaceae	Pod and seed	Seed
19. Radish	*Raphanus sativus*	Brassicaceae	Root	Seed
20. Carrot	*Daucus carota*	Apiaceae	Root	Seed
21. Beet root	*Beta vulgaris*	Chenopodiaceae	Root (Hypocotyl)	Seed
22. Onion	*Allium cepa*	Alliaceae	Bulb	Bulb, Seed
23. Garlic	*Allium sativum*	Alliaceae	Bulb (clove)	Clove, Seed
24. Palak	*Beta vulgaris* var. *bengalensis*	Chenopodiaceae	Leaf	Seed
25. Amaranthus	*Amaranthus tricolor*	Amaranthaceae	Leaf	Seed
26. Sweet potato	*Ipomoea batatas*	Convolvulaceae	Root tuber	Vine cutting
27. Curry leaf	*Murraya koenigii*	Rutaceae	Leaf	Seed, Sucker, Cutting
28. Drum stick	*Moringa oleifera*	Moringaceae	Pod, Flower, Leaf	Seed, Limb cutting

Question:

1. **List out the vegetable crops belong to the family solanaceae and alliaceae.**

2. **List out the vegetable crops with root, pod and leaf as edible part.**

3. **List out the vegetable crops having vegetative part as its propagating material.**

4. **Write down the edible part of cabbage, cauliflower, onion and potato.**

5. **List out the cucurbitaceous vegetables.**

Experiment No.: 2 **Date:**

Identification of spices and their seeds

Objective: Study and acquire knowledge about botanical description of different spice crops grown in India.

Common name	Botanical name	Family	Edible/economic part	Propagating part / method
1. Turmeric	*Curcuma longa*	Zingiberaceae	Rhizome	Rhizome
2. Ginger	*Zingiber officinale*	Zingiberaceae	Rhizome	Rhizome
3. Black pepper	*Piper nigrum*	Piperaceae	Fruit / Seed	Runner shoot cutting
4. Cinnamon	*Cinnamomum verum*	Lauraceae	Inner bark	Seed / Stem cutting / Air layering
5. Tejpat (Indian bay leaf)	*Cinnamomum tamala*	Lauraceae	Leaf	
6. Clove	*Syzygium aromaticum*	Myrtaceae	Unopened flower bud	Seed
7. Allspice	*Pimenta dioica*	Myrtaceae	Dried fruit (berry)	Seed / Shoot cutting / Air layering / Approach grafting / Stooling
8. Nutmeg	*Myristica fragrans*	Myristicaceae	Dried seed kernel	Seed / Epicotyl / Approach grafting, Patch budding
9. Mace	*Myristica fragrans*	Myristicaceae	Dried aril	
10. Small Cardamom	*Elettaria cardamomum*	Zingiberaceae	Dried fruit (capsule) and seed	Seed / Sucker
11. Saffron	*Crocus sativus*	Iridaceae	Dried stigma	Corm
12. Asafoetida	*Ferula assafoetida*	Apiaceae	Dried latex (gum oleoresin) from rhizome and tap root	Seed
13. Coriander	*Coriandrum sativum*	Apiaceae	Dry fruit and seed	Seed
14. Cumin	*Cuminum cyminum*	Apiaceae	Dry fruit and seed	Seed
15. Fenugreek	*Trigonella foenum-graecum*	Leguminaceae	Seed	Seed
16. Fennel	*Foeniculum vulgare*	Apiaceae	Seed	Seed

Question:

1. **Write down the botanical name, family, edible and propagating part of turmeric, clove, saffron and asafoetida**

2. **Make a list of spice crops belonging to family apiaceae, myrtaceae, zingiberaceae and lauraceae with their edible part**

3. **List down only the common name of seed spices.**

Experiment No.: 3 **Date:**

Types of vegetable gardens

Objective: Study and acquire knowledge regarding different types of gardens growing vegetables.

Vegetable gardens can broadly be classified into following two types depending on the acreage of cultivation, method of cultivation and purpose of vegetable production.

1. Home or kitchen garden
2. Commercial vegetable garden
   i) Market garden
   ii) Truck garden
   iii) Garden for vegetable forcing
   iv) Vegetable garden for processing
   v) Vegetable garden for seed production
   vi) Vegetable garden for export
   vii) Organic vegetable garden
   viii) Floating vegetable garden
   ix) Hydroponics

1. Home or kitchen garden: Kitchen garden or home garden is the growing place of vegetable crops around the residential houses or in their vicinity to meet vegetable requirement of the family throughout the year.

Type of kitchen garden:

(a) Garden having fruits and vegetables.

(b) Garden having only vegetables.

Principles of kitchen garden:

1) Land should preferably be selected in the backyard of the house. Rectangular shape is preferred.
2) The lay out should allow access to all parts of the garden.
3) Quick growing fruit trees e.g. papaya, kagzi lime etc. should be located on north side of the garden so that they do not shade other crops.
4) Climbers e.g. cucumber, pea etc. can be trained on the fence.
5) Several sowing or succession of sowing of one particular crop e.g. fenugreek, radish, okra, cauliflower, etc., at short intervals should be done to ensure a steady supply of vegetables for a longer period.
6) Ridges which separate the beds should be utilized for growing root vegetables e.g. radish, turnip etc.
7) Inter-space of slow growing crops e.g. cauliflower, cabbage, eggplant etc. should be used for quick growing crops like turnip, radish, leaf beet etc.

Selection of crops for kitchen garden depends on two factors i.e. size of the garden and choice of the family. Only those vegetables are grown which are suited to the region and produce satisfactory yield. The cultivars should be selected according to the suitability for the region and season. Preference is given to those crops where freshness is important from the edibility and food value point of view. Such crops include tomato, chilli, beans, pea, salad crops, leafy vegetables etc.

Advantages of kitchen garden:

1) It provides fresh, organic and nutritious vegetables for the family throughout the year and vegetables can be obtained during off season also.
2) It reduces the expenses in buying vegetables from market.
3) Kitchen garden provides good exercise to body and a healthy recreation to the mind.
4) Better utilization of the bare land, kitchen waste and kitchen water.
5) It helps to maintain home surroundings with healthier atmosphere.

2. Commercial vegetable gardening

(i) Market garden: Gardens those produce vegetables for supply to consumers in the local market is called a market garden. Since people living in cities usually have neither the space nor the time to devote to gardening, there developed a tremendous demand of vegetables. The ultimate aim of vegetable production in market gardens is their quick disposal in nearby market. Hence, nearness to market with a reliable transport should not be ignored. Earlier when a quick transport did not develop, this type of garden was confined to the immediate vicinities of cities. However, with the expansion of cities and improvement in road and transport network, such gardens are now located even beyond 30-40 km from main cities. Cropping pattern in this garden depends on the demand of local market. The land being costly, intensive methods of cultivation are followed. Growing of early varieties is preferable to catch the early market. High cost of land and labour is compensated by the availability of municipal compost, sludge and water near some cities and high return on the produce.

Benefits of market garden:

1) Market garden helps to supply fresh vegetables in large quantities regularly to cities.
2) It helps to increase farmer's income.
3) It plays important role in waste management of large cities.

(ii) Truck garden: This type of garden produces special vegetables in relatively large quantities for distant markets. This gardening generally follows a more extensive and less intensive method of cultivation than market garden. The word truck has been derived from French word 'troquer' meaning 'to barter'. Since farms are located away from the consumer markets, middleman is involved in marketing the produce. Due to large-scale production, farming is usually mechanized. In this type of garden, varieties should possess special attributes to withstand distant transportation. The cost of land and labour may be cheap. The net income is also less as it includes the cost of transport and the charges of middleman.

(iii) Garden for vegetable forcing: This type of garden is concerned with the production of vegetables out of their normal season. Growing high value vegetables like tomato, sweet pepper, cucumber, lettuce etc. under protected structures like glass house or poly house is the main feature of this kind of gardening. In protected structures, temperature, light, carbon dioxide and relative humidity are controlled artificially. Cultivation of vegetables under protected conditions ensures better quality, uniformity and extended availability period. Initial investment is high as these protected structures are costly.

(iv) Vegetable garden for processing: Garden that produces vegetables with a sole objective of supplying to the processing industry is termed as vegetable garden for processing. Vegetable production for processing mainly canning, freezing and dehydration is distinct from fresh market vegetable production. The vegetables meant for processing are grown exclusively in field under naturally occurring conditions. For processing, only one or two varieties of one or two crops are grown on a large scale to produce in bulk. The farming is generally mechanized and away from the cities. There are specific varieties for processing purpose. The varieties are selected in such a way that there is a continuous supply of raw material to feed the processing units for a longer period. The price is paid on contract basis on weight and quality of the product.

(v) Vegetable garden for seed production: Gardening for vegetable seed production is a highly specialized farming and only trained grower possessing technical know-how succeeds in such a pursuit. These types of gardens are adopted in large areas for the production of vegetable seeds. Locations prone to natural vagaries e.g. rain at the time of crop and seed maturity are avoided for seed production. Similarly, areas those are infested with diseases especially seed borne ones are also excluded from seed production. Sowing time of seed crops is adjusted in such a way that it escapes the infection by the disease causing pathogen. To maintain genetic purity, the field for seed production should be free from volunteer plants. In cross-pollinated crops, normally one crop variety is planted at one location. Beehive boxes are also placed inside the seed production blocks to enhance pollination and consequently seed yield. A proper isolation distance between varieties of the same crop and of other crops those are cross-compatible, is maintained to produce true-to-type seed. The isolation distance depends upon the crossing behaviour (self, often or cross-pollinated) of the crop and category (breeder, foundation or certified) of the seed. Off-type plants from the seed production block are removed at vegetative, flowering and fruiting/ pod formation stages.

(vi) Vegetable garden for export: Gardens those produce specific vegetables with high standard for export purpose only are called as export oriented vegetable gardens. India has been emerged as a major exporting country for a number of vegetable crops. For fresh consumption onion, potato, okra, baby corn, tomato, pickling cucumber, chilli, French bean, bitter gourd and bottle gourd are the main export oriented vegetables from India while among processed vegetables, major demand is for dehydrated onion, garlic and processed cucumber and gherkin. The Agricultural and Processed Food Products Export Development Authority (APEDA) has identified asparagus, celery, sweet pepper, sweet corn, pea and cherry tomato among non traditional vegetables for export. For export, the product should be true-to-type as per the declared variety and standards, uniform in shape, size, colour and free from chemical residues. Vegetables should be properly graded and packed in good quality boxes of appropriate sizes.

(vii) Organic vegetable garden: This type of garden avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators etc. To the maximum extent feasible, organic vegetable garden rely upon crop rotation, crop residues, animal manure, green manure, legumes, off farm organic waste, mechanical cultivation, mineral bearing rocks and aspects of biological control to maintain soil productivity and tilth, to supply nutrients and to control insects, diseases and weeds.

(viii) Floating vegetable garden: Floating gardens are found in lakes of Kashmir valley especially the Dal Lake of Srinagar. Most of vegetables in spring and summer seasons are supplied in Kashmir from floating gardens. A floating base is prepared using the grass known as Typha that grows wild in Kashmir. Compost and other organic matter spread over this base act as a seed-bed for growing vegetables. Subsequent inter-culture operations and irrigation are accomplished with the help of boats. Besides vegetables, flowers are also successfully grown in this type of garden. This is a specialized type of farming and is, more or less, restricted to the Kashmir valley.

(ix) Hydroponics: Hydroponics is generally defined as the science of growing plants without using soil by feeding them on solutions of water and mineral salts instead of relying upon traditional method of cultivating the earth. The term hydroponics is derived from the Greek words hudro-water and ponos-work means water working. Advantages of hydroponics over the traditional method of crop raising include better quality produce, quick growth, no soil or seedbed preparation, clean culture, consistent results and crop production even if the soil is sick or unfit due to salinity, poor structure and drainage problem. Hydroponic systems have some clear environmental benefits with the most significant being that they use 70-90% less water compared with many forms of conventional crop production. There should be no nutrient run off and hence reduced concerns about contamination of ground water, rivers, streams etc. Tomato, cucumber, lettuce, potato and bell pepper etc. respond favourably to the hydroponic culture. The worldwide area of hydroponics production has increased four to five times in the last ten years or so. In India, hydroponics centre was established in 1946 at the Experiment Station near Darjeeling in West Bengal with the objective to evolve simple and inexpensive methods of soilless gardening.

Question:

1. **Write down the principles and advantages of kitchen garden.**

2. **What is hydroponics?**

3. **Give an idea about floating vegetable garden.**

4. **Differentiate between market garden and truck garden.**

5. **Write about vegetable forcing.**

Experiment No.: 4 **Date:**

Kitchen garden

Objective: Study and acquire knowledge regarding a perfect kitchen garden.

Kitchen gardening: It is defined as the growing of vegetable crops in space around the residential house to meet the requirement of fresh vegetables for the family throughout the year.

Aim of kitchen garden: The ultimate aim of kitchen gardening is to use household land efficiently and effectively for growing of different kind of fruits and vegetables without any harmful chemicals and supply it to the family members throughout the year.

Types of kitchen garden:

(a) Home garden having fruits and vegetables.

(b) Home garden having only vegetables.

Advantages of kitchen garden:

i) It is source of fresh and nutritious vegetables for whole family throughout the year.

ii) It reduces the expenses in buying vegetables from market.

iii) Kitchen gardening is the best source of recreation and exercise.

iv) Better utilization of the home surrounding land, kitchen waste and kitchen water.

Planning and lay out of kitchen garden:

i) Location: (a) Backyard of the house (b) Away from big tree (c) Near to water source.

ii) Size & Shape: (a) The size of kitchen garden depends on the number of persons to be supplied vegetables. (b) Approximately, 250 sq meters area may be sufficient for a family of five members. (c) Garden sho uld be rectangular in shape.

iii) Arrangement of crops:

a) The main annual vegetables are grown on different plots.

b) The perennial vegetables and fruit crops are grown one side or at the end of garden.

c) Cucurbits and vine crops are grown near or on the fence or boundary.

d) Roots vegetables are grown on ridges of plots.

e) Leafy vegetables can be grown between two fruit crops.

iv) Soil management: The plot should be divided into different beds and their size may vary according to available area. Each bed should be leveled and connected with irrigation and drainage channel.

v) Manuring: Manure should be thoroughly incorporated in to the soil. Plan one small compost pit in corner of kitchen garden.

vi) Planting/sowing: Cauliflower, cabbage, tomato, Brinjal, chilli and onion do well when transplanted. Transplanting should be done in cloudy weather or in evening time. Vegetables like p eas, beans, cucurbits, carrot, okra, beet root, cluster bean and green leafy vegetables are sown directly in the field.

vii) Irrigation: Plants should be irrigated regularly. In small plots, irrigation by rubber pipe is better. Drip system can be fitted if possible.

viii) Path: Provide one path for easy operation and walking.

ix) Intercultural operation: These are essential to make soil loose and to keep better physical condition. Weeding, earthing up, staking, thinning etc. should be done as per need.

x) Control measures for insect and disease: maintaining sanitization is the most effective tool to make the garden insect and disease free. Use herbal control for insect and pest like neem seed oil or extract, tobacco extract and other repellent herbal plants.

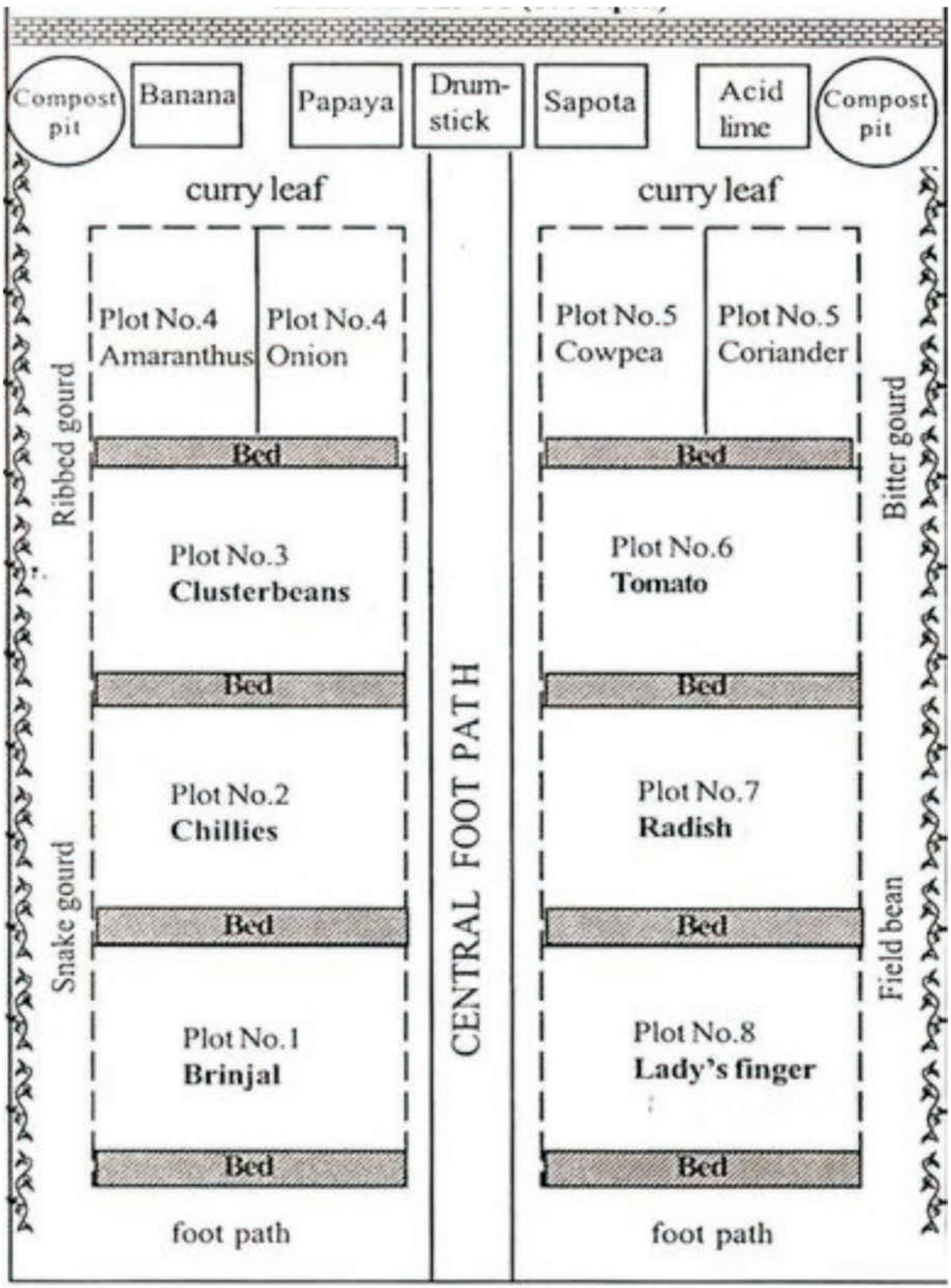
xi) Harvesting: Harvesting should be done according to requirement. Vegetables which are ready to consume should be harvested first.

Plan for model kitchen garden:

Plot Number	Crop	Season
Plot No. 1	Brinjal	July-March
	Cluster bean	July-October
	Cabbage	November-March
Plot No. 2	Okra	March-June
	Cauliflower (mid season)	July-November
	Cowpea	February-May
Plot No. 3	Cluster bean	July-October
	Onion	December-June
Plot No. 4	Onion	December-June
	Amaranthus	March-June
Plot No. 5	Cowpea	February-May
	Coriander	September-March
Plot No. 6	Tomato	July-October
	Chilli	September-April
Plot No. 7	Radish	October-November
	Chilli	September-April
On fence	Snake gourd, pointed gourd, bitter gourd, bottle gourd, sponge gourd, cucumber, pumpkin	Summer and kharif season
At end	Compost pit, drumstick, papaya, sapota etc.	Throughout the year

Question:

1. **Define kitchen gardening with its aim.**



Diagramatic representation of a model kitchen garden

2. **Write about the advantages and arrangement of crops in a kitchen garden**

3. **Draw a model kitchen garden layout with your own thought.**

Experiment No.: 5 **Date:**

Raising of nursery for vegetables

Objective: Study and acquire knowledge regarding a proper nursery management for healthy seedling growing in different vegetable crops.

Nursery: A vegetable nursery is a managed site, designed to produce seedlings grown under favorable conditions until they are ready for planting. All nurseries primarily aim to produce sufficient quantities of high quality seedlings to satisfy the needs of users.

Advantages of raising vegetable seedling in nursery:

1. Easy and convenient way to manage crops due to small area.
2. Effective plant protection measures can be taken at initial stage.
3. Healthy seedlings can be produced and provided to the consumers.
4. Seeds can properly be sown and healthy seedlings can be grown in protected structures when unfavourable environmental conditions prevail outside.
5. Economic use of land as more plants are raised on small area for transplanting in a large area.
6. Economic use of costly vegetable seed due to 100% germination is possible with proper care.
7. Early crops can be obtained in some vegetables by double transplanting of seedlings in nursery bed.

Requirements for raising seedling:

(a) Selection of site: 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 water stagnation during rainy season can be avoided.

(b) Selection of soil: Soil should be sandy loam, or loamy in texture. It should be well drained and rich in organic matter. Acidic and saline soils are not suitable for raising nursery.

(c) Soil solarization: Burning of nursery soil surface by using dry grasses and leaves is known as rabbing. Beside of that covering black thin plastic over nursery seed bed can be used for soil solarization. These practices help to destroy harmful fungi, insect eggs and pupa, worms and weed seeds by producing high heat.

(d) Soil preparation: Cross harrowing is done in order to make soil porous, well aerated and less compact. FYM or compost should be incorporated during land preparation which improves physical condition as well as provides nutrients to growing plants.

(e) Nursery beds: These are seed sowing areas prepared with fertile and clean nursery mixtures (soil, sand and FYM). Generally they are rectangular in shape with 1 to 1.8 m width and 1.8 (in hills) to 12 m (in plains) length. The lengthy side of the bed should be oriented towards the sun (east-west) so that shading can be done.

(I) Raised nursery bed: These types of beds are prepared by dumping soil about 10 to 15 cm above ground level. They are common in high rainfall areas to prevent water logging. The furrows of 2-3 cm depth and 5-7 cm apart are opened for seed sowing. The depth of seed will be 5 to 10 mm and it should be covered with fine layer of soil and compost.

Advantages of raised bed:

i. It facilitates proper drainage, therefore extremely 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 labourious and expensive also.

(II) Flat nursery bed: During spring-summer, seedlings are raised in flat bed. Generally soil is dug 15-20 cm deep and all clods are broken with the help of spade to make the soil of this bed very fine.

Advantages of flat bed:

(i) Flat bed is easy to prepare (ii) Cost for preparation is less

Disadvantages of flat bed:

(i) More chances of stagnation of excess irrigation water which is always harmful.
(ii) Soil become more compact, therefore uprooting of seedling becomes difficult.

(f) Selection of seed and seed treatment: True to type seed should be selected with high germination percentage and free from insect, disease and weed seed. Seed treatment is given to prevent seeds from diseases and to enhance germination. Fungicides like Ceresan, Thiram, Captan, Agrosan etc. are generally used for seed treatment @ 2-3 gram per kg of seed.

(g) Sowing: Seeds are sown either by broadcasting or in rows / lines. Small seeds should be sown 1 to 1.5 cm deep in soil bed. 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 initiation of germination, materials should be removed.
(2) Watering is done at frequent interval. Uniform water supply is desirable. Excessive watering should be avoided.
(3) Thinning, Weeding and Plant protection measures should be carried out as per need.

Table: Time of sowing, transplanting, seed rate, seedling age and seedling growth of different vegetables

Name of crop	Time of nursery sowing	Time of transplanting	Seed rate/ha (g)	Seedling age (weeks)	Seedling height
Tomato	1) Feb-March 2) October 3) November 4) May-June	1) March-April 2) Nov-Dec 3) Feb-March 4) June-July	500	4-6	15-20 cm
Chilli	1) May-June 2) Nov-Jan	1) June-July 2) Jan-March	750 -1000	4-6	15-20 cm
Brinjal	1) June 2) November 3) October 4) April	1) July 2) December 3) November 4) May	500 - 750	4-6	15-20 cm
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 with 3-4 complete leaf

Question:

1. **Define nursery. Write down the advantages of growing vegetable seedling in nursery.**

2. **Write about soil solarization and seed treatment.**

3. Give an idea about nursery bed. What are the advantages of raised bed?

4. Write about the transplanting criteria of tomato, cauliflower and onion.

Experiment No.: 6 **Date:**

Raising of nursery for spices

Objective: Study and acquire knowledge regarding nursery management of different spice crops.

Black pepper

Propagation and production of rooted cutting: Black pepper vines produce three types of shoot, namely (1) Primary climbing shoot with long internodes having adventitious roots at nodes which cling to the supports/ standards; (2) Runner shoots which originate from the base of the vine and creep on the ground, have long internodes which strike roots at each node and (3) Fruit bearing lateral shoots. Cuttings are raised mainly from runner shoots, though terminal shoots can also be used. Cuttings from lateral branches develop a bushy habit. Rooted lateral branches are used for raising bush pepper. Though seeds (berries) are fully viable, they are not generally used for raising plantations as seedlings will not be genetically uniform. Runner shoots from high yielding and healthy vines are kept coiled on wooden pegs fixed at the base of the vine to prevent the shoots from coming in contact with soil and striking roots. The runner shoots are separated from the vine during February-March, and after trimming the leaves, cuttings of 2-3 nodes are planted either in nursery beds or in polythene bags filled with potting mixture (soil, sand and farm yard manure in 2:1:1 ratio). Adequate shade has to be provided and the polythene bags are to be irrigated frequently. The cuttings become ready for planting during May-June.

Cardamom

Seed sowing: Seedlings/suckers can be used for propagation.

Propagation from Seeds in primary nursery:

- Collect seeds from healthy and high yielding plants.
- Seed rate – 600g/ha (fresh seeds).
- Treat with commercial grade Sulphuric acid or Hydrochloric acid for 20 minutes.
- Wash with water.
- Prepare the beds with equal quantity of well rotten cattle manure, wood ash and jungle soil.
- Sow the seeds in beds and cover with a thin layer of fine sand.
- Mulching and shading may be provided to seed beds. The beds should be kept moist but not too wet. Germination starts usually a month after sowing and continues upto three months. One year old seedlings are transplanted to secondary nursery.

Secondary nursery:

- Prepare the beds. As that of primary nursery, shade is provided by erecting overhead pandal.
- Seedlings planted at a distance of 20.0 cm x 20.0 cm.
- 18-22 months old seedlings are used for transplanting.
- Polybags of 20.0 cm x 20.0 cm size can be used

Propagation from suckers:

- Suckers from high yielding plants are planted in clonal gardens.
- Spacing 1.8 m x 0.6 m (6800 plants/ha of clonal nursery)

- Shade and Irrigation is provided, 32 – 42 suckers obtained from each planting unit in 12 months

Clove

Propagation: clove is propagated by seed also called as mother clove. Seed should be sown immediately after harvesting from the tree to avoid the viability loss.

Nursery management:

Primary nursery: seed bed of 15-20 cm height, one metre width and of convenient length should be prepared with loose soil and a layer of sand may be spread over the soil. Seeds are sown at 2-3 cm spacing in a depth of 2 cm. Seed bed should be protected from direct sunlight.

Secondary nursery: germinated seedlings are transplanted in polythene bag (30 cm x 15 cm) containing a mixture of good soil, sand and well decomposed cow dung in a ratio of 3:3:1.

Fennel

Seed rate: 3-4 kg/of seeds raised in 100 m^2 nursery

Age of seedling for transplanting: 5-6 weeks

Spacing in main field: 60.0 cm x 30.0 cm

Season: October-November in plain and May-June in hill

Question:

1. **Write about the propagation of black pepper.**

2. **Write about propagation and nursery management of clove.**

3. **Write down the propagating parts of black pepper, cardamom, clove and fennel.**

4. Write about the propagation method adopted in cardamom.

Experiment No.: 7 **Date:**

Direct seed sowing of vegetable crops

Objective: Study and acquire knowledge about sowing of seed / planting of vegetative part in some vegetable crops.

Sowing of cucurbitaceous vegetables

Almost all cucurbit seeds are directly sown in the main field except pointed gourd, little Gourd and spine gourd which are propagated by vegetative means. Pointed gourd and little gourd are propagated by stem cutting where as spine gourd is propagated mainly by tuberous root.

(1) Bottle gourd:

- Time of sowing: Seed sowing is done in the month of February to March for summer season and June – July for kharif season.
- Seed rate: 2.5 -5.0 kg / ha.
- Sowing distance: row to row: 2.0 m; plant to plant (within row): 1.0 m.
- Method of sowing: Seeds can be sown on furrow and ridge or flat bed and raised bed based on soil type and climate. First, 3 to 4 seeds are sown per hill & then at two to four leaf stage the plants should be thin out & only one plant kept per hill.

(2) Cucumber:

- Time of sowing: Seed sowing is done in the month of February to March for summer season, June –July for kharif season.
- Seed rate: 1.5-2.0 kg/ha.
- Sowing distance: row to row: 1.5 m; plant to plant (within row): 1.0 m.
- Method of sowing: Seeds can be sown on furrow and ridge or flat bed and raised bed based on soil type and climate. First, 3 to 4 seeds are sown per hill & then at two to four leaf stage the plants should be thin out & only one plant kept per hill. Seeds are sown at a depth of 2 to 3 cm in soil.

(3) Ridge gourd and Sponge gourd:

- Time of Sowing : Summer: February-March and kharif: June- July
- Sowing distance: row to row: 1.5 – 2.0 m; plant to plant (within row): 0.5 – 1.0 m.
- Seed rate : 2.0 – 4.0 kg/ha
- Sowing method- Seeds are sown by dibbling method on flat bed, raise bed, ridge & furrow. 4 to 5 seeds are sown per pit. Later on 1 plant is allowed to grow.

(4) Bitter gourd:

- Time of Sowing : Summer: February-March and kharif: June- July
- Sowing distance: row to row: 1.5 – 2.0 m; plant to plant (within row): 1.0 – 1.5 m.
- Seed rate – 3.0 to 5.0 kg / ha
- Sowing method - 3 to 5 seeds are sown per hill. Having hard seed coat the seeds are soaked in water for 24 hours then kept in gunny bag for two days and then sown in field.

(5) Water melon:

- Sowing time - Last week of January to first week of February.
- Spacing - row to row: 2.0 – 2.5 m; plant to plant (within row): 1.0 m.
- Seed rate – 4.0 to 6.0 kg/ha
- Sowing method: 1. Hill planting 2. Ridge and furrow method 3. Pit method

Sowing of leguminous vegetables

Beans and peas are direct seed sown crops and do not respond to transplanting. Since seed size is comparatively bigger and they are closely planted, a high seed rate is required for most of these vegetables.

Legume vegetables require light and well drained soil for maximum yield. They are sensitive to excess irrigation and water stagnation. Majority of legume vegetables fix atmospheric nitrogen and make it available to plants with help of *Rhizobium* bacteria present in root nodules of leguminous crops.

(1) Pea:

- **Time of sowing**: Pea is grown generally as a rabi crop. It is sown on the beginning of October to middle of November.
- **Seed rate**: 80 to 90 kg per ha is the general recommendation for mid late varieties. If sowing is done in ridge and furrow method, seed rate adopted 50 to 60 kg per ha. Seed rate also varies with growth habit of varieties for early varieties 100 to 120 kg per ha is required.
- **Sowing method**: Seed can be sown on flat bed or raised bed either by broadcasting or behind the plough at 2.5-5.0 cm depth. Overnight soaking of seed in water and GA_3 (10 ppm) improves germination.
- **Spacing**: 20.0-30.0 cm x 5.0 cm

(2) Cow pea:

- **Time of sowing**: In areas where winter is mild, cowpea can be grown through the year. In North India and Gujarat, it is sown during the month February-March as a summer crop. It is also sown in kharif season during the month of June-July.
- **Seed rate**: It depends upon the variety and spacing. In general recommendation, it should be 12.0 – 15.0 kg per hectare.
- **Sowing method**: Land is prepared to a fine tilth by 2-3 ploughing and harrowing. Field is divided into plots of convenient size and seeds are dibbled at given spacing.
- **Spacing**: 30.0 – 45.0 cm x 12.0 – 15.0 cm

(3) Cluster bean

- **Time of sowing**: Mainly it is rainy season crop and sown during month of June-July and extended up to September-October. Summer crop is raised by sowing during February-March.
- **Seed rate**: 7.0 – 10.0 kg per hectare.
- **Sowing method**: Field is prepared to a fine tilth by ploughing and harrowing. Seeds are either broadcasted or dibbled.
- **Spacing**: Seeds are dibbled at 45.0 cm x 15.0 cm or 45.0 cm x 20.0 cm.

(4) Dolichos bean (Indian bean)

- **Time of sowing:** Indian bean is sown in month of July for kharif season while in winter, sowing is done in September-October.

- **Seed rate**: It depends on the variety. For indeterminate type 20.0 – 30.0 kg/ha while for determinate type, 8.0 – 10.0 kg/ha required.
- **Sowing method**: Prepare land to fine tilth and sow seed by dibbling at a given spacing.
- **Spacing:** Seeds are dibbled at spacing of 45.0 cm x 30.0 cm for determinate type. It should be 90.0 – 120.0 cm x 50.0 – 75.0 cm for indeterminate type.

Question:

1. **Write about the seed rate and spacing of pea, cowpea, cluster bean and Indian bean.**

2. **Write down the reason of high seed rate in leguminous vegetables.**

3. Write down the time of sowing of legumes as well as cucurbits.

4. Write down the seed rate and spacing of cucurbitaceous vegetables.

Experiment No.: 8 **Date:**

Direct seed sowing of spice crops

Objective: Study and acquire knowledge about sowing of seed / planting of vegetative part in some spice crops

Planting of rhizome in turmeric

- **Propagation:** It is propagated by Rhizome, especially by mother rhizome having 4 to 5 cm long, 30 g in weight, with minimum one healthy bud. Healthy well developed well dried and disease free whole or split mother rhizome should be selected for planting. Finger rhizomes with same specifications are also used for planting.
- **Planting Time:** April- May
- **Seed Rate:** 2000 - 2500 kg rhizomes / ha. Selected rhizomes are treated with 0.25 % agallol solution for 30 minutes; rhizomes are sown at 5 to 7 cm depth in soil.
- **Planting distance:** 30 cm x 20 cm or 20 cm x 20 cm or 30 cm x 30 cm or 30 cm x 15 cm
- **Method of planting:**
  - Flat bed or raised bed
  - Ridge and furrow
- **Rhizome treatment**: It is treated with slurry of cow dung for early sprouting.

Planting of ginger rhizome

- **Planting time :** IInd fortnight of April
- **Seed rate :** 900 - 1400 kg rhizome / ha
- **Planting distance:** 30 - 45 cm row to row
  15 - 22 cm within a row (plant to plant)
- **Planting material**: Ginger is propagated by finger rhizome having following specification:
  - 4 - 5 cm length
  - Free from disease infection
  - Average weight should be 25 - 30 g
  - 1 - 2 full developed eye / bud should be present
- **Seed treatment:** For control of soft rot disease rhizome should be dipped in 0.2 % dithane M-45 (Mancozeb) solution for 10 minutes or 0.5 % Serasan solution for 10 minutes.
- **Methods of planting:**

(a) Flat or raised bed method**:** In sandy loam soil, flat beds are prepared. Raised beds are prepared for medium black or in black soil.

(b) **Furrow method:** In this method, furrows are opened at 30 - 45 cm distance and within furrow, ginger rhizomes are planted at the slope of ridge with 15 - 20 cm distance and 3 - 5 cm deep in soil.

Sowing of coriander

Sowing season: North & Central India: Mid October to mid November
Southern India: June-July to September-October
Seed rate: 10-15 kg/ha
Seed treatment: Thiram @ 2gm/kg of seed
Spacing: 30 cm x 15 cm
Sowing method: Broadcasting or line sowing

Sowing of fenugreek

Sowing season: September to November
Seed rate: 20-25 kg/ha
Seed treatment: Thiram @ 2gm/kg of seed
Spacing: 20-25 cm x 5-10 cm
Sowing method: Broadcasting or line sowing

Sowing of cumin

Sowing season: Mid November to late December
Seed rate: 90 kg/ha
Seed treatment: Thiram @ 2gm/kg of seed
Spacing: 30 cm x 15 cm
Sowing method: Broadcasting or line sowing

Sowing of fennel

Sowing season: October-November
Seed rate: 9-12 kg/ha
Seed treatment: Thiram @ 2gm/kg of seed
Spacing: 60 cm x 30 cm
Sowing method: Broadcasting or line sowing

Question:

1. **Write about the seed rate and spacing of coriander, fenugreek, cumin and fennel.**

2. **Write about planting of rhizome in turmeric.**

3. **What are the specifications of planting material for ginger transplanting?**

4. Give an idea about sowing of coriander and cumin.

Experiment No.: 9 **Date:**

Transplanting of vegetables and spices

Transplanting of vegetable crops

Objective: Study and acquire knowledge regarding transplanting procedure of vegetable crops

Planting: Planting is raising a crop by using vegetative plant part e.g. tuber of potato, yam and elephant foot yam, bulb of onion, clove of garlic, vine cutting of sweet potato, pointed gourd and little gourd etc.

Transplanting: Transplanting is defined as a process of removing fully germinated seedlings or rooted cuttings from one place (nursery bed, pot and container) to another permanent location (main field) where they grow, produce flowers, fruits and finally harvested.

Requirement of transplanting for vegetable:

i) Vegetable crops viz. tomato, Brinjal, chillies, cabbage, cauliflower, onion, grow successfully wh en they are raised through transplanting of seedlings.
ii) These crops can tolerate transplanting shocks very well.
iii) They have the ability of forming secondary roots (feeding roots) in large number in short period after transplanting.
iv) The period of crop get reduced in the main field.
v) Some vegetable seeds are smaller, lighter and costly.
vi) Good care is taken at initial stage.

Benefits of transplanting:
i) Economic use of seed and land
ii) Ease in raising seedlings on small scale
iii) Considerable seedling growth under controlled condition even during off season
iv) Achievement of uniform plant stand due to availability of healthy transplants
v) Higher yield

Selection of seedlings: Following points need to be considered for selection of seedling at the time of transplanting
i) Seedlings should be stocky and sturdy.
ii) Seedlings should have attained proper age at the time of transplanting.
iii) They should have good root system.
iv) They should be free from insect, pest and disease.

Precautions in transplanting:

i) Nursery bed should lightly be irrigated before 24 hours of uprooting the seedling for transplanting to avoid root injury.
ii) Uprooting of seedling should be followed by transplanting, as far as possible transplanting should be performed in afternoon to avoid high temperature.
iii) At time of transplanting, presence of sufficient soil moisture is essential.
iv) The depth of transplanting should be such that it could accommodate root system properly. There should not be any coiling of root.
v) Seedlings should be planted in position and pressed gently around the base so that air-pockets can be removed from root zone.
vi) While transplanting, additional leaves and root may be trimmed from seedlings, if essential depending on crop.
vii) If necessary, staking of seedling may be done.
viii) In case of onion, de-topping of seedling just before transplanting is beneficial in term of early establishment and higher survival percentage of seedling. 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.

<u>Transplanting of spice crops</u>

Black pepper

Selection of site: For planting black pepper in slopes, the lower half of northern and north eastern slopes are preferred. This will save the vines from sun scorching from southern side during summer.

Preparation of land and planting standards: With the receipt of first rains in May-June, primary stem cuttings of standard trees such as *Erythrina* spp., *Garuga pinnata*, *Grevillea robusta* (silver oak), and seedlings of *Alianthus malabarica* (Matti) are planted in pits of 50 cm × 50 cm × 50 cm size filled with cow dung and top soil. The planting is done at a spacing of 3 m × 3 m which would accommodate about 1110 standards per hectare. The black pepper vines can be trailed on the standards after three years when they attain sufficient height. Whenever E. indica is used as standard, application of phorate 10 G* @ 30 g may be done twice a year (May/June and September/October) to control nematodes and stem and root borer. When *E. indica* and *G. pinnata* are used, the primary stems are cut in March/April and stacked in shade till the stems start sprouting in May.

Planting: Pits of 50 cubic centimeters at a distance of 30 cm away from the base, on the north, eastern or north eastern side of supporting tree are taken with the onset of monsoon. The pits are filled with a mixture of top soil, farmyard manure @ 5 kg/pit and 150 g rock phosphate. Neem cake @ 1 kg, *Trichoderma harzianum* @ 50 g also may also be mixed with the mixture at the time of planting. With the onset of monsoon, 2-3 rooted cuttings of black pepper are planted individually in the pits. Lowering of the vines is a practice followed in many pepper growing regions. In this method, the vines are allowed to trail on support trees up to 1.5 m. Subsequently, the vines are carefully separated from the standard and buried in the soil around the base of the standard ensuring that the growing tip is of the vine is kept above the soil. This practice induces more leader shoots covering the entire standard and production of laterals from the base of the standard.

Cardamom

Preparation of land: All under growth should be cleared and excess shade trees or branches should be thinned out to have an even overhead canopy. Pits of 45 x 45x30-cm size are dug in April-May and filled with a mixture of topsoil and compost or well-decomposed farmyard manure. In slopy land, contour terraces may be made and pots may be taken along the contour. The spacing adopted in K'taka for the Malabar type is 2x2 m between plants and rows. In Kerala region 2-3 on either side is adopted. Staggered trenches may be taken across the slope to conserve run off rainwater. The soil collected in trenches may be utilised for earthing up during the post-monsoon period.

Spacing: Larger types : 2.5 x 2.0 m.
Smaller types : 2.0 x 1.5 m.

Planting: The planting is carried out during the rainy season commencing from June. Under Eastern Ghat hills, July planting is adopted. Seedlings are to be planted upto the collar region for better growth. Cloudy days with light drizzle are ideal for planting.

Clove

Seedlings are ready for transplanting in main field when they are 18-24 months old. Eastern and north eastern hill slopes, well drained valleys and river banks are ideal for clove plantation. Pits of 60-75 cm^3 are dug at a spacing of 6-7 metres. The pits are partially filled with compost, green leaf or cattle manure and covered with top soil. Time of transplanting is June-July or September-October (low lying areas). cloves prefer partial shade and conveniently be grown mixed with commercial crops like areca nut, coconut etc. the shade cast by these plants will provide enough protection to clove plantation from the hot sun.

Question:

1. **Write about the transplanting of black pepper.**

2. Define planting and transplanting. What are the benefits of transplanting?

3. What are the precautions to be taken for transplanting?

Experiment No.: 10 **Date:**

Fertilizer application in vegetables and spices

Objective: Study and acquire knowledge regarding different methods of fertilizer application.

The choice of methods of fertilizer application mainly depends on:

- Kind of soil
- Type of crop
- Nature of nutrient
- Irrigation facility in the area

Fertilizers are applied by different methods mainly for three purposes:

1. Easy availability of nutrients to crop
2. Reducing fertilizer loss
3. Ease in application.

Followings are several methods of applying manures and fertilizers in vegetable crops.

(I) Application of solid form of fertilizers

(II) Application of liquid form of fertilizers

(I) Application of solid form of fertilizers:

(1) Broadcasting: This method includes application of fertilizer by hand with the main objective of spreading it uniformly over the entire field.

Fertilizers are generally applied to soil with the last preparatory tillage just before planting. There are two types of broadcasting depending on the time of application.

(a) Broadcasting at planting or sowing: Fertilizer is broadcasted just before planting/sowing, at the time of ploughing. Phosphoric and potassic fertilizer and half of nitrogenous fertilizer as per recommended dose for a particular crop are applied by broadcasting.

(b) Top dressing: The method of fertilizer application in standing crop is known as top dressing. The objective of this method is to provide the nutrients, mainly nitrogen, in readily available form, for the growth of plants. Topdressing of phosphatic and potassic fertilizers is ordinarily done on pastureland and in orchards or only on fruit trees growing in between agricultural crops. Topdressing with nitrogenous and potassic fertilizer should not be done when the plant leaves are wet. Application in morning before 8 a.m. or just after rain may burn or scorch the leaves.

Disadvantages of broadcasting:

i) Inability in optimum nutrient utilization by plant root

ii) Stimulation of weed growth all over the field

iii) Fixation of Nutrients in soil

(2) Placement: It refers to the placement of fertilizers in soil at a specific place with or without reference to the position of the seed. Placement of fertilizers is normally recommended when the quantity of fertilizers to apply is small, development of the root system is poor, soil has a low level of fertility and to apply phosphatic and potassic fertilizer. The most common methods of placement are as follows:

i) Plough sole placement: In this method, fertilizer is placed at the bottom of the plough furrow in a continuous band during the process of ploughing.

ii) Deep placement: It is the placement of ammonical nitrogenous fertilizers in the reduction zone of soil where ammonical nitrogen remains available to the crop. This method ensures better distribution of fertilizer in the root zone soil and prevents loss of nutrients by run-off.

iii) Localized placement: It refers to the application of fertilizers into the soil close to the seed or plant in order to supply nutrients in adequate amount to the root of growing plants. The common methods are drilling and side dressing.

(3) Band placement: this method involves placement of fertilizer in bands. Band placement can be done in two ways.

i) Hill placement: It is practiced for the application of fertilizers in orchards. In this method, fertilizers are placed close to the plant in bands on one or both sides of the plant. The length and depth of the band varies with the nature of crop.

ii) Row placement: When the crops like sugarcane, potato, maize, cereals etc., are sown close together in rows, the fertilizer is applied in continuous bands on one or both sides of the row and that is known as row placement.

Advantages of placement:

i) Immense reduction of nutrient in soil

ii) Check in weed growth

iii) High residual response of fertilizer

iv) Higher utilization of fertilizers by the plant

v) Reduction in loss of nitrogen by leaching

vi) Better utilization of phosphates

(II) Application of liquid form of fertilizers

1) Starter solution

It refers to the application of solution of N, P_2O_5 and K_2O in the ratio of 1:2:1 and 1:1:2 to young plants at the time of transplanting, particularly for vegetables. Starter solution helps in rapid establishment and quick growth of seedlings.

2) Foliar application

It refers to the spraying of fertilizer solution containing one or more nutrients on the foliage of growing plants. Several nutrient elements are readily absorbed by leaves when they are dissolved in water and sprayed on them. The concentration of the spray solution has to be controlled; otherwise serious damage may result due to scorching of the leaves. Foliar application is effective for minor nutrients like iron, copper, boron, zinc and manganese. Sometimes insecticides are also applied along with fertilizers.

3) Application through irrigation water (Fertigation)

It is defined as the application of water soluble fertilizers through irrigation water. The nutrients are thus carried into the soil in solution. Generally nitrogenous fertilizers are applied through irrigation water.

4) Injection into soil

Liquid fertilizers for injection into the soil may be of either pressure or non-pressure types. Non-pressure solutions may be applied either on the surface or in furrows without appreciable loss of plant nutrients under most conditions.

5) Aerial application.

In areas where ground application is not practicable, the fertilizer solutions are applied by aircraft particularly in hilly areas, in forest lands, in grass lands or in sugarcane fields etc.

Question:

1. **Write about starter solution and fertigation.**

2. **What is placement? What are its advantages?**

3. Define top dressing. What are the disadvantages of broadcasting?

4. What is band placement? What are its types?

Experiment No.: 11 **Date:**

Harvesting of Vegetable Crops

Objective: Study and acquire knowledge of maturity indices and harvesting methods of different vegetable crops.

Harvesting: Harvesting is the final agricultural operation in which whole or parts of plant are removed at a time or at different intervals depending on type of vegetable and demand. In order to achieve high quality product and premium price harvesting should be done at proper stage. Early or delayed harvesting may result less yield, quality deterioration and low price in market.

Method of harvesting: In India vegetables are harvested by hand employing human labour and not mechanically as in other countries abroad. There are some traits that facilitate easy harvesting by hand, like dwarf plant in okra, determinate growth habit of tomato and French bean, short vine length in cucurbits, thorn less stem or pedicel/calyx in egg plant, non-hairy (smooth) fruits in okra, smooth leaf in radish, concentrated fruit set and joint less fruit in tomato. Hand picking enables selective harvest. Diseased, over mature, immature, defective, blemished, broken or damaged products can be rejected in the field. Harvested vegetables are kept under shade before packing and should not be placed in the sun, especially in hot weather. Normally vegetables are harvested in afternoon or evening to avoid sun and excessive heat damage.

Merit of harvesting at proper stage:

a) High market price

b) High yield

c) Product with good quality and flavour

d) Less damage by insect, pest and disease

e) Protection from high and / or low temperature effect

f) Increment in shelf life

Factors effecting harvesting of vegetable crops:

a) The stage of plant development and time of harvesting

b) Method of harvesting

c) Type of crop

d) Weather condition at the time of harvesting

e) Distance of market

f) Type of transportation

g) Purpose of harvesting

h) Length of time required to reach the consumer

Table: Maturity indices of different vegetable crops

Name of crop	Days required for harvesting after sowing	Optimum plant stage for harvesting
Cole crop		
Cabbage	100-120	Full sized solid and compact head
Cauliflower	100-130	Fully developed compact curd
Fruit vegetables		
Brinjal	70-80	Fully developed tender immature fruit
Chilli	60-90	Fully developed tender immature fruit for vegetable / salad purpose. Green or ripe fruit for pickle purpose. Full ripe fruit for drying and powder making.
Tomato	90-120	Mature green or turning or pink stage for distant market. Pink or red ripe fruit for local market and table purpose. Fully red ripe stage for processing purpose.
Okra	70-90 (Rainy) 45-50(Spring summer)	Fully developed tender immature fruit (5-7 cm long fruit)
Legumes		
Cluster bean	50-60	Fully developed tender immature pod
Cowpea	40-50	Fully developed tender immature pod
French bean	40-50	Full sized pod before seed bulge
Indian bean	60-70	Fully developed tender immature pod
Pea	100-130	Full sized immature green pod with well developed seed
Root crops		
Carrot	60-70	Well developed root with full colour development
Radish	25-30(Tropical) 45-60(Temperate)	Full sized root before becoming pithy
Beetroot	60-80(Early) 90-120(Late)	Root about 5 cm in diameter, not over mature
Tuber vegetables		
Colocasia	1.60-70(Partial harvesting) 2.125-150(final) 3.45-60 (Leave)	Immature corm Fully mature corm Tender leaf
Yam	225-250	Developed corm
Potato	Early: 60-70 Mid: 70-90 Late: 90-120	Fully developed tuber Fully developed tuber Fully developed tuber
Sweet potato	80-90 120-150	Immature , half grown tuber Fully developed mature tuber
Bulb crops		
Onion	60-70 70-80 80-120	Onion green Immature bulb Fully mature bulb
Garlic	130-150	Fully mature bulb

Cucurbits		
Cucumber	60-70	Fully developed tender immature fruit
Gourd	60-90	Fully developed tender immature fruit
Musk melon	60-90	Full slip stage
Watermelon	60-90	Dull sound on thumping, brown dry tendril near the fruit, ground spot becomes yellow
Pointed gourd	90-120	Fully developed tender immature fruit
Little gourd	120-150	Fully developed tender immature fruit
Pumpkin	100-130	Full-sized fruit
Leafy vegetables		
Amaranthus, Palak, Spinach, Fenugreek,	25-30	Fully developed green tender succulent leaf before turning yellow
Lettuce	70-90	Fully developed green tender succulent leaf before turning yellow
Celery	120-140	Fully developed green tender succulent leaf before turning yellow

Question:

1. **Write down the maturity indices of tomato, cauliflower, palak and beetroot.**

2. **Write down the harvesting method of vegetables.**

3. **Define harvesting. Write about the merits of harvesting at proper stage**

4. **Write down the maturity indices of chilli, onion and cucurbits.**

Experiment No.: 12 **Date:**

Harvesting of Spice Crops

Objective: Study and acquire knowledge of maturity indices and harvesting methods of different spice crops

Black pepper

Black pepper takes about 7-8 months after flowering to reach full maturity. In Indian plain the crop is harvested during December–January and January-April in the high ranges of Western Ghats. It is important to harvest the crop at proper stage of maturity in order to achieve a dried product of good colour and appearance. Harvesting starts when one or two berries turn yellow or red. The spikes are nipped of by hand and collected in bags. Normally, single pole bamboo ladder is used as a support for harvesting. If the berries are allowed to over ripe in plant, there may be heavy loss due to berry drop and damage by birds. Harvested spikes are generally collected in clean gunny bags. Spikes which are fallen on to the ground may be collected separately, cleaned and then pooled to the general lot.

Cardamom

In general, cardamom starts yielding from 2-3 year onwards and the yield stabilizes after 4th year. Reports suggest that the high yielding varieties can yield dry cardamom @120 kg/ha, 360 kg/ha and 510 kg/ha during the second, third and subsequent years respectively. Timely harvest and scientific post harvest operations are the factors affecting the quality of the produce. Capsules, which are just about to ripe, should be handpicked at fortnight intervals. This should be followed by various unit operations such as washing, drying, cleaning, grading, packing and marketing of the produce. Cardamom is traded as bulk and graded produce. It is graded by using sieves and the price is based on the size, colour and freshness. The 7mm and above grades with fancy green colour commands a premium price in the market.

Ginger

The crop is ready for harvesting in about 8 to 10 months depending upon the maturity of the variety. When fully mature the leaves turn yellow and the pseudo stems begin to dry. Rhizomes are lifted either with a digging-fork or with a spade. They are cleaned of roots and adhering soil particles. The green ginger is soaked in water to facilitate the removal of the skin. The skin is scraped off with pieces of sharpened bamboo. The scraped produce is washed and dried in the sun for 3 or 4 days and hand-rubbed. It is again steeped in water for two hours, dried and then rubbed to remove all the remaining bits of the skin. Sun-drying also bleaches the produce. Peeling should be done with great care and skill. The essential oil which gives ginger the aromatic character is present in the epidermal cells and hence excessive or careless scraping will result in damaging these cells leading to the loss of essential oil. Steel knives are not used as they are found to stain the produce. Storage of dry ginger for longer periods is not desirable. The yield of dry ginger is 15-25 percent of the fresh ginger depending upon the variety and location where the crop is grown. Burning of sulphur for processing ginger is not allowed.

Turmeric

The crop has to be harvested at the right maturity and is ready for harvesting in about 7 to 9 months after sowing depending upon the variety. The aromatic types mature in about 7 months, the intermediate types in about 8 months and the late types in about 9 months. Usually the land is ploughed and the rhizomes are gathered by hand picking or the clumps are carefully lifted with a spade. Harvested rhizomes are cleaned of mud and other extraneous matter adhering to them. The average yield per acre is 8 -10 tonnes of green turmeric. Fingers are separated from mother rhizomes. Mother rhizomes are usually kept as seed material. The green turmeric is cured for obtaining dry turmeric. Curing involves boiling of rhizomes in fresh water and drying it in the sun.

Coriander

The crop requires 90-110 days to be harvested. Harvesting should be done when the fruits are fully ripe and start changing from green to brown colour. The plants are cut or pulled and piled into small stacks in the field to wither for two to three days. The fruits are then threshed out from the plants by beating with sticks or rubbing with hands. The produce is winnowed, cleaned and dried in partial shade. After drying the produce is stored in gunny bags lined with paper.

Fenugreek

Crop becomes ready for harvesting in about 120-150 days. At the time of ripening or maturity, leaves and pods become yellowish and leaves start falling. Timely harvesting is very important for this crop as late harvest leads to seed losses due to pod bursting, while in early harvest, the grains remain immature and small. Harvesting should be done early in the morning. When pods are dried the plants are pulled out, dried in the sun and seeds are threshed by beating with stick or by rubbing with hands. Seeds are winnowed, cleaned and dried in the sun. They may be stored in gunny bags lined with paper.

Cumin

The crop matures 100-110 days after sowing and leaves become yellow. Plants are uprooted and stacked in small bundles for sun drying. The grains are separated by beating with light sticks and cleaned by winnowing. Yield is about 550 kg/ha. The clean seeds are stored in gunny bags.

Fennel

Crop matures in seven to eight months. Harvesting should be done before fruits are fully ripe i.e., fruits turn yellow colour, cut the stems along with umbel (inflorescence) and dry in sun for 4-5 days, thresh the fruits and clean by winnowing, yield is 250-400 kg/ha.

Clove

Clove tree begins to yield from seventh or eighth year after planting and full bearing stage is attained after about 15 to 20 years, the flowering season is September-October in plains and December to February at high altitudes. Flower buds are produced on young flush. It takes about 4-6 months for the buds to become ready for harvest. At this time, they are less than 2 cm long. The optimum stage for picking clove buds is indicated by the change in the colour from green to slightly pinkish tinge. The matured clove buds are carefully picked with hand. Care should be taken to pick the buds at the correct time as otherwise the quality of the cured produce will be lost to a considerable extent. When the trees are tall and the clove bunches are beyond the reach, platform ladders are used for harvesting. Bending the branches or knocking down the bud clusters with sticks is not desirable as these practices affect the future bearing of the tree.

Question:

1. **Write down the maturity indices of black pepper, coriander, ginger and clove.**

2. **Write down the harvesting of two seed spice.**

3. Write down the harvesting of turmeric and ginger.

4. Write down the harvesting method of black pepper and clove.

Experiment No.: 13 **Date:**

Grading and packaging of vegetables and spices

Objective: Study and acquire knowledge regarding sorting, grading and packaging of vegetables and spices

Sorting:

Sorting is often combined with grading, but in some applications both phases are separated from each other and the sorting phase is only for removing produce with surface deformities or blemishes and foreign / unwanted objects.

Grading:

Grading is an essential step in post harvest management to categorize or rank harvested vegetable and spice into different classes or groups according to the physical traits like size, shape, colour, weight and volume to fetch high price in market.

For International market three general grades are considered as 1. Extra class 2. Class I and 3. Class II

1. Extra Class: The extra class is of superior quality having excellent shape and colour of the variety and without internal defect likely to affect the inherent texture and flavour. A 5% tolerance is allowed for errors.
2. Class I: The grade is almost like Extra Class except that a 10% tolerance for error is allowed. Individual product is allowed a slight defect in shape, colour and negligible skin defect which do not affect the general appearance for keeping quality.
3. Class II: This class may exhibit some external or internal defects provided they are fit for consumption while fresh. This class is best fitted for local or short distant market. This category satisfies the needs of customers who are not too demanding and for whom price is more important than quality.

Advantages of Grading:

1. Avoidance of low selling price due to presence of substandard products or specimen.
2. Increase in marketing efficiency by facilitating buying and selling a produce without personal selection.
3. Setting of good price for graded products.
4. Avoidance of heavy marketing cost in packing and transportation.
5. Preference of consumers towards graded products without inspection

Grading of Vegetables:

The fruit vegetables such as bitter gourd, okra, bell pepper, brinjal, green chill etc. are graded on the basis of size into three classes as small medium and large. Tomato is graded on the basis of colour. However, only a few vegetables are specifically graded based on ISI grades directed by international market.

Tomato: After removing green, overripe, rotten, injured and defective tomato fruits, they are ranked into four grades as specified by ISI *viz*. Super A, Super, Fancy and Commercial.

Brinjal: As per ISI recommendation, brinjal fruits are categorized into three grades *viz*. Super, Fancy and Commercial.

Potato: Grading of potato tuber is done on the basis of diameter considered at the longer axis. Grading is done very efficiently and accurately by potato grader. After discarding oversized and under-sized tubers, the remaining healthy tubers are categorized into A (5-6 cm), B (3.5-5.0 cm), C (2.5-3.5 cm) and D (2.5-3.5 cm) grades. All the above grades are accepted for seed as well consumption purpose.

Grading of Indian cardamom:

Grades with specifications for Indian cardamom					
Grade	**Description**	**Size (mm)**	**Weight (gm/l)**	**Colour**	**General features**
AGB	Extra bold	7	435	Green	Kiln dried, 3 cornered and with ribbed appearance
AGS	Superior	5	385		
AGS 1	Shipment	4	320-350	Light green	
AGL	Light	3.5	260		
CGEB	Extra bold	8	450	Golden to light green	Round, ribbed or smooth skin
CGB	Bold	7.5	435		
CG-1	Superior	6.5	415	Light green	
CG-2	Mota, green	6	385	Green	
CG-3	Shipment	5.5	350	Cream	
CG-4	Light	3.5	280	Brown	
BL-1	-	8.5	340	Pale	Fully developed round, 3 cornered ribbed or smooth skin
BL-2		7	340	Creamy	
BL-3		5	300	Dull white	

Packing:

Packaging is defined as a method by which fresh produce or processed product reach to ultimate consumer from the production centre in safe & sound condition at an affordable price. It is an important consideration to prolong the shelf-life of vegetables and spices due to protection provided by the packages from external injuries and from being shrivelled. Adequate packaging with effective marketing can reduce the post harvest losses considerably. Different vegetables and spices require different types of packages depending upon their physical, anatomical and physiological traits. The common packages like wooden box, wire-bound box, bamboo basket, arhar (*Cajanus cajan*) stick basket, corrugated fibre board box, plastic crate, jute bag, polyethylene film, paperboard box lined with polyethylene etc. can effectively be used for packaging of vegetables and spices.

Merits of packing:

- Packed products are not subjected to immediate losses.
- They maintain their freshness for considerable period.
- Packed products have good demand and fetch comparatively high price
- Packed products are conveniently transported.
- Packed products are protected from dust and dirt and wilting.
- Packing avoids much of the labour cost and wastage during handling.

Characteristics of good packing:

- It is convenient and cheap.

- It has some aeration.
- It is attractive.

A good packing is suitable for distant transportation, loading and staking, with security and economy of space. A good packing is neither loose nor too tight because both are harmful.

Kind of packing: In India, much attention is not given on packing of vegetables and spices for home consumption. However, for export marketing it is done in proper manner because good packing carries good impression on good quality. Most commonly in India, packing is done in (a) Gunny bags (b) basket made of bamboo (c) wooden boxes (d) plastics containers (e) polythene bags (f) cartons made of cardboard. Vegetables like green chillies, brinjal, Indian bean, spine gourd, little gourd and bottle gourd are packed in 3-Ply or 5-Ply corrugated fibre board (CFB) boxes with ventilation holes depending upon the capacity. The capacity of box varies from 5kg to 7kg to 10 kg. Vegetables like colocasia are packed in capacity of 5kg and yams are packed in capacity of 10kg to 15kg gunny bags. Curry leaves are packed in plastic pouches of 30gm capacity with ventilation holes and then placed in 3-Ply CFB box. The potatoes are packed in Hessian bags (Jute bags) of the capacity of 25 kg. For vegetables like broccoli, celery, Brussels sprout and cherry tomatoes, since the export is negligible, the current packages are not available.

Packing of vegetables and spices in India as per market:

(a) Packing for distant markets:

For sending to distant markets, products are packed in bamboo baskets like okra, cluster bean, chillies, cabbage and cauliflower. Dry grasses and leaves are also used as inside the containers. Potato, sweet potato, onion and garlic are packed in gunny bags.

(b) Packing for local market:

Practically, vegetables are not packed for selling in local markets. Vegetables are carried in full of basket, gunny bags and plastic crates. These are taken out and arranged properly for sale.

(c) Packing for consumers:

In India, no packing is done for consumers. People go to market for purchasing vegetables along with hand bag, sometimes sellers giving vegetables in polythene bags.

Question:

1. **Define sorting and grading.**

2. Write about the grading of tomato, brinjal and potato.

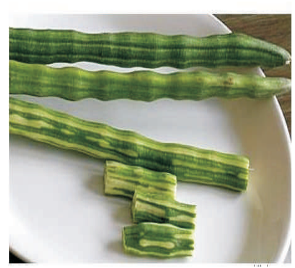
3. Define packaging. Write down its advantages.

4. Write down different packages / packaging materials used in packing of vegetables and spices.

APPENDIX-I

CROP	SEED	CROP	SEED
			
TOMATO		**BRINJAL**	
			
CHILLI		**POTATO**	
			
OKRA		**BOTTLE GOURD**	
			
WATERMELON		**CUCUMBER**	
			
RIDGE GOURD		**SPONGE GOURD**	

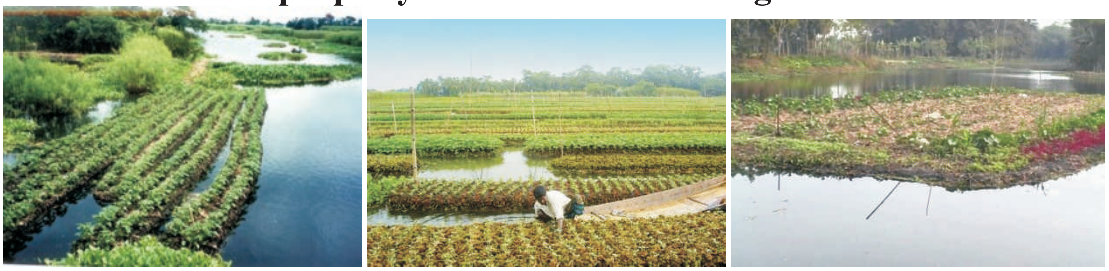
CROP	SEED	CROP	SEED
			
BITTER GOURD		POINTED GOURD	
			
MUSKMELON		CABBAGE	
			
CAULIFLOWER		PEA	
			
CLUSTER BEAN		COWPEA	
			
RADISH		CARROT	

CROP	SEED	CROP	SEED
			
BEET ROOT		ONION	
			
GARLIC		PALAK	
			
AMARANTHUS		SWEET POTATO	
			
CURRY LEAF		DRUM STICK	

APPENDIX-II			
CROP	**SEED**	**CROP**	**SEED**
			
TURMERIC		**GINGER**	
			
BLACK PEEPER		**CINNAMON**	
			
CLOVE		**ALLSPICE**	
			
NUTMEG		**MACE**	

CROP	SEED	CROP	SEED
			
SMALL CARDAMOM		SAFFRON	
			
TEJPAT		ASAFOETIDA	
			
CORIANDER		CUMIN	
			
FENUGREEK		FENNEL	

A properly maintained Kitchen garden



Different floating gardens in India

Floating garden market on Dal lake, Kashmir, India

Hydroponic system of vegetable cultivation

Sowing of vegetable seed on raised nursery bed

Sowing of vegetable seed on flat nursery bed

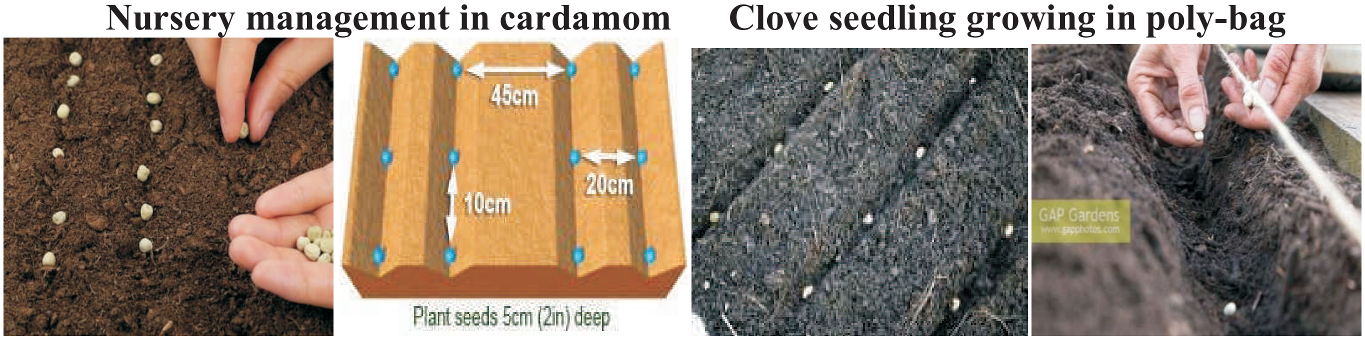
Soil solarization techniques for nursery bed

Vegetable seedling growing on plug pro tray

Nursery management for production of runner shoot cutting in black pepper

Nursery management in cardamom

Clove seedling growing in poly-bag



Seed sowing strategies in leguminous crops

Different sowing methods in cucurbits

Planting materials (mother and finger rhizome) in turmeric

Planting materials (mother and finger rhizome) in ginger


Transplanting of vegetable seedling manually and mechanically

Broadcasting

Row placement

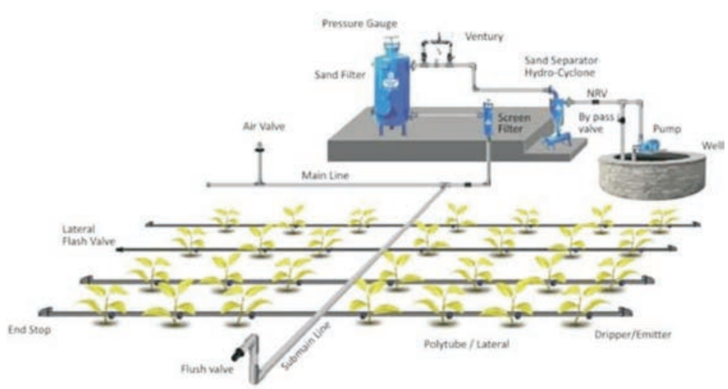
Hill placement

Drilling

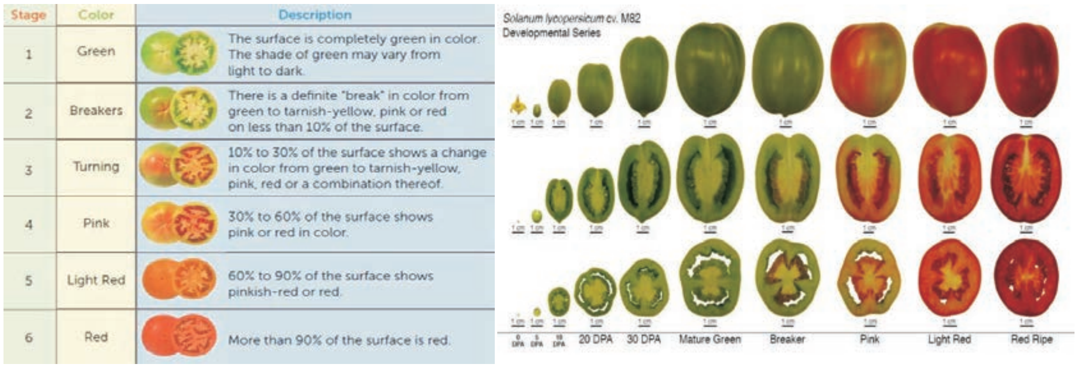
Side dressing

Starter solution

Foliar application



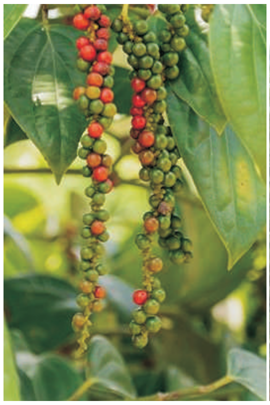
Fertigation (with drip irrigation system)



Stage	Color	Description
1	Green	The surface is completely green in color. The shade of green may vary from light to dark.
2	Breakers	There is a definite "break" in color from green to tarnish-yellow, pink or red on less than 10% of the surface.
3	Turning	10% to 30% of the surface shows a change in color from green to tarnish-yellow, pink, red or a combination thereof.
4	Pink	30% to 60% of the surface shows pink or red in color.
5	Light Red	60% to 90% of the surface shows pinkish-red or red.
6	Red	More than 90% of the surface is red.

Different harvesting stages of tomato

Maturity indices of watermelon



Maturity indices and harvesting of black pepper



Harvesting of cardamom



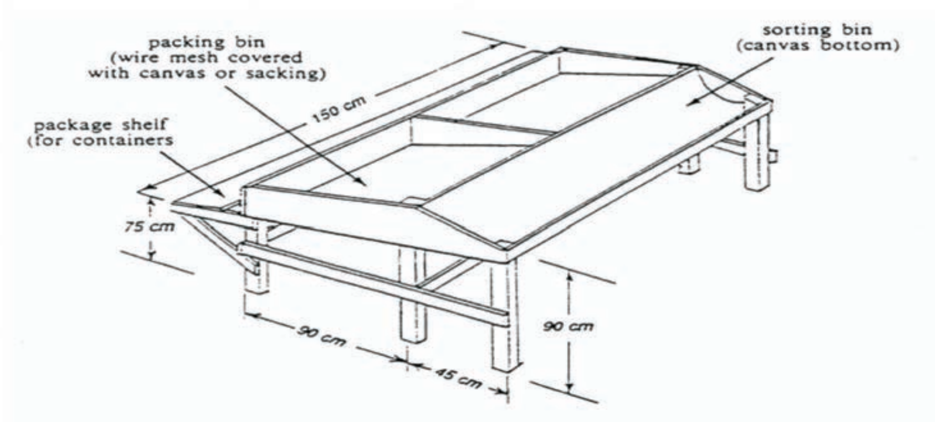

Maturity indices and harvesting of turmeric and ginger

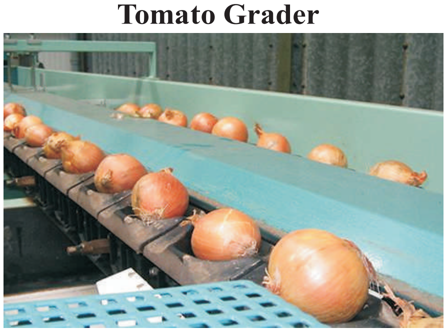
Maturity indices and harvesting of coriander, fenugreek, cumin and fennel

Maturity indices and harvesting of clove

Tomato Grader

Sorting Bench





Onion Grader

Potato Grader

Sweet potato sorter

Gunny bag

Bamboo basket

Plastic crate

Wooden box

Polyethylene packaging

Corrugated fibre box

ICAR

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE WAGHAI

Practical Manual

Pl. Phy. 3.1

Fundamentals of Crop Physiology

Third Semester, B.Sc. (Hons.) Agri.

:: Prepared By ::

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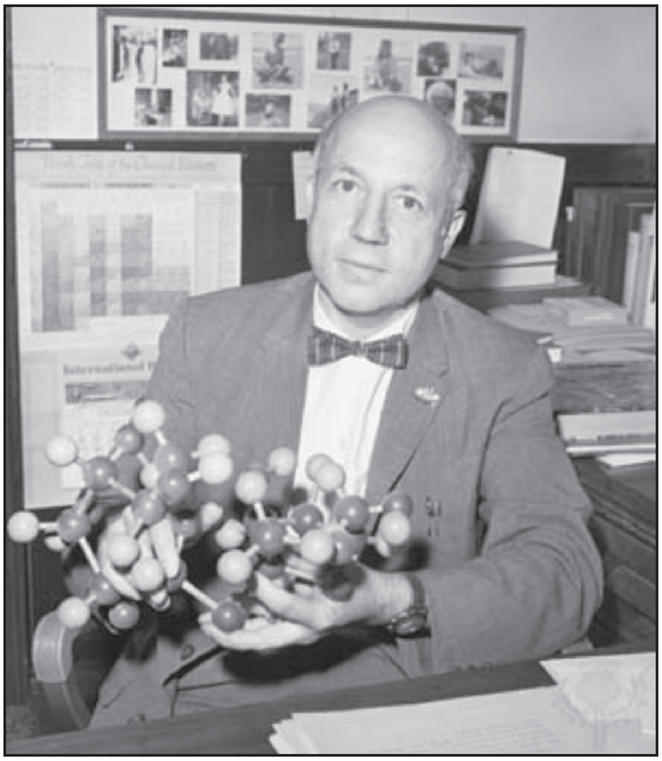

Melvin Calvin

April 8, 1911 | January 8, 1997

Hans Krebs

25 August 1900 | 22 November 1981

Stephen Hales

(Father of Plant Physiology)

17 September 1677 | 4 January 1761

Jagadish Chandra Bose

(Father of Indian Plant Physiology)

30 November 1858 | 23 November 1937

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CERTIFICATE

Reg. No. : ____________ Batch No.: _____________

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This is to certify that Mr. /Miss______________________________ studying in **Third** semester **B. Sc. (Hons.) Agriculture** has satisfactorily carried ______ out of _____ required practical exercises in the course of **Pl. Phy. 3.1 : Fundamentals of crop Physiology (2 + 1)** at Department of Genetics and Plant breeding, College of Agriculture, NAU., Waghai during the year _________________.

Course Teacher **External Examiner**

Index

Experiment : 1

To study various types of plant cell

- **Cell** (Greek word ***cellula*** means '**a small compartment**') is the structural and functional unit of all living organisms. It is a mass of protoplasm (cytoplasm with nucleus) surrounded by thin membrane containing nuclei and subcellular organelles *like* mitochondria, endoplasmic reticulum, ribosomes, plastids, golgi body.
- **Robert Hooke** (1665) coined the term cell that used a crude microscope and observed the texture of **cork's thin section** as composed of small spaces surrounded by cell wall.
- The size of cell varies widely. The smallest cell so found is of bacteria measuring 0.1µm in diameter and the largest cell is the Ostrich egg which is about six inches in diameter. Acetabularia is the largest unicellular plant. Plant cell have a rigid cell wall so shape of plant cell is fixed.

Table 1.1: Important discoveries on structure and functions of cell organelles

Year	Scientist	Discoveries
1665	Robert Hooke	First coined the term **cell.**
1670	Antony Vanluewen Hock	Observed some organization within the cell particularly nucleolus in red blood cell.
1831	Robert Brown	Discovered the nucleus.
1838	J. Schleiden	Discovered nucleolus.
1839	M.J. Schleiden & Theodar Schwann	Established the cell theory
1843	Albert Kolliker	Recognised jelly like substance in the cell known as cytoplasm
1846	Hugo Von Mohl	Suggested that cytoplasm and nucleus could be called as protoplasm
1886	R.Altmann	Discovered mitochondria and given the term bioplast
1897	C. Benda	Studied the bioplast and given name mitochondrion.
1898	Camilo Golgi	Studied Golgi apparatus

Cell Theory

Cell theory was given by **M.J. Schleiden & Theodar Schwann (1839)** along with Rudolf Virchow contributed to the theory and following theory has been proposed:

1. All living things are composed of cells and cells are the morphological and physiological unit of all living organisms.
2. All cells arise from pre-existing cells.
3. All cells are basically alike in chemical composition and metabolic activities.
4. The function of an organism as a whole is the outcome of the activities and interaction of the constituent cells.

Virus, viroids and mycoplasma do not fit in the definition of cell. These are often described as living chemicals.

Cellular organization

There are two well recognized types of cellular organization i.e. ***Prokaryotes*** and ***Eukaryotes***

Table 1.2: Differences between prokaryotic and eukaryotic cells.

Character	Eukaryotes	Prokaryotes
Cell wall	Cellulosic in plant cell, absent in animal cell	Non cellulosic, composed of amino sugar and muramic acid
Nucleus	Absent. Instead, they have a nucleoid region in the cell	Present
Cell size	Ranges in size from 0.2 µm – 2.0 µm in diameter	Size ranges from 10 µm – 100 µm in diameter
DNA arrangement	Circular	Linear
Mitochondria	Absent	Present
Cytoplasm	Present, but cell organelles absent	Present, cell organelles present
Endoplasmic reticulum	Absent	Present
Plasmids	Present	Very rarely found in eukaryotes
Ribosome	Small ribosomes	Large ribosomes
Lysosome	Lysosomes and centrosomes are absent	Lysosomes and centrosomes are present
Cell division	Through binary fission	Through mitosis
Flagella	The flagella are smaller in size	The flagella are larger in size
Reproduction	Asexual	Both asexual and sexual
Example	Bacteria and Archaea	Plant and Animal cell

Important functions of plant cell organelles

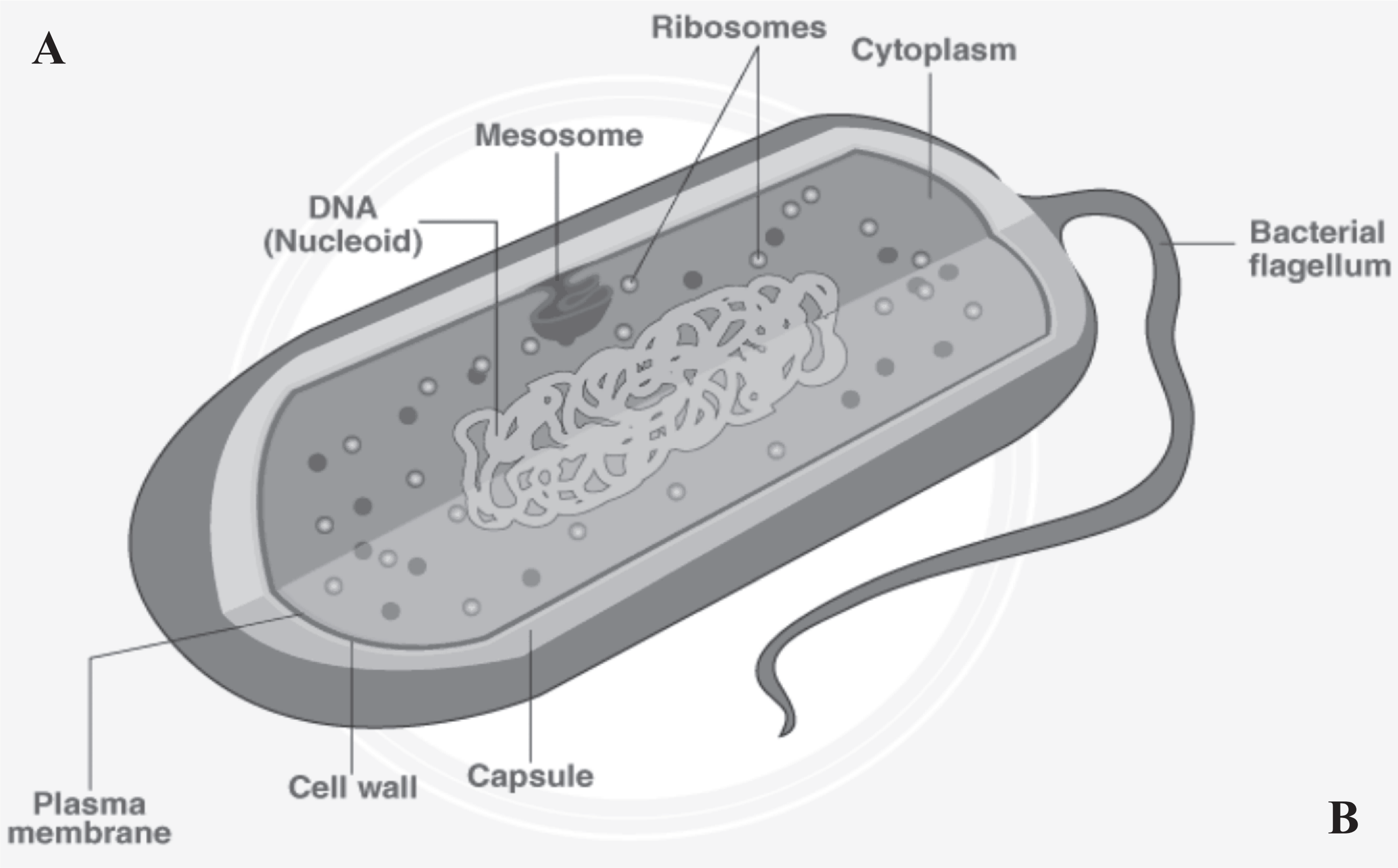
A Plant cell is consist of three parts *i.e.* **cell wall, protoplasm and vacuoles**. **Cytoplasm and nucleus together are called as protoplasm**. Cell wall and vacuoles are considered as non-living components of a plant cell. The important functions of cell organelles are enlisted in table 1.3

Table 1.3: Important functions of plant cell organelles

Part of plant cell	Function
Cell wall	Main function is mechanical support. Involved in water and some solutes transport
Plasma membrane	Control movements of solutes in and out of the cell acts as a selectively permeable membrane.
Cytoplasm	Responsible for the cell's metabolic activities.
Nucleus	Controls the activity of the cell, helps in cell division and controls the hereditary characters.
Vacuoles	Helps in maintain turgor pressure, provide shape and rigidity to the plant cell

Chloroplasts	Sites of photosynthesis.
Mitochondria	The main sites of cellular respiration, power house of cell
Endoplasmic Reticulum	Forms the skeletal framework of the cell, involved in the Detoxification, production of Lipids and proteins.
Golgi apparatus	It is mainly involved in secretion and intracellular transport.
Centrosomes	It plays a major role in organizing the microtubule and Cell division.
Plastids	Double membrane-bound organelles. There are 3 types of plastids: **Leucoplast –** Colorless plastids. **Chromoplast**–Blue, Red, and Yellow color plastids. **Chloroplast –** Green coloured plastids.
Peroxisome	Involved in the photorespiration and metabolism of lipids and catabolism of long-chain fatty acids.
Lysosomes	Helps in the digestion and removes wastes and digests dead and damaged cells. Therefore, it is also called as the "suicidal bags".
Ribosomes	Involved in the Synthesis of Proteins.

Cell organelles	Animal Cell	Plant cell
Cell wall	Absent	Present
Vacuoles	Absent	Present
Chloroplast	Absent	Present
Centrosome	Present	Absent



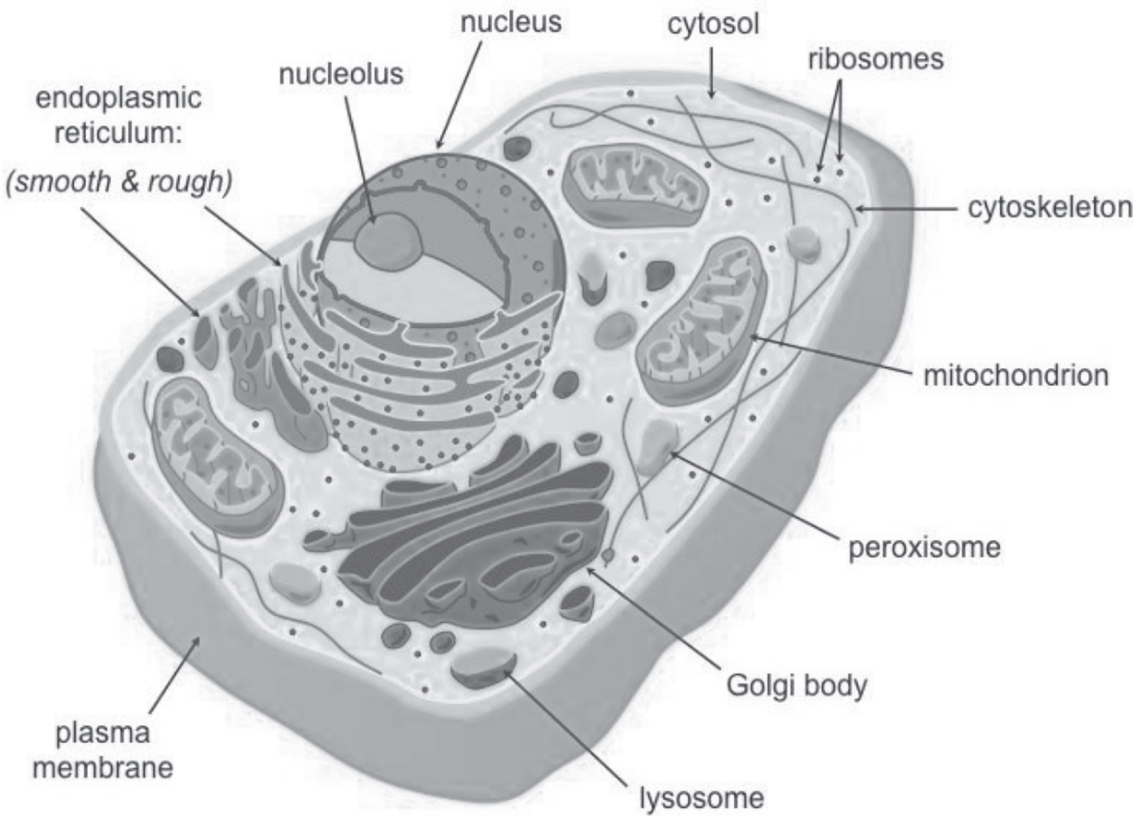


Fig.1.1. Diagramme of A) Prokaryotic cell B) Eukaryotic cell

Preparation of Temporary Mounts of an Onion Peel

Objective: To prepare a stained temporary mount of an onion peel and to record observations and draw labelled diagrams.

Apparatus and materials required: An onion, glass slide, watch glass, coverslip, forceps, needles, brush, blade, filter paper, safranin, glycerine, dropper, water, and a compound microscope.

Procedure

1) Take an onion and remove its outermost peel.
2) Now cut a small part from an inner scale leaf with the help of a blade.
3) Separate a thin, transparent peel from the convex surface of the scale leaf with the help of forceps.
4) Take a clean slide and put a drop of safranin in the centre of the slide.
5) Keep this peel in a watch glass containing water
6) Add two drops of safranin stain in the watch glass to stain the peel.
7) With the help of a brush and needle transfer the peel on the slide. Glycerine prevents the peel from drying up.
8) Carefully cover it with a coverslip and avoid any air bubble from entering interring the coverslip.
9) Remove any excessive glycerine with a filter paper.
10) Observe the prepared mount of the peel under the low and high magnification of a compound microscope.

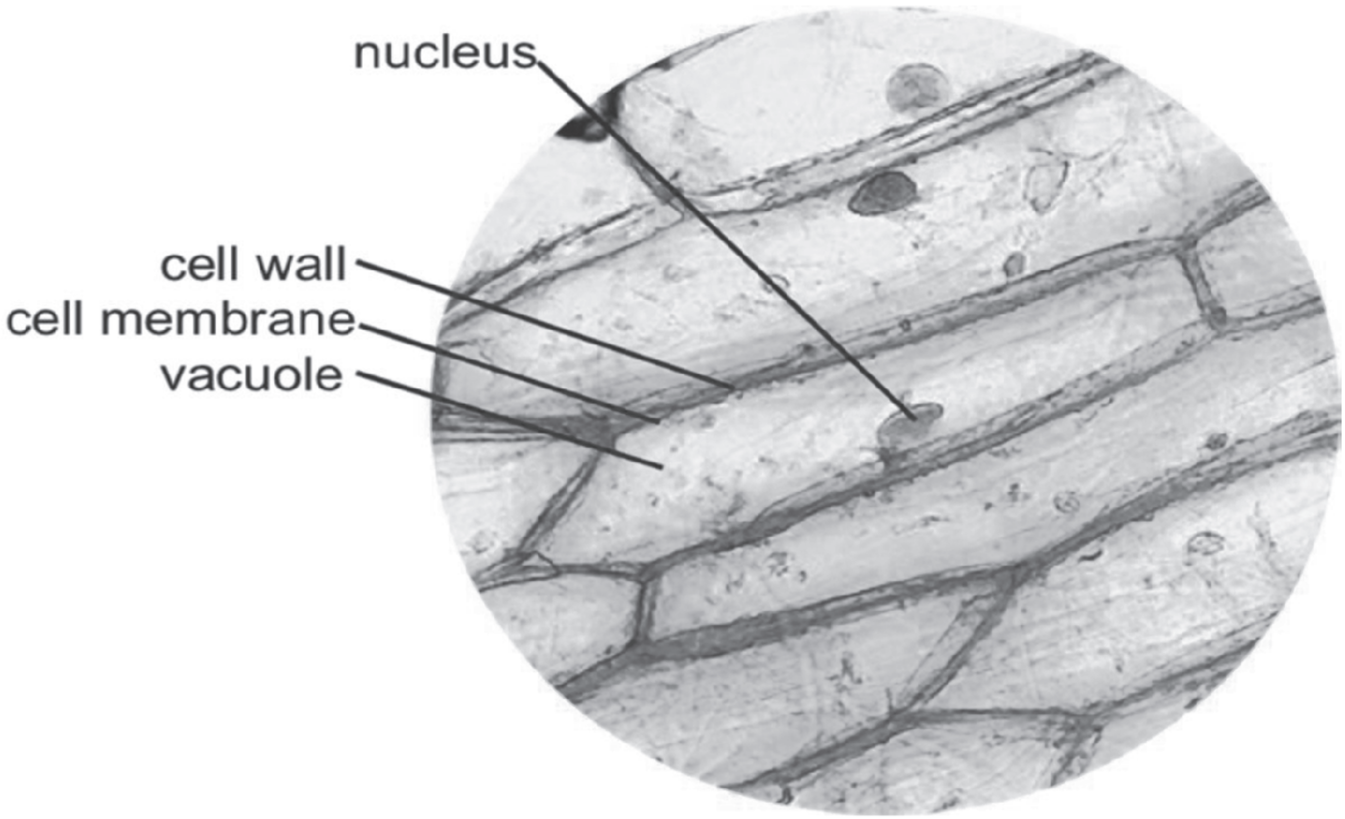


Fig.1.2. Diagramme of onion peel cell

Experiment : 2

To demonstrate the process of osmosis

It was first discovered by **Abbe Nollet** in the year 1748. The importance of osmosis in plant physiology was recognized by **Traube** (1867) developed a crude chemical semi permeable membrane. Osmosis is special kind of diffusion of solvent (through semipermeable membrane. **Osmosis is the process of movement of solvent (water) molecules from the region of lower concentrated solution to higher concentrated solutions through semipermeable membrane.**

Or.

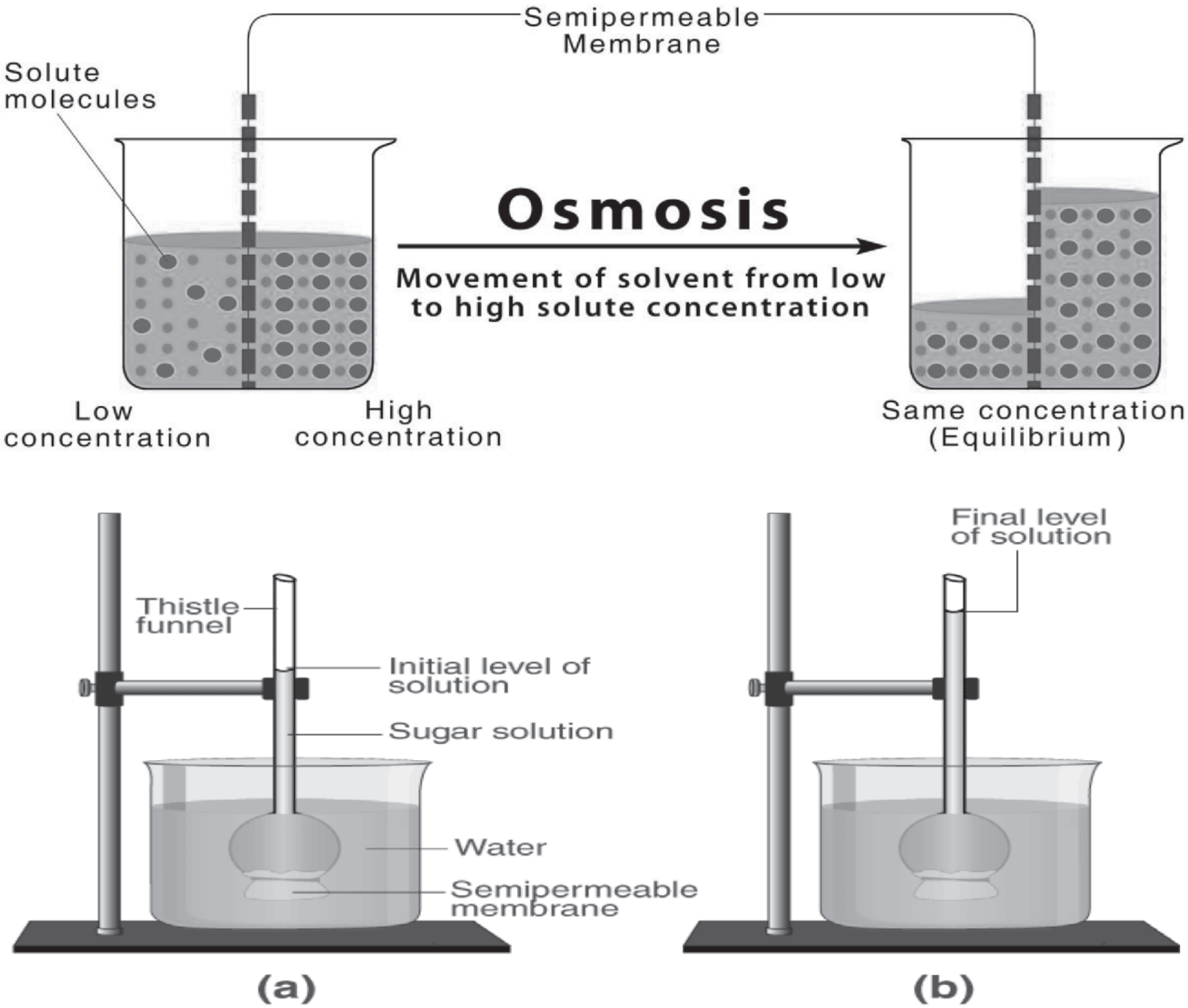
When two solutions of different concentrations are separated by a selectively permeable membrane, diffusion of water or solvent molecules takes place from the solution of lower concentration to the solution of higher concentration. When pure water is separated from a solution by a semi permeable membrane, pure water tends to enter into the solution by osmosis and create pressure in solution which known as **osmotic pressure or osmotic potential.** It is one components of water potential which become more negative with addition of solute.

Osmotic pressure is directly proportional to concentration of dissolved solutes in solution more concentrated solution has higher osmotic pressure. Osmotic pressure increase with in temperature increase. **Osmosis measured in terms of atmosphere.** The living cells in plants form osmotic system due to presence of semi-permeable membrane and cell sap always has certain osmotic pressure.

Types of membrane

1. **Permeable:** This kind of membrane allows both solvent and solute molecules through them. E.g. cell wall.
2. **Impermeable:** This kind of membrane prohibit the diffusion of both solvent and solute molecules through them e.g. Casparian strip endodermis of root
3. **Semi permeable:** This kind of membrane allows diffusion of solvent molecules only. E.g. membrane of collodion of parchment paper
4. **Selectively or differentially permeable:** This kind of membrane allows (select) some substance to pass through it much more readily than others. E.g. Plasma membrane of plant cell, tonoplast and membrane surrounding cell organelles.

Diffusion	Osmosis
Occurs in liquid, gas and even solids.	It is limited only to the liquid medium.
Does not require a semipermeable membrane.	Requires a semipermeable membrane.
Depends on the presence of other particles.	Depends on the number of solute particles dissolved in the solvent.
Does not require water for the movement of particles.	Requires water for the movement of particles.
Both the molecules of solute and solvent can diffuse.	Only the solvent molecules can diffuse.
The flow of particles occurs in all the directions.	The flow of particles occurs only in one direction.



To demonstrate the process of osmosis

Importance of osmosis in plants

1. The absorption of large amount of water by root hairs occurs through osmosis.
2. It helps in movement of absorbed water from one cell to another cell.
3. It maintains the water balance inside the cell for metabolic activities.
4. Maintains the form and shape of cell and thus keeps the plasma membrane near the cell wall.
5. The expansion of cell is dependent upon turgidity which itself is dependent upon osmosis.
6. Plant showing resistance to drought and frost have higher osmotic pressure, thus, helping the cells not allowing to loss water too easily and depress the freezing point of the cell sap preventing ice formation.

Demonstration of Osmosis by Potato Osmoscope

Objective: To demonstration of osmosis using a potato osmometer **and to record observations.**

Apparatus and materials required: A Large potato without peel, petridish, pin, knife, distilled water, 20% sugar solution

Procedure

1. First peeled potato using the knife cut both ends of the potato to make it flat.
2. Use the knife to make a cavity at the center of the potato from one of the flat sides almost up to the bottom.
3. Pour distilled water into the Petri dish until it is half full.
4. Now, place the potato in the Petri dish.
5. Fill half the cavity made in the potato with 20% sugar solution.
6. Mark the level of sugar solution in the cavity using a pin.
7. The potato now functions as an osmometer.
8. Leave the osmometer undisturbed for about two hours.
9. Mark the rise in the level of the sugar solution in the cavity with another pin.

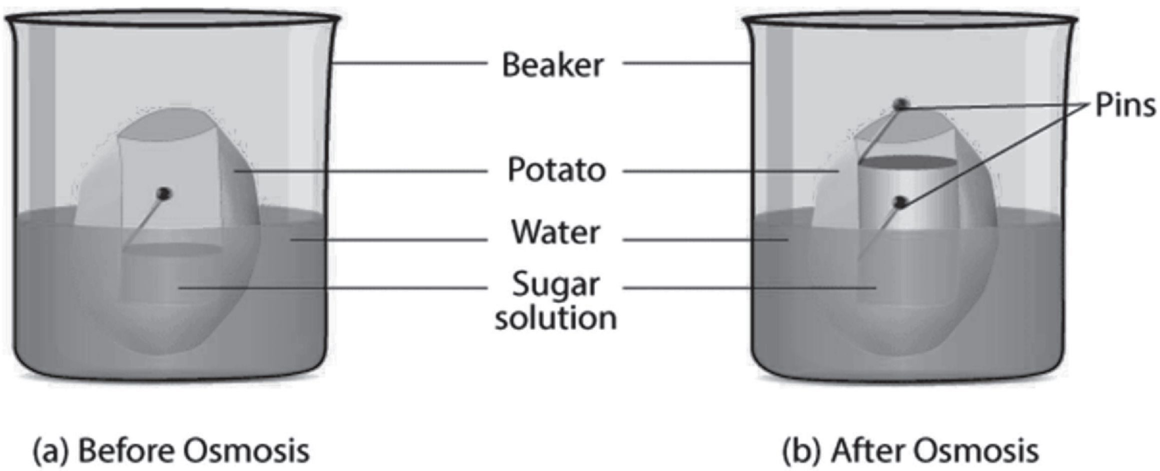


Fig.2.3 Osmosis by potato osmoscope

Observation:

The level of sugar solution in the potato cavity rises after some time due to the entry of water into the sugar solution through the selectively permeable membrane of the cells of the potato.

Conclusion:

The movement of water from the Petri dish to the potato cavity occurs because of the difference in the concentration of solvent molecules in the two regions: sugar solution in the potato cavity and pure water in the Petri dish.

Experiment : 3

To demonstrate the process of Plasmolysis in plants

Plasmolysis literally means **"Shrinkage of the protoplasm".** When a cell is placed in a solution, it will either shrink, swell or will remain unchanged depending upon the concentration of the solution, generally three types of solution is present

Types of Solution

- **Isotonic solution:** Outer solution has the same concentration than inside the cell. Cell remains stable in isotonic solution or there is no entry or exist of water from the cell.
- **Hypotonic solution:** The outside solution has lower solute concentration than inside the cell. The cell swells as water enters the cell (endosmosis).
- **Hypertonic solution:** The outside solution has higher solute concentration than inside the cell. Water from cell moves out so the protoplasm of the cell shrinks and stores in the center of the cell (exosmosis).

When a cell placed in any above mention solution following three situations will occurs.

1) If a plant tissue or cell is placed in a **hypertonic solution** (a solution having higher concentration than that of the cell sap), water is lost from cell by osmosis **(exosmosis)** as a result, the protoplasm shrinks and leaves the cell wall. This phenomenon known as **plasmolysis** and defined as **shrinkage of protoplast of cell from its cell wall under the influence of a hypertonic solution.** In the initial stage of plasmolysis at which the first sign of shrinkage of the protoplasm from the cell wall become observe is known as **incipient plasmolysis.**
2) Plasmolysis is a reversible phenomenon. If a plasmolysed cell is placed in **hypotonic solution** (a solution less concentrated than the cell sap) **endosmosis** occurs and water from outside enters into the protoplasm. As a result the protoplasm as well as the cell as a whole attains their original shape and size respectively. This phenomenon is called **deplasmolysis.**
3) If a cell is placed in an **isotonic solution** (a solution having concentration just equal to the concentration of cell sap) neither shrinking nor swelling of the protoplasm occurs.

Importance of plasmolysis

1) It helps to detect whether a particular cell is living or dead as the plasmolysis does not take place in a dead cell.
2) Plasmolysis is involved in killing of weeds in lawns by salting/herbicide. This phenomenon useful for remove weeds from clay tennis and other playing ground
3) Plasmolysis is employed in number of practical ways like a salting of pickles, meat or fish and sweetening of jams and jellies to kill the spores of bacteria and fungi responsible for their decay and spoilage.
4) It indicates the semipermeable nature of the plasmamembrane.

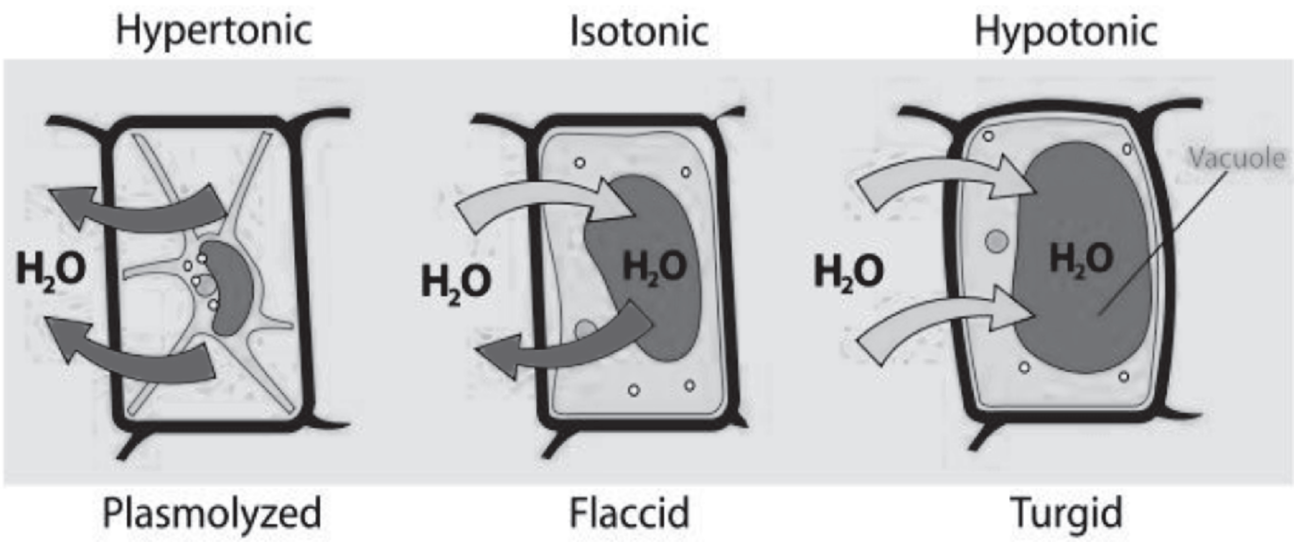


Fig 3.1 Movement of water in hypertonic, isotonic and hypotonic solution

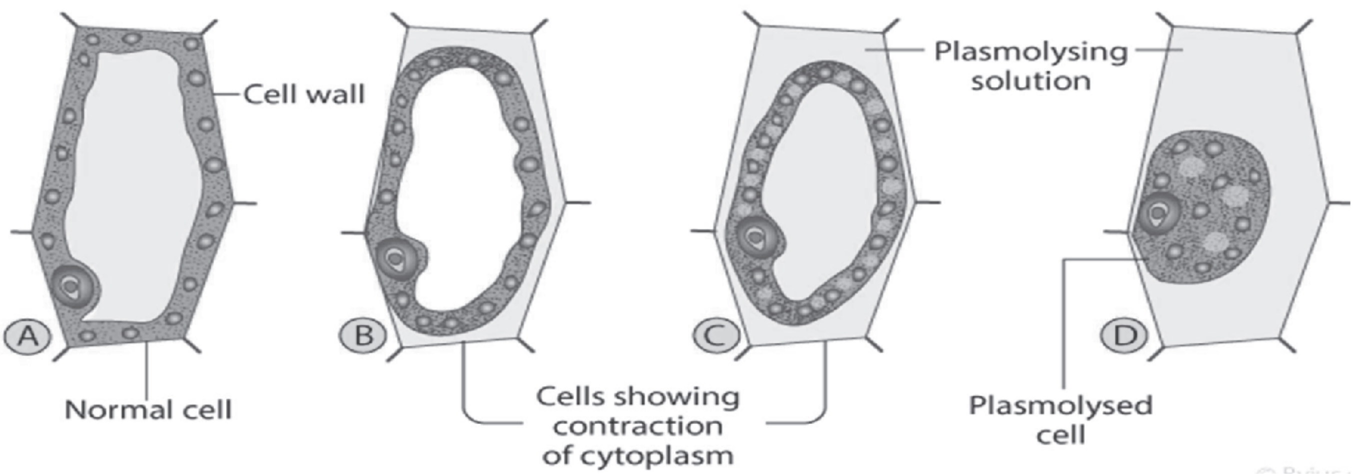


Fig 3.2 Different stages of plasmolysis

To study the process of plasmolysis in plants

Objective: To demonstrate plasmolysis in plant under hypotonic and hypertonic solutions using salt solution.

Apparatus and materials required: onion, forceps, needles, glass slides, cover slips, microscope, droppers, sodium chloride solution 5% and 0.1%

Procedure

- Take two glass slides and place them on the table.
- Take an onion from the Petri dish.
- Fold the leaf and tear it along the lower side of the leaf.

- Using a forceps, pull out two small segments of thin transparent layer from the lower epidermis of the onion leaf.
- Place the epidermal peels on both glass slides.
- Using a dropper, take some sodium chloride 0.1% solution from the beaker.
- Put 1 to 2 drops of solution on one slide.
- Using another dropper, take sodium chloride 5% solution from the beaker.
- Put 1 to 2 drops of solution on the next slide.
- Place a cover slip over the peel of both slides using a needle.
- Place the slides one by one under the compound microscope.
- Observe them under the microscope.

Experiment : 4

To demonstrate the process of imbiation in dry seeds

The adsorption of liquid by the solid particles of a substance without forming a solution is called **Imbibition**. The substance which can imbibe or absorb a liquid without forming a solution is known as **imbibant**. Wooden door in rainy season swell due to imbibition phenomenon. In case of dry seeds water is initially absorbed by imbibition and thereafter water absorbed by osmosis. The plant imbibant are made up of hydrophilic colloids are e.g. proteins, pectic compounds, starch and cellulose. Among them protein has high imbibitional capacity as compared to starch and cellulose, (Protein > Starch > Cellulose) while cellulose has little imbibitional capacity. During the process of imbiation a pressure is created which is known as imbibitional pressure. It develops due to the matric potential of the imbibant, hence called **matric potential** and is denoted as **Ψm** and is measured in bars or **Mega Pascals (MPs).**

Factors Affecting imbibition

1. **Temperature:** The rate of imbibition increase with increasing temperature because the increased temperature raises the kinetic energy of the system. The situation is reverse at low temperature.
2. **Pressure:** Since the imbibition pressure comprises hundreds of atmosphere, the colloidal particles can imbibe water against a lot of pressure.
3. **Solute concentration:** Increase in concentration of solute present in the imbibant decrease rate of imbibition.
4. **pH: The pH of the medium also influences the** imbibition. Cellulose, a negatively charged colloid imbibe maximum in alkaline medium whereas it absorbs least in the acidic medium. The reverse is true in case of positively charged colloids.
5. **Texture of imbibant:** The cohesion of molecules of the imbibant largely affects the amount of water imbibed. A densely packed imbibant will imbibe lesser water than loosely packed one. E.g. bulk by bulk wood absorb less water than gelatin.

Significance of imbibition

1. Imbibition is the first step of water absorption by roots of higher plants. It is also plays an important role in the uptake of soil water by the root hair.
2. The absorption of water by a germinating seeds occurs by imbibition. Seed coats of germinating seeds are also burst by imbibitional pressure.

To study the different factor affects rate of imbibition process of dry seeds.

Objective: 1) to study the variation in the imbibition rate by different seeds (differ in their organic constitute) **2)** to study the effect of temperature on imbibition rate **3)** to study the effect of solute concentration on imbibition rate.

Apparatus and materials required: Seeds of rice, pigeon pea, groundnut, 50ml beaker double, distilled water, blotting paper, weighing balance, hot water cold water, and normal water, sodium chloride solution 10%, 20% and 30%.

Procedure 1)

1) Take 5 g of each seeds of rice, pigeonpea and groundnut in to 50 ml beaker.
2) Pour 30 ml distilled water into it and keep it at room temperature for 3 to 4 hrs.
3) Remove the seeds from the beaker after 3 to 4 hrs and blot of their surface water with the help of blotting paper.
4) Take final weight of each soaked seed separately and record observation.

Sr. No	Name of seed	Seed quality	Initial wt. (W_1)	Final wt. (W_2)	Amount of water absorbed (W_1- W_2)	Remark
1	Pigeonpea	Protein	5 g			
2	Groundnut	Medium protein	5 g			
3	Rice	Low protein	5 g			

Procedure 2)

1) Take 5 g of seeds of pigeonpea in to three 50 ml beaker.
2) Pour 30 ml hot water, cold water and normal water into three separate 50 ml beaker and allow them 3 to 4 hrs for imbibe.
3) Remove the seeds from the beaker after 3 to 4 hrs and blot of their surface water with the help of blotting paper.
4) Take final weight of each soaked seed separately and record observation.

Sr. No	Name of seed	Water condition	Initial wt. (W_1)	Final wt. (W_2)	Amount of water absorbed (W_1- W_2)	Remark
1	Pigeonpea	Normal water	5 g			
2	Pigeonpea	Hot water	5 g			
3	Pigeonpea	Cold water	5 g			

Procedure 3)

1) Take 5 g of each seeds of rice, pigeonpea and groundnut in to 50 ml beaker.
2) Pour 30 ml of 10%, 20% and 30% Nacl solution in three different beakers keep it at room temperature for 3 to 4 hrs.
3) Remove the seeds from the beaker after 3 to 4 hrs and blot of their surface water with the help of blotting paper.
4) Take final weight of each soaked seed separately and record observation.

Sr. No.	Name of seed	Water condition	Initial wt. (W_1)	Final wt. (W_1)	Amount of water absorbed (W_1- W_2)	Remark
1	Pigeonpea	10% Nacl	5 g			
2	Pigeonpea	20% Nacl	5 g			
3	Pigeonpea	30% Nacl	5 g			

Experiment : 5

To study the structure and distribution of stomata

Stomata are minute pores of elliptical shape surrounded by two specialized epidermal cells called guard cell. The guard cells are **kidney shaped in dicot and dumble shaped in monocot.** The part of wall of the guard cells surrounding the pore is thickened and inelastic due to the presence of secondary layer of cellulose but rest of the walls is thin, elastic and permeable. Each guard cell has a cytoplasmic lining and a central vacuole containing cell sap. It contains a nucleus and number of poorly developed chloroplast which is incapable of photosynthesis. This epidermal cell surrounding guard cells are specialized and called subsidiary cells which support the movement of guard cells. The major role of stomata is to allow carbon dioxide entry to drive photosynthesis and at the same time allow the exit of water is evaporate, cooling the leaf. Plants have many stomata (upto 400 per mm^{-1}) on their leaf surface and they are usually on the lower surface to minimize water loss. The number of stomata per unit leaf surface varies widely with species and environmental conditions. They also vary from leaf of the same plant and even in different parts of same leaf. As a rule, the younger leaves on the top of the plant have greater number of stomata per unit area than those situated below.

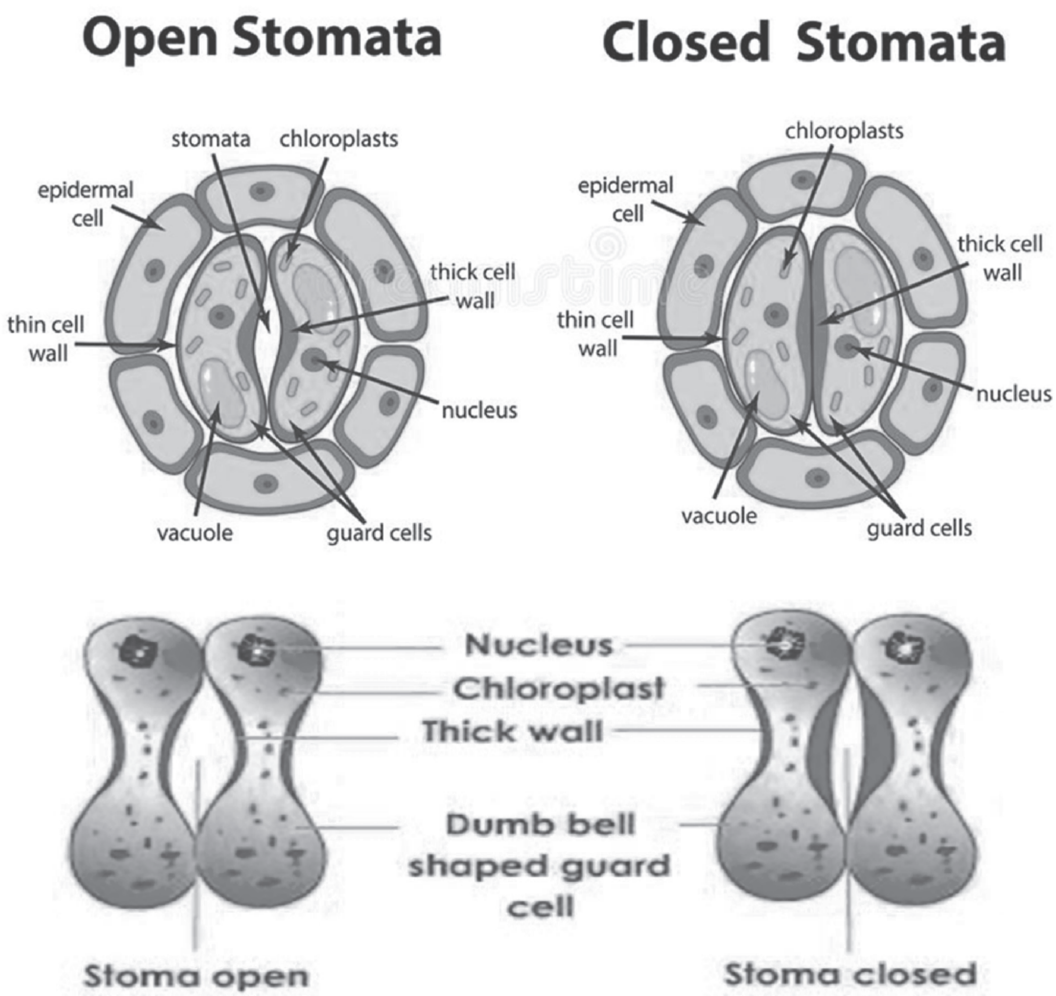


Fig.5.1 (A) Kidney shaped stomata in dicot leaf (B) Dumbell shaped stomata in monocot leaf

Stomatal distribution

The pattern of stomatal distribution is different in different plants. Accordingly, the plants can be divided into three groups:

1. **Hypostomatous plants:** In these plants, stomata found only on **lower epidermis of the leaves** e.g. most woody plants, oak, apple, orange etc.
2. **Epistomatous plants:** In these plants, stomata found only **on upper surface of the leaves** e.g. water lily.
3. **Amphistomatous plants:** In these plants, stomata found **on both the surface of leave** e.g. monocots and herbaceous dicots (bean, maize, sunflower). In these plants stomata are usually more abundant on the lower surface of leaves.

Sometimes, stomata may be absent or functionless if present, e.g. in submerged water plants. Thus, on the basis of the presence of stomata on leaf surfaces, the plants have been divided in following five groups:

1. **Apple or Mulberry type:** The stomata found only on the under surface of leaves.
2. **Potato type:** The stomata found more on the lower surface than on the upper surface of leaves.
3. **Oat type:** Stomata found equally on both the surfaces of leaves.
4. **Water lily type:** Stomata found only on upper surface of leaves.
5. **Potamogeton type:** Stomata either absent or functionless. Most of the submerged aquatic plants belong to this category.

Loftfield classified the stomata in three groups on the basis of their daily movement.

1. **Alfalfa type:** The stomata remain open throughout the day and closed at night. These types of stomata are found mostly in thin leaves **mesophytes**, e.g. pea, bean, radish, mustard etc.
2. **Potato type:** The stomata are open throughout the day and night except for a few hours in the evening, e.g. onion, cabbage, pumpkin etc.
3. **Barley type:** The stomata are open only for a few hours in a day, e.g. wheat, barley etc.

Stomatal frequency and stomatal index

The number of stomata per unit area of the leaf is called as stomatal frequency. The stomatal index is defined as the percentage number of stomata as compared to all the epidermal cells in a unit area of leaf *i.e.*

$$\mathbf{I = (S \div E + S) \times 100}$$

Here, **I** = Stomatal index

S = Number of stomata per unit area

E = Number of epidermal cells per unit area

To determine the stomatal index

Objective: To study the stomatal distribution on the upper and lower leaf surfaces and to calculate the stomatal index.

Apparatus and materials required: Leaves, compound microscope, forceps, blade, needle, glass slide, cover slip, dropper, distilled water, glycerine, and safranin solution, filter paper, brush.

Procedure

1. Take leaves from different types of plants such as sugarcane, rice maize etc.
2. Take out the peel from the upper surface and lower surface of the leaves using sharp blade.
3. Put them immediately in water so that they do not get dry.
4. Using a brush put the leaf peel on the clean glass slide.
5. Pour one drop of safranin solution over the peel with the help of dropper and allow it to stain for two minutes.
6. Remove excess stain using a filter paper.
7. Pour a drop of glycerine over the leaf peel.
8. Place a cover slip gently on the leaf peel with the aid of needle.
9. Remove the excess glycerine using a filter paper.
10. Observe the glass slide under the microscope.
11. Observe the shape of guard cells and count the number of stomata in the peels of both upper and lower epidermis of the leaf and calculate the stomatal index/ stomatal frequency using formula.

Observation:

Sr No.	Name of plant	No of epidermal cell	No. of stomata	Stomatal index
1	Sugarcane			
2	Rice			
3	Wheat			
4	Maize			
5	Sunflower			

Experiment : 6

Measurement of transpiration using ganong's potometer

Transpiration is a physiological process of plants where the plant loses water in the form of water vapor through the aerial parts of the plant and in the form of liquid is known as guttation. Transpiration occurs through stomata. **Curtis** (1926) has called that "**Transpiration is a necessary evil"** because it has certain advantages as well as disadvantages.

Types of transpiration

1. **Stomatal transpiration:** When loss of water occurs through stomata, it is termed as stomatal transpiration. About **80-90%** of the total transpiration takes place through stomata.

2. **Cuticular transpiration:** When loss of water occurs from the leaves and herbaceous stem by direct evaporation from the epidermal cell through cuticle, the process is known as Cuticular transpiration. Cuticle us the waxy layer present on all above ground tissue of the plant and serve as barrier to water movement out of the leaf. The amount of water lost through it is cuticular transpiration is comparatively small and account only **10-20%** of the total water loss from the leaf.

3. **Lenticular transpiration:** Water loss from lenticular (lenticell) space is known as lenticular transpiration. Lenticels are the area in the bark of a tree, which are filled with loosely arranged cells known as **complementary cell.** Lose of water from lenticular space is negligible about 0.1%. Lenticular transpiration can take place continuously in day and night, as there is no mechanism to stop or reduce it.

Significance of transpiration:

1. It creates suction force and helps in ascent of sap thus affects the absorption of water and minerals by roots.

2. It helps in evaporating excess amount of water.

3. It maintains suitable temperature for leaves and also renders cooling effect to the plant body.

4. It brings about opening and closing of stomata which indirectly influence the process of photosynthesis and respiration

Disadvantages:

1. Transpiration results in water deficit inside the plant body which causes injury to the plants by desiccation.

2. Rapid transpiration causes mid-day leaf water deficit known as temporary wilting.

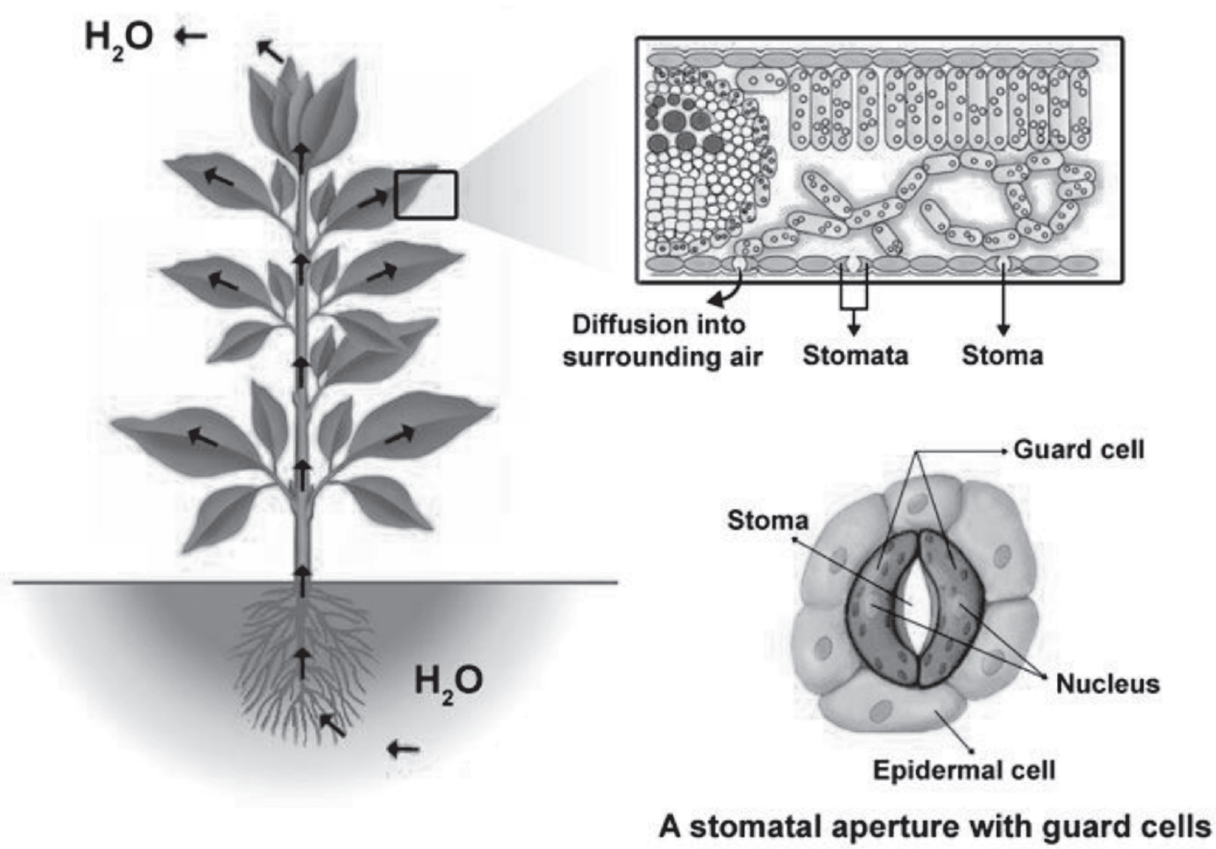


Fig.6.1 Mechanism of transpiration in plant

Environmental factors that affect the rate of transpiration

1. **Light:** Stomata are triggered to open in light so plants transpire more rapidly in the presence of light than in the dark.
2. **Temperature:** Plants transpire more rapidly at higher temperatures because water evaporates more rapidly as the temperature rises.
3. **Humidity:** Humidity is expressed as the percentage of water vapour present in the atmosphere. The higher the relative humidity of the outside atmosphere, the lower the rate of transpiration.
4. **Wind**: When there is no breeze, the air surrounding a leaf surface becomes increasingly humid, thus decreasing the rate of transpiration. The increase in the wind velocity increases the rate of transpiration by removing the humidity from the leaf surface.

A **potometer** is a device, which is used to measure water uptake by shoot during transpiration. It is also known as **transpirometer**. The Ganong's potometer is used to measure the transpiration rate in a laboratory. The Ganong's potometer comprises a glass tube, which is bent twice, a glass cylinder having a wide mouth. A capillary tube is inserted in a horizontal glass bar attached to a reservoir. A wide-mouthed glass cylinder is present towards the front end of the apparatus. A rubber cork with a hole is fitted on the mouth of the glass cylinder. A freshly cut twig is placed in this hole. The horizontal bar has graduated readings marked over it. It has a bent end with a nozzle opening. A beaker containing coloured water is placed below this horizontal bar with the bent end inserted into it. A reservoir is connected to the horizontal bar to store water. The entire set up is placed on a flat surface.

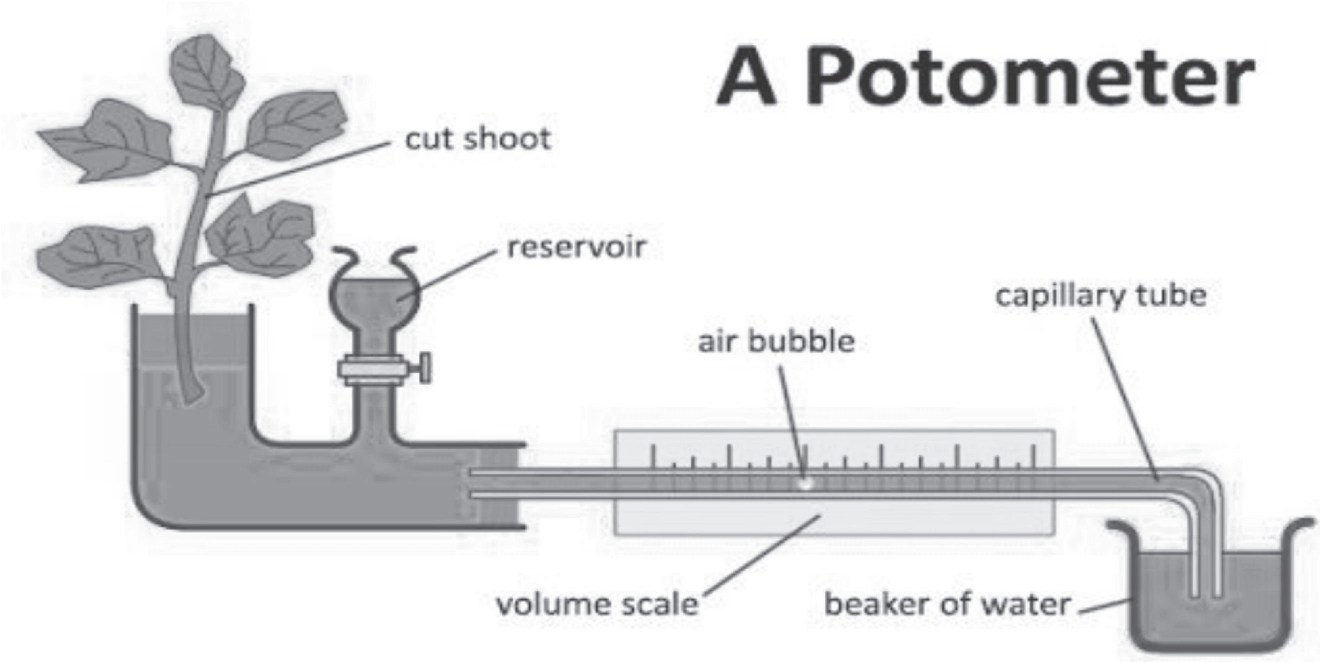


Fig.6.2 Ganong's potometer

1. Fill the apparatus with water through the water reservoir.
2. Insert a freshly cut twig in the water of the vertical arm through the hole of the cork.
3. Make all the joints air-tight by applying grease.
4. Insert an air bubble in the graduated tube and keep the whole apparatus in sunlight.
5. Note the initial and final readings of the bubble in given time in different conditions like sunlight, shade, darkness and by placing the plant in front of a fan in sunlight.

Experiment : 7

To study root pressure in plants

If a well-aerated plant growing vigorously in spring is cut off slightly above the ground, water is seen to exude from the cut end of the stump through the xylem. This phenomenon is known as **exudation or bleeding.** **Priestley** was one of the first explain the process of exudation or bleeding is due to pressure developed in root system and this pressure **called as root pressure** which helps in upward movement of water. **Stephen hales** who coined the **term root pressure**, described this method in 1727 and recorded pressure of over one atm and believe that root pressure is responsible for **ascent of sap or upward movement of water.** It occurs in small herbaceous plants, when soil water potentials are higher and transpiration rate is low. During night when stomata are closed, transpiration is very low or zero and soil moisture is very high, root cells continue to pump mineral ions into the xylem of the vascular cylinder, lowering the water potential. As a result water flows into root cortex, generating positive pressure in root. As transpiration rates increase in morning, water is transported through the plant and lost to the atmosphere so positive pressure in not developed in root. Root pressure relatively week, maximum root pressure measured is below **2atmosphere** and thus it is no not explain ascent of sap. Root pressure is measured by **mercury manometer**.

Objective: To demonstrate the root pressure in plant.

Material: A well-watered potted plant. Knife, a tube attached with manometer, glass tube, colored water, thread.

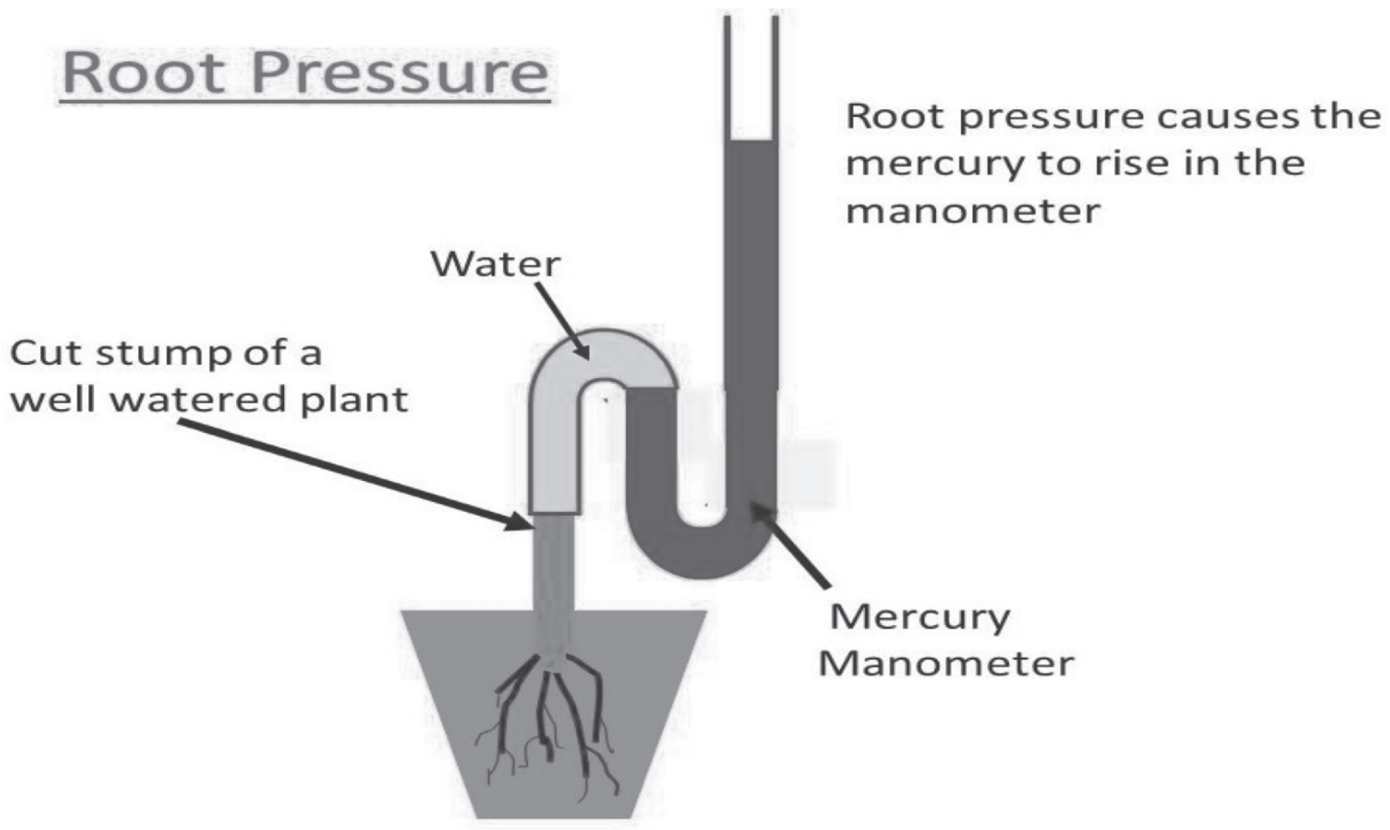


Fig.7.1 Measurement of root pressure by mercury manometer

Procedure:

1. Water a potted herbaceous plant and keep it over night
2. Next early morning cut off the stem a few centimeters above the soil level or near to the root.
3. Fix a long and narrow glass tube to the cut end of the stump with the help of tuber tubing.
4. Pour a little colored water in the glass tube and mark its level.
5. Connect the glass tube to a manometer and observe the experimental setup.
6. Record the observation after few minutes.

Experiment : 8

To separate the plant pigment by paper chromatography

Photosynthetic plants convert light energy from the sun to chemical energy. During photosynthesis, molecules referred to as pigments are used to capture light energy. Pigments are chemical compounds which reflect only certain wavelengths of visible light. Plant leaves contain four primary pigments: chlorophyll a (dark green), chlorophyll b (yellowish-green), xanthophyll (yellow) and carotenoids (orange).

To separate and visualize the four primary pigments of green plants, we can use a simple technique called chromatograph. The word chromatography originated from two **Greek** words '**chroma**' meaning **'color'** and **graphing'** meaning **'to write'**. Chromatography means **color writing** and it was first employed by a **Russian scientist Mikhali Tsvet (1906).** Chromatography is a laboratory technique for rapid and efficient separation organic components of a mixture and purification of compounds. In paper chromatography, the stationary phase is a special quality paper called **chromatography paper**. **Mobile phase** is a solvent or a mixture of solvents. A solution of the mixture is spotted on a line about 2 cm above from the bottom of the paper, called **original line or base line** and then suspended in a chromatography chamber containing suitable solvent. The solvent rises up the paper by capillary action and flows over the spot. The paper selectively retains different components according to their differing partition in the two phases. The paper strip so developed is called **Chromatogram**. The spots of the separated coloured compounds are visible at different heights from the position of initial spot on the chromatogram. The spots of the separated colourless components may be observed either under ultraviolet light or by the use of an appropriate spray reagent. The distance travelled by the solvent from the original line is called **solvent front.**

Retention factor (Rf): It is defined as the ration of the distance traveled by the solute to the distance traveled by the solvent.

$$\textbf{Rf value} \quad \frac{\textbf{Distance traveled by the pigments or solute from the base line (cm)}}{\textbf{Distance traveled by solvent from the base line (cm)}}$$

Rf value depends on temperature, nature of the substance, nature of the solvent, presence of impurities, quality of the filter paper.

Types of Paper chromatography:

1) **Ascending paper chromatography:** In this type of paper chromatography in which the solvent rises up (against gravity) is called ascending paper chromatography.

2) **Descending paper chromatography:** In this types chromatography in which the solvent is taken on the top in a container and is allowed to come down (towards gravity), this is termed as descending paper chromatography.

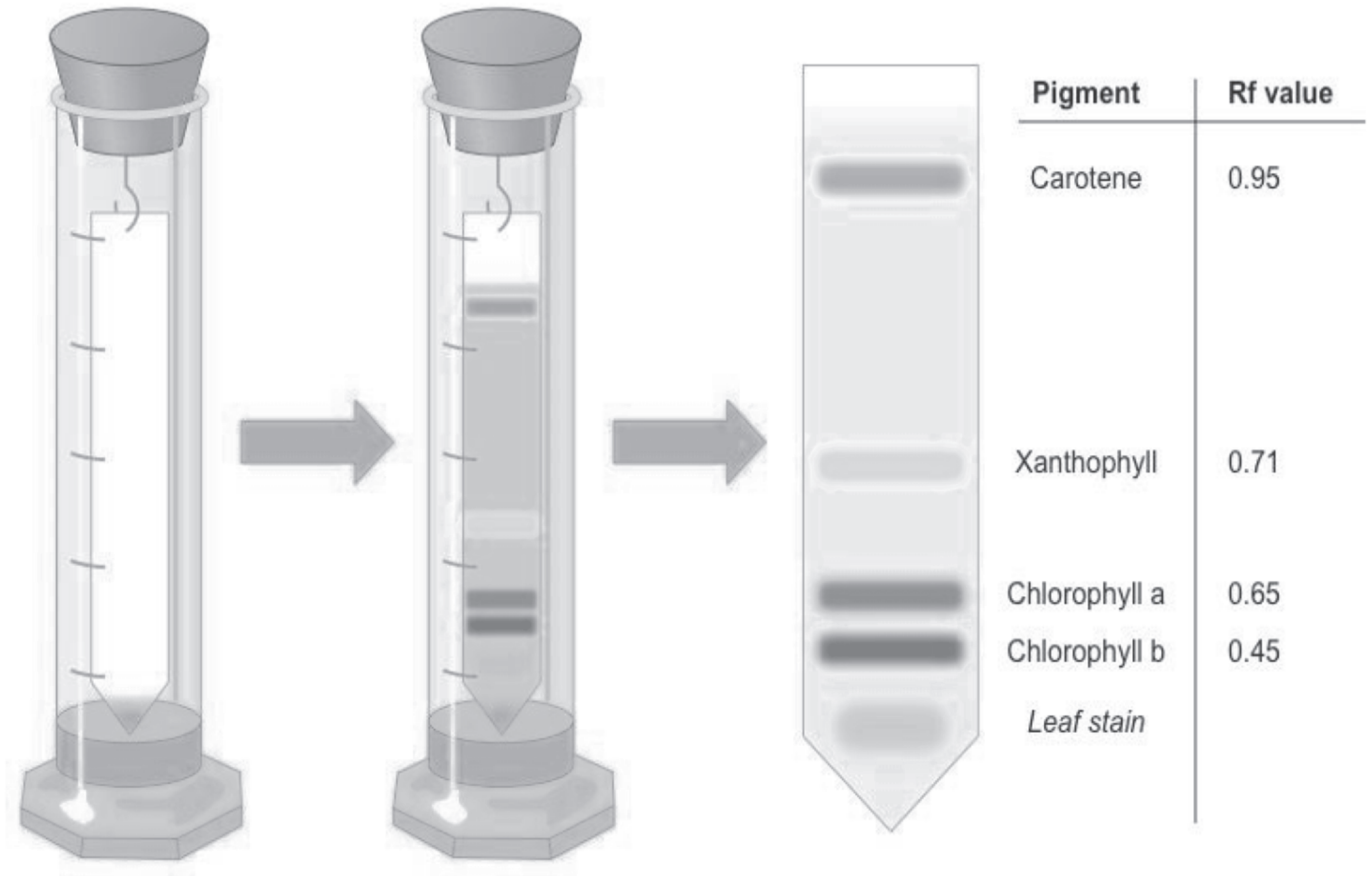


Fig.8.1 Separation of different photosynthetic pigments through paper

Materials: Fresh spinach leaves, 80%aceton, chromatography chamber, mortar and pestle, scissors, pencil, petroleum ether, spatula, scale, filter paper, thread, watch glass, stapler.

Procedure:

- Take a few freshly plucked green spinach leaves.
- Using scissors cut the spinach leaves into small pieces and let them fall into the mortar.
- Take a measuring cylinder that contains 5ml of acetone and pour it into the mortar.
- Grind the spinach leaves using the mortar and pestle.
- Place the extract into a watch glass using a spatula.
- Take a strip of filter paper having a narrow notch at one end of the strip.
- Take a pencil and a scale and draw a horizontal line with a pencil about 2-3 cm away from the tip of the notch.
- Put a drop of the pigment extract in the middle of the line with the help of a capillary tube/dropper.

- Allow the drop to dry and repeat till four or five drops are placed on the paper.
- Take the chromatographic chamber/beaker and pour ether acetone solvent in it.
- Fold one end of the filter paper strip and staple it.
- Using a thread, hang the filter paper strip in the chromatographic chamber.
- The loading spot should remain about 1 cm above the solvent level.
- Leave the chromatographic chamber undisturbed for some time.
- We can observe, as the solvent moves through the paper, it spreads the different pigments of the mixture to various distances.
- When the solvent rises about 3/4th up the strip, remove the strip carefully and let it dry and calculate Rf value.

S. No.	**Color of the pigment band**	**Distance traveled by pigment band**	**Distance travelled by solvent front**	**Rf value**	**Name of pigment**
1					
2					
3					
4					

Experiment : 9

Measurement of chlorophyll content by Acetone method

Photosynthetic pigments are of three types *i.e.* **chlorophyll, carotenoids and phycobillins**. The chlorophyll and carotenoids are insoluble in water and can be extracted only with organic solvents. Chlorophylls, the green pigment of plants, are the most important pigments active in photosynthetic process. Chlorophyll a and b are the most abundant in higher plants. Both chlorophyll a and b have a cyclic tetrapyrrolic ring structure (porphyrin) with an isocyclic ring containing **magnesium** atom at its center. The phytol chain of the chlorophyll extends from one of the pyrrole rings. The **chlorophyll a** has **methyl group** (-CH,) attached to the third carbon and **chlorophyll b** has an **aldehyde** (HC=0) attached to the third carbon. In addition to minor differences in the structure, chlorophyll a and b exhibit different absorption spectra. Chlorophyll is the principal pigment involved in photosynthesis. It absorbs light in violet blue and red regions of the visible spectrum and reflects green light and thus leaves appears green in colour. It absorbs light energy only in the visible part of spectrum 400- 700 and it known as photosynthetically active radiations. **Action spectrum** is a graph showing the effectiveness of different wavelength of light stimulating the process of photosynthesis, where the response could be measured in terms of oxygen produced at different wavelength of light. Absorption spectra are the measure of the extent to which a given substance absorbs the light of different colour and wavelength. It is a function of relationship between absorption and optical density (OD) and wavelength expressed in nanometres (nm).

Materials: Fresh leaf material, 80% acetone, distilled water, filter paper, glass markers, beaker, funnel, measuring cylinders, spectrophotometer, mortar, pestle.

Procedure:

1. One gram of leaf sample was finely cut and gently mixed with a clean pestle and mortar.
2. Grind leaf material in to fine powder with the help of 20ml of 80% acetone was added.
3. Transfer the green liquid in to test tube by filter through Whatman no 1 paper or thereafter, the sample was centrifuged at 500 rpm for 5 minutes.
4. The supernatant was transferred to 100 ml volumetric flak. The final volume was made up to 100 ml with addition of 80% acetone.
5. The colour absorbance of the solution was estimated by a spectrophotometer using 645 and 663nm wavelength against the solvent. Acetone (80%) was used as a blank.

Calculations:

The spectrophotometer is adjusted by using 80% acetone as blank sample. The optical density of chlorophyll pigment extracted is determined and then amount of chlorophyll a and chlorophyll b is determined using Arnon's formula.

Chlorophyll a = $(12.7(A_{663}) - 2.69(A_{645})] \text{ x } V/1000 \times W$

Chlorophyll b $[22.9(A_{645})\ 4.68(A_{663}) \text{ x } V/1000 \times W$

Total chlorophyll = $[22.2\ (A_{645} + 8.02(A_{663})] \text{ x } V/1000 \times W$

A= Optical density

V= Final volume of 80% acetone (in ml)

W= weight of leaf material (in g)

Experiment : 10

Estimation of photosynthesis rate in crop plants using infrared gas analyzer (IRGA)

A discrete sensor to measure photosynthesis is not yet available. So estimation of CO_2 provides an alternative and direct method for estimation of productivity. **Infrared gas analyzer (IRGA)** is the instrument used for measuring photosynthetic rate of crop plants. Hetero atomic gas molecules absorb the IR radiation but not identical atom is the principle used in this instrument. In this instrument, the gas molecules are sending through series of chamber like leaf chamber, silica gel chamber, IR cell and IR detector. There is an IR source for emitting IR radiation to IR cell. The hetero atomic molecule in the air (water) is absorbed by silica gel. Some amount of CO_2, present in the gas is absorbed by the plant and remaining amount is passed through IR cell. CO_2, can absorb some amount of IR radiation and remaining radiation is detected by IR detector and meter will show the reading. This experiment can be done in the presence of light and without light. The difference between two readings will give CO_2, consumption by the plant in the stipulated time. It is instantaneous, non- destructive method which allows separate investigation of individual leaf, and it separate photosynthetic gain from respiratory losses. Infrared gas analysis of CO_2 is the most widespread contempory method of determining photosynthesis and respiration. It is very sensitive but costly method. Three types of IRGA are available i.e. 1) closed 2) semi closed and 3) open.

Principle of IRGA

1. Infrared Gas Analyzer is used for the measurement of a wide range of hetero atomic gas molecules like CO_2, H_2O, NH_3, CO, SO_2, N_2O and NO

2. Hetero atomic gas molecules have characteristic absorption spectrum in the infrared region.

3. Absorption of radiation by a specific hetero atomic gas molecule is directly proportional to its concentration in the air.

4. The CO_2 present in the air is absorbed by the leaf and remaining is detected by IRGA.

Closed System of IRGA

In this system, a leaf is clamped in a leaf chamber and air is circulated around the leaf repeatedly. The decrease in CO, concentration over time is measured to determine the photosynthetic rate. The major disadvantage in this system is that the measurement of photosynthetic rates is done under constantly depleting CO, concentration around the leaf. Further, since the leaves transpire simultaneously there will be a constant buildup of humidity in the chamber. Increase in humidity alters the vapour pressure difference (VPD) between the leaf and its ambient air. Small changes in VPD have been shown to significantly alter the stomatal opening and hence the gas exchange rates. These advantages are overcome in the open system of measurements,

Open System of IRGA

In this system the leaf is clamped in a chamber through which ambient air is passed continuously. The change in CO_2, concentration before the air enters the leaf chamber and in the air leaving the leaf chamber is determined to compute the photosynthetic rates. If photosynthetic rate is high, then the air leaving the chamber will have less CO_2, than the air entering it. The difference between the CO_2, concentration at a given flow rate is determined to compute the photosynthetic rate.

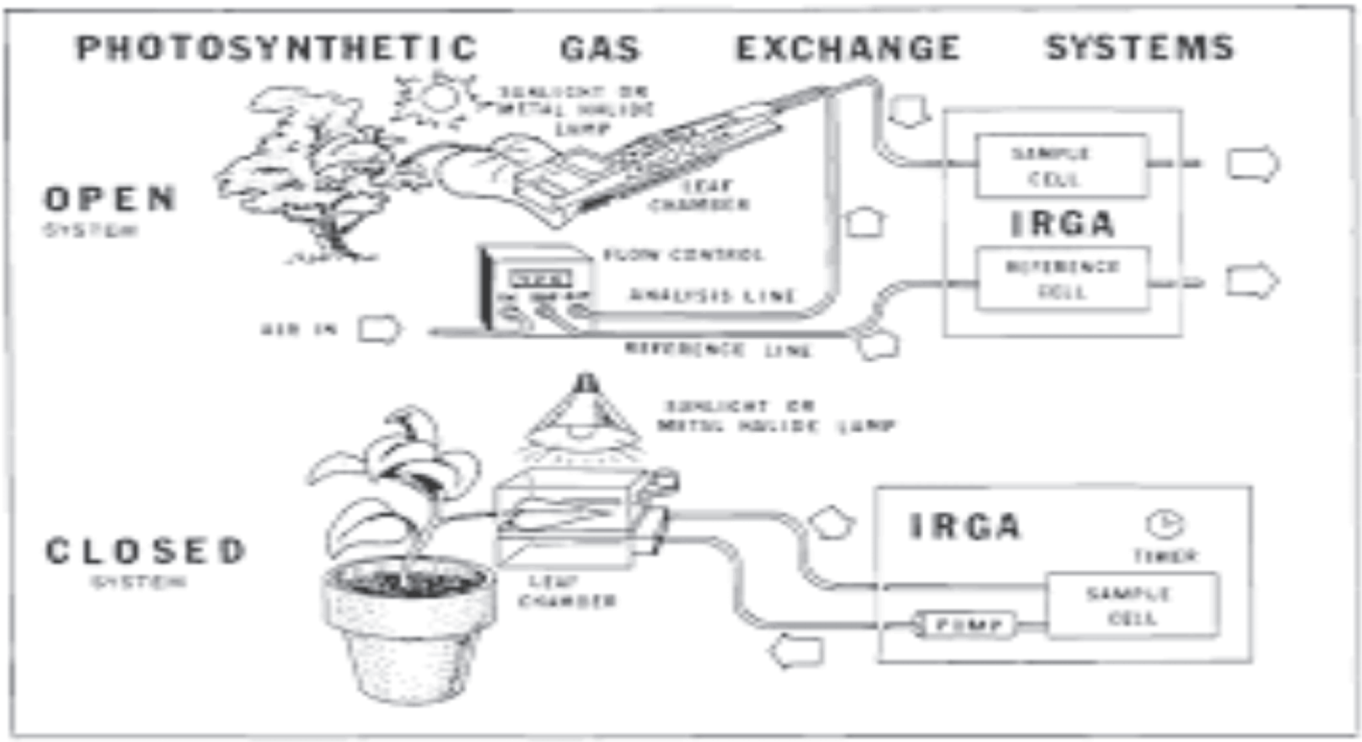


Fig.10.1 Open and closed Infrared gas analyzer

Experiment : 11

Measurement of relative water content (RWC)

Relative water content (RWC or relative turgidity) of a leaf is probably the most appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit. Or is a measurement of plant hydration status relative to its maximal water holding capacity at full turgidity. The term relative water content (RWC) stated by **Slatyer** in 1967 is a useful indicator of the state of water balance of a plant essentially because it expresses the absolute amount of water, which the plant requires to reach artificial full saturation. It provides a measurement of the water deficit of the leaf, and may indicate a degree of stress expressed under drought and heat stress. Genotypes which maintain high leaf RWC values during water deficit stress are more physiological advantages or we can say that it perform well under water stress conditions.

Typical values of RWC range between

- Fully turgid and transpiring leaves RWC range between **98%**
- Leaf RWC at wilting is around **60 -70%**
- Severely desiccated and dying leaves **30-40%**

Materials: Leaf, cork borer, petridish, weighing balance, water, hot air oven, butter paper bag and observation sheet

Procedure:

1. Select the physiologically functional leaf for estimation relative water content (a normally 3rd leaf from the top).
2. Make the leaf disc of equal size with the help of cork borer
3. Accurately record the weight of leaf disc individual. This weight is call as **fresh weight (fw)**
4. Put this disc on Petri dish contain water for one hour
5. After one hour take out the leaf disc from water and wipe-out the water droplets sticking on the surface of leaf disc by using filter paper. Immediately record the weight of leaf disc and this weight is called as **turgid weight (tw).**
6. Transfer the leaf disc to a butter paper cover and then keeps the cover in hot air oven at 80^0c for 48 hours. Record the **dry weight (dw).**
7. Calculate the RWC by using following formula.

$$\text{Relative water content (RWC)} = \frac{\text{Fresh weight (fw)} - \text{Dry weight (dw)}}{\text{Turgid weight (tw)} - \text{Dry weight (dw)}} \times 100$$

Observation:

Crop	Fresh wt.	Turgid wt.	Dry wt.	RWC (%)
Rice	20	29	15	
Maize	20	36	18	
Green gram	20	27	09	
Wheat	20	42	14	

Experiment : 12

Measurement of respiration using ganong's respirometer

Respirations are catabolic process, which involves the breakdown of complex substance into simple substance with a simultaneous release of energy. The process of respiration involves the utilization of oxygen with the release of carbon dioxide. Germinating seeds have high rate of respiration, which can be calculated by using **Ganong's respirometer.** Generally, in plants carbohydrate is most important substrate. However, some seed also contains stored fats and proteins. The general equation for respiration is:

$$C_6H_{12}O_6 + 6H_2O + 6O_2 = 6CO_2 + 12H_2O + \text{Energy}$$

Materials and equipment: Pre-soaked seeds, water, thread, 1% potassium hydrogen oxide solution, Ganong's respirometer, rubber tube, wooden stand, a small tube.

Procedure:

1. Take 25 pre-soaked gram seeds in the bulb of Ganong's respirometer.
2. Before closing the mouth of the bulb with stopper, add 1% KOH solution in the small tube present in the bulb.
3. Fill the water in the tube and note down the initial level of water.
4. Observe the change in water level at the interval of one hour.
5. The rise in water level is direct measurement of the volume of O_2 consumed during respiration by the germinating seeds. Rate of respiration can be expressed as (Fig.10.1):

Increase in water level = Volume of O_2consumed/Time (h) × Number of seeds.

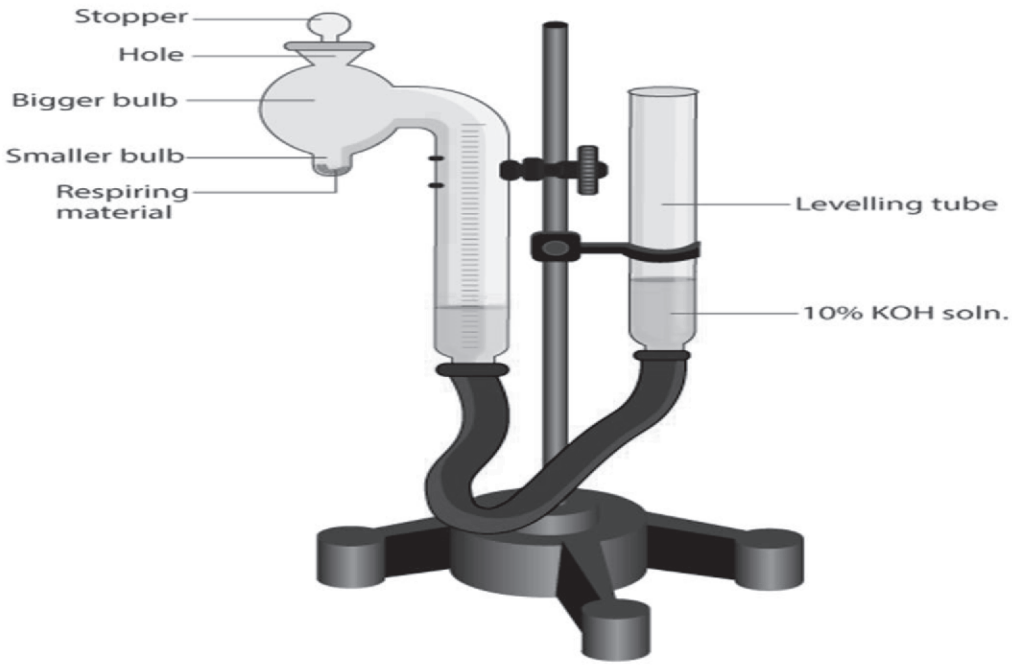


Fig.12.1 Ganong's respirometer

Experiment : 13

Tissue test for mineral nutrients of plants

To complete life cycle normally, a living organism requires the supply of a large number of substance from outside. This supply is called **nutrition**. The study of how plants obtain and use mineral nutrient is called **mineral nutrition**. All elements found in plant are not essential for its growth and life cycle, The term essential nutrient was proposed by **Arnon and stout (1939)** and concluded that, for an element to be considered essential, it must fulfill following criteria and this criteria is called as **criteria for essentiality.**

1. A given plant must be unable to complete its life cycle in the absence of the mineral elements.
2. The function of the element must not be replaceable by another mineral element.
3. The element must be directly involved in plant metabolism.

On the basis of these criteria, only **17 elements** were found essential to higher plants. On the basis of relative concentration in plant tissue these nutrient have been classified in two groups.

1) **Micronutrient:** These elements are needed in a concentration equal to or **less than 100 mg kg $^{-1}$** of dry matter **(< 100 ppm)**. They are also called as **trace elements**. **Molybdenum, zinc, copper, manganese, boron, iron, nickels and chlorine** and included in this group.

2) **Macronutrient:** These elements are needed in a concentration of more **than 100 mg kg^{-1}** of dry matter **(>100 ppm)**. **Carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium**, **sulphur** included in this group.

In additions to these essential elements, some elements stimulate growth but are not essential to all plant (do not follow essentially criteria) or which are essential only for certain plant species, or under specific conditions, are known as **beneficial elements.** E.g. **Sodium, silicon, cobalte**

The crop growth and productivity is conditioned by many factors of which, the nutrient status (Content) of plant parts such as leaf, stem, etc. play a critical role. Moreover the leaf and stem are considered as the indicator parts of plants for assessing the nutrients content of plant. Each crop plant requires the essential element at a specific concentration at different growth stages and it is known as **'critical level'.** When the nutrients content of plant depletes below the critical level the plants may exhibit some symptoms. The requirement or otherwise the availability of nutrients can be assessed by **i) plant diagnosis ii) soil analysis and iii) plant analysis by two methods a) by qualitative test and b) by quantitative estimation.** Based on the plant or soil tests, the required nutrients can be applied for crops to sustain the growth and rectify the deficiency disorders. The rapid tissue test would efficient way for rectifying the nutritional problems for quick recovery; however the quantitative estimation of both plant and soil for nutrients concentration will be more useful and economic for applying fertilizers either as basal or foliar and would be the long term strategy to cope up with nutritional problems.

For rapid tissue test to assess the nutrient status, different parts of plant should be taken as indicator tissue and some of the representative crops are furnished below:

	Nutrient					
Crop	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Cereals	Stem/Midrib	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Pulses	Petiole	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Oil seeds	Petiole	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Cotton	Petiole	Petiole	Petiole	Petiole	Petiole	Petiole
Banana	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina
Papaya	Petiole	Petiole	Petiole	Petiole	Petiole	Petiole
Vegetables	Petiole, Leaf blade	Petiole Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade

Fruit trees: Either leaf blade/mid rib/leaf lamina can be taken.

Ornamentals, Tea, coffee, etc.: The leaf blade should be taken.

Micronutrients: The leaf lamina/ leaf blade/ mid rib portion of leaf can be taken.

Procedure for tissue test

Nitrogen

Reagent: 1-% diphenylamine in conc. sulphuric acid**.** Small bits of leaf or petiole are taken in a petridish and a drop of 1% diphenylamine is added. The development of blue colour indicated the presence of nitrate – nitrogen. The degree of colorations indicates the amount of nitrogen present in that leaf.

Dark blue : Sufficient Nitrogen
Light blue : Slightly deficient Nitrogen
No colour : Highly deficient Nitrogen

Phosphorous

Reagents: (1) Ammonium molybdate solution, (2) Stannous chloride powder.

Eight gm ammonium molybdate is dissolved in 100 ml of distilled water. To this, add 126 ml of conc. Hydrochloric acid (HCL) and volume is made up to 300 ml with distilled water. This stock solution is kept in an amber coloured bottle and at the time of use it is taken and diluted in the ratio of 1:4 using distilled water. A tea spoonful of freshly chapped leaf bits are taken in a test tube and 10 ml of ammonium molybdate reagent is added and kept for few minutes. After shaking, a pinch of stannous chloride is added. Colour development is observed.

Dark blue : Sufficient Phosphorus

Bluish green : Slightly deficient Phosphorus

No colour : Highly deficient Phosphorus

Potassium

Reagent: (1) Sodium cobalt nitrate reagent, (2) Ethyl alcohol (95%).

Take 5 gm cobalt nitrate and mix with 30 gm of sodium nitrate in 80ml of distilled water. To this, 5ml of glacial acetic acid is added. The volume is made up to 100 ml distilled water. Dilute reagent prepared (5 ml) with 15 mg sodium nitrate to 100 ml using distilled water.

Finally cut leaf bits are taken in a test tube and 10 ml diluted reagent is added and shaken vigorously for few a minutes and kept for 5 minutes. Then add 5 ml of ethyl alcohol reagent, allowed to stand for 3 minutes. The solution is observed for the formation of turbidity.

No turbidity	:	Deficiency of Potassium
Slightly turbidity	:	Moderate deficiency
High turbidity	:	Sufficient Potassium

Calcium

Morgan's Reagent: 30 ml of glacial acetic acid and 100 grams of sodium acetate are dissolved in a little of distilled water

Procedure: 0.5 g of finally cut plant material is taken into a glass vial (both of healthy plant and deficient plant in different vials) and 5 ml of Morgan's reagent is added in test tube. After allowing it to stand for 15 minutes, 2 ml of glycerin and 5 ml of 10% ammonium oxalate is added and the solution is shaken for 2 minutes. The turbidity resembling after 15 minutes indicate the amounts of calcium in normal plant tissue.

Magnesium

Reagents

(1) 5% pure sucrose solution
(2) 2% Hydroxylamine hydrochloride
(3) Titan yellow
(4) Sodium hydroxide

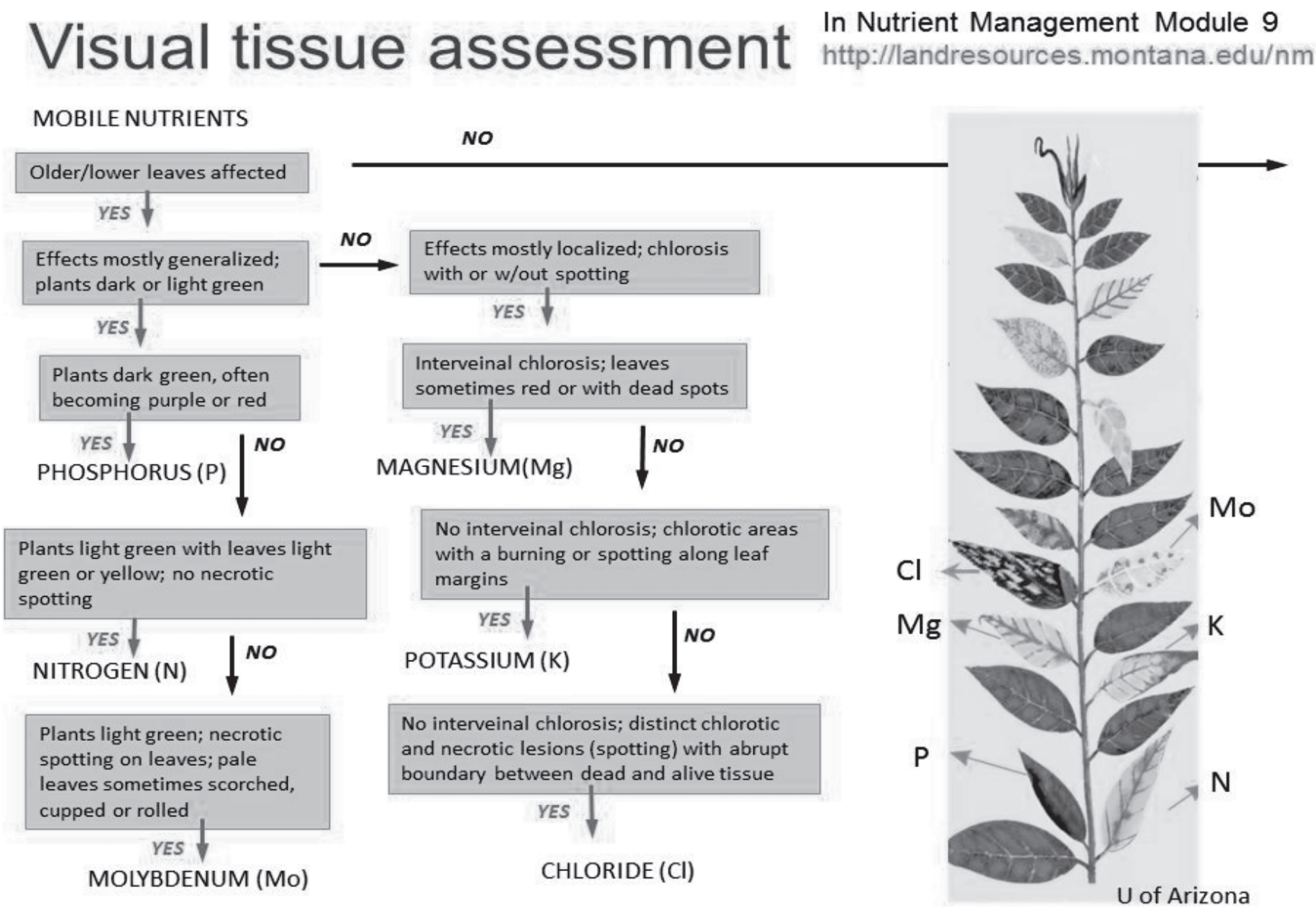
150 mg of Titan yellow is dissolved in 75 ml of 95% ethyl alcohol and 25 ml distilled water. This solution is stored in darkness.

Procedure

To a tea spoonful of finely cut material, following reagents are added in sequence. One ml of 5 % sucrose solution, 1 ml of 2 % Hydroxylamine hydrochloride and 1 ml of Titan Yellow. Finally solution was made alkaline with 2 ml of 10% NaoH. Red colour indicates the presence of magnesium and yellow colour indicates absence or traces of Magnesium.

Iron

Finely cut leaf materials (0.5g) are taken into a glass vial and 1ml of con. Hcl is added in it. After 15 minutes, 10ml of distilled water and 2-3 drops of con HNO3 are added. 10 ml of this solution is pipetted out into a specimen tube after 2 minutes and 5ml of 20% ammonium thiocynate is added and stirred. Further, 2 ml of amyl alcohol is added, shake well and allowed to stand for few minutes. The intensity of red colour in amyl alcohol layer indicates the quantity of iron.


Visual tissue assessment
In Nutrient Management Module 9
http://landresources.montana.edu/nm
MOBILE NUTRIENTS
Older/lower leaves affected
YES
NO
Effects mostly generalized; plants dark or light green
YES
NO
Plants dark green, often becoming purple or red
YES
PHOSPHORUS (P)
NO
Plants light green with leaves light green or yellow; no necrotic spotting
YES
NITROGEN (N)
NO
Plants light green; necrotic spotting on leaves; pale leaves sometimes scorched, cupped or rolled
YES
MOLYBDENUM (Mo)
Effects mostly localized; chlorosis with or w/out spotting
YES
Interveinal chlorosis; leaves sometimes red or with dead spots
YES
MAGNESIUM(Mg)
NO
No interveinal chlorosis; chlorotic areas with a burning or spotting along leaf margins
YES
POTASSIUM (K)
NO
No interveinal chlorosis; distinct chlorotic and necrotic lesions (spotting) with abrupt boundary between dead and alive tissue
YES
CHLORIDE (Cl)
Mo
Cl
Mg
K
P
N
U of Arizona

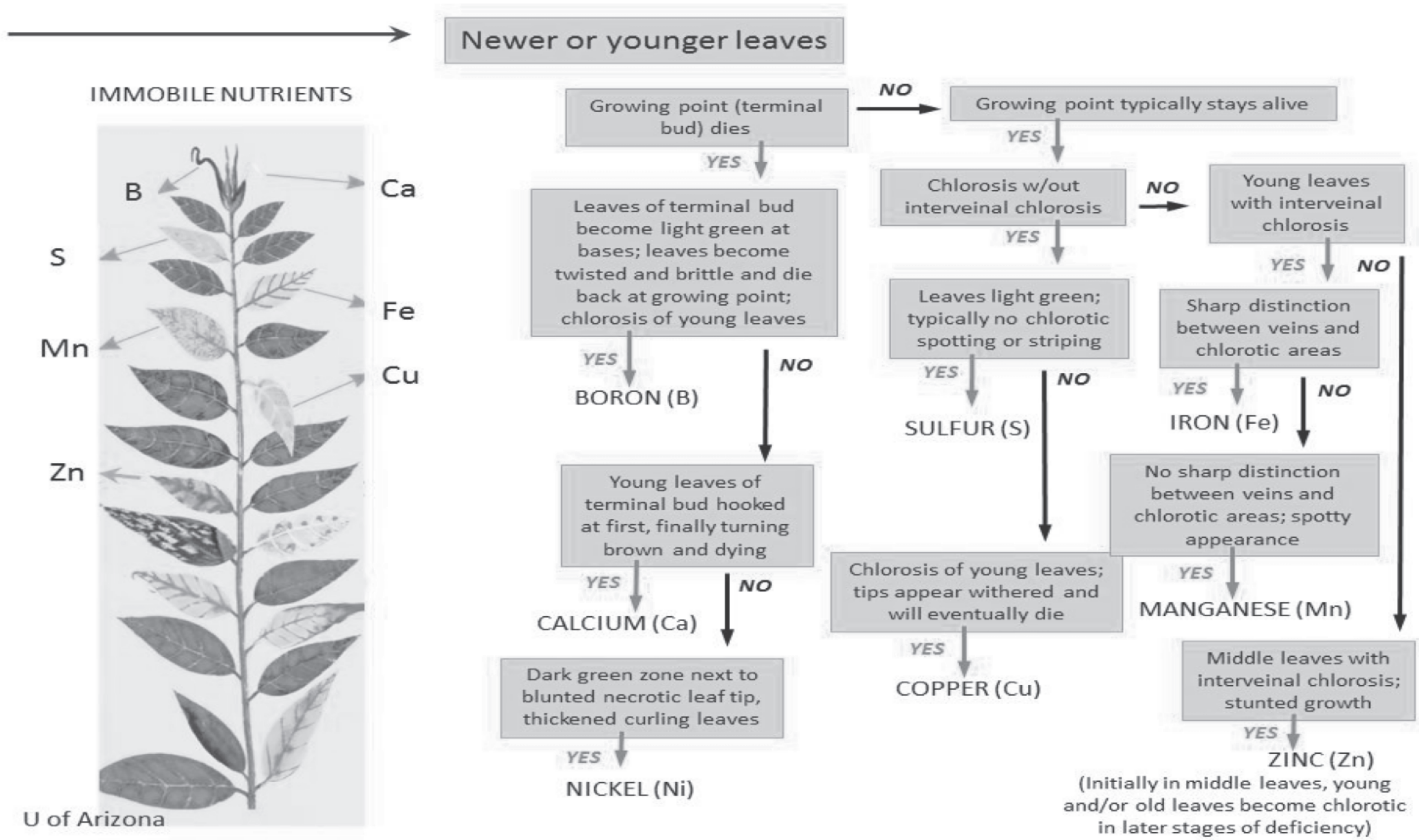
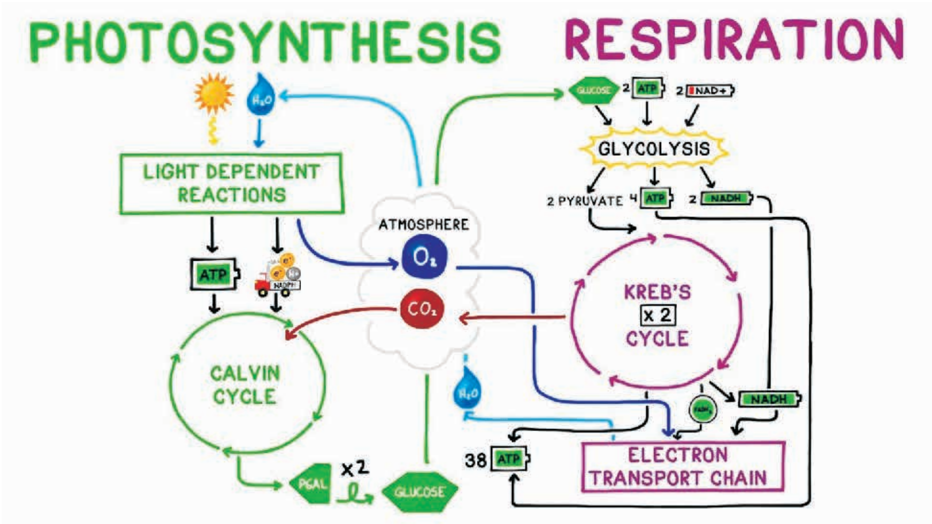


Fig. 13.1: Visual tissue assessment for nutrient deficiency Reference: Montana state university

NOTES


PHOTOSYNTHESIS
RESPIRATION
H_2O
LIGHT DEPENDENT REACTIONS
ATP
NADPH
ATMOSPHERE
O_2
CO_2
CALVIN CYCLE
PGAL
x2
GLUCOSE
2 ATP
2 NAD+
GLYCOLYSIS
2 PYRUVATE
4 ATP
2 NADH
KREB'S
x 2
CYCLE
NADH
38 ATP
ELECTRON TRANSPORT CHAIN


MINOLTA
SPAD
57.6
ON
OFF
AVERAGE
ALL DATA CLEAR
DATA RECALL
1 DATA DELETE


CI-340
CI-340

DEPARTMENT OF GENETICS AND PLANT BREEDING

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