MSCBOT-609(L)

M.Sc. IV Semester

LABORATORY PRACTICAL IV

DEPARTMENT OF BOTANY
SCHOOL OF SCIENCES
UTTARAKHAND OPEN UNIVERSITY

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Title	**:**	**Laboratory Practical IV**
ISBN No.	**:**	
Copyright	**:**	**Uttarakhand Open University**
Edition	**:**	**2025**

Published By: Uttarakhand Open University, Haldwani, Nainital-263139

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BLOCK-1-BIOSTATISTICS

UNIT-1- PREPARATION OF QUESTIONNAIRE AND DATA COLLECTION

Contents:

1.1 OBJECTIVES

- Adopt a structure for developing questionnaires.
- Recognize the characteristics of an effective questionnaire
- To gather data (primary data) from respondents dispersed across a large area
- To attain quick and accurately gathering trustworthy information through questionnaires.

1.2 INTRODUCTION

The most efficient and frequently used method for gathering primary data is the questionnaire. It is appropriate for any research issue. A questionnaire is a crucial instrument for social and scientific study. A questionnaire is a form with a list of questions that the respondents must answer. According to Goode Hatt, a questionnaire is "often referred to as a tool for getting answers to questions by employing a form that the respondent fills in oneself." A questionnaire is a sampling tool for research that consists of a list of questions developed for a certain group of people. Researching a specific subject on which you wish to draw a conclusion is occasionally important (Crawford 1990; Sudman and Bradburn 1973). These inquiries are given to the respondents. A questionnaire can be used to understand opinions, gather primary data for future research, or simply get feedback. The term "questionnaire" can be defined as an intentionally and methodically constructed set of questions used to analyse a problem or any subject. In other words, a questionnaire is a series of different kinds of questions relating to a particular subject or issue, expressed in a logical sequence and structure, and used to gather data.

1.3 QUALITIES OF A QUESTIONNAIRE

The design of a questionnaire will depend on whether the researcher wants to gather quantitative data or qualitative data for the sake of better understanding or developing hypotheses about a subject (to test specific hypotheses that have previously been generated). A good questionnaire has the following qualities:

1. The study goals ought to be met via a well-designed questionnaire. Even though it might seem clear, many research surveys leave out crucial information owing to poor planning and inadequately examine certain issues due to a lack of comprehension. A portion of this is inevitable, to a certain extent. Every survey is going to have some questions that go unanswered and create a need for additional research, but the goal of excellent questionnaire design is to "minimise" these issues.
2. The information should be as precise and comprehensive as is practical. The questionnaire's creator must make sure that respondents comprehend the questions completely and are unlikely to refuse to respond, lie to the interviewer, or attempt to hide

their attitudes. A well-designed survey will be structured and written to motivate participants to offer truthful, objective, and comprehensive answers.

3. A well-designed questionnaire should make it simple for respondents to provide the relevant information and for the interviewer to record the response. It should also be set up to allow for accurate analysis and interpretation.
4. The interview would be structured so that the respondent(s) remain interested throughout and would be kept concise and to the point.

1.4 TYPES OF QUESTIONNAIRE

The questionnaire can be categorised using the following criteria:

1. On the basis of structure and distinguishes:

(i). **Structured undisguised:** Structured and undisguised questions are involved in this kind of questionnaire. There are only a few possibilities for responding. A structured signifies that the questions answers have already been decided. Respondents must choose an answer from a list of options. Undisguised questions are those questions that are not hidden and are open-ended, therefore, are directly questioned. Respondents may be aware of the researcher's questions. As an illustration, consider the four agriculture products a, b, c, and d. Here, customers are prompted to choose their favourite product.

(ii). **Unstructured undisguised:** Free questions are posed in an unstructured questionnaire. There are more options available in their response. They are free to choose however they want to respond. In other words, the responses of questions are not predetermined. For instance, the customer is requested to list the top products in a specific category.

(iii). **Structured disguised:** Structured refers to the idea that the questions to be answered will have predetermined answers. Disguised refers to a deceptive method of inquiry. Although they are unsure of the question's precise intent, customers can respond with ease. For example which of the following product is more harmful? Why?

(iv). **Unstructured disguised:** The response is not fixed in this case. The choice of how to respond is entirely up to the respondent. Disguised refers to something conceal.

2. On the basis of use/purpose:

(i). **Questionnaire for personal interview:** This questionnaire is suitable to use during a face-to-face interview. More inquiries and indirect queries requiring justification or clarification may be included.

(ii). **Questionnaire for telephone survey:** This survey is designed to gather data over the phone. Naturally, such a questionnaire only has a small number of brief and straightforward questions.

(iii). **Questionnaire for mail survey:** This survey was intended for a mail-in poll. Respondents are asked to return this questionnaire fully completed. Additionally, there are a few short, straightforward questions. But it asks additional questions.

3. On the basis of administration:

(i). **Interviewer-administered questionnaire:** Both the interviewer and the respondents must be present when this questionnaire is being conducted. Here, each respondent is questioned individually. Either in the same questionnaire or on a separate form, their response is noted.

(ii). **Self-administered Questionnaire:** The interviewer provides the respondent with a blank sheet of paper to fill out. It is still possible to do this without an interviewer. This kind of questionnaire is used for mail surveys.

4. On the basis of type of questions, there can be two types of questionnaire:

(i). **Simple Questionnaire:** A predetermined number of the same-type questions are included in this questionnaire. Only dichotomous, multiple-choice, or other options may be present. It's only marginally useful.

(ii). **Multiple Questionnaires:** It involves variety of questions. Such questionnaire consists of certain questions of different categories. It is a popular questionnaire.
It involves many different questions. This questionnaire comprises of a number of questions from several categories. This is the most frequently used method.

1.5 KEY ISSUES RELATED TO QUESTIONNAIRE

The following issues should be kept in mind while preparing the questionnaire:

1. Deciding on information to be collected by questionnaire.
2. Deciding on type of questionnaires to be used (e.g., questionnaire for mail, telephone, or personal interview).
3. Deciding on the content and necessity of each question, and determining whether respondents can answer it.
4. Deciding on methods of administering questionnaire and recording response.
5. Deciding on wording, sentences, and physical layout of questionnaire.
6. Deciding on size of questionnaire or number of questions.
7. Deciding on type of questions (e.g., open-ended, direct, multiple-choice etc.).
8. Deciding on the order or sequence of questions.
9. Deciding on language to be used.
10. Deciding on pretest, review and final draft.

1.6 PRELIMINARY DECISIONS IN QUESTIONNAIRE DESIGN

The basic design of questionnaire generally goes through three phases:

Phase I: Developing a Design, Strategy

1. **Deciding on the information required:** The first step is to determine "what things do you need to know from the respondent in order to accomplish the objectives of the survey?" Even if one already has an idea of the type of data to be gathered. Secondary data and exploratory research can still be useful for collecting primary data. When using secondary data, the researcher must be aware of previous work on the same or related issues, as well as any factors that have already been explored and any new information that has been uncovered and how the current survey can expand on the information already discovered. Additionally, a small number of early informal interviews with target respondents will offer a peek of reality and might help clarify concepts related to the information that required.
2. **Define the target respondents:** In order to generalise from the sample data that will be obtained, the researcher must first determine the population that will be studied. Next, researchers need to create a sampling frame. Thirdly, the intended respondents' age, education, and other characteristics must be taken into consideration when constructing the questionnaire.
3. **Choose the method(s) of reaching target respondents:** The design process for the questionnaire should include thinking about how to get the data to the target respondents. The following are the primary survey research techniques:
    - Telephone interviews
    - Personal interviews
    - Group or focus interviews
    - Mailed questionnaires
4. **Decide on question content:** The question "Is this query really needed? " must be one that all researchers are willing to address. It can be surprising how easy it is to include questions without considering how they would help to fulfill the goals of the study as they are outlined in the research proposal. A question shouldn't be asked unless the data it generates will be directly useful in testing one or more of the hypotheses developed during the research design. Simple, non-threatening, and/or viewed as fascinating opening questions can substantially help in obtaining the respondent's involvement in the survey and help to build rapport.
5. **Data collection:** The researcher identifies the kind of questionnaire that will be used in this stage to describe how the data will be collected. There are four different kinds of questionnaires.

a. **Structured-Undisguised Questionnaire**: The most common kind, it involves asking questions that are logically ordered and written in a clear, direct manner. All respondents receive the identical questions in the same phrasing and order. Both administering and tabulating them is relatively straightforward.
b. **Unstructured-Disguised Questionnaire**: This questionnaire, which is the exact reverse of the prior form, conceals the goal of the study and exhibits no discernible patterns or tendencies. Projective approaches are typically used in such a questionnaire to gather data. The respondent receives a concealed or camouflaged stimulus, and their answer is unstructured.
c. **Unstructured-Undisguised Questionnaire**: The objective is made apparent in this form of questionnaire, although the questions are typically left open-ended. For example, How do you feel about excessive use of chemical fertilizers in agriculture? There is no restriction on how the respondents can answer. Usually, these questions are asked during in-depth interviews.
d. **Structured-Disguised Questionnaire:** This questionnaire's goal is to conceal the study's motivation while facilitating simple coding and analysis. This strategy is founded on the idea that direct questions may bend or prejudice respondent's responses, but if the questions are disguised, we can ask the respondents more objectively that what they know, what they feel. Although easy tabulation and analysis are provided by such questionnaires, this approach is not always preferred due to the time and effort required to craft covert questions. For example, the inquiry from before will be phrased as: What are the effects of excessive chemical fertilizers on soil?
   (a) It creates soil infertile
   (b) It causes serious health issues
   (c) .....
   (d) .....

Phase II: Constructing the questionnaire

6. **Develop the question wording:** Survey questions can be classified into three forms, i.e. closed, open-ended and open response-option questions.

   (i) Closed questions: These are defined as those questions that ask respondents to choose from a distinct set of pre-defined responses.

   A**dvantages**:

   - It offers the respondent a simple way to express his response.
   - Analysis is simple and clear because responses can be categorised with ease.
   - The respondent is free to specify which kinds of answers are best suited to their objectives.
   - It prompts the respondent so that the respondent needs to rely less on recollection while responding to a question.

   Disadvantages:

   - Closed questions deny the respondent the chance to provide an alternative response to those that are suggested.

- Closed questions make recommendations for solutions that respondents may not have previously thought about.

(ii). Open-ended questions: The respondent is asked to answer a question in his or her own words. There are no suggested solutions. For instance, "What do you appreciate best about this agricultural product?

Advantages:

- They give the respondent the freedom to respond in his own terms without being influenced by any specific choices the interviewer may have suggested.
- They frequently reveal the subjects that matter the most to the respondent, and this may provide information that was not initially intended when the survey was started.
- Respondents have the option to "qualify" their responses or highlight the conviction in their positions.

Disadvantages:

- It could be challenging for respondents to adequately and completely "articulate" (or explain) their attitudes or motivations in their responses.
- Respondents could neglect to bring up crucial aspects, which prevent them from providing a complete response. Some respondents need to be reminded or prodded as to the possible forms of answers.
- Verbatim comments are used to collect data; this information needs to be classified and divided into smaller, more manageable groups. There are many potential for inaccuracy in the recording and interpretation of the interviewees' responses, and analysis of this can take a while.
- Respondents will typically respond to open questions in many "dimensions." When asked, "When did you buy your tractor?", for instance, one of numerous answers, such as "Just recently," "Last year," "When I sold my last tractor," or "When I acquired the farm," can be given. Unless the researcher is going to be presented with responses that can't be aggregated or compared, such responses need to be pressed further.

(iii). Open response-option questions: Mostly eliminate the disadvantages of both the afore-mentioned types of questionnaire. An open response-option is a form of question which is both open-ended and includes specific response-options as well. For example, What features of this implement do you like? Options:

- Price
- Performance
- Weight
- Quality

- Others mentioned:

Advantages:

- By prompting the responder to explore specific response alternatives later, the researcher can avoid potential issues with weak memory or poor articulation.
- It is relatively simple to record an interview.

Disadvantage: In order to come up with plausible/likely response possibilities before printing the questionnaire, the researcher must have a comprehensive understanding of the subject. However, if this comprehension is attained, it will be considerably simpler to collect data and analyse it.

Phase III: Drafting and refining the questionnaire:

7. **Putting questions into a meaningful order and format:** Following should be included in the design of questionnaire.
    - **Opening questions:** Opening questions must be simple to respond to and not at all intimidating to the respondents. The first question is very important since it introduces the respondent to the interview and establishes the nature of the work that needs to be completed. They are prone to stop talking right away if they find the first question to be confusing, above their level of expertise, or in some other way embarrassing. On the other hand, they are urged to go on if they find it simple and enjoyable to respond to the introductory question.
    - **Question flow:** In order for one question to naturally lead into the next, they should flow in some sort of psychological order. In order for one question to naturally lead into the next, they should flow in some sort of psychological order. It is best to combine questions together that pertain to the same topic or a specific component of it. It could be unsettling for respondents to be invited to return to a topic they believed they had already expressed their ideas on or to have the conversation constantly change topics.
    - **Question variety:** When asked the same questions repeatedly, respondents quickly get bored and restless. Therefore, switching up the respondent's task sometimes usually results in better response. Even if it is not analysed, an occasional open-ended question can offer much-needed reprieve from a long list of inquiries that force respondents to confine their responses to pre-coded categories. The pace can be changed and interest increased by using questions that require respondents to display cards or photos.
    - **Closing questions:** It is normal for a participant to lose interest in the questionnaire as it gets to the end. He might provide sloppily thought-out replies to the subsequent queries due to irritation or exhaustion. Therefore, if at all possible, the items that are of particular importance should be included in the first section of the questionnaire. To avoid interviewees quitting before crucial data is

gathered, potentially uncomfortable questions should be saved for the end. The researcher should pay close attention to how the interview form is presented and laid out when creating the questionnaire. It is important to make the interviewer's job as simple as possible.

8. **Physical appearance of the questionnaire:** The quantity and quality of marketing data collected can be significantly impacted by the physical design of a questionnaire. The response rate affects the amount of data. Poorly designed questions may appear to be complex, lengthy, and time-consuming. The physical design of the questionnaire can also have an impact on the quality of the data; for example, needlessly complex layouts make it more challenging for interviewers—or respondents, in the case of self-completion questionnaires-to finish this work effectively. The data gathered by a questionnaire can benefit disproportionately from paying attention to a few simple details.

    - **Use of booklets:** Booklets make it simpler for the interviewer or respondent to move through the material than loose or stapled sheets of paper. Additionally, fewer pages usually get misplaced.
    - **Simple, clear formats:** The ease with which interviewers or respondents are able to complete a questionnaire can also be improved by the clarity of the questionnaire's presentation.
    - **Creative use of space and typeface:** There is a tendency for people to put too much information on a page in an effort to cut down on the number of pages in a questionnaire. This defeat the purpose since it makes the questionnaire seem difficult. Use of vacant space in questionnaires makes them easier to use, gets more responses, and when filled up, has fewer errors.
    - **Use of colour coding:** Using colour coding to administer questionnaires can be helpful. Several different sorts of respondents are frequently included in a single poll (e.g. wholesalers and retailers). The handling may be made simpler by printing the surveys on two distinct colours of paper.
    - **Interviewer instructions:** Instructions for the interviewer should be written next to the relevant questions. The answer is recorded following the question, along with instructions on where to ask follow-up questions to elicit additional information.

A questionnaire should, in general, be as brief as possible. A lengthy questionnaire precedes a lengthy interview, which increases the risk of respondent boredom (and hasty, poorly thought-out responses), interruptions from other people, and higher expenditures in terms of interviewing time and resources. An interview shouldn't last more than 30-45 minutes in a rural setting.

9. **Piloting the questionnaires:** Even after the researcher followed the recommended steps, the draught questionnaire was only created by one or two people. It is impossible to predict whether it will produce the desired results until it has actually been utilised in interviews and with responders. For this reason, it is essential to pre-test the questionnaire before using it in a comprehensive survey to find any errors that need to be fixed. The questionnaire's pretest is used to ascertain the following:

    - Whether the way the questions are framed will lead to the desired results
    - Whether the questions have been arranged in the most efficient manner.
    - Whether each class of respondent can understand the questions
    - Which questions should be added, which ones should be more specific, and which ones should be removed.
    - How well-written the interviewers' instructions are

    For the pre-test, typically a limited sample of respondents is chosen. A good representation of the sort of respondents who will be interviewed for the main survey should be found among the respondents chosen for the pilot survey. The questions and the questionnaire will have matured into its final shape if a comprehensive pilot test has been conducted on it. The questionnaire still needs to be laid out and assembled in its final form, which is a mechanical process. To accomplish this, questions will need to be grouped and ordered properly, given numbers, and interviewer instructions will need to be added.

1.7 TIPS FOR A GOOD QUESTIONNAIRE

1. **Keep in mind the underlying assumption:** The questionnaire should be prepared to target a particular group of people and then be shared with them for your response sheet to be practical. Make sure it is crystal clear, valid, and engaging. Spend some time identifying the questions that address all the subareas and perspectives of your research. Make a list of all the characteristics of your target population, including its demographics, educational attainment, and socioeconomic status. This is need to decide how many time periods to conduct the survey after covering all of your questions across all dimensions and focus groups. Some surveys are conducted among various group clusters, necessitating the use of multiple time frames.
2. **The format of the questions depends on the method:** It is dependent upon the type of analysis method choosen subsequently. For instance, different format need to utilise when using a statistical and probability strategy on distinct questions.
3. **Avoid open-ended questions if possible:** Always choose the closed-ended questions if you can group your options into categories. The respondents will answer more quickly and more effectively. If you must use open-ended inquiries, place them at the start of the

conversation. Make sure all follow-up questions are succinct. Otherwise, it's always possible that respondents won't finish the survey.

4. **Provide instructions:** Notify survey participants how to finish the form. Allow them to contact you if they have any queries or require further explanations.
5. **Use simple language.** It's crucial to keep your queries as pertinent as possible because respondents may have varied backgrounds.
6. **Arrange it in a logical order.** Before asking particular questions, begin your questionnaire with broad inquiries.
7. **Do not use the 'Other' category:** Any questionnaire's respondents are always eager to finish it. In this situation, selecting an option like "Other" enables skipping this question and moving on to the next. Overall, it doesn't improve the content of your response sheet in any way.
8. **Always pre-test:** Pre-test your survey with a select group of people from your target or general audience. It will enable you to quickly assess the success of your questionnaire. It will also give you the chance to make any necessary changes before launching the survey. Ask a few people to respond to your survey, then solicit their feedback. You can use this to highlight errors and queries that need to be edited.
9. **Keep it short:** Long questionnaires may be intimidating for respondents to complete. In contrast to a survey questionnaire, respondents will think they are taking an exam.
10. **Try to minimise the number of questions.** Don't cram the questionnaire with too many questions; instead, pay attention to the quality. People will be reluctant to see many queries. Additionally, you'll find yourself asking questions twice that are virtually identical in meaning, which will lead to confusion.

1.8 SUMMARY

A good survey needs a well-designed questionnaire. However, as there is no theory of questionnaires to serve as a guide, the researcher must build his or her own intuition for what constitutes "excellent design." A good questionnaire aids in the direct accomplishment of the study goals, provides thorough and accurate data, is simple for interviewers and respondents to complete, is created in a way that allows for solid analysis and interpretation, and is brief.

The different separate steps are involved: Decide on the information needed, specify the target respondents, choose the technique or methods to contact the respondents, decide on the question's topic, wording, and order; Verify the length of the questionnaire, test it beforehand, then create the final one.

Overall, while creating a questionnaire, use a systematic process, starting with defining the objectives and ending with data analysis. Check out various tools for producing questionnaires and choose the one that best suits you.

1.9 GLOSSARY

Assessment: Often used as a synonym for evaluation. The term is sometimes recommended for processes that are focused on quantitative or testing approaches.
Closed-ended questions: A broad category of questions that provide a set of possible responses from which to choose.
Data analysis: The process by which meaning, themes, and useful information are extracted from raw quantitative or qualitative data.
Data: refer to numeric files that are created and organized for analysis.
Focus group: A group selected for its relevance to an evaluation that is engaged by a trained facilitator in a series of discussions designed for sharing insights, ideas, and observations on a topic of concern to the evaluation.
Open-ended questions: Questions that stimulate free thought by asking people to write their answer in their own words rather than choosing from a predetermined set of response options. Open-ended questions allow for spontaneous, unstructured, descriptive responses.
Pilot test: In the case of surveys or interviews, a pilot test can determine whether the instrument used is well suited to the intended respondents, if the instructions and questions are clear, the time required to complete the instrument, and how easily the instrument can be implemented.
Qualitative data: Information that refers to the quality of something.
Quantitative data*:* Information that can be handled numerically
Questionnaires: An instrument useful in gathering focused, limited information from a specific population.
Sample: A collection of units or observations from the larger population. For example, it is usually not possible to survey an entire population, but one can select a sample or portion of the population to survey.
Statistic: A number that describes some characteristic, or status, of a variable.
Survey: A method for gathering quantitative or qualitative information directly from a defined population.

1.10 SELF-ASSESSMENT QUESTIONS

1.10.1 Multiple choice questions

1. Which of the following are known as the types of research data?
   a. Organised data and unorganised data
   b. Qualitative data and quantitative data
   c. Processed data and unprocessed data
   d. None of the above
2. Which of the following statements is true about the collection of data?
   a. The data that is collected from the place of origin is known as primary data

b. The data that is collected from the place of origin is known as secondary data
c. The data that is collected from the place of origin is known as tertiary data
d. None of the above

3. Which of the following statements is true about data in research?
   a. The data used for research is quantitative
   b. The data used for research can be qualitative but never quantitative
   c. The data used for research can be both quantitative and qualitative
   d. The data used for research can be quantitative but never qualitative
4. Which of the following statements is not true about the collection of data?
   a. In the structured interview, the interviewer asks a set of pre-planned questions in a standard format
   b. In the observation method, the researcher collects data with the help of their observational skills
   c. In an indirect interview, the investigator directly asks the informants for the data
   d. In a direct interview, the researcher meets the interviewees directly to collect the data
5. Which of the following situations is suitable for direct personal investigation?
   a. It is suitable when the field of investigation is large and complex
   b. It is suitable when the information to be collected is complex and confidential
   c. It is suitable when the researcher needs second-hand data for their research
   d. It is suitable when direct contact with the interviewees is not possible

1.10.2 True and False

1. The source of data that is collected and compiled by others is known as secondary data.
2. The term "data" came from the Latin root term datum.
3. Census Report is the true example of Secondary data.
4. Structured observation is a part of descriptive study.
5. Primary data is also known as first-hand or original data.

1.10.3 Fill in the blanks

1. A _____ refer to numeric files that are created and organized for analysis.
2. _____ is it called when the data source is gathered and compiled with others?
3. What _____ data is it called when the data is sourced from the place of origin?
4. The _____ investigation is used to collect data from the third parties
5. The _____ data is much more reliable than secondary data because it is collected directly from respondents.

Answer Key:

1.10.1: 1. (b); 2. (a); 3(c); 4. (c); 5. (b)

1.10.2: 1. True; 2. True; 3. False; 4. True; 5. True

1.10.3: 1. Data; 2. Secondary data; 3. Primary data; 4. indirect oral investigation; 5. primary data

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1.13 TERMINAL QUESTIONS

1.13.1 Short answer type questions

1. Summarise the qualities of a good questionnaire.
2. Where interviewer instructions pertaining to responses to a particular question should be placed on the questionnaire?
3. Name the three advantages of open-ended questions.
4. What is the recommended duration of interviews carried out in rural situations?
5. What are the key characteristics of opening questions in a questionnaire?

1.13.2 Long answer type questions

1. Design a questionnaire to know the changes in agriculture and agricultural products in the last 50 years of your locality.
2. What do you understand by questionnaire? Discuss the qualities and types of a questionnaire.
3. Discuss the preliminary decisions in questionnaire design.
4. Describe the major instructions for a good questionnaire.

UNIT-2 DATA TABULATION, INTERPRETATION AND REPORTING

Contents

2.1- OBJECTIVES

After reading this unit you will be able to -

- Understand the basic concepts of data tabulation in biostatistics,
- Data interpretation and
- How to develop your data interpretation into a report.

2.2- INTRODUCTION

Biostatistics is the application of statistics in the field of biological sciences. It is a tool of statistics applied to the data that is derived from the biological sciences. Therefore, it is an integral part of biological sciences to keep information or data in concise, appropriate and logical manner. Data tabulation provides refining of raw data and cast it in the form of vertical columns and horizontal rows. The information derived from data tabulation is used to analyse the novelty of the data through different methods being adopted under data interpretation. Finally, the inference or results of the data are kept as a record in the form of report.

2.3- DATA TABULATION

Tabulation is defined as a systematic and logical arrangement of numeric data in the format of horizontal rows and vertical columns to help in comparison and statistical analysis of the data. Tabulation means processing data or information by organizing it into a table. With the help of tabulation, numeric information is cast logically and orderly into columns and rows, to help its readers for better statistical interpretation of the data given.

Tabulation of data in statistics thus a method of storing classified data in a tabular form. It may be complex, double or simple, depending upon the type of categorization of data.

The purpose of tabulation is to display a large number of complex information in a systematic manner, which will be fruitful to draw valid, correct and precise interpretations from the data given or provided.

2.3.1- Parts of Table in Tabulation

In order to tabulate data accurately and precisely, one must understand some of the essential parts of a table which are as follows:

1-Table Number: This is the first section of a table and is presented on top of any table to facilitate straightforward identification and for further reference.

2- Title of the Table: One of the most related parts of any given table is its title. The title of the table describes its contents. It is important that the title should be short and crisp and exactly worded to define the table's contents efficiently.

3- Column Headings or Captions: Captions are the piece of information on the table which is at the top of each column that tells the figures under each column.

4- Row Headings: The title of every horizontal row comes under the row heading.

5- Body of a Table: This is the part that includes the numeric information collected from examined facts. The data in the body is displayed in rows which are read horizontally starting from left to right and the data in the columns are read vertically from top to bottom.

2.3.2- Types of Tabulation

Tabulation can be classified into the following types:

1. Simple Tabulation or One-way Tabulation

When the data are tabulated to one aspect, it is declared to be a simple tabulation or one-way tabulation.

For example: the tabulation of data on the population of plants on earth divided by one feature like size/height of the plant is an example of a simple tabulation.

2. Double Tabulation or Two-way Tabulation

When the given data are tabulated according to two characters at a time, it is stated to be a double tabulation or a two-way tabulation.

For example: suppose that a table has to show the highest population of plants in various states of India. This can be achieved by a one-way table. However, if the population of plants has to be analysed in terms of the total number of Angiosperms and Gymnosperms in every state, it will ask for a two-way table.

3. Three-way Tabulation

Similar to the above-mentioned category, three-way charts show information handled from three mutually dependent and interrelated subjects.

Let us consider the same above example and elaborate on that further with the added category in the table. Now we need the position of trees amongst the Angiosperms and Gymnosperms populations in each state. The tabulation for such categories has to be placed down in a three-way table.

4. Complex Tabulation

When the data are tabulated according to various characteristics, it is stated to be a complex tabulation.

For example tabulation of data on the plant population of the planet is divided into three or more characteristics like habit, flower, seed; pollination etc. is an example of a complex tabulation.

2.3.3- Objectives of Tabulation

Objectives of tabulation essentially connect the gap between the groups of data and help to analyse them. The primary objectives of tabulated data along with the uses of tabulation are discussed below:

1. To simplify complex data: Data or information presented in such a format decreases the bulk of information, i.e., it lessens raw data in a more simplified and exact form that can be easily interpreted by a common person in less time.

2. To highlight important information: Representing any data in rows and columns extends the scope to highlight the relevant information by presenting facts clearly and precisely without textual information. Thus this automatically contains any crucial data without difficulty.

3. To enable easy comparison: When data is displayed in an orderly manner in rows and columns, it becomes more obvious to perform the comparison of quantity on the grounds of several parameters. For example, it becomes more straightforward to determine the month when a country has experienced the highest amount of rainfall if the information is presented in a table. Otherwise, there is always room for making an error in processing the data correctly.

4. To facilitate statistical analysis: Tables serve as the most reliable source of classified data for statistical analysis. The task of computing percentage, distribution, correlation, etc., becomes more manageable if data is presented in the form of a table.

5. To save space: A table presents facts in a more reliable way than the textual structure. Hence, it saves space without losing the quality and quantity of data.

2.3.4- How is data in tabulation executed

Tabulation of data can be carried out manually or with the aid of a computer. Frequently, the achievement of data tabulation depends on the cost, kind and scope of the study and such factors.

If tabulation is conducted out on a computer, the answers are saved in numeric form. However in the case of tabulation by hand, one can use lists, tally, card sort and count methods. The methods are explained as follows:

Tabulation of data through Direct Tally Method: In this method, the codes are initially written down in tally sheets. Then a stroke is marked on codes to denote the answer. After each fourth stroke code, the fifth response is presented by putting a horizontal or diagonal line within the stroke.

Tabulation of data through Card Sort and Count Method: This is possibly the most effective hand tabulation method where the data is entered in cards of various dimensions and shapes with the help of a set of holes. Following the cards belonging to the individual categories are separated and counted, and their frequency is entered.

Tabulation of data through List and Tally Method: In this method, a large number of applications are listed in one sheet. The answers to each question are then inserted into rows, and the code corresponding to a specific question is outlined in columns.

2.3.5- Rules of Tabulation

There are some general rules of tabulation discussed below that must be followed while creating tables.

1-The tables represented should be self-explanatory. Moreover, footnotes form a portion of tables, they should not be necessary to define the meaning of the data displayed in a table.

2-If the amount of information is valuable, it is best to place them on multiple tables rather than a single one.

3- However, each table design should also be complete in itself and must serve the goal of the analysis.

4-The figure of rows and columns should be kept minimum to present data in a brief and concise manner.

5-Before the actual tabulation, data should be approximated, wherever required.

6- Stubs and titles should be self-explanatory and need not require the assistance of footnotes to be comprehended.

7- If certain conditions of data gathered cannot be tabulated under any stub or captions, they should be placed in a separate table with the heading of miscellaneous.

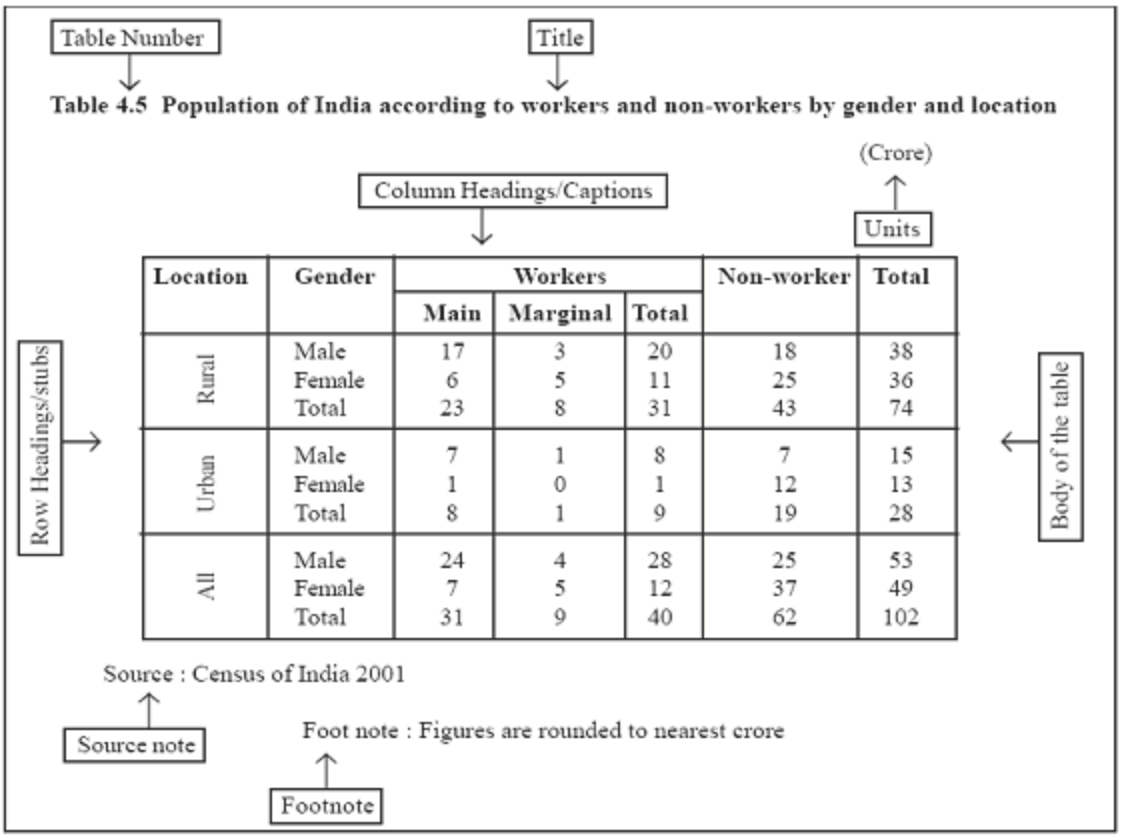
8- Quantity and quality of data should never be negotiated under any situation while creating a table.

Table Number: .....
Title: .....
(Head Note, if any)

Stub (Row Heading)	Caption (Column Heading)				Total (Rows)
	Sub-head		Sub-head		
	Column-head	Column-head	Column-head	Column-head	
Stub Entries (Row Entries) . . .		Body			
Total Columns					

Source Note:
Footnote:

Figure 2.3 Format for tabulation of data. (A)



Location	Gender	Workers			Non-worker	Total
		Main	Marginal	Total		
Rural	Male	17	3	20	18	38
	Female	6	5	11	25	36
	Total	23	8	31	43	74
Urban	Male	7	1	8	7	15
	Female	1	0	1	12	13
	Total	8	1	9	19	28
All	Male	24	4	28	25	53
	Female	7	5	12	37	49
	Total	31	9	40	62	102

Figure 2.4 Arrangement of data in the form of table.

2.4 DATA INTERPRETATION

It is the process of receiving data through some predefined processes which will help in assigning some meaning to the data that finally leads to the relevant conclusion.

It involves taking result of data analysis, making inferences on relations studied and using them to conclude.

2.4.1- Methods for Data interpretation

There are two main methods for data interpretation:

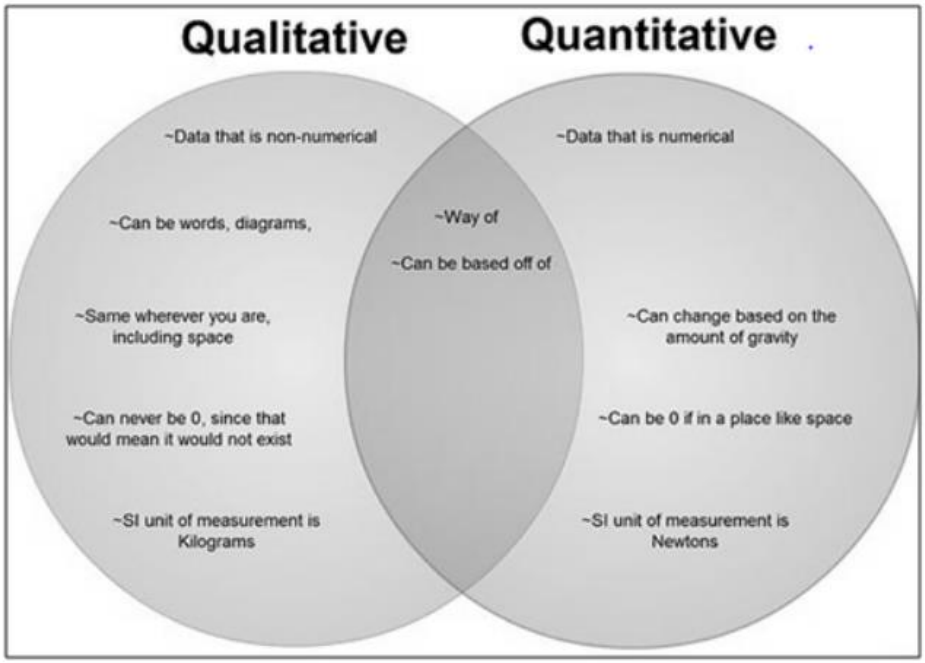
i. Qualitative Data interpretation method
ii. Quantitative Data interpretation method

In qualitative data interpretation, it is used to analyse qualitative data which is also known as categorical data. This method uses texts, rather than numerical data or patterns to describe data. It is gathered using variety of person- to – person techniques. There are two main types of qualitative data, namely nominal and original data. Both these types can be interpreted using same method, but original data interpretation is much easier than nominal data. In quantitative data interpretation, this method is used to analyse quantitative data, which is also known as

numerical data.This method contains numbers and analysed with use of numbers and not texts. There are two mains types of quantitative data namely discrete and continuous data. In discrete data we have provided the data along with their relevant frequencies whereas, in continuous data there is division of data in terms of class intervals and ratio data.

	Quantitative	Qualitative
Purpose	To study relationships, cause and effect	To examine a phenomenon as it is, in rich detail
Design	Developed prior to study	Flexible, evolves during study
Approach	Deductive; tests theory	Inductive; may generate theory
Tools	Uses preselected instruments	The researcher is primary data collection tool
Sample	Uses large samples	Uses small samples
Analysis	Statistical analysis of numeric data	Narrative description and interpretation

(A)



(B)

Figure 2.5 (A) & (B) Comparison between qualitative and quantitative approach of data interpretation.

2.4.2- Techniques of Data interpretation

Data interpretation is an art that one learns through and experience. It involves the following steps:

i. Generalization and concept formulation
ii. Extraneous information (irrelevant or unrelated to the subject being studied) must be considered, which prove to be a key factor in understanding the problem under consideration.
iii. Before final interpretation consult a subject expert to point out the omission of errors if any in the completed work or task assigned.
iv. Considering all relevant factors to avoid false generalization.

2.4.3-Reasons for interpretation

i. Serve as a guide for future research work.
ii. Researcher can better appreciate only through interpretation and to understand the real significance of the study.
iii. Interpretation of explanatory research/ study after results into hypothesis of experimental research work, results in transition from exploratory to experimental.

2.4.4- Precautions while writing interpretation are

i. Data must be appropriate and unbiased.
ii. Data must be trustworthy.
iii. Adequate for drawing relevant inference.
iv. The data reflect good homogeneity.
v. Proper analysis has to be done through sufficient statistical methods.
vi. Remain cautious about the errors, which is possible in the process of interpreting results.

2.4.5- Diagrammatic representation of Data

It is the prerequisite for data interpretation. The data presentation can be done by the following diagrams:

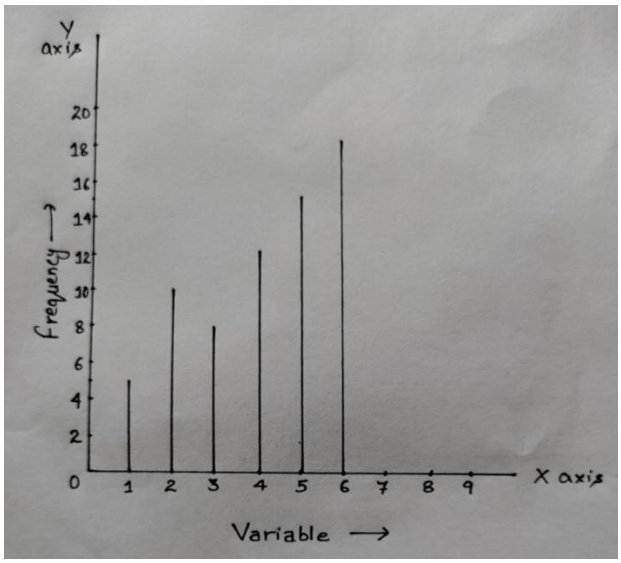
i. **Line diagram**

This is the simplest of all the diagrammatical representations as it consists of drawing vertical lines. Each vertical line being equal to the frequency. The variant values are presented on x- axis while corresponding frequencies are presented of y-axis.

For example: Construct the line diagram for the given data

Variable	1	2	3	4	5	6
Frequency	5	10	8	12	15	18

Solution:



Line diagram

ii. **Bar diagram**

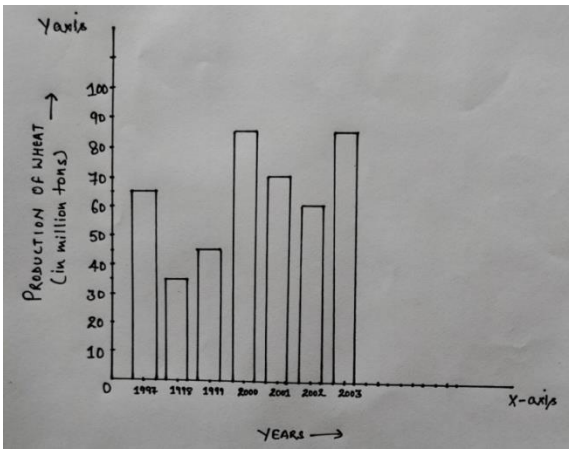
It consists of a group of equidistant rectangles. One for each group or category of the data in which the values represented by the length or height of the rectangles. The width of each rectangle should have uniform width on the same base line.

For example: Production of wheat in different years in Punjab is provided in the following table

Year	1997	1998	1999	2000	2001	2002	2003
Production of Wheat (in million tons)	65	35	45	85	70	60	85

Represent this data in Bar-diagram.

Solution:



Bar diagram

iii. Angular or Pie- Diagram

Circle may be divided into various sections or segments representing certain proportion or percentage to the total are known as angular/pie-diagram.

It can be easily understood with the help of following example:

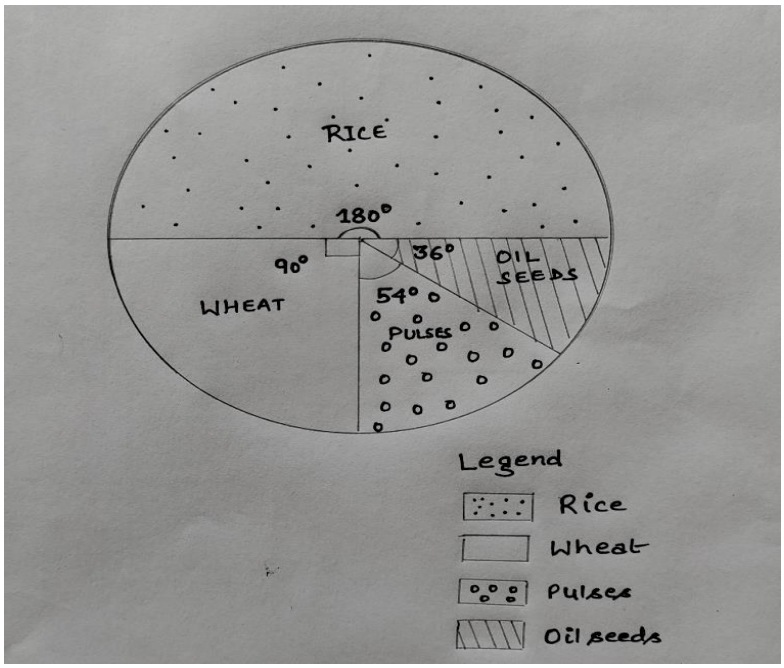
Design a single diagram to exhibit the information relating to the production of various crops in a particular year

Crop	Rice	Wheat	Pulses	Oil seeds
Production (in million tons)	200	100	60	40

Solution: One of the best single diagram to represent the given data is pie-diagram. To construct it first of all the given data have to be arranged as follows:

Crop	Production (in million tons)	Production percentage	Angle of the circle calculation
Rice	200	200/400 x 100 = 50%	50/100 x 360 = 180^o
Wheat	100	100/400 x 100 = 25%	25/100 x 360 = 90^o
Pulses	60	60/400 x 100 = 15%	15/100 x 360 = 54^o
Oil seeds	40	40/400 x 100 = 10%	10/100 x 360 = 36^o
Total	400	100 %	360^o

On the basis of the table following angular/pie-diagram is constructed:



Pie-diagram

iv. Pictograms or pictographs

This is a technique of presenting data through appropriate pictures. It is one of the very popular devices used when the statistical facts are to be presented to a layman (who doesn't have any mathematical knowledge).

"A pictograph is a representation of data using images or symbols." Pictographs are typically used in concepts like data handling. They help in laying the foundation for data interpretation based on pictorial information.

Advantages of Using Pictograph

1. A pictograph helps to represent large and complex data in the simplest ways possible.
2. Pictographs are easy to read, and we can study all the data in one look.
3. In pictograms no need to give a lengthy explanation.
4. As a pictograph uses visual elements, it will be more attractive and interesting to the viewers and readers.
5. Pictographs make data handling easier.

6. Pictographs also help in formatting the statistics visually.

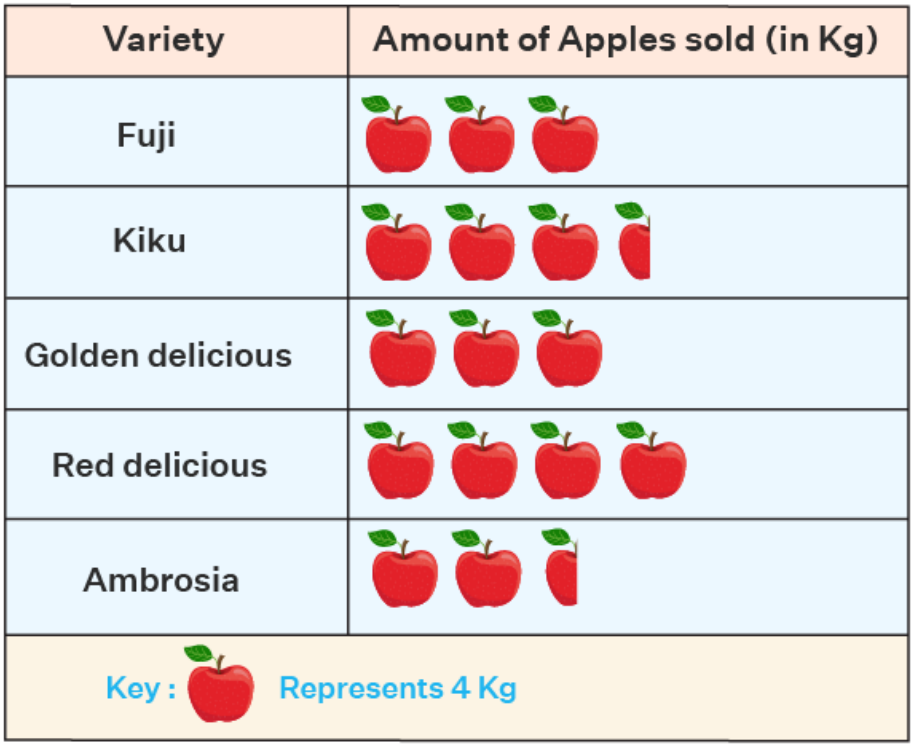


Figure-2.6. Pictogram showing different varieties of apples sold in Kilograms.

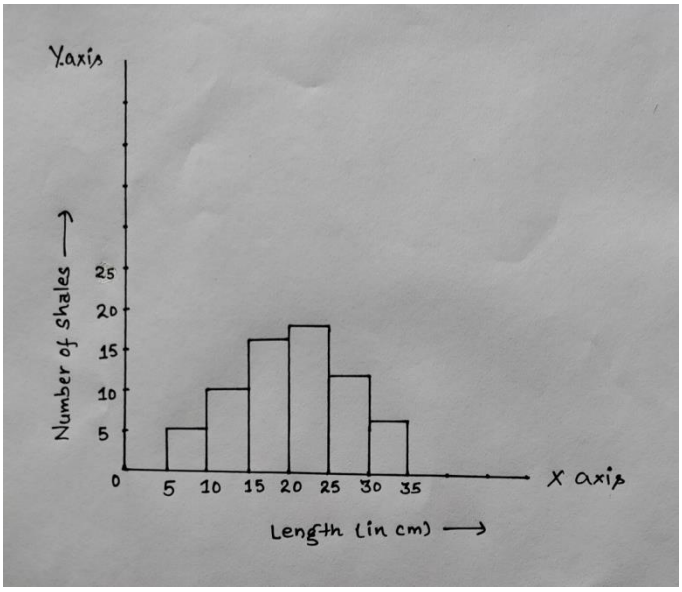
2.4.6- Graphic Representation of data

To study the relationship between two variables under study the graph is used. Graphs are more obvious, precise and accurate than diagram. Moreover it can be efficiently used for further statistical analysis. Graphical representation is based upon nature of data given which can be easily understood by following diagrams.

i. **Histograms:** one of the most important and useful method of presenting frequency distribution of continuous series.

For example: 67 fossilized shales containing plant impressions, selected from a coal mine have length given below:

Length (in centimetre)	5-10	10-15	15-20	20-25	25-30	30-35
Number of Shales	5	10	16	18	12	6



Histogram

Major differences between Bar Graph/diagram and Histogram

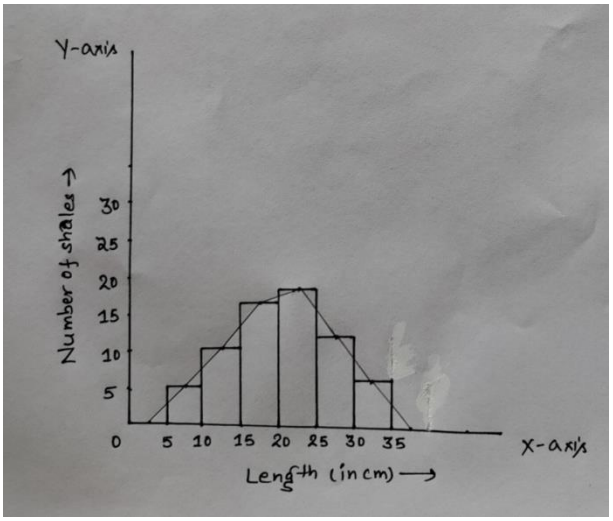
Bar Graph	Histogram
Equal space between every two consecutive bars.	No space between two consecutive bars. They should be attached to each other.
X-axis can represent anything.	X-axis should represent only continuous data that is in terms of numbers.

ii. **Frequency Polygon:** A frequency polygon is a line graph of class frequency plotted against class midpoint. It can be constructed in two ways from histogram and without the use of histogram.

a) With the help of histogram: first draw a histogram of the given data and then join the mid of each rectangle by straight line

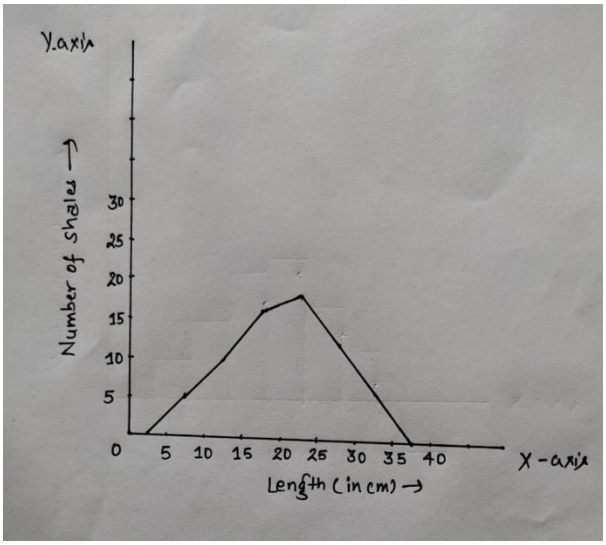
Draw frequency polygon for the following data using histogram

Length (in cm)	5-10	10-15	15-20	20-25	25-30	30-35
Number of Shales	5	10	16	18	12	6



Frequency polygon using histogram

b) Without histogram: Take the mid-points of various class intervals and then plot the frequency corresponding to each point and join these points by straight line.

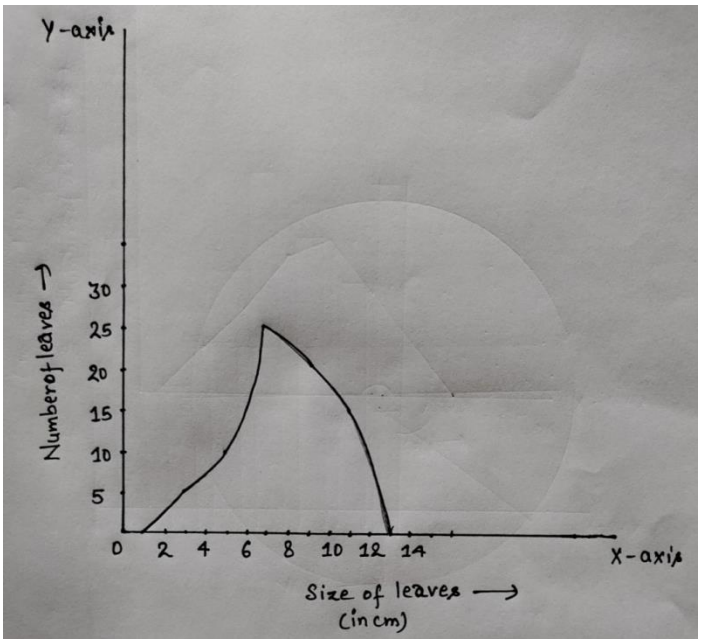


Frequency polygon without histogram

iii. Smooth frequency curve: These curves are drawn with free hand (without using scale).

For example: Draw a smooth frequency curve from the following data-

Length of leaves (in cm)	2-4	4-6	6-8	8-10	10-12
Number of leaves	5	10	25	20	25



Smooth frequency curve

iv. Cumulative frequency curve or Ogive

Ogive or Cumulative Frequency Curve is a curve of a data set obtained by an individual through the representation of cumulative frequency distribution on a graph. As there are two types of cumulative frequency distribution; i.e. **less than cumulative frequencies** and **more than cumulative frequencies,** the ogives are also of two types:

1. Less than Ogive

2. More than Ogive

Less than ogive: This consists in plotting less than cumulative frequencies against the upper boundaries of the respective classes.

More than ogive: Here the more than cumulative frequencies are plotted against the lower class boundaries of the respective classes. Points are joint by smooth free hand curve.

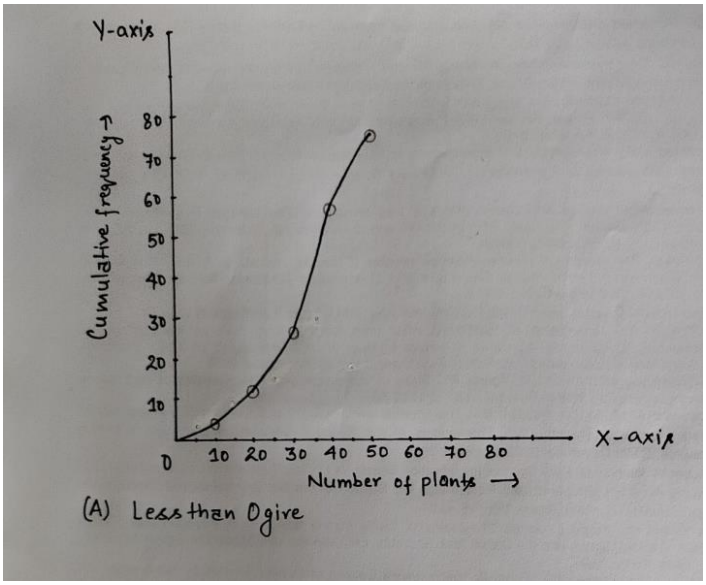
Cumulative frequency is defined as the sum of all the previous frequencies up to the current point. To find the popularity of the given data or the likelihood of the data that fall within the certain frequency range, Ogive curve helps in finding those details accurately.

For example: Draw less than and more than Ogive curve for the following data-

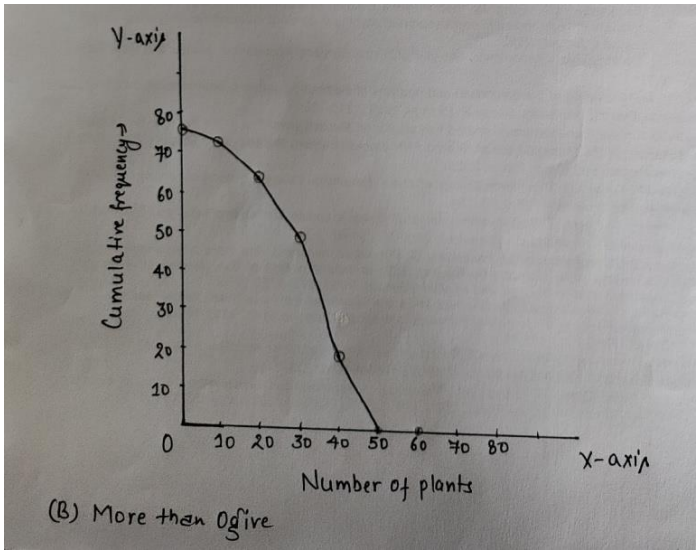
Length of plants (in cm)	0-10	10-20	20-30	30-40	40-50
Frequency	3	9	15	30	18

Solution

Length less than	Cumulative frequency	Length more than	Cumulative frequency
10	3	0	75
20	3+ 9= 12	10	75-3= 72
30	3+9+ 15=27	20	72-12= 63
40	3+9+15+30=57	30	63-27= 48
50	3+9+15+30+18=75	40	48-30= 18



(A) Less than Ogive



(B) More than Ogive

2.5- REPORT WRITING/REPORTING

A report is a written document on a particular topic, which conveys information and ideas and may also make recommendations.

Research report is the oral or written presentation of evidence and the finding in such a way that it is readily understood and assessed by the reader and enables him to verify the validity of the conclusions.

2.5.1- Characteristics or features of good research report:

1- All points in the report should be clear to read.
2- Report should be concise with necessary information under proper headings and sub headings.
3- All information should be correct and supported by evidence.
4- All relevant material should be included.

2.5.2- Purpose of Research Report

1- Transmission of knowledge.
2- Presentation of findings.
3- Examining the notability of generalizations.
4- Inspiration for further research.

2.5.3- Significance of report writing

1-It is major component of research study for research task remains incomplete till it is presented.
2-It gives generalization and findings of little value.
3-The purpose of research is not values until it is known to others.
4-It is last part of research study and need set of skills for writing.
5- It needs assistance and guidance from experts.

2.5.4- Steps in Report writing

Logical analysis of the subject matter

It is the development of subject in two ways:

i. **Logically**: basis of mental connections and associations between one thing and another by means of analysis.
ii. **Chronologically:** it is based on a connection or sequence in time or occurrence.

Preparation of the final outline

It is the framework upon which long written works are constructed.

Preparation of the rough draft

1-It follows logical analysis of subject and preparation of final outline.

2-It includes about what researcher has done, procedure adopted, methodology, analysis, limitations and suggestions regarding the problem.

Rewriting and polishing of the rough draft

1. It requires more time than writing of rough draft.
2. It is like careful revision and making good piece of writing.
3. It checks the weakness of report for logical development or presentation.
4. It exhibits definite pattern.
5. It checks mechanics of writing like grammar, spelling, tenses etc.

Preparation of final bibliography

1-It includes list of books in pertinent way, contains all those research work.

2-It should arrange alphabetically and divide into two parts.

3-It includes first part (name of books and pamphlets), second part (names of magazine and newspaper articles).

Format: (for books and pamphlets)

- Name of author, last name first.
- Titles (in italics), place, publisher, date of publication, number of volumes.
- For example: Karun, K.M. and Puranik, A., *Handbook on Biostatistics for health professionals*, Kerala, Biostatistical Consultancy Center (BCC), 2015.

For magazine and newspaper

- Name of author, last name first.
- Title of the article in quotation mark.
- Name of the periodical (underlined), Volume number.
- Date and page number.
- For example: Robert V. Roosa, "Coping with short- term International Money Flows" The Banker, London, September, 1971, p.995.

Writing the final draft

1. It should be in concise and objective style, simple language.
2. Avoid vague expressions like "it seems", "there may be".
3. Avoid abstract terminology and technical jargon.
4. Example must be mentioned.
5. It should create enthusiastic among people and maintain interest.
6. It should mention the attempt to solve problems and contribution of solution for a problem.

2.5.5-Difference between a report and an essay

A report will be visually quite different from an essay.

It will have the following:

i. Headings and distinct sections.

ii. Graphs, charts, photographs, and so on if appropriate.

Depending on its length and purpose, a report may include any or all of the following:

1. Title / Author.
2. Abstract.
3. Aims / Objectives.
4. Introduction.
5. Materials and Methods.
6. Results.
7. Discussion / Conclusion.
8. Reference list.

By laying it out with headings and sub-headings, the reader can locate specific pieces of information without trawling the whole document. It should be easy to navigate through. A good report will show clear purpose and objectives and have a logical structure.

2.5.6- Format of a report

A report structure is usually based on the following format, but you should always check with your tutor in case they expect something different.

1. Title page: explains what the practical was about.

2. Author: explains who did the work.

3. Abstract: this should be a full, but succinct, summary of the whole report. Check it is required as per the demand.

4. Introduction: this sets the scene for the reader. It gives background information on the subject of the report and explains why the work was done and indicates the central hypothesis.

5. Materials and Methods: explains how the work was done and should contain sufficient detail to allow another student to repeat the work.

6. Results: must include a written explanation of the results of the study with graphs, diagrams or tables to display the data obtained. Remember to accurately label and number your charts, graphs or diagrams for easy reference in the text.

7. Discussion / Conclusions: used to discuss the results, their meaning and importance, and to compare with those of other published work, either in textbooks or scientific articles and reviews. You will need to refer back to your introduction and, if you have one, hypothesis to write your conclusion. It should be clear and to the point, detailing the conclusion your report has come to.

8. Reference list: this should be a formatted list of any texts you have used in construction of the report, as with any academic assignment. Please check with your tutor which style you are required to use.

2.6- SUMMARY

Data tabulation is an important aspects to present data in a simple, concise, relevant and compatible manner. A table usually arranged data in vertical columns and horizontal rows which makes the arrangement more appropriate for the data interpretation. On the basis of data arranged we can draw both qualitative and quantitative interpretations. These interpretations can make quite understanding with the help of diagrammatical representations mainly line diagrams, bar diagrams, histograms, frequency polygon, ogive etc. The diagrammatical tools provide vast platform for a logical and realistic interpretation. To sum up the knowledge gain with the data tabulation and data interpretation it is necessary to cast it in the form of documentation which we called as report. A report is an essential part of statistical analysis as with the help of it the knowledge is easy to get transferred to its readers.

2.7- GLOSSARY

Column: A column is a vertical alignment of data.

Cumulative frequency: Cumulative frequency is defined as the sum of all the previous frequencies up to the current point.

Data: A set of values recorded on one or more observational units.

Frequency: A frequency in statistics is the number of times an event or observation happened in an experiment or study.

Interpretation: An explanation or understanding of something.

Observation: A character and its measurement.

Observational unit: The source that gives or provides the observation.

Population: It is an entire group of observational unit.

Report: An account or statement describing in detail an event, situation, or the like, usually as the result of observation, inquiry, etc.

Row: A row is a horizontal alignment of data.

Sample: It is a part of population chosen for statistical studies.

Sample unit: Each member of a population called sampling unit.

Sigma: Sum of all the data. It is denoted by $\sum$.

Variable: A quantity that varies. For e.g. Height, weight etc. which is usually denoted by x.

2.8- SELF ASSESSMENT QUESTIONS

Q1: A table 9.5 represents population of trees on the basis of flowering and non-flowering in the hills and plains as:

Location	Tree habit	Type		Non-flowering
		Main	Marginal	
Hills	Angiosperms	4	2	0
	Gymnosperms	17	15	22
Plains	Angiosperms	12	7	0
	Gymnosperms	3	1	34

the source of the data is MoEF Report 2017 and figures are rounded to nearest hundred. Present the given data and the information in a tabular form (after following each and every prerequisites of a table).

Q2: Differentiate the following:

i. Qualitative and Quantitative Data interpretation with the help of relevant example in terms of biostatistics.
ii. More than and less than Ogive.

Q3: Describe different steps to format a report?

Q4: Draw bar diagram for the following data:

Year	1995	1996	1997	1998	1999
Rice Production (in million tons)	35	22	30	38	42

Q5: What is Pie-diagram? Draw pie-diagram for the given data:

Name of fruit	Apple	Orange	Banana	Grapes	Papaya
Production in quintal	140	120	90	60	40

2.9- REFERENCES

1. Arumugam, N.(2015). Basic concepts of Biostatistics. pp. 1-274. ISBN: 9789384826710.
2. Banerjee, P.K. (2004). Introduction to Biostatistics. pp. 1-389. ISBN: 81-219-2329-8.
3. Mahajan, B.K. (2010). Methods in Biostatistics. pp. 1-198. ISBN: 9789352703104.

2.10- SUGGESTED READINGS

1. Arumugam, N. (2015). Basic concepts of Biostatistics. pp. 1-274. ISBN: 9789384826710.
2. Banerjee, P.K. (2004). Introduction to Biostatistics. pp. 1-389. ISBN: 81-219-2329-8.

2.11- TERMINAL QUESTIONS

2.11.1- Multiple choice questions

Q1: Under which we can analysed numerical data-

(a) Qualitative data interpretation (b) Quantitative data interpretation
(c) Both a and b (d) None of the above

Q2: If the information or data are from three mutually dependent categories then the best way to represent such data is-

(a) One way tabulation (b) Two way tabulation
(c) Three way tabulation (d) All of the above

Q3: Angular diagram is also known as-

(a) Bar diagram (b) Line diagram
(c) Histogram (d) Pie-diagram

Q4: The technique of presenting data through appropriate pictures is-

(a) Pictogram (b) Pictograph
(c) Both a and b (d) None of the above

Q5: Which of the following is a written document on a particular topic which convey information or idea-

(a) Report (b) Article

(c) Factual description (d) None of the above

2.11.1 Answer Key: 1. (b), 2. (c), 3. (d), 4. (c), 5. (a).

UNIT-3- MEASUREMENT OF MEAN, MODE, MEDIAN, STANDARD DEVIATION AND STANDARD ERROR

Contents:

3.1 OBJECTIVES

After reading this unit learners will be able:

- To know about mean, median and mode
- To understand standard deviation and standard error

3.2 INTRODUCTION

Mean, median, mode, standard deviation, and standard error are all very basic but crucial statistical concepts utilised in data science. These ideas are utilised in the data preprocessing steps of nearly every machine learning method. These ideas are a part of descriptive statistics, which is essentially how we explain and comprehend the data.

Central tendency (Mean / Median /Mode) is the central value of a set of grouped or ungrouped data. Central tendency does not depict any individual value of the data set. However, it gives the overall summary of the set of data. This value depicts the nature and characteristics of an entire set of data. A measure of central tendency (also referred to as measures of centre or central location) is a summary measure that attempts to describe a whole set of data with a single value that represents the middle or centre of its distribution. There are three main measures of central tendency i.e., mean, median and mode.

In general, the mean is the average of the data in the dataset. Median is the midpoint of the set of grouped or ungrouped data. Mode is the value that is repeated a maximum number of times in the set of data.

Important points of measures of central tendency

Following are the important point of the measures of central tendency:

- Mean is directly the sum of all the elements in a group or set, divided by the number of elements.
- Median is the middle value of the data that is arranged in ascending order.
- The mode represents the most commonly occurring value in a dataset. In some cases, a dataset may comprise multiple modes, while some datasets may not possess any mode at all.
- The three measures of central values are correlated.
- Mean is the chosen measure of central tendency when information is normally distributed.
- Median is the most beneficial measure of central tendency when data is skewed.

- While working with nominal variables, the mode is the most helpful measure of central tendency.
- Mean and median can not be zero unless all information are zero. However, there may be no mode in the dataset.

3.3 MEAN

Mean is the measure of the average of a set of values which can be calculated by dividing the sum of all the observations by the total number of observations. There are four different ways to measure the mean of a data set. They are arithmetic mean, geometric mean, harmonic mean, and weighted arithmetic mean. Usually, arithmetic mean is calculated because it is easy to calculate.

$$Mean = \frac{x1 + x2 + x3 + \cdots xn}{n}$$

Types of Data: The data can be present in Non tabular (ungrouped) form and tabular form.

Type 1: Non tabular or ungrouped data: When the data is present in a simple form without any tabulation.

Let x_1, x_2, x_3 , . . . , x_n be n observations.

We can find the arithmetic mean using the mean formula = Mean, $\bar{x} = \frac{(x1 + x2 + x3 + \ldots\ldots\ldots)}{n}$

Example: If the plants heights of 5 trees are 150 cm, 160 cm, 176 cm, 190 cm, and 194 cm. Find the mean height.

Mean height, $\bar{x} = \frac{(150+160+176+190+194)}{5} = \frac{870}{5} = 174$

Mean, $\bar{x}$ = 174 cm, thus, the mean height of plants is 174 cm.

Type 2: Tabular form or Frequency Distribution: When the data is present in tabular form, we use the following formula:

Mean, $\bar{x} = \frac{(x1f1 + x2f2 + \ldots + xnfn)}{(f1 + f2 + \ldots + fn)}$

(A): Simple tabular form: When data is represented by the simple tabular form.

Example 1: Find the mean of the following distribution:

X	8	6	9	10	15
f	5	10	10	6	10

Solution: Calculation table for arithmetic mean:

xi	fi	xi.fi
8	5	40
6	10	60
9	10	90
10	6	60
15	10	150
	∑ fi=40	∑ xi.fi = 400

Mean, $\bar{x} = \frac{(\sum \text{xi.fi})}{(\sum fi)} = \frac{400}{40} = 10$

(B): Class intervals tabular form: When data is represented by the complex or intervals tabular form.

Example: Find the mean increment height of the plants in a given data set.

Class	Increment in height (cm)
00−10	4
10−20	8
20−30	10
30−40	8
40−50	4
50−60	2

Solution: Hence, we get the following table:

Number of plants	Mid value (Xi)	Frequency (fi)	xi.fi
00−10	5	4	20
10−20	15	8	120
20−30	25	10	250
30−40	35	8	280
40−50	45	4	180
50−60	55	2	110
		∑ **fi**=36	∑ **xi.fi**=960

Mean, $\bar{x} = \frac{(\sum \text{xi.fi})}{(\sum fi)} = \frac{960}{36} = 26.67$

Advantage of the mean

- The mean can be used for both continuous and discrete numeric data.

Limitations of the mean

- The mean cannot be calculated for categorical data, as the values cannot be summed.
- As the mean includes every value in the distribution the mean is influenced by outliers and skewed distributions.

3.4 MEDIAN

Median is the middle value of the given data set. Usually, the data is arranged in ascending or descending order before determining the median. If there are an odd number of observations, the median is the value represented by the middle of the data set. However, when there are even numbers of observations, the median will be calculated as the mean of the two middle values.

$$\text{Median} = \frac{(n+1)^{th}}{2} \text{ observation}$$

If the dataset holds an even number of data value, i.e., n= even, the median is computed by the formula.

$$\text{Median} = \frac{\left\{\left(\frac{\text{n}}{2}\right)^{\text{th}} \text{ observation} + \left(\frac{\text{n}}{2}+1\right)^{\text{th}} \text{ observation}\right\}}{2}$$

Formula to calculate the median of grouped data is: $\text{Median} = l + \left(\frac{\frac{n}{2} - cf}{f}\right) \times h$

For the above formula “l” is the lower limit of the median class, ‘f’ denotes the frequency of the median class, ‘h’ is the width of the median class, ‘cf’ denotes the cumulative frequency of the class preceding the median class.

Type of Data: There are two types of data in median

Type 1: Ungrouped Data

- Arrange the data in ascending or descending order.
- Let the total number of observations be n.

Example 1: If n is odd: Let's consider the data: 62, 60, 42, 32, 25, 43, 28. What is the median?

Solution: Arranging in ascending order: 25, 28, 32, 42, 43, 60, 62.

Here, n (number of observations) = 7

So, $\left(\frac{7+1}{2}\right) = 4$, ∴ Median = 4^{th} observation = 42

Example 2: If n is even: Let's consider the data: 51, 68, 25, 35, 79, 44. What is the median?

Solution: Arranging in ascending order, we get: 25, 35, 44, 51, 68 and 79.

Here, n (no. of observations) = 6, So, $\frac{6}{2} = 3$

Using the median formula = Median = $\left(\frac{3^{rd}\text{ observation} + 4^{th}\text{ observation}}{2}\right)$

= $\left(\frac{44+51}{2}\right)$ = 47.50

Type 2: Grouped Data: When the data is continuous and in the form of a frequency distribution, the median is found as shown below:

- The median class (n = total number of observations i.e. $\sum f_i$) where (n/2) lies.
- Use the following formula to find the median.

$$\text{Median} = l + \left(\frac{\frac{n}{2} - cf}{f}\right) \times h$$

Where, l = lower limit of median class, cf = cumulative frequency of the class preceding the median class, f = frequency of the median class, h = class size

Example: Find the median plant height for the following distribution:

Class	0−10	10−20	20−30	30−40	40−50
Frequency	4	16	10	6	8

Solution: We need to calculate the cumulative frequencies to find the median.

Classes	Frequency	Cumulative frequency
00−10	4	4
10−20	16	4+16=20
20−30	10	20+10=30
30−40	6	30+6=36
40−50	8	36+8=44
	∑f= 44	

Here n = 44, So, $\frac{n}{2} = \frac{44}{2} = 22$

Median Class = (20 − 30), l = 20, f = 10, cf = 20, h = 10

Using the formula: Median $= \mathrm{l} + \left(\frac{\frac{\mathrm{n}}{2} - \mathrm{cf}}{\mathrm{f}}\right) \times \mathrm{h}$

$= 20 + \left(\frac{22 - 20}{10}\right) \times 10 \quad = 20 + \left(\frac{2}{10}\right) \times 10$

$= 20 + 2 = 22$, So the median is 22

Advantage of the median

- The median is less affected by outliers and skewed data than the mean and is usually the preferred measure of central tendency when the distribution is not symmetrical.

Limitation of the median

- The median cannot be identified for categorical nominal data, as it cannot be logically ordered.

3.5 MODE

The mode is the most commonly occurring value in a distribution. In other words, the value that has repeated more times in a data set is called its mode. Mode can sometimes have multiple values. In certain cases where all the values are unique, the mode does not exist at all.

$$\boldsymbol{Mode = 3 \times Median - 2 \times Mean}$$

Types of Data: The data can be present in non tabular (raw) form and tabular form.

Type 1: Ungrouped Data: In this case, we have to identify the observation which occurs maximum times.

Mode = Observation with maximum frequency

Example: Calculate the mode of the following data: 7, 5, 9, 4, 7, 6, 7, 3, 1

Solution: Here, the value 7 appears the most number of times.

Thus, mode = 7.

Type 2: Grouped Data: When the data is continuous, the mode can be found using the following steps:

- Find modal class i.e. the class with maximum frequency.
- Find mode using the following formula:

$$\text{Mode} = l + \left(\frac{fm - f1}{2fm - f1 - f2}\right) \times h$$

Where, l = lower limit of modal class, f_m = frequency of modal class, f_1 = frequency of class preceding modal class, f_2 = frequency of class succeeding modal class, h = class width

Example: Find the mode of the given data:

Height intervals	0−20	20−40	40−60	60−80	80−100
Number of Plants	10	15	18	9	6

Solution:

The highest frequency = 18, so the modal class is 40-60, l = lower limit of modal class = 40; f_m = frequency of modal class = 18; f_1 = frequency of class preceding modal class = 15; f_2 = frequency of class succeeding modal class = 9; h = class width = 20

Using the mode formula, $\text{Mode} = l + \left(\frac{fm-f1}{2fm-f1-f2}\right) \times h$

$$= 40 + \left(\frac{18 - 15}{(2 \times 18) - 15 - 9}\right) \times 20$$

$$= 40 + \left(\frac{3}{12}\right) \times 20 = 45$$

Advantage of the mode

- The mode has an advantage over the median and the mean as it can be found for both numerical and categorical (non-numerical) data.

Limitations of the mode

- There are some limitations to using the mode. In some distributions, the mode may not reflect the centre of the distribution very well.
- It is also possible for there to be more than one mode for the same distribution of data, (bi-modal, or multi-modal).

- The presence of more than one mode can limit the ability of the mode in describing the centre or typical value of the distribution because a single value to describe the centre cannot be identified.
- In some cases, particularly where the data are continuous, the distribution may have no mode at all (i.e. if all values are different).

3.6 RELATION BETWEEN MEAN, MEDIAN AND MODE

The three measures of central values i.e. mean, median and mode are closely connected by the following relations (called an **empirical relationship**).

2 Mean + Mode = 3 Median

For example, we have data whose mode = 60 and median = 40

Then, we can find the mean using the above mean, median, and mode relation.

$2\ Mean + Mode = 3\ Median$

$2\ Mean = 3\ \times 40 - 60$

$2\ Mean = 120 - 60$

$Mean = \frac{60}{2} = 30$

3.7 STANDARD DEVIATION

Standard Deviation (SD) is a measure which shows how much variation (such as spread, dispersion, spread,) from the mean exists. The standard deviation indicates a "typical" deviation from the mean. It is a popular measure of variability because it returns to the original units of measure of the data set. Like the variance, if the data points are close to the mean, there is a small variation whereas the data points are highly spread out from the mean, then it has a high variance. Standard deviation calculates the extent to which the values differ from the average. Standard Deviation, the most widely used measure of dispersion, is based on all values. Therefore a change in even one value affects the value of standard deviation. It is independent of origin but not of scale. It is also useful in certain advanced statistical problems.

It is a measure of dispersion of observation within dataset relative to their mean. It is square root of the variance and denoted by the Greek alphabet Sigma (σ). Standard deviation is expressed in

the same unit as the values in the dataset so it measure how much observations of the data set differs from its mean.

$$\sigma = \sqrt{\frac{(x-\bar{x})^2}{n}}$$

Variance: The square of standard deviation is called variance and is denoted by σ^2.

Coefficient of standard deviation: It is the ratio of the standard deviation to its arithmetic mean

$$\text{Coefficient of standard deviation} = \frac{\sigma}{\bar{x}}$$

$$\text{Coefficient of variance} = \frac{\sigma}{\bar{x}} \times 100$$

Types of Data: The data can be present in non tabular (ungrouped) form and tabular form.

Type 1: Ungrouped data: Where the data is scattered.

Example: There are a total of 100 trees in a forest. Statistically, it means that the population is 100. We use the standard deviation equation for the entire population. if we know a number of fruits every tree has. Statistically, let's consider a sample of 5 and here you can use the standard deviation equation for this sample population. This means we have a sample size of 5 and in this case, we use the standard deviation equation for the sample of a population.

Consider the number of fruit 5 trees have; 4, 2, 5, 8, 6.

Mean: $\overline{X} = \frac{\sum x}{n} = \frac{x1+x2+x3+\cdots+xn}{n}$

$= \frac{(4+2+5+8+6)}{5} = 5$

$xn - \bar{x}$ for every value of the sample

$x1 - \bar{x} = 4 - 5 = -1$

$x2 - \bar{x} = 2 - 5 = -3$

$x3 - \bar{x} = 5 - 5 = 0$

$x4 - \bar{x} = 8 - 5 = 3$

$x5 - \bar{x} = 6 - 5 = 1$

By the formula:

$= (x1 - \bar{x})^2 + (x2 - \bar{x})^2 + \ldots\ldots\ldots + (x5 - \bar{x})^2$

$= (-1)^2 + (-3)^2 + (0)^2 + (3)^2 + (1)^2 = 20$

Standard deviation:

$$\text{S.D.} = \sqrt{\frac{\sum(xn-\bar{x})^2}{n-1}} = \sqrt{\frac{20}{4}} = \sqrt{5} = 2.236$$

Type 2: Grouped Data: The methods of calculating the standard deviation depend upon the nature of data and also on the number of observations for grouped data.

(a). Standard deviation for Simple grouped data

(i) Direct method: In case of simple series, the standard deviation can be obtained by the formula

$$\sigma = \sqrt{\frac{(x-\bar{x})^2}{n}} = \sqrt{\frac{\sum d^2}{n}}$$

Where d= $x - \bar{x}$, x= value of the variable or observation, $\bar{x}$= arithmetic mean, n= total number of observations

Example: Find the standard deviation of 16, 13, 17, 22

Solution: Here, arithmetic mean = $\bar{x} = \frac{16+13+17+22}{4} = \frac{68}{4} = 17$

Let us prepare the following table in order to calculate the standard deviation

(x)	d= $x - \bar{x} = x - 17$	$(x - \bar{x})^2$
16	−1	1
13	−4	16
17	0	0
22	5	25
		$\sum d^2 = 42$

Now, $\sigma = \sqrt{\frac{(x-\bar{x})^2}{n}} = \sqrt{\frac{42}{4}} = 3.2$

(ii) Short cut method: This method is applied for to calculate the standard deviation, when the mean of the data comes out to be a fraction. In this case, it is very difficult and tedious to find the deviation of all observation from the mean by the earlier method.

$$\sigma = \sqrt{\frac{\sum d^2}{n} - \left(\frac{\sum d}{n}\right)^2}$$

Where d= $(x - A)$, A= Assumed mean, n= Total number of observations

Example: Find the standard deviation of the following data: 48, 43, 65, 57, 31, 60, 37, 48, 59, 78

Solution: Let us prepare the following table in order to calculate the values of SD.

Value (x)	d= $(x - A)$, (A= 50)	d^2
48	−2	4
43	−7	49
65	15	225
57	7	49
31	−19	361
60	10	100
37	−13	169
48	−2	4
59	9	81
78	28	784
n= 10	$\sum d = 26$	$\sum d^2 = 1826$

Here, $= A + \frac{\sum d}{n} = 50 + \frac{26}{10} = 52.60$

This is a fraction. Let us apply the short-cut formula in order to calculate SD

$$\sigma = \sqrt{\frac{\sum d^2}{n} - \left(\frac{\sum d}{n}\right)^2} \quad = \sqrt{\frac{1826}{n10} - \left(\frac{26}{10}\right)^2}$$

$$= \sqrt{182.60 - 6.76} \quad = \sqrt{175.84} \quad = 13.26$$

(a) Standard deviation for discrete series:

(i) **Direct method:** The standard deviation for the discrete series is given formula

$$\sigma = \sqrt{\frac{\sum f\,(x-\bar{x})^2}{n}}$$

Where, $\bar{x}$ is arithmetic mean, x is the size of the item, and f is the corresponding frequency in the case of discrete series. But when the mean has a fractional value, then the following formula is applied to calculate S.D.

$$\sigma = \sqrt{\frac{\sum fd^2}{n} - \left(\frac{\sum fd}{n}\right)^2}$$

Where, $d = x - A$, A = assumed mean, n= $\sum f$ = total frequency.

(b) Standard deviation in continuous series:

(i) Direct method: The standard deviation in the continuous series is obtained by the following formula.

$$\sigma = \sqrt{\frac{\sum f\,(x-\bar{x})^2}{n}}$$

Where, x = mid value, $\bar{x}$ is arithmetic mean, f= frequency, n= total frequency.

(ii) Short method: The formula for short method to find the standard deviation of continuous series is

$$\sigma = \sqrt{\frac{\sum fd^2}{n} - \left(\frac{\sum fd}{n}\right)^2 \times i}$$

Where, $= \frac{x-A}{i}$, A= assumed mean, n= total frequency, i= class width.

Example: Find the standard deviation from the following data and also find the coefficient of variation

Size	10	11	12	13	14	15	16
Frequency	2	7	11	15	10	4	1

Solution: Let us prepare the following table

Size	Frequency (f)	d= x−A A=13	fd	fd^2
10	2	−3	−6	18
11	7	−2	−14	28
12	11	−1	−11	11
13	15	0	0	0
14	10	1	10	10
15	4	2	8	16
16	1	3	3	9
	n= ∑f= 50		∑fd = −10	$\sum fd^2 = 92$

Now, Arithmetic mean= $\bar{x} = A + \frac{\sum fd}{n} = 13 + \frac{(-10)}{50} = 12.80$

Here, $\bar{x}$ **= 12.8 is a fraction,**

So, $\sigma = \sqrt{\frac{\sum fd^2}{n} - \left(\frac{\sum fd}{n}\right)^2} = \sqrt{\frac{92}{50} - \left(\frac{-10}{50}\right)^2}$

$= \sqrt{1.84 - 0.04} = \sqrt{1.80} = 1.342$

The coefficient of variation= $\frac{\sigma}{\bar{x}} \times 100$

$= \frac{1.342}{12.8} \times 100 = 10.40$

Example: Find the standard deviation for the following distribution:

Height	**10–20**	**20**–30	**30**–40	**40**–50	**50**–60	**60**–70	**70**–80
No. of plants	**5**	**12**	**15**	**20**	**10**	**4**	**2**

Solution: Let us prepare the following table in order to calculate the SD.

Height	**No. of plants**	**Mid value (x)**	**d =** $\frac{x-45}{10}$	**fd**	**Fd²**
10–20	**5**	**15**	−3	−15	**45**
20–30	**12**	**25**	**−2**	−24	**48**
30–40	**15**	**35**	−1	−15	**15**
40–50	**20**	**45**	**0**	**0**	**0**
50–60	**10**	**55**	**1**	**10**	**10**
60–70	**4**	**65**	**2**	**8**	**16**
70–80	**2**	**75**	**3**	**6**	**18**
	$\sum f = n = 68$			$\sum fd = -30$	$\sum fd^2 = 152$

$\sigma = \text{i} \times \sqrt{\frac{\sum fd^2}{n} - \left(\frac{\sum fd}{n}\right)^2} = 10 \times \sqrt{\frac{152}{68} - \left(\frac{-30}{68}\right)^2} = 14.30$

Merits and demerits of standard deviation

Merits:

1. It is based on all the observations
2. It lends itself to further algebraic treatment.
3. It is less affected by fluctuations of sampling as compared to other measures of dispersion.
4. It is extremely useful in correlation.
5. Like mean deviation, there is no artificiality in it.

Demerits

1. It is difficult to compute unlike other measures of dispersion.
2. It gives more weightage to extreme values.

3.8 STANDARD ERROR

The **Standard Error** is one of the mathematical tools used in statistics to estimate the variability. It is abbreviated as SE. The standard error of a statistic or an estimate of a parameter is the standard deviation of its sampling distribution. The sample mean of a data is generally varied from the actual population mean. It is used to measure the amount of accuracy by which the given sample represents its population. The accuracy of a sample that describes a population is identified through the SE formula. The samples mean which deviates from the given population and that deviation is given as;

$$SE = \frac{s}{\sqrt{n}}$$

Where S is the standard deviation and n is the number of observations.

Steps to calculate standard error

- Note the number of measurements (n) and determine the sample mean (μ). It is the average of all the measurements.
- Determine how much each measurement varies from the mean.
- Square all the deviations determined in step 2 and add altogether: $\Sigma(x_i - \mu)^2$
- Divide the sum from step 3 by one less than the total number of measurements (n-1).
- Take the square root of the obtained number, which is the standard deviation (σ).
- Finally, divide the standard deviation obtained by the square root of the number of measurements (n) to get the standard error of your estimate.

Example: Calculate the standard error of the given data: 5, 10, 12, 15 and 20

Solution: First we have to find the mean of the given data;

$$Mean = \frac{(5 + 10 + 12 + 15 + 20)}{5} = \frac{62}{5} = 12.40$$

Now, the standard deviation can be calculated as;

S = Summation of difference between each value of given data and the mean value/Number of values.

Hence, $S = \sqrt{\frac{(5-12.40)^2 + (10-12.40)^2 + (12-12.40)^2 + (15-12.40)^2 + (20-12.40)^2}{5}} = 5.004$

Therefore, SE can be estimated with the formula; $SE = \frac{s}{\sqrt{n}} = \frac{5.004}{\sqrt{5}} = 2.39$

3.9 SUMMARY

In statistics, the aim is to gather and analyze vast amounts of numerical data, in particular for the purpose of deducting the proportions in total from those in the representative sample.

Mean vs. Average

The word 'average' denotes a representative of a whole set of observations. It is a single which describes the entire series of observations with their varying sizes. It is a typical value occupying a central position where some observations are larger and some others are smaller than it. Average is a general term which describes the center of a series. The values of variable tend to concentrate around the central value. It is the central part of the distribution and therefore also called the measures of central tendency.

Mean vs. median:

Parameters	**Mean**	**Median**
Definition	Average of given data	The central value of data
Calculation	Add all values and divide by the total number of observations	Arrange data in ascending/ descending order and find the middle value
Values of data	Every value is considered for calculation	Every value is not considered
Effect of extreme points	Greatly affected by extreme points	Does not get affected by extreme points

Standard error vs standard deviation:

Standard Deviation	**Standard Error**
It describes variability within a single sample.	It describes variability across multiple samples of a population.

It is a descriptive statistic that can be calculated from sample data.	It is an inferential statistic that can only be estimated.
Standard deviation measures how much observations vary from one another.	Standard error looks at how accurate the mean of a sample of data is compared to the true population mean.
The formula for standard deviation calculates the square root of the variance,	The formula for standard error calculates the standard deviation divided by the square root of the sample size.

3.10 GLOSSARY

Arithmetic mean: The result of summing all measurements from a population or sample and dividing by the number of population or sample members. The arithmetic mean is also called the average, which is a measure of central tendency.
Average: The arithmetic mean of a set of observations. The average is a measure of central tendency of a scattering of observations, as is also the median and mode.
Central Tendency: The tendency of quantitative data to cluster around some variate value.
Continuous variable: when variables are present in some range e.g. height, diameter and weight of seedlings or saplings or trees.
Data: Any observation are made and presented in the form of numbers.
Data: Information or measurements obtained from a survey, experiment, investigation, or observational study. Data are stored in a database, usually in electronic form.
Discrete variable: A discrete variable is measured on the nominal or ordinal scale, and can assume a finite number of values within an interval or range. Discrete variables are less informative than are continuous variables.
Individuals variables: When each data has individual identity.
Mean: That value of a variate such that the sum of deviations from it is zero, and thus it is the sum of a set of values divided by their number.
Median: The median is the middle most number in an ordered series of numbers. It is a measure of central tendency, and is often a more robust measure of central tendency, that is, the median is less sensitive to outliers than is the sample mean.
Mode: The mode is the most common or most probable value observed in a set of observations or sample.
Population: It consists of all possible values of a variable e.g. the numbers of heads of each 100 tosses of 5 coins or several possible measurements of a parameter.
Sample: It is a part of population (in some cases, a sample may include the whole of the population), the measuring unit.
Standard deviation: The sample standard deviation is the square root of the sample variance.
Standard Error: The positive square root of the variance of the sampling distribution of a statistic.

Variable: The variability or variation in data or sample is called variable. Instead of writing variable each time, the variables are denoted by the symbol X or Y. Variables are generally used in quantative terms such as height, weight, numbers etc.

3.11 SELF-ASSESSMENT QUESTIONS

3.11.1 Multiple choice questions

1. The application of statistical methods in biology is called
   (a). Statistics in biology (b). Statistics in vitro
   (c). Biostatistics (d). All of the above
2. Which of the following is not a disadvantage of using mean?
   (a). It is affected by extreme values
   (b). It cannot be computed in grouped data with open-ended class intervals
   (c). It does not possess the desired algebraic property
   (d). None of the above
3. To calculate the median, all the items of a series have to be arranged in a/an _____.
   (a). Descending order (b). Ascending order
   (c). Ascending or descending order (d). None of the above
4. Mode refers to the value within a series that occurs _____ number of times.
   (a). Maximum (b). Minimum
   (c). Zero (d). Infinite
5. A _____ is not a measure of central tendency.
   (a). Mode (b). Mean
   (c). Range (d). Median

3.11.2 True and False

1. Mean represent the magnitude of scores of the central tendency measures?
2. Mean, Median and Range are the first three results of a central tendency test.
3. Standard deviation is always greater than or equal to the mean of a data set.
4. If a data set is symmetrical, then the mean, median, and standard deviation are equal.
5. In a given data set 2,8,4,3,4,3,11 the median is 11.

3.11.3 Fill in the blanks

1. _____ is the central value of a set of grouped or ungrouped data.
2. There are three main measures of central _____, _____ and _____.
3. _____ is directly the sum of all the elements in a group or set, divided by the number of elements.
4. _____ is the middle value of the data that is arranged in ascending order.
5. The _____ represents the most commonly occurring value in a dataset.

Answer Key:

3.11.1: 1. (c); 2. (c); 3. (c); 4. (a); 5. (c)
3.11.2: 1. True; 2. False; 3. True; 4. True, 5. False
3.11.3: 1. Central tendency; 2. mean, median and mode; 3. Mean; 4. Median; 5. mode

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3.13 SUGGESTED READINGS

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3.14 ACKNOWLEDGEMENTS

The author of the unit is greatly indebted to Dr. Beena Tewari Fulara, Assistant Professor (AC), Department of Forestry, School of Earth and Environmental Sciences, Uttarakhand Open University, Haldwani and Dr. Shivangi Upadhyay, Assistant Professor (AC), Department of Mathematics, School of Science, Uttarakhand Open University, Haldwani for their constant help during the writing of the unit.

3.15 TERMINAL QUESTIONS

3.15.1 Short answer type questions

6. Give formula for calculating mean of ungrouped data series.
7. How can relationship between mean, median and mode be depicted by an equation?
8. Give one difference between median and mode.
9. How many types of central tendencies are used in statistics?
10. Write any difference between standard deviation and Standard error.

3.15.2 Long answer type questions

5. Find the mean of the given data set.

Class intervals	0–10	10–20	20–30	30–40	40–50	50–60
Frequency	8	16	20	16	8	4

6. Find the median of the following distribution.

Class intervals	0–20	20–30	30–40	40–50	50–60
Frequency	8	32	20	12	16

7. Find the mode of the given data.

Class intervals	0–10	10–20	20–30	30–40	40–50
Number of Plants	20	30	36	18	12

8. Find the standard deviation from the following data and also find the coefficient of variation.

Class intervals	**10–20**	**20**–30	**30**–40	**40**–50	**50**–60	**60**–70	**70**–80
No. of plants	**5**	**12**	**15**	**20**	**10**	**4**	**2**

9. Find the standard error from the given data set 25, 30, 32, 35 and 40

UNIT-4- CORRELATION AND REGRESSION ANALYSIS

Contents:

4.1 OBJECTIVES

After reading this unit, you will be able:

- To understand the concept and types of correlation.
- To understand the concept of regression, simple and multiple regression analysis.
- To understand the problems of correlation coefficient and regression analysis.

4.2 INTRODUCTION

In the previous unit, you studied various measures of central tendency and measures of dispersion, which is a univariate analysis involving the use of a single variable. However, we are often interested in analysing two variables together to determine the relationship between them. In this unit, we will cover the concepts of correlation and regression analysis. Correlation and regression analysis are the most powerful statistical tools for data analysis; they help us to decode complex data, provide insights into relationships, and predict future trends.

Correlation analysis enables us to understand the relationship between two or more variables and how changes in one variable correlate with changes in another, a crucial statistical technique in fields ranging from social sciences to natural sciences. Regression analysis is a statistical technique used to model the relationship between a dependent variable and one or more independent variables. The primary goal is to understand how changes in the independent variables are associated with changes in the dependent variable. This method is widely applied in various fields, including social sciences, economics, biology, and engineering.

4.3 CORRELATION

Correlation is a statistical tool used to measure the degree of association or relationship between two variables. It helps us to understand how changes in one variable can be related to changes in another.A change in one variable result in a negative or positive change in another. It is used in the analysis of quantitative data, where variables have numerical values.The coefficient of correlation, typically denoted as **r,** measures the degree of relationship between two variables. Its value ranges from –1 to 1. A value of +1 indicates a perfect positive linear relationship, while –1 implies a perfect negative linear relationship.

4.3.1 Types of Correlation

4.3.1.1 Positive and Negative Correlation:

A positive correlation indicates that two variables are directly related to each other, which means both variables tend to increase or decrease together, i.e. changes in both variables occur

simultaneously in the same direction. Example: the relationship between the amount of sunlight exposure and plant growth. In contrast, a negative correlation indicates an inverse relationship, where variables move in opposite directions, i.e. the increase in the value of one variable is associated with a decrease in the value of another variable, or vice versa. Example: the relationship between the dosage of a medicine and side effects experienced by patients.

4.3.1.2 Simple and Multiple Correlations:

Simple correlation, often called bivariate correlation, involves measuring the relationship between two variables. It focuses on understanding how changes in one variable are associated with changes in another. Example: the relationship between crop yield and amount of fertilizers applied during the cropping season. Multiple correlation is a type of correlation which involves more than two variables simultaneously. Instead of examining the relationship between just two variables, it explores how a dependent variable is correlated with two or more independent variables. Example: effect of optimal use of fertilizers and irrigation levels on crop yield.

4.3.1.3 Linear and Curvilinear Correlation:

In a linear correlation, the relationship between two variables is such that the ratio of change in one variable to the change in the other variable remains constant. It is represented by a straight line. In a curvilinear or non-linear correlation, the relationship between two variables does not follow a constant ratio. Instead of a straight line, the relationship may be represented by a curve.

4.3.1.4 Perfect Positive and Perfect Negative Correlation:

A perfect positive correlation occurs when the two variables are directly proportional to each other; the relationship between two variables is such that one variable increases exactly in proportion to the other variable. The correlation coefficient (r) is +1 if the correlation is perfect positive. A perfect negative correlation occurs when the two variables are inversely proportional to each other; the relationship between two variables is such that one variable increases exactly as the other variable decreases, or vice-versa. The correlation coefficient (r) is –1 if the correlation is perfect negative.

When variables are not dependent on each other, then there is no/zero correlation. The value of the correlation coefficient (r) is 0 for absolute no/zero correlation.

4.3.2 Methods to Study Correlation

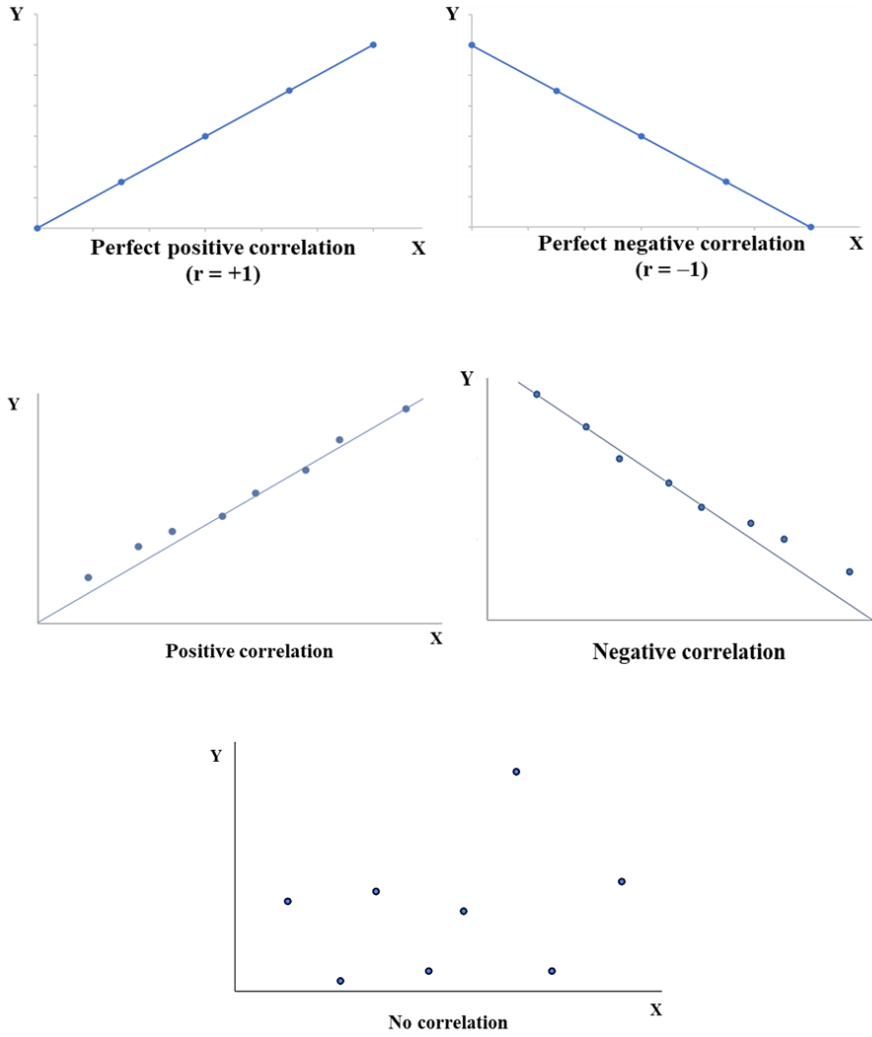
- Scatter Diagram
- Karl Pearson's Coefficient of Correlation
- Rank Correlation

4.3.2.1 Scatter Diagram

A scatter diagram is a simple graphical representation of the correlation between the two variables. In a scatter diagram, statistical data of both variables are plotted as dots on a graph. It indicates both the degree and type of correlation. It provides a visual representation of the data,

making it easier to identify correlation patterns between variables. It displays individual data points on a two-dimensional graph, with one variable on the x-axis (horizontal) and the other on the y-axis (vertical). Each point on the plot represents a pair of values for the two variables.

In a scatter diagram representing a perfect positive correlation (r= +1), the data points form a straight line that slopes upward from the lower left to the upper right, and all the data points fall precisely on the straight line. But if the data points form a straight line that slopes downward from upper left to lower right, and all the data points fall precisely on the straight line, it represents a perfect negative correlation (r= –1). A scatter diagram indicates a positive correlation when a pattern of dots shows a linear path from the lower left to the upper right. But, if points move from the upper left to the lower right in a linear path, it suggests a negative correlation. If the data points are scattered randomly with no clear pattern, it suggests no correlation between the variables. The closeness of the data points to each other indicates the strength of the relationship. If the data points are tightly clustered, it suggests a strong correlation.



Merits:

- A scatter diagram is an easy method that doesn't require complex calculations.
- A scatter diagram is a non-mathematical method which provides a visual representation of the correlation between two variables.
- A scatter diagram is often used as a preliminary step in data analysis.

Demerits:

- A scatter diagram is limited to represent the relationship between two variables only. If there are more than two variables to consider, additional methods may be required for analysing the correlation between them.
- A scatter diagram shows the direction of the relationship; it doesn't provide a quantitative (numerical value) measure of the strength of the correlation.
- The exact degree of correlation cannot be calculated by scatter diagram.
- The effectiveness of a scatter diagram depends on the quality of the data. Inaccurate or incomplete data can lead to misinterpretations.

4.3.2.2 Karl Pearson's Coefficient of Correlation

Karl Pearson's coefficient of correlation, denoted as r, is a measure of the degree of linear relationship between two variables. It was developed by the British statistician Karl Pearson. It is a widely used statistical method which provides a numerical measure for calculating the correlation between two variables. The value of r is $-1 \leq r \leq +1$.

$r \leq -1$; negative correlation

$r \geq +1$; positive correlation

$r = +1$; perfect positive correlation

$r = -1$; perfect negative correlation

$r = 0$; no correlation

The formula for calculating KarlPearson's coefficient of correlation:

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \times \Sigma(y - \bar{y})^2}}$$

where,

r= Karl Pearson's coefficient of correlation

$\bar{x}$= Mean of x variable

$\bar{y}$= Mean of y variable

Example 1: Calculate Karl Pearson's coefficient of correlation from the following data:

x	10	6	9	5	12	13	11	14
y	5	3	6	7	11	13	10	9

Solution:

$$\text{Mean } (\bar{x}) = \frac{\Sigma x}{n}$$

$$\bar{x} = \frac{10 + 6 + 9 + 5 + 12 + 13 + 11 + 14}{8}$$

$$\bar{x} = \frac{80}{8} = 10$$

$$\bar{y} = \frac{5 + 3 + 6 + 7 + 11 + 13 + 10 + 9}{8}$$

$$\bar{y} = \frac{64}{8} = 8$$

x	$x-\bar{x}$	$(x-\bar{x})^2$	y	$y-\bar{y}$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
10	10–10 = 0	0	5	5–8 = –3	9	0
6	6–10 = –4	16	3	3–8 = –5	25	20
9	9–10 = –1	1	6	6–8 = –2	4	2
5	5–10 = –5	25	7	7–8 = –1	1	5
12	12–10 = 2	4	11	11–8 = 3	9	6
13	13–10 = 3	9	13	13–8 = 5	25	15
11	11–10 = 1	1	10	10–8 = 2	4	2
14	14–10 = 4	16	9	9–8 = 1	1	4
		$\Sigma(x-\bar{x})^2 = 72$			**$\Sigma(y-\bar{y})^2 = 78$**	**$\Sigma(x-\bar{x})(y-\bar{y}) = 54$**

According to formula,

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \times \Sigma(y - \bar{y})^2}}$$

$$\Sigma(x-\bar{x})^2 = 72$$
$$\Sigma(y-\bar{y})^2 = 78$$
$$\Sigma(x-\bar{x})(y-\bar{y}) = 54$$

Put all the values in the formula,

$$r = \frac{54}{\sqrt{72 \times 78}}$$

$$r = \frac{54}{74.93}$$

$$r = 0.72 \text{ (positive correlation)}$$

Example 2: Marks obtained by seven students in botany and zoology are given below:

Marks in Botany (x)	64	65	66	67	68	69	70
Marks in Zoology (y)	66	67	68	69	70	71	72

Calculate Karl Pearson's coefficient of correlation from the given data.

Solution:

$$\text{Mean } (\bar{x}) = \frac{\Sigma x}{n}$$

$$\bar{x} = \frac{64 + 65 + 66 + 67 + 68 + 69 + 70}{7}$$

$$\bar{x} = \frac{469}{7} = 67$$

$$\bar{y} = \frac{66 + 67 + 68 + 69 + 70 + 71 + 72}{7}$$

$$\bar{y} = \frac{483}{7} = 69$$

x	$x-\bar{x}$	$(x-\bar{x})^2$	y	$y-\bar{y}$	$(y-\bar{y})^2$	$(x-\bar{x})(y-\bar{y})$
64	64–67 = –3	9	66	66–69 = –3	9	9
65	65–67 = –2	4	67	67–69 = –2	4	4
66	66–67 = –1	1	68	68–69 = –1	1	1
67	67–67 = 0	0	69	69–69 = 0	0	0
68	68–67 = 1	1	70	70–69 = 1	1	1
69	69–67 = 2	4	71	71–69 = 2	4	4

70	70–67 = 3	9	72	72–69 = 3	9	9
		$\Sigma(x-\bar{x})^2 = 28$			**$\Sigma(y-\bar{y})^2 = 28$**	**$\Sigma(x-\bar{x})(y-\bar{y}) = 28$**

According to formula,

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \times \Sigma(y - \bar{y})^2}}$$

$$\Sigma(x-\bar{x})^2 = 28$$
$$\Sigma(y-\bar{y})^2 = 28$$
$$\Sigma(x-\bar{x})(y-\bar{y}) = 28$$

Put all the values in the formula,

$$r = \frac{28}{\sqrt{28 \times 28}}$$

$$r = \frac{28}{28}$$

$r = 1$ (perfect positive correlation)

4.3.2.3 Spearman Rank Correlation Coefficient

Spearman rank correlation coefficient is denoted by ρ (rho), named after British psychologist Charles Spearman. It is a non-parametric statistical measure of the correlation between two variables, calculated by ranking the variables and then measuring a coefficient of rank correlation. Spearman rank correlation coefficient measures the strength and direction of monotonic association between two ranked variables. The value of the Spearman rank correlation coefficient is $-1 \leq \rho \leq +1$. The + sign indicates a positive correlation, and the – sign indicates a negative correlation.

The formula for Spearman rank correlation coefficient:

$$\rho = 1 - \frac{6\Sigma D^2}{n(n^2 - 1)}$$

$$D = R_1 - R_2$$

where,
n = number of observations
D = difference between ranks for each pair
ρ = Spearman rank correlation coefficient

R_1 = Rank of first variable
R_2 = Rank of second variable

Example 1: The marks obtained by the students in chemistry and physics are given below:

Marks in Chemistry	41	25	49	19	10	43	9	6	30
Marks in Physics	31	35	45	23	7	49	12	4	33

Calculate Spearman rank correlation coefficient from the given data.

Solution:

Chemistry		**Physics**		**$D = R_1 - R_2$**	**D^2**
Marks	**Rank (R_1)**	**Marks**	**Rank (R_2)**		
41	3	31	5	3–5 = –2	4
25	5	35	3	5–3 = 2	4
49	1	45	2	1–2 = –1	1
19	6	23	6	6–6 = 0	0
10	7	7	8	7–8 = –1	1
43	2	49	1	2–1 = 1	1
9	8	12	7	8–7 = 1	1
6	9	4	9	9–9 = 0	0
30	4	33	4	4–4 = 0	0
					$\Sigma D^2 = 12$

According to formula,

$$\rho = 1 - \frac{6\Sigma D^2}{n(n^2 - 1)}$$

$$n = 9$$
$$\Sigma D^2 = 12$$

Put all these values in the formula,

$$\rho = 1 - \frac{6 \text{ x } 12}{9(9^2 - 1)}$$

$$\rho = 1 - \frac{72}{9(80)}$$

$$\rho = 1 - \frac{72}{720}$$

$$\rho = 1 - 0.1$$

$$\rho = 0.9 \text{ (positive correlation)}$$

4.3.3 Uses of Correlation

- Correlation helps to assess the strength and direction of the relationship between two variables.
- Correlation is utilized in environmental studies to understand the relationships between climate variables, such as temperature and precipitation, to predict patterns and trends.
- In epidemiology, correlation is used to analyse the relationships between various factors and the occurrence of diseases.
- Correlation analysis is used in marketing to understand the relationships between various marketing strategies and consumer behaviour.
- In educational research, correlation can be used to study the relationship between variables like study habits and academic performance.

4.4 REGRESSION

Regression is a statistical technique used to analyse the relationship between a dependent variable and one or more independent variables. Independent variable is the variable that is used to predict or explain the variation in the dependent variable. It is also known as predictor variable or explanatory variable. The dependent variable is the variable whose value is studied and measured and depends on the independent variable. It is also known as the outcome variable or response variable.

The primary goal of regression analysis is to understand how the independent variable impacts the dependent variable and to make predictions based on this relationship. The regression analysis includes linear (simple and multiple) and non-linear regression analysis. Out of these, simple linear and multiple regression analyses are the most commonly used models.Non-linear regression analysis uses non-linear equations for more complex relationships between variables. Regression analysis is widely used in diverse fields such as economics, finance, biology,

psychology, and engineering. It provides valuable insights into relationships within data, helps to make predictions, and is a fundamental tool in statistical modeling.

4.4.1 Simple Linear Regression

Simple linear regression is a statistical method used to model the relationship between two variables, i.e., a single independent variable (X) and a dependent variable (Y). The relationship is linear, which means that changes in the independent variable are associated with a change in the dependent variable. The goal of simple linear regression is to find the best-fitting line (regression line) that describes the linear relationship between the variables.

The simple linear regression model is expressed by the following equation:

$$Y = a + bX + e$$

where,

Y = dependent variable

X = independent variable

a = intercept

b = slope

e = error/residual

Therefore, with the help of a simple linear regression model, the following two regression lines are obtained:

1. **Regression equation of Y on X:** $Y = a + bX$
2. **Regression equation of X on Y:** $X = a + bY$

The values of a and b in the equation are obtained by following normal equations:

Y on X:	**X on Y:**
$\Sigma Y = Na + b\Sigma X$	$\Sigma X = Na + b\Sigma Y$
$\Sigma XY = a\Sigma X + b\Sigma X^2$	$\Sigma XY = a\Sigma Y + b\Sigma Y^2$

The method mentioned above is known as the direct method, but it becomes complex when the values of X and Y are large, and it can be simplified by taking the deviation of X and Y from their respective mean.

In this case, regression equation are expressed as:

1. **Regression equation of Y on X:** $(Y-\bar{Y}) = b_{YX}\,(X-\bar{X})$
2. **Regression equation of X on Y:** $(X-\bar{X}) = b_{XY}(Y-\bar{Y})$

Here b denoted as b_{yx}or b_{xy} is called regression coefficient or slope coefficient.Regression coefficient can be calculated by:

Method	**X on Y**	**Y on X**

Using coefficient of correlation (r) and standard deviation (σ)	$b_{XY} = r\frac{\sigma X}{\sigma Y}$	$b_{YX} = r\frac{\sigma Y}{\sigma X}$
Using actual values of x and y series	$b_{XY} = \frac{N\Sigma XY - \Sigma X\,\Sigma Y}{N\Sigma Y^2 - (\Sigma Y)^2}$	$b_{YX} = \frac{N\Sigma XY - \Sigma X\,\Sigma Y}{N\Sigma X^2 - (\Sigma X)^2}$
Using deviations from assumed mean	$b_{XY} = \frac{N\Sigma dXdY - \Sigma dX\,\Sigma dY}{N\Sigma dY^2 - (\Sigma dY)^2}$	$b_{YX} = \frac{N\Sigma dXdY - \Sigma dX\,\Sigma dY}{N\Sigma dX^2 - (\Sigma dX)^2}$
	$dx = x - a;\ dy = y - a$	
Using deviation from actual mean	$b_{XY} = \frac{\Sigma xy}{\Sigma y^2}$	$b_{YX} = \frac{\Sigma xy}{\Sigma x^2}$
	$x = X - \bar{X};\ y = Y - \bar{Y}$	

The coefficient of correlation is the geometric mean of the two regression coefficients, calculated by: $r = \sqrt{bxy \times byx}$

4.4.2 Multiple Linear Regression

Multiple linear regression is an extension of simple linear regression used to model the relationship between a dependent variable and two or more independent variables. In this type of regression, the model assumes a linear relationship between the dependent variable and each independent variable andaims to estimate the coefficients that define this relationship. Multiple linear regression is a powerful tool for modeling complex relationships between a dependent variable and multiple independent variables.

The multiple linear regression model is expressed by the following equation:

$$Y = a + bX_1 + cX_2 + dX_3 + e$$

where,

Y = dependent variable

X_1, X_2, X_3 = independent variables

a = intercept

b, c, d = slope

e = error/residual

Example 1: Calculate the two regression equation for X on Y and Y on X for the following data:

X	10	12	16	11	15	14	20	22
Y	15	18	23	14	20	17	25	28

Solution:

X	**Y**	**X^2**	**Y^2**	**XY**

10	15	100	225	150
12	18	144	324	216
16	23	256	529	368
11	14	121	196	154
15	20	225	400	300
14	17	196	289	238
20	25	400	625	500
22	28	484	784	616
$\Sigma X = 120$	**$\Sigma Y = 160$**	**$\Sigma X^2 = 1926$**	**$\Sigma Y^2 = 3372$**	**$\Sigma XY = 2542$**

N=8 for both X and Y

Regression equation of X on Y: $X = a + bY$

Two normal equations are:

$\Sigma X = Na + b\Sigma Y$

$\Sigma XY = a\Sigma Y + b\Sigma Y^2$

Substitute the values in above normal equations

$120 = 8a + 160b$ …….(i)

$2542 = 160a + 3372b$ ……..(ii)

Solve equations (i) and (ii) by simultaneous equation method

Multiply equation (i) by 20 we get $2400 = 160a + 3200b$ ……(iii)

Rewrite equations (ii) and (iii)

$2542 = 160a + 3372b$

$2400 = 160a + 3200b$

(–) = (–) (–)

$142 = 172b$

$142 = 172b$

$$b = \frac{142}{172}$$

$b = 0.825$

Substitute the value of b in equation (i)

$120 = 8a + (160 \times 0.825)$

$120 = 8a + 132$

120 – 132 = 8a
–12/8 = a
–1.5 = a

The value of a = –1.5, b = 0.825

Regression equation of X on Y:
X = –1.5 + 0.825Y

Regression equation of Y on X: Y = a + bX
Two normal equations are:
$\Sigma Y = Na + b\Sigma X$
$\Sigma XY = a\Sigma X + b\Sigma X^2$

Substitute the values in above normal equations
160 = 8a + 120b …….(iv)
2542 = 120a + 1926b ……..(v)

Solve equations (iv) and (v) by simultaneous equation method
Multiply equation (iv) by 15 we get 2400 = 120a + 1800b ……(vi)

Rewrite equations (v) and (vi)
2542 = 120a + 1926b
2400 = 120a + 1800b
(–) = (–) (–)
142 = 126b

142 = 126b

$$b = \frac{142}{126}$$

b = 1.1269

Substitute the value of b in equation (iv)
160 = 8a + (120 x1.1269)
160 = 8a + 135.228
160 – 135.228 = 8a
24.772/8 = a
3.0965 = a

The value of a = 3.0965, b = 1.1269

Regression equation of Y on X:
Y = 3.0965 + 1.1269X

Example 2: Find out two regression equation for X on Y and Y on X for the following data:

X	2	4	6	8	10	12
Y	4	2	5	10	3	6

Solution:

X	**Y**	**$x = X - \bar{X}$**	**$y = Y - \bar{Y}$**	**xy**	**x^2**	**y^2**
2	4	2–7 = –5	4–5 = –1	5	25	1
4	2	4–7 = –3	2–5 = –3	9	9	9
6	5	6–7 = –1	5–5 = 0	0	1	0
8	10	8–7 = 1	10–5 = 5	5	1	25
10	3	10–7 = 3	3–5 = –2	–6	9	4
12	6	12–7 = 5	6–5 = 1	5	25	1
$\Sigma X = 42$	**$\Sigma Y = 30$**			**$\Sigma xy = 18$**	**$\Sigma x^2 = 70$**	**$\Sigma y^2 = 40$**

$$\bar{X} = \frac{\Sigma X}{n} = \frac{42}{6} = 7$$

$$\bar{Y} = \frac{\Sigma Y}{n} = \frac{30}{6} = 5$$

Regression coefficient of X on Y:

$b_{XY} = \frac{\Sigma xy}{\Sigma y^2} = \frac{18}{40} = 0.45$

Regression equation of X on Y:

$(X - \bar{X}) = b_{XY}(Y - \bar{Y})$

$X - 7 = 0.45\,(Y - 5)$

$X - 7 = 0.45Y - 2.25$

$X = 0.45Y - 2.25 + 7$

$X = 0.45Y + 4.75$

Regression coefficient of Y on X:

$b_{YX} = \frac{\Sigma xy}{\Sigma x^2} = \frac{18}{70} = 0.257$

Regression equation of Y on X:

$(Y-\bar{Y}) = b_{YX}\,(X-\bar{X})$
$Y-5 = 0.257\,(X-7)$
$Y-5 = 0.257X-1.799$
$Y = 0.257X-1.799+5$
$Y = 0.257X+3.201$

4.4.3 Uses of Regression

- Regression analysis is used in business to forecast business opportunities and risks.
- It is used to analyse historic stock prices and data to predict future stock prices and sales.
- It is used to identify risk factors, understand disease patterns in a population, and develop public health interventions.
- It is used to assess the impact of educational policies on student outcomes.
- Researchers use regression analysis to explore relationships, make predictions, and draw meaningful conclusions from research data. Researchers should carefully select the appropriate regression model depending on the nature of the data and the research question.
- Regression analysis is commonly applied in agriculture to analyse and model relationships between various factors (soil characteristics, fertilizers, irrigation, etc.) affecting crop yield, quality, and overall agricultural productivity.

4.5 SUMMARY

Correlation is a statistical method used to determine the degree of relationship between two variables. Regression analysis refers to assess the relation between dependent and one or more independent variables.

Basis	**Correlation**	**Regression**
Nature	It measures the degree of relationship between two variables.	It helps to predict the value of one variable on the basis of one or more other variables.
Purpose	It is a measure typically denoted by the correlation coefficient (r), which ranges from –1 to +1.	It involves developing an equation to represent the relationship between variables.
Prediction	It does not suggest a cause-and-effect relationship between variables.	It allows for predictions and can be used to identify the impact of one variable on another.
Output	To find a numerical value that summarizes the relationship between	To find an equation that can be used for predicting values of the dependent

variables.

variable based on the values of the independent variable.

- Scatter diagram is a graphical method to find correlation between two variables.
- Karl Pearson's coefficient of correlation: $r = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\sqrt{\Sigma(x-\bar{x})^2 \times \Sigma(y-\bar{y})^2}}$
- Correlation coefficient r lies between –1 and +1, i.e., $-1 \leq r \leq +1$.
- Spearman rank correlation coefficient: $\rho = 1 - \frac{6\Sigma D^2}{n(n^2-1)}$
- Simple linear regression describes and predicts the linear relationship between two variables, X and Y, where one is an independent variable, and the other is a dependent variable. It is expressed as: $Y = a + bX + e$
- Multiple regression analysis predicts the value of a dependent variable based on the values of two or more independent variables. It is expressed as: $Y = a + bX_1 + cX_2 + dX_3 + e$

4.6 GLOSSARY

Correlation: Correlation is a statistical tool that describes how changes in one variable can be associated with changes in another.

Correlation coefficient: A statistical measure which computes the strength and direction of the relationship between two variables. Its value ranges from –1 to 1.

Positive Correlation: A relationship between two variables in which an increase in one is associated with an increase in the other, and vice versa.

Negative Correlation: A relationship between two variables in which an increase in one is associated with a decrease in the other, and vice versa.

Scatter plot: A graphical representation of the relationship between two variables, with one variable on the x-axis and the other on the y-axis.

Regression Analysis: A statistical method that models the relationship between a dependent variable and one or more independent variables.

Dependent Variable: The variable being predicted or measured in a regression model. It is also known as response or outcome variable.

Independent Variable: The variable used to predict the value of the dependent variable. It is also known as the predictor or explanatory variable.

Simple Linear Regression: It is used to model the relationship between a single dependent and a single independent variable.

Multiple Linear Regression: It is used to model the relationship between a dependent variable and two or more independent variables.

Intercept: It is also called constant. It represents the predicted value of the dependent variable when all independent variables are zero.
Slope: It represents the change in the dependent variable associated with a one-unit change in the independent variable.
Residuals: The differences between the observed and predicted values of the dependent variable.
Regression Line: The line that represents the relationship between dependent and independent variables.
Multicollinearity: It is a statistical concept in which two or more independent variables in a regression model are highly correlated.

4.7 SELF ASSESSMENT QUESTIONS

4.7.1 Multiple choice questions

1. What is the range of correlation coefficient?
   (a). 0 to 1 (b). 0 to 10
   (c). –1 to +1 (d). 0 to 100
2. The values of two variables moving in the same direction…….
   (a). Correlation is positive
   (b). Correlation is negative
   (c). No correlation
   (d). None of the above
3. In a simple linear regression equation Y = 3X + 10, what does the coefficient 3 represent?
   (a). Intercept (b). Slope
   (c). Residual (d). Dependent Variable
4. Which of the following method is used to study correlation?
   (a). Karl Pearson's Correlation Coefficient
   (b). Scatter Diagram
   (c). Spearman Rank Correlation Coefficient
   (d). All of the above
5. In regression analysis, which variable is called predictor variable?
   (a). Independent Variable (b). Dependent Variable
   (c). Slope (d). None of the above

4.7.2 True or False

6. A correlation coefficient of +1 indicates a perfect positive correlation.
7. Simple linear regression involves more than one independent variables.
8. In regression analysis, the variable being predicted is called the dependent variable.
9. The correlation coefficient measures the strength and direction of the relationship between two variables.

10. The intercept in the regression equation represents the change in the dependent variable associated with a one-unit change in the independent variable.

4.7.3 Fill in the blanks

6. In a regression equation Y = a + bX, a represents the_____, and b represents the_____.
7. A correlation coefficient of_____ indicates a perfect negative linear relationship.
8. The correlation coefficient (r) value is 0 for_____correlation.
9. _____regression is used to determine the relationship between a dependent variable and two or more independent variables.
10. Simple correlation is a type of correlation which involves measuring the relationship between_____variables.

Answer Key:

4.7.1: 1. (c); 2. (a); 3. (b); 4. (d); 5. (a)
4.7.2: 1. True; 2. False; 3. True; 4. True; 5. False
4.7.3: 1. Intercept, slope; 2.−1; 3. Zero/no; 4. Multiple linear regression; 5. Two

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4.10 ACKNOWLEDGEMENTS

The author of the unit is highly thankful to Dr. Saraswati Nandan Ojha, Assistant Professor, Department of Botany, School of Sciences, Uttarakhand Open University, Haldwani and Dr. Deepak Kumar, Assistant Professor, Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, for their unwavering support and assistance in writing the unit.

4.11 TERMINAL QUESTIONS

4.11.1 Short answer type questions

11. Differentiate between correlation and regression.
12. Write the formula for Karl Pearson's and Spearman Rank Correlation coefficients.
13. Differentiate between simple linear regression and multiple linear regression.
14. Write a short note on scatter diagram.
15. Describeregression coefficient in brief.

4.11.2 Long answer type questions

1. Calculate Spearman rank correlation coefficient from the following data:

Marks in Botany	72	65	68	55	60	74	63	67	70	52
Marks in Zoology	62	78	80	69	71	83	57	89	75	64

2. Find out regression equation for X on Y and Y on X for the following data:

X	1	3	5	7	9	4	6
Y	2	4	3	7	5	6	1

3. Calculate Karl Pearson correlation coefficient from the following data:

X	10	6	9	10	12	13	11	9
Y	9	4	6	9	11	13	8	4

4. Find out regression equation for X on Y and Y on X for the following data:

X	5	10	15	20	25	30	35
Y	6	8	14	20	22	24	32

5. Calculate correlation coefficient from the following data:

UNIT-5- STUDY OF CHI-SQUARE TEST

Contents:

5.1 OBJECTIVES

After reading this unit, you will be able:

- To understand the concept of chi-square test.
- To conduct a chi-square test for goodness of fit.
- To conduct a chi-square test for independence.
- To conduct a chi-square test for homogeneity.

5.2 INTRODUCTION

In the previous unit, you studied the concepts of correlation and regression analysis, which are used to determine the relationship between two variables.However, we are interested in determining the association or dependence between the two categorical variables, for which the chi-square test is used. It is commonly used in hypothesis testing, especially in categorical variables. Therefore, it is a significant tool in statistical analysis, having relevance in diverse fields ranging from biology to social sciences, quality control, and market research.

5.3 CHI-SQUARE TEST

Chi-square test is a non-parametric test as its value is not obtained from the observations in a population. It is a valuable statistical tool used to compare an "observed" ratio with an "expected ratio". It is used to find how closely the former fits the latter.The measure of chi-square helps to determine whether there is any significant difference between observed and expected frequencies. Thus, it is used to tell whether the discrepancies between observed and expected frequencies are due to an error in sampling or due to chance. It is denoted by the symbol χ^2. It is calculated as the sum of squared differences between observed and expected frequencies divided by the expected frequencies. The formula for calculating chi-square (χ^2) is:

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

E is expected frequency and O is observed frequency

5.3.1 Characteristics of Chi-Square Test

- Chi-square is a statistic, not a parameter.
- The value ofthe chi-square is always positive, with a minimum value of zero.
- The chi-square test is used when both variables under consideration are categorical.
- It is based on events or frequencies, not on mean and standard deviation.

5.3.2 Hypothesis Testing

A test of hypothesis, also known as a hypothesis test or statistical test, is a method used in statistics to make decisions about a population parameter based on sample data. The process involves setting up two competing hypotheses, the null hypothesis (H_0) and alternative hypothesis (H_a), about the population parameter and using statistical techniques to evaluate the evidence provided by the sample data.

5.3.2.1 Null Hypothesis

The null hypothesis, denoted as H_0, is a statistical hypothesis that suggests there is no significant difference or relationship between the variables being studied. Hypothesis testing determines whether the null hypothesis is accepted or rejected within a certain confidence level. The null hypothesis assumes that if the hypothesis shows any kind of difference or relationship between the variables, it is due to chance or sampling error.

5.3.2.2 Alternative Hypothesis

The alternative hypothesis, denoted as H_a, is a contradiction of the null hypothesis. It suggests that there is a significant difference between the variables being studied. The acceptance or rejection of the alternative hypothesis depends on the acceptance or rejection of the null hypothesis.

5.3.2.3 Critical Region and Acceptance Region

The critical region, also known as the rejection region, is a range of test statistic values under which the null hypothesis is rejected at a specific significance level in hypothesis testing. If the observed test statistic is in the critical region, then the null hypothesis is rejected, and the alternative hypothesis is accepted. Acceptance region (confidence interval) is a range of test statistic values under which the null hypothesis is accepted. If the observed test statistic is in the confidence interval, then the null hypothesis is accepted, and the alternative hypothesis is rejected.

5.3.2.4 Level of Significance

The level of significance, often denoted by the Greek letter α, is a critical parameter used in hypothesis testing to determine the threshold for accepting or rejecting the null hypothesis. Generally, 5% or 1% level of significance is considered, but 2% or 0.5% is also used.

5.3.2.5 Degree of Freedom

The degree of freedom (abbreviated as df) represents the number of independent observations in the sample that are free to vary. It is used to find out whether a chi-square value is statistically significant or not.

- If the data is represented as a series of variables in a row or column, df = n–1 (n is the number of observations).
- When data is represented in the contingency table, df = (R–1)(C–1); R is the number of rows and C is the number of columns

5.4 TYPES OF CHI-SQUARE TEST

There are mainly three types of chi-square test commonly used in statistics:

- Chi-square test for goodness of fit
- Chi-square test for independence
- Chi-square test for homogeneity

5.4.1 Chi-Square Test for Goodness of Fit

The chi-square test for goodness of fit is used to determine whether a sample data fits an expected set of data from a population with normal distribution. It is used to assess whether discrepancies between the observed and expected frequency distributions of theoretical models are similar or in good agreement. Thus, it shows whether a set of observed values is similar to expected values under the applicable model.

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

Steps for calculating the chi-square test for goodness of fit:

- Formulate a hypothesis along with the level of significance.
  Null hypothesis: No significant difference between the variables.
  Alternative hypothesis: Significant difference between the variables.
  - Calculate chi-square by using the formula:

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

- Degree of freedom (df) = n–1; n is number of items in the series.
- Find the table value of χ^2 at a certain level of significance (usually 5%) and n–1 degree of freedom.
- If the calculated value of chi-square is more than the tabular value of chi-square, then the null hypothesis is rejected, and it is concluded that there is a significant difference between the observed and expected frequencies, indicating that the data do not fit the specified distribution. But if the calculated value of chi-square is less than the tabular value of chi-square, then the null hypothesis is accepted, and it is concluded that there is no significant difference between the observed and expected frequencies, supporting that the data fits the specified distribution.

Example 1: In a cross between tall and dwarf garden pea plants, the F_2 individuals are 788 tall and 276 dwarfs. Apply chi-square for goodness of fit at a 5% level of significance and test whether the results agree with the expected ratio of 3:1.

Solution:
Null hypothesis- 3:1; **Alternative hypothesis-** 1:1

Observed (O)	**Expected (E)**	**O − E**	**$(O-E)^2$**	**$\frac{(O-E)^2}{E}$**
Tall = 788	$\frac{3}{4}\times 1064 = 798$	$788 - 798 = -10$	100	0.1253
Dwarf = 276	$\frac{1}{4}\times 1064 = 266$	$276 - 266 = 10$	100	0.3759
Total = 1064				$\chi^2 = \Sigma\frac{(O-E)^2}{E}$
				$\chi^2 = \mathbf{0.5012}$

The table value of χ^2 at 0.05 level of significance for df 2–1 = 1 is 3.84.
The calculated value of χ^2 = 0.5012 is less than the table value of χ^2. Thus, the null hypothesis is accepted (variation is not significant), and the data show goodness of fit to ratio 3:1.

Example 2: A cross between violet and white coloured flowersin a garden pea plant, the progenies are 45 violet and 42 white coloured flowers. Apply the chi-square test for goodness of fit at a 5% level of significance and test the results for goodness of fit.

Solution:
Null hypothesis- 1:1; **Alternative hypothesis-** 3:1

$$\chi^2 = \Sigma\frac{(O-E)^2}{E}$$

Observed (O)	**Expected (E)**	**O − E**	**$(O-E)^2$**	**$\frac{(O-E)^2}{E}$**
Violet = 45	$\frac{1}{2}\times 87 = 43.5$	$45 - 43.5 = 1.5$	2.25	0.0517
White = 42	$\frac{1}{2}\times 87 = 43.5$	$42 - 43.5 = -1.5$	2.25	0.0517
Total = 87				$\chi^2 = \mathbf{0.1034}$

The table value of χ^2 at 0.05 level of significance for df= 2–1 = 1 is 3.84.
The calculated value of χ^2 = 0.1034 is less than the table value of χ^2. Thus, the null hypothesis is accepted (variation is not significant), and the data show goodness of fit to ratio 1:1.

5.4.2 Chi-Square Test for Independence or Contingency Chi-Square Test

The chi-square test for independence is applied to determine whether there is a significant association between two categorical variables. The data is organized into a contingency table with any number of rows or columns, in which each row represents a category for one variable and each column represents a category for the other variable. It measures the difference between observed and expected frequencies under the assumption that the variables are independent.

Steps for calculating the chi-square test for independence:

- Formulate a hypothesis along with level of significance.
  Null hypothesis: No association between the variables.
  Alternative hypothesis: Association between the variables.
- Compute expected frequency (E_{ij}) of the two categorical variables by using the formula:

$$E_{ij} = \frac{R_i \times C_j}{n}$$

Where,
R_i= Sum total of the row in which E_{ij}lies
C_j= Sum total of the column in which E_{ij}lies
n = Total sample size

- Calculate chi-square by using formula:

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

- Degree of freedom (df) = (R–1)(C–1)
  R is number of rows, and C is the number of columns
- Find the table value of χ^2 at a certain level of significance (usually 5%) and (R–1)(C–1) degree of freedom.
- If the calculated value of chi-square is less than the tabular value of chi-square, then the null hypothesis is accepted, and if the calculated value of chi-square is more than the tabular value of chi-square, then the null hypothesis is rejected.

Example 3:A study conducted in a school wherethe favourite colour of boys and girls is recorded. Apply the chi-square of independence at the 5% level of significance to test whether colour and gender are independent on the basis of the data provided.

Gender	Blue	Black	Pink
Boys	100	140	60
Girls	20	40	140

Solution:
Null hypothesis-Gender and preferred colour are independent.
Alternative hypothesis-Gender and preferred colour are not independent.

Observed frequency table:

Gender	Blue	Black	Pink	Total
Boys	100	140	60	300
Girls	20	40	140	200
Total	120	180	200	500 = n

$$E_{ij} = \frac{R_i \times C_j}{n}$$

Expected frequency table:

Gender	Blue	Black	Pink
Boys	$\frac{300 \times 120}{500} = 72$	$\frac{300 \times 180}{500} = 108$	$\frac{300 \times 200}{500} = 120$
Girls	$\frac{200 \times 120}{500} = 48$	$\frac{200 \times 180}{500} = 72$	$\frac{200 \times 200}{500} = 80$

$$\chi^2 = \frac{(100-72)^2}{72} + \frac{(20-48)^2}{48} + \frac{(140-108)^2}{108} + \frac{(40-72)^2}{72} + \frac{(60-120)^2}{120} + \frac{(140-80)^2}{80}$$

$$\chi^2 = \frac{(28)^2}{72} + \frac{(-28)^2}{48} + \frac{(32)^2}{108} + \frac{(-32)^2}{72} + \frac{(-60)^2}{120} + \frac{(60)^2}{80}$$

$$\chi^2 = \frac{784}{72} + \frac{784}{48} + \frac{1024}{108} + \frac{1024}{72} + \frac{3600}{120} + \frac{3600}{80}$$

$$\chi^2 = 10.88 + 16.33 + 9.48 + 14.22 + 30 + 45$$

$$\chi^2 = 125.91$$

Degree of freedom= (2–1)(3–1) = 2

The table value of χ^2 at 0.05 level of significance for df= 2 is 5.99.

The calculated value of χ^2 = 125.91 is more than the table value of χ^2. Thus, the null hypothesis is rejected. Therefore, the alternative hypothesis is accepted, and it is concluded that gender and preferred colour are not independent.

Example 4:A study is conducted to assess whether there is a relationship between smoking and respiratory disease. Based on the data provided, apply the chi-square test at a 5% level of significance to test whether smoking and respiratory disease are independent.

	Respiratory Disease	No Respiratory Disease
Smoker	75	105
Non-smoker	25	95

Solution:

Null hypothesis-Smoking habit and respiratory diseaseare independent.

Alternative hypothesis-Smoking habit and respiratory diseaseare not independent.

Observed frequency table:

	Respiratory Disease	No Respiratory Disease	Total
Smoker	75	105	180
Non-smoker	25	95	120
Total	100	200	300 = n

$$E_{ij} = \frac{R_i \times C_j}{n}$$

Expected frequency table:

	Respiratory Disease	No Respiratory Disease
Smoker	$\frac{180 \times 100}{300} = 60$	$\frac{180 \times 200}{300} = 120$
Non-smoker	$\frac{120 \times 100}{300} = 40$	$\frac{120 \times 200}{300} = 80$

$$\chi^2 = \frac{(75-60)^2}{60} + \frac{(25-40)^2}{40} + \frac{(105-120)^2}{120} + \frac{(95-80)^2}{80}$$

$$\chi^2 = \frac{(15)^2}{60} + \frac{(-15)^2}{40} + \frac{(-15)^2}{120} + \frac{(15)^2}{80}$$

$$\chi^2 = \frac{225}{60} + \frac{225}{40} + \frac{225}{120} + \frac{225}{80}$$

$$\chi^2 = 3.75 + 5.625 + 1.875 + 2.8125$$

$$\chi^2 = 14.0625$$

Degree of freedom= (2–1)(2–1) = 1
The table value of χ^2 at 0.05 level of significance for df= 1 is 3.84.
The calculated value of χ^2 = 14.0625 is more than the table value of χ^2. Thus, the null hypothesis is rejected. Therefore, the alternative hypothesis is accepted, and it is concluded that smoking habit and respiratory disease are not independent.

5.4.3 Chi-Square Test for Homogeneity

The chi-square test for homogeneity is used to determine whether the distribution of categorical variables is the same across different groups or populations. It assesses whether a single categorical variable from two or more populations has the same distribution.

Steps for calculating the chi-square test for homogeneity:

- Formulate a hypothesis along with a level of significance.
  Null hypothesis: Homogeneity exists among the sample.
  Alternative hypothesis: Homogeneity does notexist among the sample.
- Chi-square of each individual sample is calculated by using formula:

$$\chi^2 = \Sigma \frac{(O - E)^2}{E}$$

- Add individual chi-square to give a total chi-square.
- Degree of freedom is the sum of the degree of freedom in the individual chi-square.
- Calculate the chi-square for the summed data of all samples.
- Subtract the chi-square of summed data from the summed chi-square to obtain homogeneity chi-square.
- Subtract the degree of freedom of summed data from the degree of freedom of summed chi-square to obtain the degree of freedom for homogeneity chi-square.
- If the calculated value of chi-square is less than the tabular value of chi-square, then the null hypothesis is accepted. If the calculated value of the chi-square is more than the tabular value of the chi-square, then the null hypothesis is rejected.

Example 5: In a genetics experiment, four self-fertilized F_1garden pea plants for yellow and green pod colour show the following data:

Garden pea plant	1	2	3	4
Yellow pod	21	32	14	70
Green pod	15	8	6	30

Conduct a chi-square test for homogeneity for a 3:1 ratio in garden pea plants.

Solution:
Null hypothesis-3:1; **Alternative hypothesis**-1:1

Individual chi-square:

	Observed (O)	**Expected (E)**	**O − E**	**$(O-E)^2$**	**$\frac{(O-E)^2}{E}$**	**χ^2**	**df**
1	21	27	−6	36	1.33	5.33	2 − 1 = 1
	15	9	6	36	4		
2	32	30	2	4	0.13	0.53	2 − 1 = 1
	8	10	−2	4	0.4		
3	14	15	−1	1	0.06	0.26	2 − 1 = 1
	6	5	1	1	0.2		
4	70	75	−5	25	0.33	1.33	2 − 1 = 1
	30	25	5	25	1		
						$\Sigma\chi^2 = 7.45$	**df = 4**

Summed chi-square:

Observed (O)	**Expected (E)**	**O − E**	**$(O-E)^2$**	**$\frac{(O-E)^2}{E}$**	**χ^2**	**df**
137	147	−10	100	0.68	2.72	2 − 1 = 1
59	49	10	100	2.04		

	Chi-Square	**Degree of Freedom**
Total	7.45	4
Summed Data	2.72	1
Homogeneity	4.73	3

The table value of χ^2 at 0.05 level of significance for df= 3 is 7.82.

The calculated value of χ^2 = 4.73 is less than the table value of χ^2. Thus, the null hypothesis is accepted, i.e. homogeneity exists among the samples.

5.5 APPLICATIONS OF CHI-SQUARE TEST

- The chi-square test can assess whether an observed frequency distribution fits a theoretical or expected distribution.
- It is often used to determine whether there is a significant association between two categorical variables in a contingency table.
- It can also be used to test whether the distributions of categorical variables are identical across different groups or populations.
- It is widely used in genetics to assess whether there is an association between genotype and phenotype frequencies.
- It can be employed in market research to analyze survey data and determine if there are significant differences in behaviours across different demographic groups.
- In manufacturing or quality control processes, chi-square tests can be used to determine a significant difference between observed and expected defect rates or assess whether different production lines or batches have similar defect rates.
- It is commonly used in ecological studies to assess species distributions, population dynamics, or habitat preferences.

5.6 SUMMARY

The chi-square test is an important statistical methodfor analysing categorical data and determining whether observed frequencies differ significantly from expected frequencies. There are three common types of chi-square tests: test for goodness of fit, test for independence and test for homogeneity. It is essential to understand the applications and limitations of the chi-square test in order to make meaningful interpretations. Proper application of the chi-square test can lead to valuable insights in various fields such as biology, ecology, social sciences, genetics, market research, etc.

- Formula for calculating chi-square:$\chi^2 = \Sigma\frac{(O-E)^2}{E}$. O is observed frequency and E is expected frequency.
- The chi-square test involves hypothesis testing and formulation of null and alternate hypotheses. Interpretation of the chi-square statistic occurs in relation to the degrees of freedom and significance level and involves comparing calculated chi-square values with critical values or p-values to determine statistical significance. Higher chi-square values than tabular chi-square valuesindicate stronger evidence against the null hypothesis.

5.7 GLOSSARY

Chi-square Test: This is a statistical test used to determine whether there is a significant association between categorical variables. It is denoted by the symbol χ^2.

Hypothesis: A hypothesis is a concept or idea about a phenomenon or relationship between variables that must be tested.

Hypothesis Testing: Hypothesis testing is a statistical method used to make inferences about population parameters or relationships between variables based on sample data.

Null Hypothesis: This hypothesis suggests that there is no significant difference or association between categorical variables. It is denoted by symbol H_0.

Alternative Hypothesis: This hypothesis suggests that there is a significant difference or association between categorical variables. It is denoted by the symbol H_a.

Critical Value: The threshold value used to determine whether to reject the null hypothesis, typically based on a chosen significance level.

Level of Significance: The predetermined threshold for determining statistical significance is typically set at 0.05 or 0.01. It is denoted by the symbol α.

Degree of Freedom: The degree of freedom isthe number of independent values in a data sample, which have freedom to vary.

Critical Region: The critical region, also known as the rejection region, is a range of values for a test statistic beyond which the null hypothesis is rejected.

Chi-Square Test for Goodness of Fit: This is a statistical test that assesses whether the observed frequency distribution matches or is in good agreement with the expected frequency distribution under the theoretical model.

Chi-Square Test of Independence: This is a statistical test used to determine whether there is a significant association between two categorical variables.

Chi-Square Test for Homogeneity: A statistical test used to determine whether the distribution of frequencies within categories of a single variable is the same across different groups or populations.

5.8 SELF ASSESSMENT QUESTIONS

5.8.1 Multiple choice questions

1. Critical value for a chi-square statistic depends on which of the following?
   (a). Degree of freedom (b). Sum of frequencies
   (c). Number of variables (d). None of the above

2. How many degrees of freedom are typically involved in a chi-square test of independence for a contingency table with R rows and C columns?
   (a). R+C (b). R×C

(c). (R-1)(C-1) (d). None of the above

3. What type of data is used for the chi-square test?
   (a). Interval data (b). Categorical data
   (c). Non-continuous data (d). None of the above

4. What is a null hypothesis state in a chi-square test?
   (a). There is no significant difference between groups
   (b). There is a significant difference between groups
   (c). Both a and b
   (d). None of the above

5. A goodness of fit can be applied by using:
   (a). Chi-square distribution (b). Nominal distribution
   (c). Both a and b (d). None of the above

5.8.2 True or False

11. Chi-square test is a non-parametric test.
12. The null hypothesis for a chi-square test on a contingency table is that the two variables are independent.
13. A chi-square test is applied when the data are measured on a nominal scale.
14. The chi-square test is used to compare means between groups.
15. Null hypothesis and alternative hypothesis are contradictory.

5.8.3 Fill in the blanks

1. The chi-square test is calculated as the sum of squared differences between the _____ and expected frequencies divided by the expected frequency.
2. If the calculated value of chi-square is less than the tabular value of chi-square, then the null hypothesis is _____.
3. The chi-square test is used to determine whether there is a significant _____between categorical variables.
4. The formula for calculating chi-square is _____.
5. _____region in a chi-square test represents values of the test statistic that lead to rejection of the null hypothesis.

Answer Key:

5.8.1: 1. (a); 2. (c); 3. (b); 4. (a); 5. (a)

5.8.2: 1. True; 2. True; 3. False; 4. False; 5. True

5.8.3: 1. observed; 2. accepted; 3. difference/association; 4. $\chi^2 = \Sigma \frac{(O-E)^2}{E}$; 5. critical

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5.11 ACKNOWLEDGEMENTS

The author of the unit is highly thankful to Dr. Saraswati Nandan Ojha, Assistant Professor, Department of Botany, School of Sciences, Uttarakhand Open University, Haldwani and Dr.

Deepak Kumar, Assistant Professor, Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, for their unwavering support and assistance in writing the unit.

5.12 TERMINAL QUESTIONS

5.12.1 Short answer type questions

1. Describe the chi-square test in brief.
2. Write applications of the chi-square test.
3. Define null and alternative hypothesis.
4. Explainthe chi-square test for independence in brief.
5. Define critical value and degree of freedom.

5.12.2 Long answer type questions

1. A marketing researcher surveys to determine if there is an association between gender (male/female) and preferred social media platforms (Facebook, Instagram, Whatsapp).Conduct a chi-square test of independence at a 5% level of significance to test whether there is a significant association between gender and preferred social media platforms based on the data provided.

Gender	Facebook	Instagram	Whatsapp
Men	60	40	30
Women	50	70	30

2. In a genetics experiment, the expected genotype frequencies are 25% for homozygous dominant (AA), 50% for heterozygous (Aa), and 25% for homozygous recessive (aa). After observing the genotypes of 200 fruit flies, 45 AA, 95 Aa, and 60 aa individuals are recorded. Conduct a chi-square goodness-of-fit test to determine if the observed genotype frequencies match the expected frequencies.

3. An educational researcher surveys 150 students from three grade levels, i.e. Grade 10, Grade 11, and Grade 12. Conduct a chi-square test for homogeneity to determine if there is a significant difference in teaching method preferences across the three grade levels at a 5% significance level.

Teaching Method	Grade 10	Grade 11	Grade 12
Lecture	60	50	40
Discussion	40	60	50
Hands-on	50	40	60

4. A researcher wants to investigate whether there is a relationship between education level and employment status among 400 individuals. Conduct a chi-square test of independence to determine if there is a significant association between education level and employment status at a 5% significance level.

	Employed	**Unemployed**
High School	90	60
Bachelor	120	40
Master	80	30
Doctorate	50	20

5. In a genetic experiment, the expected phenotypic ratios according to Mendel's laws are 9:3:3:1 for the four possible phenotypes. The observed phenotypic frequencies in 400 offspring are 110 with phenotype A, 90 with phenotype B, 90 with phenotype C, and 110 with phenotype D. Conduct a Chi-square goodness-of-fit test to determine if the observed frequencies match the expected Mendelian ratios at a 5% significance level.

UNIT-6- Study of ANOVA

Contents:

6.1 OBJECTIVES

After reading this unit, you will be able:

- To understand the concept of analysis of variance.
- To understand the procedure of ANOVA.

6.2 INTRODUCTION

In this chapter, we will explore the concepts of analysis of variance, a statistical tool used to compare the means of more than two groups and determine if there are statistically significant differences among them. This chapter aims to provide a comprehensive understanding of ANOVA and its practical applications in various domains. ANOVA is widely used in fields such as psychology, biology, economics, and engineering, where it is employed to compare treatments, assess the effectiveness of interventions, and analyses experimental data, underscoring its practical relevance and importance.

6.3 ANALYSIS OF VARIANCE

Analysis of variance, or ANOVA, is a statistical technique for comparing the means of variations of more than two samples or populations. It is based on variations between and within the samples. This concept was developed by the renowned statistician R. A. Fischer. ANOVA is a generalized form of the t-test used to compare the means of two groups. It helps to understand the influence of one or more independent variables on a dependent variable.

6.3.1 Assumptions of ANOVA

- The data should be normally distributed.
- The observations should be independent of each other.
- The variance among groups should be equal.
- ANOVA require random sampling.

6.3.2 Types of ANOVA

6.3.2.1One-Way ANOVA

It is the simplest type of analysis of variance. It is a statistical test that compares the mean of three or more samples based on a single factor. It is used to determine if there are any statistically significant differences between the means of these groups.It requires a numeric response variable, Y (dependent variable), and a single explanatory variable, X (independent variable). It helps to identify whether variations in the independent variable lead to significant

differences in the dependent variable. It tests the null hypothesis, which states that all group means are equal.Example:

- Test scores of students from different classes.
- Effect of different fertilisers on crop production.

6.3.2.2 Two Way ANOVA

The two-way analysis of variance (ANOVA) is an extension of the one-way ANOVA that examines the effect of two independent variables on a dependent variable.Example:

- Effect of teaching method and study time on student score.
- Effect of diet and exercise on weight loss.

6.3.3Calculation of One-Way ANOVA

Direct Method

- Set null and alternative hypothesis.
- Calculate the mean of each group.
- Calculate the overall or grand totalmean.
- Calculate the **sum of squares between groups (SSB)**.

$$\mathrm{SSB} = \mathrm{n}_1(\overline{\mathrm{X}}_1 - \overline{\mathrm{X}})^2 + \mathrm{n}_2(\overline{\mathrm{X}}_2 - \overline{\mathrm{X}})^2 + \ \ldots\ldots\ldots\ldots\ldots \mathrm{n}_\mathrm{k}(\overline{\mathrm{X}}_\mathrm{k} - \overline{\mathrm{X}})^2$$

- Calculate the **sum of squares within groups (SSW)**.

$$\mathrm{SSW} = \Sigma(\mathrm{X}_1 - \overline{\mathrm{X}}_1)^2 + \Sigma(\mathrm{X}_2 - \overline{\mathrm{X}}_2)^2 + \ \ldots\ldots\ldots\ldots\ldots \Sigma(\mathrm{X}_\mathrm{k} - \overline{\mathrm{X}}_\mathrm{k})^2$$

- Calculate **degree of freedom**.

  Degree of freedom between groups ($\mathbf{df_B}$): $\mathrm{df}_\mathrm{B} = \mathrm{K} - 1$; K is number of groups

  Degree of freedom within groups ($\mathbf{df_W}$): $\mathrm{df}_\mathrm{W} = \mathrm{N} - \mathrm{K}$; K is number of groups, N is number of observations.

- Calculate the **mean square between groups (MSB)**.

$$\mathrm{MSB} = \frac{\mathrm{SSB}}{\mathrm{df}_\mathrm{B}}$$

- Calculate the **mean square within groups (MSW)**.

$$\mathrm{MSW} = \frac{\mathrm{SSW}}{\mathrm{df}_\mathrm{W}}$$

- Calculate **variance ratio ($\mathbf{F_{calculated}}$)**.

$$\mathrm{F} = \frac{\mathrm{MSB}}{\mathrm{MSW}}$$

  Normally MSB>MSW, but if MSB<MSW, inverse ratio of F is taken, i.e.,

$$\mathrm{F} = \frac{\mathrm{MSW}}{\mathrm{MSB}}$$

- If the calculated value of F is more than the critical value, then the null hypothesis is rejected.

ANOVA Table

Source of Variation	Sum of Squares	df	Mean Square	F Statistic
Between groups	SSB	df_b	MSB	$F = \frac{MSB}{MSW}$
Within groups	SSW	df_w	MSW	
Total	SST	df		

Example 1: The data on the test scores for a sample of students under three different teaching methods is given below. Perform one-way ANOVA to determine if there are significant differences in the mean test scores among the three teaching methods.

Method 1	Method 2	Method 3
78	90	75
85	92	78
82	85	74
88	87	72
76	89	70

Solution:

Null hypothesis: There is no significant difference in mean test scores among the three teaching methods.

Alternative hypothesis: There is a significant difference in mean test scores among the three teaching methods.

Method 1	Method 2	Method 3
78	90	75
85	92	78
82	85	74
88	87	72
76	89	70

$\Sigma X_1 = 409$ $\Sigma X_2 = 443$ $\Sigma X_3 = 369$

Sample mean:

$$\overline{X}_1 = \frac{409}{5} = 81.8$$

$$\overline{X}_2 = \frac{443}{5} = 88.6$$

$$\overline{X}_3 = \frac{369}{5} = 73.8$$

Overall mean:

$$\overline{X} = \frac{\overline{X}_1 + \overline{X}_2 + \overline{X}_3}{3}$$

$$= \frac{81.8 + 88.6 + 73.8}{3} = 81.4$$

Sum of squares between groups (SSB):

$$SSB = n_1(\overline{X}_1 - \overline{X})^2 + n_2(\overline{X}_2 - \overline{X})^2 + \ \ldots\ldots\ldots\ldots\ldots n_k(\overline{X}_k - \overline{X})^2$$

$$SSB = 5(81.8 - 81.4)^2 + 5(88.6 - 81.4)^2 + \ 5(73.8 - 81.4)^2$$

$$SSB = 5(0.4)^2 + 5(7.2)^2 + \ 5(-7.6)^2$$

$$SSB = 5(0.16) + 5(51.84) + \ 5(57.76)$$

$$SSB = 548.8$$

Sum of squares within groups (SSW):

Method 1		**Method 2**		**Method 3**	
$\mathbf{X_1}$	$(\mathbf{X_1 - \overline{X}_1})^2$	$\mathbf{X_2}$	$(\mathbf{X_2 - \overline{X}_2})^2$	$\mathbf{X_3}$	$(\mathbf{X_3 - \overline{X}_3})^2$
78	$(78 - 81.8)^2 = 14.44$	90	$(90 - 88.6)^2 = 1.96$	75	$(75 - 73.8)^2 = 1.44$
85	$(85 - 81.8)^2 = 10.24$	92	$(92 - 88.6)^2 = 11.56$	78	$(78 - 73.8)^2 = 17.64$
82	$(82 - 81.8)^2 = 0.04$	85	$(85 - 88.6)^2 = 12.96$	74	$(74 - 73.8)^2 = 0.04$
88	$(88 - 81.8)^2 = 38.44$	87	$(87 - 88.6)^2 = 2.56$	72	$(72 - 73.8)^2 = 3.24$
76	$(76 - 81.8)^2 = 33.64$	89	$(89 - 88.6)^2 = 0.16$	70	$(70 - 73.8)^2 = 14.44$
	$\Sigma(\mathbf{X_1 - \overline{X}_1})^2 = \mathbf{96.8}$		$\Sigma(\mathbf{X_2 - \overline{X}_2})^2 = \mathbf{29.2}$		$\Sigma(\mathbf{X_3 - \overline{X}_3})^2 = \mathbf{36.8}$

$$SSW = \Sigma(X_1 - \overline{X}_1)^2 + \Sigma(X_2 - \overline{X}_2)^2 + \ \ldots\ldots\ldots\ldots\ldots \Sigma(X_k - \overline{X}_k)^2$$

$$SSW = 96.8 + 29.2 + 36.8 = 162.8$$

Degree of freedom (df):

Degree of freedom between groups (df_B):

$$df_B = K - 1 = 3 - 1 = 2$$

Degree of freedom within groups (df_W):

$$df_W = N - K = 15 - 3 = 12$$

Mean square between groups (MSB):

$$MSB = \frac{SSB}{df_B} = \frac{548.8}{2} = 274.4$$

Mean square within groups (MSW):

$$MSW = \frac{SSW}{df_W} = \frac{162.8}{12} = 13.56$$

Source of Variation	Sum of Squares	df	Mean Square	F Statistic
Between groups	$SSB = 548.8$	$df_b = 2$	$MSB = 274.4$	$F = \frac{MSB}{MSW} = \frac{274.4}{13.56}$
Within groups	$SSW = 162.8$	$df_w = 12$	$MSW = 13.56$	$F = 20.2$
Total	$SST = 711.6$	14		

The calculated value of F at 0.05 at df_b= 2 and df_w= 12 is 20.2, which is greater than the critical value at 0.05 level ($F_{Tabulated}$= 3.89).

Hence, null hypothesis is rejected and it is concluded that there is a significant difference in mean test scores among the three teaching methods.

Short Cut Method

- Set null and alternative hypothesis.
- Calculate the total ofall the observationsfrom all samples.

$$T = \Sigma X_1 + \Sigma X_2 + \Sigma X_3 \dots\dots\dots\dots\dots \Sigma X_k$$

- Calculate **correction factor**.

$$CF = \frac{T^2}{N}; \text{N is number of observations}$$

- Calculatethe **total sum of squares (SST)**.

$$SST = (\Sigma X_1^2 + \Sigma X_2^2 + \Sigma X_3^2 + \dots\dots\dots\dots\dots\dots\dots\dots\dots \Sigma X_k^2) - CF$$

- Calculate the **sum of squares between groups (SSB)**.

$$SSB = [\frac{(\Sigma X_1)^2}{n_1} + \frac{(\Sigma X_2)^2}{n_2} + \frac{(\Sigma X_3)^2}{n_3} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + \frac{(\Sigma X_k)^2}{n_k}] - CF$$

- Calculate the **sum of square within groups (SSW)**.

$$SSW = SST - SSB$$

- Calculate **degree of freedom**.

  Degree of freedom between groups, $df_B = K - 1$; K is number of groups

  Degree of freedom within groups, $df_W = N - K$; N is number of observations; K is number of groups

- Calculate the **mean square between groups (MSB)**.

$$MSB = \frac{SSB}{df_B}$$

- Calculate the **mean square within groups (MSW)**.

$$MSW = \frac{SSW}{df_W}$$

- Calculate **variance ratio ($F_{calculated}$)**.

$$F = \frac{MSB}{MSW}$$

  Normally MSB>MSW, but if MSB<MSW, inverse ratio of F is taken, i.e.,

$$F = \frac{MSW}{MSB}$$

- If the calculated value of F is more than critical value then null hypothesis is rejected.

Example 2:A study compare the effectiveness of three different diets on weight loss. The weight losses (in pounds) for a sample of people following each diet for one month are recorded below:

Diet A	Diet B	Diet C
4	8	12
6	9	11
5	6	14
7	10	13

Perform a one-way ANOVA to determine if there are significant differences in the mean weight loss among the three diets.

Solution:

Null hypothesis: The means of weight loss for all three diets are equal.
Alternative hypothesis: The means of weight loss for all three diets are not equal.

Diet A (X_1)	ΣX_1^2	**Diet B (X_2)**	ΣX_2^2	**Diet C (X_3)**	ΣX_3^2
4	16	8	64	12	144
6	36	9	81	11	121
5	25	6	36	14	196
7	49	10	100	13	169
$\Sigma X_1 = 22$	**$\Sigma X_1^2 = 126$**	**$\Sigma X_2 = 33$**	**$\Sigma X_2^2 = 281$**	**$\Sigma X_3 = 50$**	**$\Sigma X_3^2 = 630$**

Total of all the observations in all three samples:

$$T = \Sigma X_1 + \Sigma X_2 + \Sigma X_3 \dots\dots\dots\dots\dots \Sigma X_k$$

$$T = 22 + 33 + 50 = 105$$

Correction factor:

$$CF = \frac{T^2}{N} = \frac{(105)^2}{12} = \frac{11025}{12} = 918.75$$

Total sum of squares (SST):

$$SST = (\Sigma X_1^2 + \Sigma X_2^2 + \Sigma X_3^2 + \dots\dots\dots\dots\dots\dots\dots\dots \Sigma X_k^2) - CF$$

$$SST = (126 + 281 + 630) - 918.75$$

$$SST = 1037 - 918.75$$

$$SST = 118.25$$

Sum of squares between groups (SSB):

$$SSB = [\frac{(\Sigma X_1)^2}{n_1} + \frac{(\Sigma X_2)^2}{n_2} + \frac{(\Sigma X_3)^2}{n_3} + \dots\dots\dots\dots\dots\dots + \frac{(\Sigma X_k)^2}{n_k}] - CF$$

$$SSB = [\frac{(22)^2}{4} + \frac{(33)^2}{4} + \frac{(50)^2}{4}] - 918.75$$

$$SSB = [\frac{484}{4} + \frac{1089}{4} + \frac{2500}{4}] - 918.75$$

$$SSB = 1018.25 - 918.75$$

$$SSB = 99.5$$

Sum of square within groups (SSW):

$$SSW = SST - SSB$$

$$SSW = 118.25 - 99.5 = 18.75$$

Degree of freedom (df):

Degree of freedom between groups (df_B):

$$df_B = K - 1 = 3 - 1 = 2$$

Degree of freedom within groups (df_W):

$$df_W = N - K = 12 - 3 = 9$$

Mean square between groups (MSB):

$$MSB = \frac{SSB}{df_B} = \frac{99.5}{2} = 49.75$$

Mean square within groups (MSW):

$$MSW = \frac{SSW}{df_W} = \frac{18.75}{9} = 2.083$$

Source of Variation	Sum of Squares	df	Mean Square	F Statistic
Between groups	$SSB = 99.5$	$df_b = 2$	$MSB = 49.75$	$F = \frac{MSB}{MSW} = \frac{49.75}{2.083}$
Within groups	$SSW = 18.75$	$df_w = 9$	$MSW = 2.083$	$F = 23.88$
Total	$SST = 118.25$	11		

The calculated value of F at 0.05 at df_b= 2 and df_w= 9 is 23.88, which is greater than the critical value at 0.05 level ($F_{Tabulated}$= 4.26).

Hence, null hypothesis is rejected and it is concluded that there is a significant difference in mean weight loss among the three diets.

6.3.4Calculation of Two-Way ANOVA

- Calculate grand total (T) i.e. sum of all the values.
- **Correction factor:**

$$CF = \frac{T^2}{N};\ N \text{ is Number of observations}$$

- **Sum of squares between the columns (SSC):**

$$SSC = \frac{\Sigma(\Sigma X_c)^2}{n_c} - CF$$

n_c is number of units in each column

- **Sum of squares between the rows (SSR):**

$$\mathrm{SSR} = \frac{\Sigma(\Sigma \mathrm{X_r})^2}{\mathrm{n_r}} - \mathrm{CF}$$

n_r is number of units in each row

- **Total sum of squares (SST):**

$$\mathrm{SST} = (\Sigma \mathrm{X_1^2} + \Sigma \mathrm{X_2^2} + \Sigma \mathrm{X_3^2} + \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \Sigma \mathrm{X_k^2}) - \mathrm{CF}$$

- **Residual sum of squares (SSE):**

$$\mathrm{SSE} = \mathrm{SST} - (\mathrm{SSC} + \mathrm{SSR})$$

- **Degree of freedom:**

  df between columns (df_c): $c - 1$;

  df between rows (df_r): $r - 1$;

  df between residuals (df_e): $(c - 1)(r - 1)$

- **Mean squares:**

  Mean square between columns (MSC):

$$\mathrm{MSC} = \frac{\mathrm{SSC}}{\mathrm{df_c}}$$

  Mean square between rows (MSR):

$$\mathrm{MSR} = \frac{\mathrm{SSR}}{\mathrm{df_r}}$$

  Mean square for residual (MSE):

$$\mathrm{MSE} = \frac{\mathrm{SSE}}{\mathrm{df_e}}$$

- Calculate **variance ratio ($F_{calculated}$)**.

  Between columns:

$$\mathrm{F} = \frac{\mathrm{MSC}}{\mathrm{MSE}}$$

  Between rows:

$$\mathrm{F} = \frac{\mathrm{MSR}}{\mathrm{MSE}}$$

- If the calculated value of F is more than critical value then null hypothesis is rejected.

ANOVA Table

Source of Variation	Sum of Squares	df	Mean Square	F Statistic

Between columns	SSC	df_c	MSC	$F = \frac{MSC}{MSE}$
Between rows	SSR	df_r	MSR	$F = \frac{MSR}{MSE}$
Residuals	SSE	df_e	MSE	
Total	SST	df		

Example 3: The use of three different types of fertilizers on theyield per acre of three varieties of a crop is given below:

Fertilizer	**Crop Varieties**		
	V_1	**V_2**	**V_3**
Fertilizer A	58	56	64
Fertilizer B	48	52	68
Fertilizer C	54	44	52

Perform a two-way ANOVA to analyse the data and interpret the results.

Solution:

Null hypothesis: There is no significant difference in mean values of the three varieties of a crop and three types of fertilizers on crop yield.

Alternative hypothesis: There is a significant difference in mean values of the three varieties of a crop and three types of fertilizers on crop yield.

Fertilizer	**Crop Varieties**			
	V_1	**V_1**	**V_1**	**Total**
Fertilizer A	58	56	64	**178**
Fertilizer B	48	52	68	**168**
Fertilizer C	54	44	52	**150**
Total	**160**	**152**	**184**	**496**

Grand total: $\Sigma X = 496$

Correction factor:

$$CF = \frac{T^2}{N} = \frac{(496)^2}{9} = 27335.11$$

Sum of squares between the columns (SSC):

$$SSC = \frac{\Sigma(\Sigma X_c)^2}{n_c} - CF$$

$$SSC = [\frac{(160)^2}{3} + \frac{(152)^2}{3} + \frac{(184)^2}{3}] - 27335.11$$

$$SSC = [8533.33 + 7701.33 + 11285.33] - 27335.11$$

$$SSC = 27519.99 - 27335.11 = 184.88$$

Sum of squares between the rows (SSR):

$$SSR = \frac{\Sigma(\Sigma X_r)^2}{n_r} - CF$$

$$SSR = [\frac{(178)^2}{3} + \frac{(168)^2}{3} + \frac{(150)^2}{3}] - 27335.11$$

$$SSR = [10561.33 + 9408 + 7500] - 27335.11$$

$$SSR = 27469.33 - 27335.11 = 134.22$$

Total sum of squares (SST):

$$SST = [\Sigma X_1^2 + \Sigma X_2^2 + \Sigma X_3^2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \Sigma X_k^2] - CF$$

$$SST = [(58)^2 + (56)^2 + (64)^2 + (48)^2 + (52)^2 + (68)^2 + (54)^2 + (44)^2 + (52)^2] - 27335.11$$

$$SST = 27784 - 27335.11 = 448.89$$

Residual sum of squares (SSE):

$$SSE = SST - (SSC + SSR)$$

$$SSE = 448.89 - (184.88 + 134.22)$$

$$SSE = 448.89 - 319.1 = 129.79$$

Degree of freedom:

df between columns: $\mathbf{df_c} = c - 1 = 3 - 1 = 2$

df between rows: $\mathbf{df_r} = r - 1 = 3 - 1 = 2$

df between residuals: $\mathbf{df_e} = (c - 1)(r - 1) = 2x2 = 4$

Source of Variation	Sum of Squares	df	Mean Square	F Statistic

Between crop varieties	$SSC = 184.88$	2	$MSC = \frac{SSC}{df_c}$ $MSC = \frac{184.88}{2}$ $MSC = 92.44$	$F = \frac{MSC}{MSE}$ $F = \frac{92.44}{32.4475}$ $F = 2.848$
Between fertilizers	$SSR = 134.22$	2	$MSR = \frac{SSR}{df_r}$ $MSR = \frac{134.22}{2}$ $MSR = 67.11$	$F = \frac{MSR}{MSE}$ $F = \frac{67.11}{32.4475}$ $F = 2.068$
Residuals	$SSE = 129.79$	4	$MSE = \frac{SSE}{df_e}$ $MSE = \frac{129.79}{4}$ $MSE = 32.4475$	
Total	$SST = 448.89$	8		

F- between crop varieties: F tabulated$_{(2,4)}$ i.e., 6.94 is greater than F calculated i.e., 2.848, hence null hypothesis is accepted.

F- between fertilizers: F tabulated$_{(2,4)}$ i.e., 6.94 is greater than F calculated i.e., 2.068, hence null hypothesis is accepted.

Hence, there is no significant difference in mean values of the three varieties of a crop and three types of fertilizers on crop yield.

6.4 SUMMARY

Analysis of Variance (ANOVA) is a statistical test used to compare the means of more than two groups to determine if there are statistically significant differences among them. It is categorized into two main types i.e., one-way ANOVA and two-way ANOVA. One-way ANOVA tests the effect of a single independent variable (factor) on a dependent (response) variable. Whereas, Two-Way ANOVA examines the effect of two independent variables simultaneously on a dependent variable. ANOVA tests the null hypothesis that all group means are equal. ANOVA uses the F-statistic to test the hypothesis about group means.If the F-statistic is greater than the critical value from F-distribution table, reject the null hypothesisindicating significant difference among the group means. In case of One-Way ANOVA, F-ratio is calculated by MSB/MSW,

while in case of Two-Way ANOVA, F ratio is calculated by MSC/MSE (between columns) and MSR/MSE (between rows).

6.5 GLOSSARY

Analysis of Variance (ANOVA): It isa statistical method used to analyze the differences between means of various groups.

One-way ANOVA: It is used when there is only one categorical independent variable influencing a continuous dependent variable.

Two-way ANOVA: It is used when there are two categorical independent variablesinfluencing a continuous dependent variable, and also examines their interaction effect.

Sum of Squares: It is calculated as sum of squares of deviation of the values for mean of the sample.

Mean Squares:It is calculated by dividing sum of squares with appropriate degree of freedom.

F-statistic: The test statistic used in ANOVA to determine whether the group means are significantly different from each other.

6.6 SELF ASSESSMENT QUESTIONS

6.6.1 Multiple choice questions

1. What does ANOVA stand for?
   a) Analysis of Values b) Analysis of Variance
   c) Analysis of Variables d) All of the Above

2. Which ANOVA is used when there is one categorical independent variable and one continuous dependent variable?
   a) One-way ANOVA b) Two-way ANOVA
   c) MANOVA d) ANCOVA

3. Which of the following assumptions is required for ANOVA?
   a) Homogeneity of variance b) Independence of observations
   c) Normal distribution of data d) All of the above

4. In one-way ANOVA, what does the F-statistic represent?
   a) The ratio of between-group variance to within-group variance.
   b) The sum of between-group and within-group variances.
   c) The difference between the largest and smallest variances.
   d) None of the above

5. Which of the following is a requirement for performing ANOVA?

a) The dependent variable must be continuous.
b) The independent variable must be categorical.
c) The data must be normally distributed.
d) All of the above

6.6.2 True or False

1. One-way ANOVA is used when there are two independent variables.
2. If the calculated value of F in ANOVA is greater than the critical value, we reject the null hypothesis.
3. The assumption of homogeneity of variances is not necessary for ANOVA.
4. ANOVA can be used to test hypothesis about medians rather than means.
5. ANOVA assumes that the data in each group are normally distributed.

6.6.3 Fill in the blanks

11. ANOVA stands for_____.
12. The F-ratio in an ANOVA table is calculated as the ratio of Mean Square Between Groups to _____.
13. The degree of freedom between groups is calculated as _____ and within groups is calculated as _____.
14. The null hypothesis in a one-way ANOVA states that all group means are _____.
15. The primary purpose of ANOVA test is used to analyze if there are significant differences among the _____ of various groups.

Answer Key:

6.6.1: 1. (b); 2. (a); 3. (d);4. (a); 5. (d)
6.6.2: 1.False; 2. True; 3. False; 4. False; 5. True
6.6.3:1. Analysis of variance; 2. Mean Square Within Groups 3. K-1 and N-K; 4.Equal; 5. Means

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6.9 ACKNOWLEDGEMENTS

The author of the unit is highly thankful to Dr. Saraswati Nandan Ojha, Assistant Professor, Department of Botany, School of Sciences, Uttarakhand Open University, Haldwani and Dr. Deepak Kumar, Assistant Professor, Department of Botany, L.S.M. Govt. P.G. College, Pithoragarh, for their unwavering support and assistance in writing the unit.

6.10TERMINAL QUESTIONS

6.10.1 Short answer type questions

16. Write a short note on ANOVA.
17. Differentiate betweenone-way ANOVA and two-way ANOVA.
18. How is the F-ratio calculated? What does the F-ratio represent in ANOVA?
19. What are the main components of the ANOVA table?
20. How is sum of squares between groups and within groups calculated?

6.10.2 Long answer type questions

1. Compute the mean squares and F-ratio for the following ANOVA table:

Source of Variation	Sum of Squares	Degree of Freedom
Between Groups	90	3
Within Groups	180	16
Total	270	19

2. Perform a one-way anova on the following data and determine if there is a significant difference between the group means:

Group A	Group B	Group C
20	30	25
22	29	24
19	31	26
23	32	27
21	30	28

3. In an agricultural study, the yield of a crop is measured under three different irrigation methods. The yields (in kg) are recorded as follows. Perform a one-way ANOVA to determine if there are significant differences in crop yield among the irrigation methods.

Method 1	Method 2	Method 3
50	63	70
53	69	79
55	66	72
51	61	78
57	64	76

4. Compute the mean squares and F-ratio for the following ANOVA table:

Source of Variation	Sum of Squares	Degree of Freedom
Between Columns	6924.77	2

Between Rows	18894.39	2
Residuals	6771.22	4

5. The following data represents cholesterol levels (mg/dl) for different combinations of diet and exercise. Perform a two-way ANOVA to determine if diet, exercise, and their interaction significantly affect cholesterol levels.

	Exercise Plan 1	**Exercise Plan 2**	**Exercise Plan 3**
Diet A	120	130	140
	122	132	142
	121	136	148
Diet B	152	176	168
	156	174	166
	159	177	162

BLOCK-2-FOREST ECOLOGY

UNIT-1- ON THE BASIS OF GIVEN DATA SET EXPLAIN CLIMATE OF DIFFERENT SITES/LOCATIONS

Contents:

1.1 OBJECTIVES

After reading this unit learners will be able:

- To differentiate the climatic zone
- To know the various method to predict the climate or climate change
- To understand the climatic conditions prevailing on the study sites

1.2 INTRODUCTION

The climate of a place refers to its long-term pattern of weather (Shepherd et al. 2005). It is possible for the weather to shift from hour to hour, day to day, month to month, or even year to year. The weather patterns of an area are regarded as its climate, and are typically observed for at least 30 years.

Different parts of the world have different climates. Some parts of the world are hot and rainy nearly every day. They have a tropical wet climate. Others are cold and snow-covered most of the year. They have a polar climate. Between the icy poles and the steamy tropics are many other climates that contribute to Earth's biodiversity and geologic heritage.

1.3 METHODS TO DETERMINE THE CLIMATE

Climate change is a long-term phenomenon that takes place over many years. Modern techniques are being used by scientists to interpret the Earth's climate change pattern. Many scientists, including chemists, biologists, physicists, oceanographers, and geologists, are working on various elements of climate research. The following methods can be used to measure climate change:

1. **Reading rings to probe the past:** Ancient climates can be inferred from trees, corals, and limestone deposits (speleotherms), such as stalactites and stalagmites in caves. Trees and corals both have a very long lifespan. The growth of each year is represented by a fresh layer, or "growth ring." The layers offer details on the temperature, precipitation, and other environmental factors present at the time of creation. The growth rings include elements from the environment and so preserve a history of the ecosystem.

2. **Air bubbles in Antarctic ice are time capsules:** Ice at the South Pole contains air bubbles that are up to 800000 years old. Snow traps air bubbles when it falls and is compressed to form ice. Scientists have drilled 3200 metres into the ice to sample air from ancient times. They've tested the air in the bubbles to see how much of each gas (e.g., oxygen, carbon dioxide, nitrogen) it contains. Carbon dioxide levels have gone up and down in cycles of about 100000 years. The temperatures and carbon dioxide concentrations shown in the graph occurred at Vostok in Antarctica during the last

400000 years. It seems that when carbon dioxide levels are high, the temperature goes up too (Fig 1.1).

3. **Argo floats measure the oceans:** The world's ocean currents are carrying more than 3500 Argo floats. These tiny robots continuously collect temperature and salinity data. Every float spends the majority of its time 2000 metres below the surface, but every 10 days it comes to the surface to provide data to satellites. The initial Argo floats were released in 1999 by Australian CSIRO scientists. Currently, 26 nations are taking part, collecting data and creating a detailed picture of the warming waters (Fig 1.2).

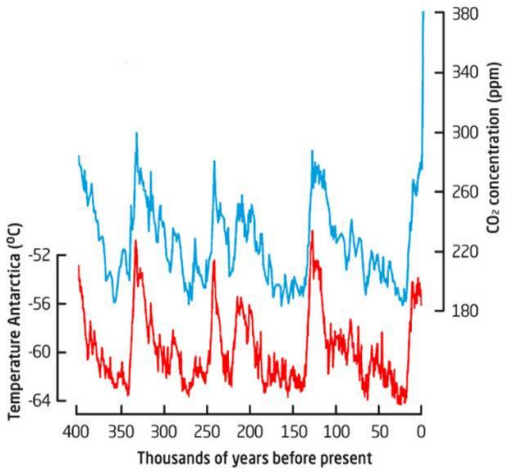

Fig. 1.1: This graph shows how carbon dioxide in the air and temperature at Vostok have changed over time. Source: Adapted from Nature 453, 15 May 2008

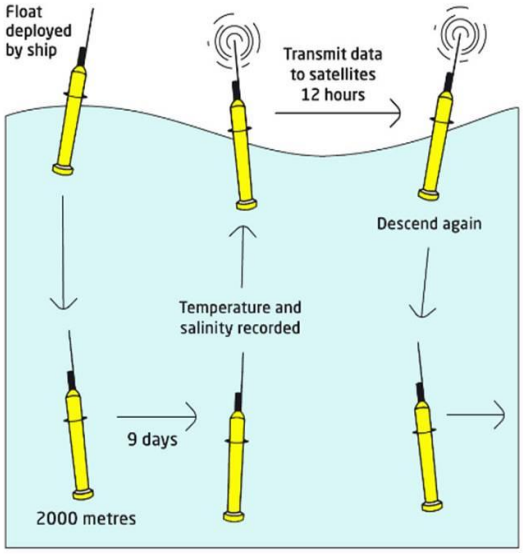

Fig. 1.2: There are thousands of Argofloats taking measurements in the world's oceans.

3. **Water in the ice holds secrets too:** The ice water around the bubble shows what the temperature was like at the time. Ice is made of a mixture of ordinary water and heavy water (deuterium). Heavy water has at least one hydrogen atom slightly larger than normal so it is harder to evaporate and freeze as ice. Only high temperature can do this. So if there is a lot of heavy water in the ice it indicates that the temperature was high. Scientists use ratio of heavy to normal water in ice layers to estimate average temperatures at the time the ice was made.

4. **Measuring carbon in the air:** Since the 1950s, scientists have been closely examining the atmosphere of the Earth. They are measuring the amount of carbon dioxide and other carbon-containing gases in the atmosphere. Carbon-12 and a heavier carbon-13 are the two naturally occurring isotopes of carbon that make up carbon dioxide gas. Since plants prefer to absorb carbon dioxide that includes carbon-12, neither they nor the fossil fuels

they produce contain much carbon-13. Since the 1950s, researchers have continuously taken air samples. They discovered that carbon-12, a form of carbon that is growing in the atmosphere, is most likely a result of the burning of fossil fuels. Carbon dioxide gas is emitted into the atmosphere when carbon is burnt. It is measured in parts per million (ppm) by volume, or the quantity of carbon dioxide units per million air units.

5. **Arctic sea ice melting away:** The satellite photographs demonstrate how significantly less summer sea ice there was in 2007 compared to 1983 (Fig 1.3 a&b). Arctic regions are experiencing a faster increase in average temperatures than other parts of the planet. Sea ice is melting quickly, and soon shipping lanes will be ice-free throughout the year. The white surface of the Arctic during periods of ice cover reflected sun light back into space. The radiation is now absorbed by the dark water surface. This sets up a feedback loop that will protect the planet from cooling. You can see how much less summer sea ice there is now than there was in 1979.

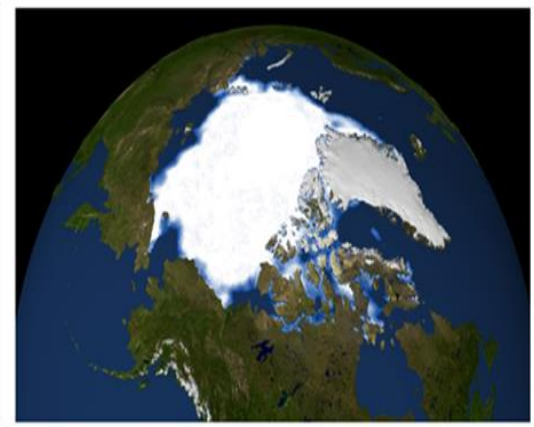

Fig: 1.3 (a): This photograph shows the extent of sea ice in the summer of 1983. Source: NASA/Goddard Space Flight Center Scientific Visualization Studio

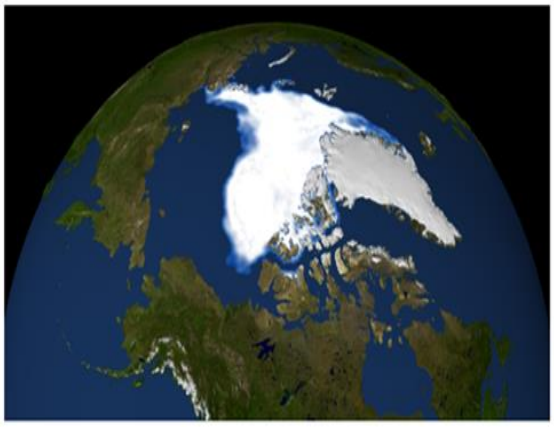

Fig: 1.3 (b): Satellite photos show that by 2007 the extent of summer sea ice was reduced. Source: NASA/ NASA/Goddard Space Flight Center Scientific Visualization Studio

6. **Yearly weather records are averaged to describe the climate:** What is currently occurring outside the window is the weather. The past few years have seen measurements of the daily temperature and precipitation. Daily conditions throughout the year have been noted in these weather records. The records paint a picture of the typical circumstances, or climate, in each location when averaged over a number of years. Thus, a locality's climate refers to the long-term pattern of meteorological conditions that prevail there. Weather data is gathered using thermometers and rain gauges. In order to decrease the likelihood of falsely high readings caused by heat in cities, temperatures are now also measured by satellites.

1.4 ON THE BASIS OF GIVEN DATA SET EXPLAIN CLIMATE OF DIFFERENT SITES/ LOCATIONS

India possesses a large variety of climates, which can be broadly categorized into five regions with distinct climates. The significant difference in the climatic data across the zones defines unique thermal comfort requirements for buildings located in different zones. Table 1.1 highlights the differences in weather data in the five climate zone.

Using a given data set (at least 30 years) of average temperature (maximum and minimum) and precipitation collected by the "averaged yearly weather records method" as describe above, the climatic condition of a specific region can be inferred. For example: If we collected the average annual weather records of last 30 years (temperature and precipitation) of two different locations (Site A and Site B), following is the climate description of the data.

As per the given data set (for Site-A) the mean monthly maximum temperature of the site is range between 8 and 22^{o}C while the mean monthly minimum temperature is between 2 and 15^{o}C. January is considered to be the coldest month and the highest temperature is recorded during June. The total average rainfall is 2527 mm annually with most of the rainfall occurring during the monsoon months.

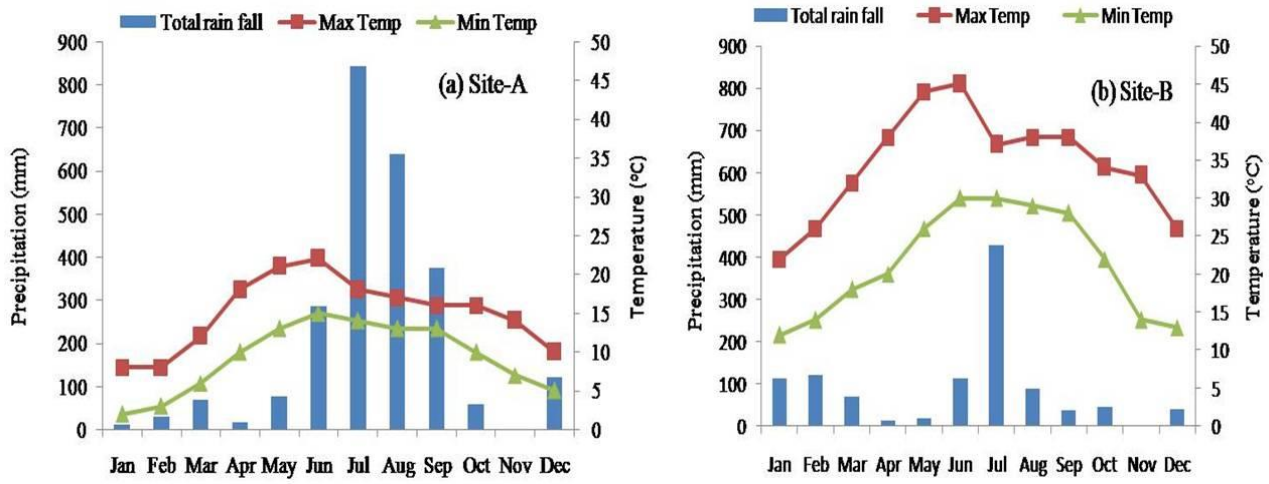

Fig 1.4: Climatic conditions prevailing on two different sites/ locations

The mean monthly maximum temperature for site B is reported 45 to 22^{o}C and mean monthly minimum temperature is between 12 and 30^{o}C. The summer season is extremely hot. Total precipitation reported as 1086 mm and most of the precipitation occurred during the months of the rainy seasons.

Table 1.1: List of major climatic zone of India

Climate zone	Description	Mean temperature (°C)					Mean relative humidity	Annual precipitation	Sky condition	Regions
		Summer middy (High)	Summer night (Low)	Winter Midday (High)	Winter night (Low)	Diurnal variation				
Hot and Dry	High temperature/ Low humidity and rainfall/ Intense solar radiations and generally clear sky/ hot winds during the day and cool winds during night/ sandy and rocky ground with little vegetation/ low underground water table and few source of surface water	40-45	20-30	5-25	0-10	15-20	Very low 25-40%	Low <500mm /yr	Cloudless skies with high solar radiation, causing glare	Rajasthan, Gujrat, West-East Madhya Pradesh, Central Maharastra etc
Warm and Humid	Temperature is modeately high during day and night/ very high humidity and rainfall/ Diffused solar radiation if cloud cover is high and intense if sky is clear/ calm to very high winds from prevailing wind directions/ abundant vegetation/ provision for drainage of water is required	30-35	25-30	25-30	20-25	5-8	High 70-90%	High > 1200 mm/Yr	Overcast (cloud cover ranging between 40 and 80%) causing unpleasent glare	Kerela, Tamilnadu, Costal parts of Orrissa Andhra Pradesh etc
Temperate	Moderate temperature/ Moderate humidity and rainfall/ sloar radiation same through out the	30 to 34	17 to 24	27 to 33	16 to 18	8 to 13	High 60 to 85%	High > 1000 mm/yr	Mainly clear, occasionally overcast with dense low	Bangalor, Goa Parts of the

	year and the sky is generally clear/ High winds during summer depending on topography/ Hilly or high plateau region with abundant vegetation								clouds in summer	Deccan
Cold (sunny/ cloudy)	Moderate summer temperature and very low in winter/ low humidity in cold/ sunny and high humidity in cold/cloudy/ low precipitation in winter/ Cold winds in winter/ very less vegetation in cold/ abundant vegetation in rainy season	17 to 24	4 to 17	-7 to 8	-14 to 0	25 to 25/5	Low 10-50% High: 7.-80%	Low < 200 mm, Moderate 1000mm/yr	Clear with cloud cover < 50%/ overcast for	Jammu & Kashmir, Ladakh, Himanchal Pradesh, Uttarakhand/ Sikkim Arunanchal Pradesh
Composite	This applies when 6 months or more do not fall within any of the above categories/ High temperature in summer and cold in winter/ Low humidity in summer and high in monsoons/ High direct radiations in all seasons expect monsoons/ occasional hazy sky/ hot winds in summer, cold winds in winter, strong winds in monsoon/ variable landscape and seasonal vegetation	32 to 43	27 to 32	10 to 25	4 to 10	35 to 22	Variable dry periods=20-50%, wet = 50-95%	Variable 500-1300 mm/yr, during monsoon reaching 250 mm in the wettest month	Variable overcast and dull in the monsoon	Uttar Pradesh, Haryana, Punjab, Bihar, Jharkhand, Chattisgarh, Madhya Pradesh etc.

(Source: https://www.firstgreen.co/climate-zone-map-of-india/)

1.5 FACTORS DETERMINE THE CLIMATE OF A REGION

Climate is the long-term phenomenon of a particular region. The climate changes in a particular region are based on the atmosphere and environmental conditions of that region. Factors that affect the climate of a place include:

1. **Elevation:** In places at higher regions or high altitudes, the atmosphere experiences less pressure. As the gas residing in the atmosphere rises, it experiences feeling less pressure, hence causing it to expand.
2. **Latitude:** Higher altitude areas are far from the equator and receive less sunshine, while areas closer to the equator get more sunlight and are hotter than areas at higher latitudes. Low precipitation or rainfall can also brought on by sunlight.
3. **Topography:** Landforms are referred to as topography. Latitudes and elevation ranges are the key factors that lead to fluctuation in surface temperatures hence leading to climate change.
4. **Vegetation:** Trees make up the majority of the local vegetation. When water vapour from photosynthesis is released into the atmosphere, it changes the surface energy fluxes and may cause clouds to form.
5. **Ocean Currents:** Ocean currents can relocate heat energy from land to sea or vice versa, thus changing the local temperature.
6. **Prevailing winds:** Specific air masses are dispersed and disseminated by winds. The climate of a region is influenced by the wind's direction. While a wind from a dry area would bring hot air, one from a humid area would bring cool air.

1.6 SUMMARY

Climate is the long-term weather pattern in a region, typically averaged over 30 years. More rigorously, it is the mean and variability of meteorological variables over a time spanning from months to millions of years. Some of the meteorological variables that are commonly measured are temperature, humidity, atmospheric pressure, wind, and precipitation. The climate of a location is affected by its latitude, longitude, terrain, altitude, land use and nearby water bodies and their currents.

1.7 GLOSSARY

- **Climate:** The average and variations of weather in a region over long periods of time.
- **Climate change:** Includes both global warming and its effects, such as changes to precipitation, rising sea levels, and impacts that differ by region
- **Radiation:** Energy transfer in the form of electromagnetic waves or particles that release energy when absorbed by an object.
- **Weather:** Atmospheric condition at any given time or place.
- **Corals:** are marine invertebrates within the class Anthozoa of the phylum Cnidaria.
- **Elevation:** It is distance above sea level.
- **Latitude:** It is a coordinate that specifies the north–south position of a point on the surface of the Earth or another celestial body.

- **Topography:** It is the arrangement of the natural and artificial physical features of an area.
- **Vegetation:** It is an assemblage of plant species and the ground cover they provide

1.8 SELF-ASSESSMENT QUESTIONS

1.8.1 Multiple choice questions

1. Climate is a:
   (a). Long time phenomena (b). Short time phenomena
   (c). Both a and b (d). None of the above
2. The climate of a region is influence by the
   (a). Vegetation cover (b). Latitude
   (c). Altitude (d). All of the above
3. Whether can change:
   (a). Hour to hours (b). Day to days
   (d). Year to years (d). All of the above

1.8.2 True and False

1. Ocean current has no impact on climate.
2. Topography is refers to as arrangement of the natural and artificial physical features of an area.
3. Different parts of the world have different climates.

1.8.3 Fill in the blanks

1. The average and variations of weather in a region over long periods of time is called _____.
2. Daily conditions throughout the year have been noted in these _____ records.
3. A place receives very little rainfall, and the temperature is high throughout the year, the climate of that place will be _____ and _____.

Answer Key:

1.8.1: 1.(a); 2.(d); 3.(d)
1.8.2: 1. False; 2. True; 3. True
1.8.3: 1. Climate; 2. Weather; 3. hot and dry

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1.11 TERMINAL QUESTIONS

1.11.1 Short answer type questions

1. Write the difference between weather and climate.
2. Describe the various factors that determine the climate of a region.

1.11.2 Long answer type questions

1. Discuss the various methods to determine the climate of a region.
2. Discuss the various climatic zone of India

UNIT-2- STUDY OF DIFFERENT FOREST (E.G., CHIR-PINE & OAK) SOIL CHARACTERISTICS,

Contents:

2.1 OBJECTIVES

After reading this unit learners will be able:

- To know about basic nature of soil
- To determine the various physical properties of the soil
- To determine the various chemical properties of the soil

2.2 INTRODUCTION

The word soil is derived from a Latin word *'solum'* means earthy material in which plants grow. According to Stone (1975), soil is an ecosystem component involving a vast number of organisms and individual chemical process. According to Dokyachev (1979) soil is the result of the action and reciprocal influences of parental rocks, climate, topography, plants, animals and age of the land. Soil is the loose, fragile, unconsolidated top layer of earth's crust and is the mixture of weathered rock materials and organic detritus, both of which are formed through the physical, chemical and biological processes.

Soil serves a vital function in nature, providing nutrients for plant to grow as well as habitat for micro and macro organisms. Healthy soil enables vegetation to flourish, releases oxygen, holds water and diminishes destructive storm runoff, breaks down waste materials, binds and breaks down pollutants and serves as the first course in the larger food chain (Rodriguez-Iturbe 2000).

The study of soil is helpful in practices of agriculture, horticulture, forestry, etc., such as cultivation, irrigation, artificial drainage and use of fertilizers. The healthy growth of plant generally depends upon the type of soil, availability of water and nutrients. In view of this, the awareness of soil type is increased in recent years to achieve high yield. Therefore, it is essential to understand the nature of soil, type of soil and the influence of soil on environment. The present unit deals with the physical and chemical composition of the soil.

2.3 SOIL ANALYSIS

Soil has a complex structure. It can be described as the three- phase system composed of solids (organic and inorganic matters), liquids (especially water) and gases (mainly nitrogen, oxygen and carbon di oxide). In the present unit, physical and chemical properties of the soils have discussed to evaluate the ecological functioning of the two different forests soils (Chir-pine forest and oak forest) at different depth layer i.e. surface layer (0-15 cm) and deeper layer (15-30 cm).

The soil samples can take randomly (for example from 20 places) in all the direction using a zigzag pattern (Fig 2.1). Large fragment of plant material should remove by hand sorting and thoroughly mix to prepare a composite sample. The soil samples should collect seasonally (summers, rainy and winter) to get the precise and more accurate soil quality. Avoid taking soil samples when the soil is very wet, dry or frozen.

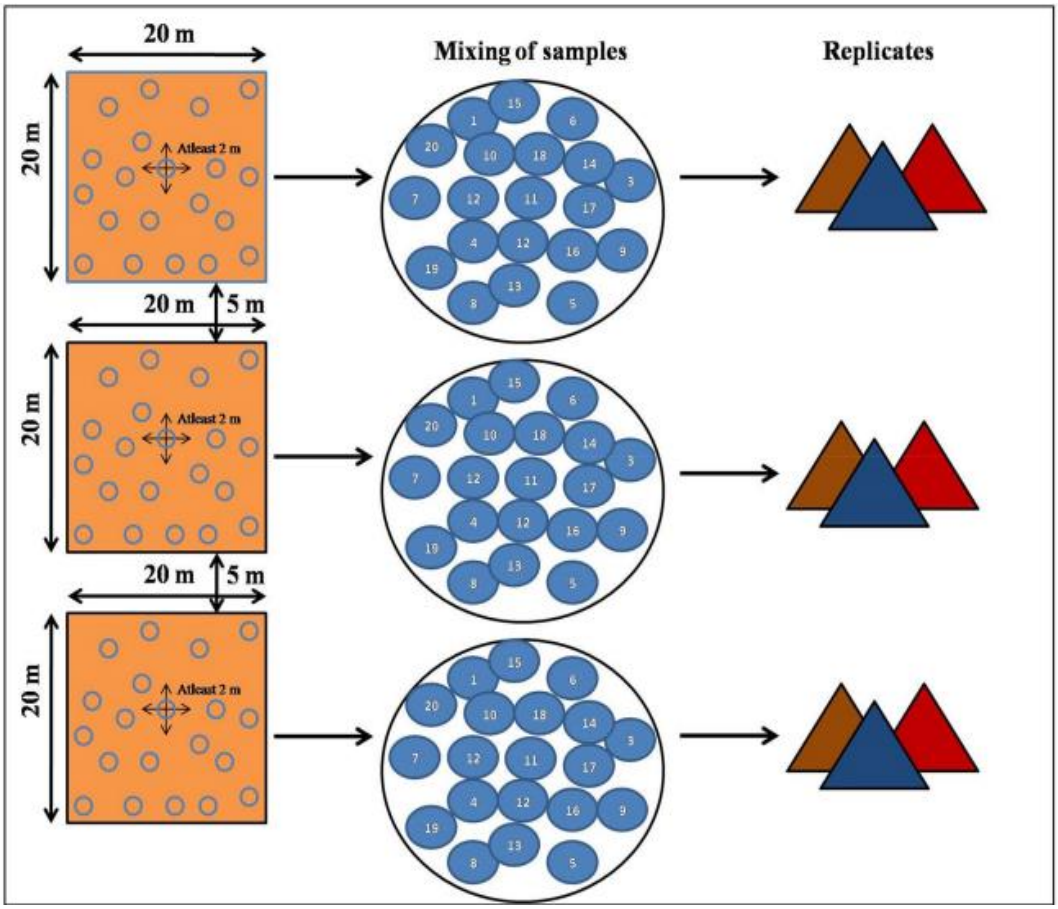

Fig 2.1: Sampling deign for collection of soil samples (Source: Padalia et al. 2022)

The soil sample can be gathered from the different depth layers according to the research design or requirement. Than samples brought to the laboratory and spread over paper sheet to air dry in shade. Coarse concretion, stone and pieces of roots, fresh/ decomposed leaves, stone and other un-decomposed organic residues should remove. The composite sample must be dividing into two parts for physical and chemical analysis of soil. For physical characteristics of the soil (soil colour, texture, moisture and bulk density) different various standardized methods are followed.

Air dried samples should passed through the 2 mm mesh sieve and stored in plastic zip lock bags for further chemical analysis . The soil chemical properties include soil pH, carbon, and nitrogen content.

2.4 SOIL PHYSICAL PROPERTIES

The physical properties of forest soils affect every aspect of soil fertility and productivity. Soil physical properties determine the ease of root penetration, the availability of water and the ease of water absorption by plants, amount of oxygen and other gases in the soil, and the degree to which water moves both laterally and vertically through the soil. Soil physical properties also influence the natural distribution of vegetation, their growth and biomass production (Bargali et al., 2018 a,b; Manral et al. 2022; Manral et al. 2017).

However, soil physical properties are largely controlled by the size, distribution and arrangement of soil particles.

The vegetation also influences the physical properties of soil to a great extent (Padalia 2017; Padalia et al. 2018). It improves the soil structure, infiltration rate, water holding capacity, hydraulic conductivity and aeration (Padalia et al. 2022). The effects of the textural properties of soil are frequently reflected in the composition and the rate of growth in the vegetation. Some important soil properties are discussed below:

1. **Soil Colour:** The colour is usually the first visible and noticeable properties of the soil. The topsoil is usually darker than lower layers (or horizons) because this is where organic matter accumulates but it does not reflect the entire soil.

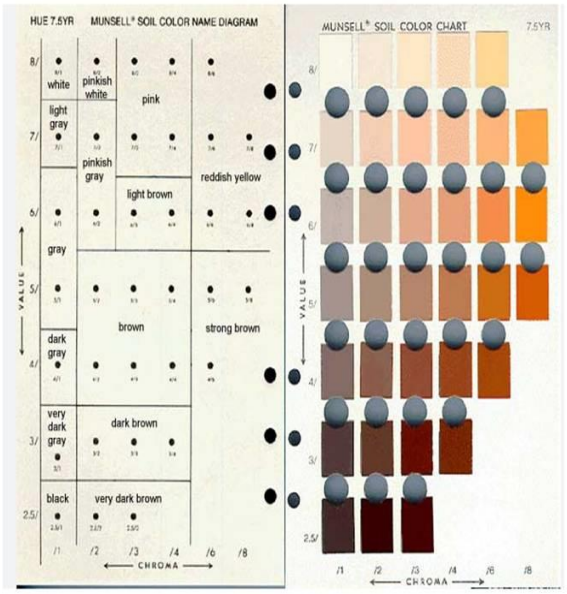

Fig. 2.2.Munsell's soil colour chart

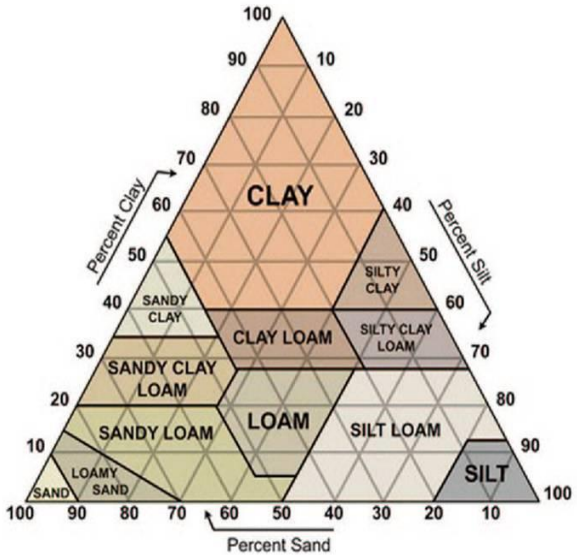

Fig. 2.3: Soil textural triangle (USDA)

Soil colour is usually due to 3 main pigments: black (rich in organic matter), red (rich in iron and aluminium oxides) and white (deposition of silicates and salt). Colour can be a useful indicator of some of the general properties of a soil, as well as some of the chemical processes that are occurring beneath the surface.

Table 2.1: Soil colour and its characteristics
(Source: Adapted from Soil Constraints and Management Package)

Soil colour	Soil types and characteristics	Typical management and implications
Black soil	These soils are often associated with high levels of organic matter (peats).	Water logging or drainage problem, low pH, high denitrification
	Vertosols (cracking clay soils)	Workability and tillage problems

White/ pale and bleached	These soils are often referred to as bleached or 'washed out'. The iron and manganese particles have been leached out due to high amounts of rainfall or drainage.	Leaching of nutrients and low plant available water
Red	This colour indicates good drainage. Iron found within the soil is oxidised more readily due to the higher oxygen content. This causes the soil to develop a 'rusty' colour. The colour can be darker due to organic matter.	High phosphorus fixation, low plant available water
Yellow to yellow brown	These soils often have poorer drainage than red soils. The iron compounds in these soils are in a hydrated form and therefore do not produce the 'rusty' colour.	Moderate phosphorus fixation, low plant available water, compaction
Brown	Soils associated with moderate organic matter level and iron oxides.	Low to moderate phosphorus fixation, low to moderate plant available water
Grey/ Grey green	These soils are associated with very poor drainage or waterlogging. The lack of air in these soils provides conditions for iron and manganese to form compounds that give these soils their colour.	Water logging or drainage problem, High denitrification risk, Methane emission hazard, Water logging or drainage problem

To determine the color of soil, various soil samples are compared with various colour chips of Munsell's soil colour chart (Fig 2.1). The colour of soil particles matched with the colour of the colour chips and the notations given on the chart are observed. This gives the colour characteristics of various soils.

2. **Soil Texture:** Soil texture is one of the most important physical properties of the soil. It refers the basic composition of the soil, which consists of sand, silt and clay contents. Soil texture directly or indirectly determines water intake rate (absorption), water storage, tilling and amount of aeration.

   The soil texture is determine after removing the ores and stone pieces from the air dried soil and then soil is sieved through a series of sieves with different size holes (Misra 1968). The proportion of the soil particles is calculated by the weight machine. The criteria of soil

classification as given by International Soil Testing Association (ISTA) is follow and texture by the United States Department of Agriculture (USDA) textural triangle as follow. Soil textural class names can be obtained from the "USDA textural triangle" (Fig. 2.3).

3. **Bulk Density:** The volume-weight relationship of soil in oven dry conditions is termed as bulk density (Gupta and Sharma 2008). It may be expressed as gm/cm^3. The soils having high bulk density has been found to be inhibitive to root penetration and low permeability and infiltration.

   To determine soil bulk density, soil samples must be collected by means of a special mental core – sampling cylinder of known volume from different depth layers without disturbing the natural structure. After that, soil samples should be brought to the laboratory and oven dried at 80°C till constant weight following Misra (1968).

   $$\text{Bulk density } (\text{g/cm}^3) = \frac{\text{Weight of oven dried soil}}{\text{Volume of cylinder}}$$

   Volume of the cylinder = ($\pi r^2 h$)

4. **Soil Moisture:** Soil moisture is an important soil character to determine the growth and composition of the vegetation. In favorable moisture conditions, increasing temperature results in an exponential increase in decomposition rates. Soil gets moisture from infiltration of precipitated water and irrigation. It's content in soil at any time more or less dependent upon the water holding capacity of soil. However, it drains through percolation, evaporation and uptake by plants.

   To determine the moisture content of the soil, a fresh homogenized soil samples are collected and weighted. After that the samples get dried in an oven at 80^{o}C to obtain the constant weight. The soil is then cooled and its weight is recorded (Misra 1968). The difference in the initial and the final weight is used to calculate the moisture content (Jackson 1958).

   $$\text{Soil moisture content } (\%) = \frac{\text{Fresh weight of soil} - \text{Dry weight of soil}}{\text{Dry weight of soil}} \times 100$$

2.5 SOIL CHEMICAL PROPERTIES

The chemical properties of the soil are the important factor for the growth of the vegetation. It included the pH, macro-nutrient (soil organic matter, carbon stock, nitrogen, phosphorus, potassium, calcium, sulphur etc), micro nutrients (iron, zinc, copper, manganese, boron etc), cation and anion exchange etc. Among them, the most important factor is soil fertility, i.e., the essential nutrients available in the soil for the growth of plants. The selective absorption of nutrient elements by different tree species and their capacity to return them to the soil brings about changes in soil properties (Singh et al. 1986). Concentration of elements in the soils is a good indicator of their availability to plants. Their presence in soil gives good information towards the knowledge of nutrient cycling and bio-chemical cycle in the soil–plant ecosystem (Huang et al. 2007; Pandit and Thampan 1988). The total amount of element contained in

the soils depends on nature of parent material. The chemical composition of different horizons of a soil also showed a good deal of variation.

1. **Soil pH:** Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. Soil pH is defined as the negative logarithm of the hydrogen ion concentration. With the increase of hydrogen ions in the soil the pH decreased therefore, becoming more acidic soil. The pH scale goes from 0 to 14 with pH 7 as the neutral point. From pH 7 to 0 the soil is increasingly more acidic and from pH 7 to 14 the soil is increasingly more alkaline or basic.

   To determine the soil pH, soil suspension is prepared in the ratio of 1: 2 to determine the soil pH with the help of glass electrode.

2. **Soil Organic Carbon :** Soil organic carbon is one of the important soil properties influence the productivity of soil. The role of soil organic carbon is to maintain soil fertility.

   Soil organic carbon is estimated by the modified Walkely-Black method (Walkely and Black 1934). Organic matter in the soil is oxidized with a mixture of potassium dichromate ($K_2Cr_2O_7$) and concentrate H_2SO_4 utilized the heat of dilution of H_2SO_4. Unused $K_2Cr_2O_7$ is back-titrated with ferrous sulphate ($FeSO_4.7H_2O$) using ortho-phenanthroline as an indicator.

   Reagents:

   1. Standard potassium dichromate solution (1N): 49.04 g of $K_2Cr_2O_7$ (dried at 105° C for 2 hrs) was dissolved in distilled water and diluted to 1 litre in volumetric flask.
   2. Ferrous ammonium sulphate solution (0.5N): 140 g of $FeSO_4.7H_2O$ or 196.10 g of $FeSO_4.(NH_4)\ SO_4.6H_2O$ was dissolved in 600 ml water, 20 ml conc. H_2SO_4 was added to it, the solution was cooled and dilute to 1 litre in a volumetric flask.
   3. Diphenylamine indicator: 0.5g diphenylamine was dissolved in a mixture of 20 ml water and 100ml of conc. H_2SO_4.
   4. Sulphuric acid (96%)
   5. Orthophosphoric acid (85%) or sodium fluoride chemically pure.

   Procedure: 1 g of soil is accurately weighed and placed in a dry Erlenmeyer flask (500 ml). Two blanks were prepared to standardize $FeSO_4$ solution. 10 ml dichromate solution is added and flask is swirled gently for 1 minute and then 20 ml concentrated H_2SO_4 is added and flask was again swirled for 2 to 3 times. The flask is allowed to stand for 30 minutes for oxidation of soil organic carbon.

   The content is diluted with 200 ml distilled water and 10 ml of phosphoric acid, 0.2 g sodium fluoride and 1 ml of diphenylamine indicator is added to it. The contents were titrated with ferrous ammonium sulphate solution till the colour flashed from blue violet to green.

Calculation: $$\text{Organic carbon (\%)} = \frac{10(B-T)}{B} + \frac{0.003\times100}{\text{Wt of soil (g)}}$$

Where,

B= Volume (ml) of ferrous (ammonium) sulphate solution required for blank titration.

T=Volume of ferrous (ammonium) sulphate solution needed for titration of soil sample.

Total organic carbon (%) = Organic carbon estimated × 1.3

Soil organic matter (%) = Total C (%) × 1.724 (Jeckson 1958)

3. **Total Soil Nitrogen:** Nitrogen is an essential element for all growth processes in plants. The continuous use of inorganic N is responsible for above ground vegetation growth and healthy green foliage of plants as well as protein and chlorophyll development.

Total soil nitrogen is generally determined by the Kjeldahl digestion and titration method. This process worked on the principle of dried and homogenized material is digested in a suitable Kjeldahl tube with sulfuric acid. To raise the temperature potassium sulphate is added and copper sulphate is used as a catalyst. After adding sodium hydroxide to the digestion solution the produced ammonium from all nitrogen species is evaporated by distillation as ammonia. This is condensed in a conical flask with boric acid solution. The amount is titrated against indicator with sulfuric acid.

Reagents

1. Sulphuric acid (H_2SO_4)
2. Potassium sulphate (catalyst mixture): 200 g of potassium sulphate, 20 g of copper sulphate pentahydrate and 20 g of titanium dioxide, with the crystal structure of anatase.
3. Sodium hydroxide (NaOH, 10 mol/L)
4. Boric acid solution (20 g/L): 20 g of pure boric acid (H_3PO_4) was dissolved in about 700 ml of hot water. The solution remains cooled down and transferred to it 1 litre volumetric flask containing 200 ml of ethanol and 20 ml of mixed indicator solution. After mixing contents of the flask, approximately 0.05 N NaOH added cautiously until the colour is reddish purple. Then dilute the solution was diluted with distilled water and mixed thoroughly.
5. Mixed indicator**:** Dissolve 0.1 g of bromocresol green and 0.02 g of methyl red in 100 ml ethanol.
6. Ammonium sulphate (NH_4SO_4)

Procedure: The process included two phase (i) digestion (ii) distillation and titration.

(i). Digestion: Place dried soil sample (about 1g) with 10 ml H_2SO_4 in the digestion flask and swirl until the acid is thoroughly mixed with the sample. Allow the mixture to stand for cooling. After that, add 2.5 g of the catalyst mixture and heat until the digestion mixture becomes clear. Boil the mixture gently for up to 5 hr., so that the H_2SO_4 condenses about 1/3 of the way up to the neck of the flask. Care should taken that the temperature of the solution does not exceed 400°C.

$$\text{Organic N} + H_2SO_4 \rightarrow \underset{\text{(Ammonium sulphate)}}{(NH_4)_2SO_4} + H_2O + CO_2 + \text{other sample matrix by products}$$

(ii). Distillation and Titration: After completion of the digestion, allow the flask to cool and add 20 ml of water slowly while shaking. Then swirl the flask to bring any insoluble material into suspension and transfer the contents to the distillation apparatus. Rinse three times with water to complete the transfer. Add 5 ml of boric acid to a 200 ml conical flask and place the flask under the condenser of the distillation apparatus in such a way that the end of the condenser dips into the solution. Add 20 ml of sodium hydroxide (NaOH) to the funnel of the apparatus and run the alkali slowly into the distillation chamber. Distil about 100 ml of condensate (the amount for quantitative results depends on the dimensions of the apparatus), rinse the end of the condenser, add few drops of mixed indicator to the distillated and titrated with sulfuric acid to a violet endpoint.

$$\underset{\text{(Ammonium sulphate)}}{(NH_4)_2SO_4} + 2NaOH \xrightarrow{\Delta} \underset{\text{(Ammonia)}}{2NH_3\uparrow} + Na_2SO_4 + 2H_2O$$

Calculation: $\text{Total Nitrogen (\%)} = \frac{\text{NH4–N in digested sample–blank reading} \times 0.075 \times 100}{\text{Sample size (mg)}}$

2.6 STUDY OF TWO DIFFERENT FOREST SOIL CHARACTERISTICS

Forest vegetation affects the soil carbon and nitrogen cycles due to the differences in quality and quantity of litters, root exudates, and soil properties. Vegetation strongly affects soil quality, including soil volume, chemistry and texture, which feed-back to affect various vegetation characteristics, including productivity, structure and floristic composition. Soils sustain the forest and provide raw materials for its life by recycling fallen leaves, woody debris, and dead animals and Bargali et al., (2015) described, different tree species can significantly change their influence on soil properties as well as on soil fertility. Variation in soil properties strongly influenced by forest vegetation and topography therefore, varied with variation in relation to physiographical distribution (Khan and Kamlakar, 2012).

Banj-oak (*Quercus leucotrichophora*) and chir-pine (*Pinus roxburghii*) are two dominant forest species of Indian Centaral Himalaya. Vegetation cover of these dominated forests plays an important role in understanding soil carbon cycle, soil carbon balance and the physico-chemical properties of the soil. In this chapter, the physico-chemical properties are measured and compared both forests (Table 2.2).

Table 2.2: Soil properties of two different forests of Indian Central Himalayan Region

Forest type	Colour	Sand (%)	Silt (%)	Clay (%)	Bulk density (g cm^{-3})	Moisture (%)	pH	C (%)	N (%)

Banj-oak forest	Black	70	15	15	0.60	10.79	6.37	3.70	0.58
Chir-pine forest	Light brown	60	30	10	1.10	7.36	7.56	1.65	0.15

The soil of Banj-oak forest is black in colour. The texture of the soil is sandy with good amount of clay content. The bulk density and moisture is reported as 0.60 g cm^{-3} and 10.79 %, respectively. The colour of Chir-pine forest is light brown in colour with high silt content. Bulk density is comparatively higher in Chir-pine forest while the moisture content was lower. The soil carbon and nitrogen was reported 1.65 and 0.15, respectively.

2.7 SUMMARY

Soil is defined as the topmost layer of the earth's surface that supports life and is rich in minerals and microorganisms that cover the entire land visible to us. All living creatures, including plants, animals, and microorganisms, grow and reside on the soil.

We notice different types of soil based on colour, texture, and composition in different places. The varieties of vegetation in different places are evidence of different types of soil. Soil has various physical, chemical, and biological properties. Based on these categories, the soil is classified into sandy, clayey, and loamy based on some physical properties like texture, colour, and water-holding capacity. Some chemical properties like pH, salinity, organic matter content, nitrogen percentage etc., also decide the soil type.

2.8 GLOSSARY

Bulk density: The dry mass of soil per unit bulk volume of soil. Expressed as Kg/m^3 or g/cm^3
Clay: That mineral fraction of the soil with particles smaller than 0.002 mm in diameter
Humus: Organic matter, also called 'humus', forms from the decay of leaves, plants and other life.
pH: pH is a measure of acidity; standing for Potenz Hydrogen. It is measured from 1 (acid) through 7 (neutral) to 14 (alkaline) expressed on a logarithmic scale. Most soil is about pH 3 to 8.
Sand: That mineral fraction of the soil with particles from 0.063 - 2.0 mm in diameter
Silt: That mineral fraction of the soil with particles from 0.002 - 0.063 mm in diameter
Soil: Soil is a combination of four constituents: mineral material (sand, silt, clay and rock particles), organic material, air and water. Soil is made from the breaking down of rocks and organic matter by physical, chemical and biological processes.

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2.11 TERMINAL QUESTIONS

2.11.1 Short answer type questions

2. What do you understand by soil bulk density?
3. How would you determine soil moisture?
4. Briefly describe the pH of soil.

2.11.2 Long answer type questions

1. What do you understand by soil?
2. Briefly describe the physical properties of soil.
3. Briefly describe the chemical properties of soil.

UNIT-3- PRODUCTIVITY ESTIMATION OF TWO FOREST TREE SPECIES BY HARVEST METHOD

Contents:

3.1 OBJECTIVES

After reading this unit learners will be able:

- To know about harvest method to estimate the productivity
- To calculate the productivity of the forest

3.2 INTRODUCTION

Synthesis of organic material from inorganic substances like carbon dioxide and water is referred to as primary production. In other words, productivity is the rate at which energy is stored by green plants in the form of edible organic substances per unit of time. The rate at which energy or biomass is produced per unit area/unit time is typically used to quantify productivity. This rate is expressed in such terms as kilocalories per square per year (kcal/m^2/yr) a measured or energy or germs per square meter per year. There are various methods are used to calculate primary productivity, including radioactive tracer method, carbon dioxide flux method, light and dark bottle method, chlorophyll concentration, harvest method and dimension analysis. In this chapter we will discussed only about the harvest method in detail.

3.3 HARVEST METHOD

A productivity measuring technique, most commonly used for estimates of primary productivity, especially in situations in which predation is low (e.g. among annual crops, on certain heathlands, in colonizing grasslands, and sometimes in pond ecosystems). Sample areas are harvested at intervals throughout the growing season, and the material is dried to estimate dry weight or calorific value. The method may also be used for woodlands, although usually only one final felling and dry-weight estimation is feasible. In such situations it is generally more reliable and ecologically more desirable to use indirect, non-destructive estimates (e.g. by monitoring carbon dioxide profiles).

Destructive sampling method (or harvesting method) and developed allometric equation can both be used to estimate individual-level biomass. For tree biomass estimate, destructive sampling method is more accurate than the use of developed allometric equation, because all the developed allometric equations are fitted (derived) from the biomass data based on the destructive sampling method. However, destructive method needs to cut down several sample trees and is thus expensive and time-consuming; moreover, it is not practical to weigh all the biomass for each tree in a stand or forest.

This method is widely used to estimate in terrestrial ecosystem. It is the most useful for estimating the production of cultivated land range and communities of annual plants were production starts from zero at seedling or planting time becomes maximum at harvest and is subject to minimal use by consumers.

The technique involves removing vegetation at periodic intervals and drying the samples to a constant weight. To obtain accurate the production of plant biomass must be sampled throughout the growing season and the contribution of each species must be determined. Different species of plants reach their peak production at different times during the growing season. The difference in standing crop biomass between harvests periods expressed as germs per square meter per unit time provides an estimate of net

primary productivity. Caloric values of the material can be determined through use of a calorimeter and biomass can be converted to calories. Net primary productivity is then expressed as kilocalories per square meter per year.

Harvest method provides information about above ground productivity usually because low ground productivity requires the samples of root biomass which is difficult at best. Although the roots of some annual and crops plant may be removed from the soil the task become more difficult with grass and herbaceous species and even more so with forest trees.

3.4 METHOD TO CALCULATE THE PRODUCTIVITY

The general procedure for estimating biomass using destructive sampling method is to cut down several sample trees and weigh its different components (e.g., foliage, branch, stem, and root), respectively. After field survey, the components of the sample trees are collected and immediately taken to the laboratory to determine the water content. Subsequently, the (total) biomass can be determined by multiplying the fresh weight by the dry/fresh weight ratio. Then allometric equation can be fitted between the sampling biomass and *D* (and/or H) (e.g., Figure 1), and the developed equation can be employed to estimate individual-level biomass for each standing tree.

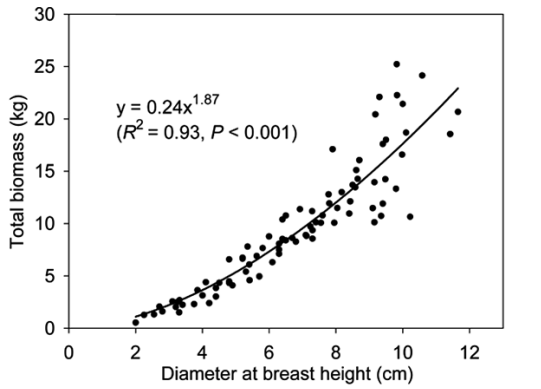

Figure 1: The relationship between the total biomass (y, kg) and D (x, cm) for the moso bamboo (Phyllostachys edulis) in South Anhui Province, China (Source of image: Qi et al. 2015)

3.5 PRODUCTIVITY ESTIMATION OF TWO DIFFERENT FORESTS

The regression equation varies with the plant species and climate, therefore, a locally developed regression is most reliable for the calculation biomass and net primary productivity of an ecosystem. Singh and Singh (1992) developed the regression equations for the important Central Himalayan tree species. The allometric relationship between the biomass of the tree components (y kg tree^{-1}) and circumference at breast height (x cm) for oak dominant forest and pine dominant forest is given below. The equation used were Ln Y= a+b Ln x

Forest type 1: Regression equation for Oak dominant forest (Rawat and Singh 1988).

Species Name	Biomass (kg / tree)	Intercept (a)	Slope (b)
Quercus leucotrichophora	Bole	-0.523	1.367
	Branch	-0.718	1.302
	Twig	0.065	0.895
	Foliage	-0.976	1.254
	Stump root	0.982	0.904
	Lateral root	-0.312	0.809
	Fine root	-1.326	0.504
Inter species	Bole	-0.861	1.425
	Branch	-0.908	1.327
	Twig	-0.506	1.028
	Foliage	-1.106	1.042
	Stump root	0.098	0.948
	Lateral root	-2.346	0.997
	Fine root	-2.874	0.197

Forest type 2: Regression equation for Pine dominant forest (Chaturvedi and Singh 1987)

Species Name	Biomass (kg / tree)	Intercept (a)	Slope (b)
Pinus roxburghii	Bole	-6.418	2.598
	First order branch	-9.833	2.978
	Other branch	-9.833	2.630
	Foliage	-6.111	1.872
	Cone	-5.007	1.113
	Stump root	-7.220	2.448
	Lateral root	-9.161	2.593
	Fine root	-9.102	2.469
Inter species	Bole	-0.861	1.425
	Branch	-0.908	1.327
	Twig	-0.506	1.028
	Foliage	-1.106	1.042
	Stump root	0.098	0.948
	Lateral root	-2.346	0.997
	Fine root	-2.874	0.529

3.6 SUMMARY

The term productivity refers to the rate of generation of biomass in an ecosystem, usually expressed in units of mass per volume (unit surface) per unit of time, such as grams per square metre per day (g m^{-2} d^{-1}). Harvest method is one of the most common method to calculate the primary productivity. Cutting down many sample trees and weighing each one separately (for example, the leaves, branch, stem, and root) is the basic approach for calculating biomass through destructive sampling. After a field survey, the sample trees individual parts are gathered and sent to a lab where the water content will be assessed. By multiplying the fresh weight by the dry/fresh weight ratio, is possible to calculate the (total) biomass. The sampling biomass can then be fitted into an allometric equation with D (and/or H), and the resulting equation can be used to calculate the individual-level biomass for each standing tree.

3.7 GLOSSARY

Biomass*:* The sum of all living organisms in a given area.
Climate**:** The long-term average weather patterns of a particular place.
Environment**:** The biotic and abiotic surroundings of an organism or population, and the chemical interactions between these factors that influence their survival, development, and evolution. An environment can vary in scale from microscopic to global.
Habitat**:** A specific ecological area that is inhabited by specific plant and animal species.
Productivity: productivity is the rate at which energy is stored by green plants
Seedling: a young plant grown from seed.
Vegetation: plants considered collectively, especially those found in a particular area or habitat.
Net primary productivity: the rate of accumulation of biomass or energy. The energy utilised during metabolic processes such as respiration is excluded from gross productivity (GPP).
Allometric equations: It provides biomass estimates from tree measurements such as diameter at breast height (DBH), height, and/or wood density.

3.8 SELF-ASSESSMENT QUESTIONS

3.8.1 Multiple choice questions

1. Primary productivity of a terrestrial ecosystem depends upon
   (a) Photosynthesis (b) Environmental factors
   (c) Availability of nutrients (d) All of the above
2. The basic requirement for any ecosystem to function and sustain is
   (a) Enormous amount of water (b) Constant input of solar energy
   (c) Fertile soil (d) Oxygen
3. The amount of biomass or organic matter produced per unit area over a time period by plants during Photosynthesis
   (a) Biomass production (b) Primary production
   (c) Secondary production (d) Assimilation

3.8.2 True and False

4. The primary productivity has no unit
5. The net primary productivity is designated by NPP
6. The rate of storage of organic matter not used by consumers (heterotrophs) is called the net productivity.

3.8.3 Fill in the blanks

- The _____ is the is the rate of biomass production
- Net primary productivity = _____ – respiration.
- The regression equation varies with the _____ and _____ factors.

Answer Key:

3.8.1: 1.(d); 2.(b); 3.(b)
3.8.2: 1. False; 2. True; 3. True
3.8.3: 1. Productivity; 2. Gross primary productivity; 3. Plant species, climatic

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3.11 TERMINAL QUESTIONS

3.11.1 Short answer type questions

5. What do you understand by biomass?
6. Discuss the plant productivity in brief.
7. What is the difference between Net primary productivity and Gross primary productivity

3.11.2 Long answer type questions

3. Discuss the harvest method in detail.
4. Describe the general procedure for estimating biomass using destructive sampling method or harvest method.

UNIT-4 PREPARATION OF HERBARIUM OF FOREST VEGETATION

4.1 INTRODUCTION

It is essential to prepare a herbarium of local forest flora or vegetation to record and preserve the rich floral diversity present in the neighboring forest areas. Trees, shrubs, herbs, and climbers are among the native plant species that must be carefully collected during their flowering and fruiting seasons in order to be correctly identified. Every specimen is dried, mounted, and labeled with important information including the botanical name, local name, habitat, phenology (flowering and fruiting timing), and local applications (e.g., fiber, lumber, fuel, fodder, medicinal, etc.). For example, *Bhurans* (*Rhododendron arboreum*) grows in temperate forests and flowers from February to April; its flowers are locally used to make juice believed to have heart health benefits. Similarly, *Timla* (*Ficus auriculata*), found near edges of agriculture land, fruits from June to August and is used as food and fodder. Such herbarium records not only support taxonomic and ecological studies, forest management, conservation planning, and environmental education, helping researchers but also help protect traditional knowledge and promote sustainable forest use in the region.

4.2 OBJECTIVES

After reading this unit learners will be able to-

- *Identify* and *list* local forest plant species commonly found in the area.
- *Recall* the essential tools and materials required for herbarium preparation.
- *Explain* the significance of herbarium collections in botanical studies and forest conservation.
- *Describe* the steps involved in collecting, pressing, drying, and mounting plant specimens.
- *Demonstrate* proper techniques for collecting and preserving plant specimens during fieldwork.

4.3 HERBARIUM

Herbarium is a collection of properly pressed, dried and poisoned plant specimens mounted on a sheet and arranged according to some accepted system of classification in a pigeon holes of steel or wooden almirah or compactor. It is an important source of data used by researchers in many plant-related sciences and is most often used for taxonomic research. Herbaria are centres where plant taxa are studied which includes identification, nomenclature, classification, distribution and use. There are several plants in the world and it is impossible to identify them without assigning them in a definite system. This was the beginning of the systematic botany and arrangement of plants in definite system is one of the steps of the process. Before arranging them it is necessary to collect plants according to certain system. The collected plant is the plant specimen and the specimens are the prime sources for floristic studies. Plant materials must be carefully selected, collected and preserved in such a way that they provide a clue for identification and later arranged accurately for classification.

The science of creation of herbarium started way back in the 16th century when Luca Ghini (1490-1556) developed the first Herbarium. Ever since then, there has been remarkable progress both in the areas of collection of plant specimens and the techniques that have been adopted through research over the years for enhancing the storage life of herbarium specimens. The concept of preserving plant specimens in dried form is 450 years old. The oldest preserved herbarium specimen is kept in Rome, collected by the naturalist Gherardo Cibo a pupil of Luca Ghini (1532). Luca Ghini made many plant collecting journeys in Italy. The plants were presented in this way by him and the first herbarium of the world was established in 1545 in University of Padua, Italy. The first Botanic Garden was also established in the same year. The word 'Herbarium' was originally applied not to collection of plants but to a book dealing with medicinal herbs.

4.4 TOOLS FOR HERBARIUM PREPARATION

The necessary tools used in making herbarium are given below:

- Secateurs
- Knife
- Pruning shears
- Blotting sheets or Newspaper
- Vasculum (metal box)
- Plastic bags
- Plant press (Plywood / Iron)
- Digging Tool
- Field book
- Lead pencil
- Hand lens
- String tags
- Field note book
- First-aid Box

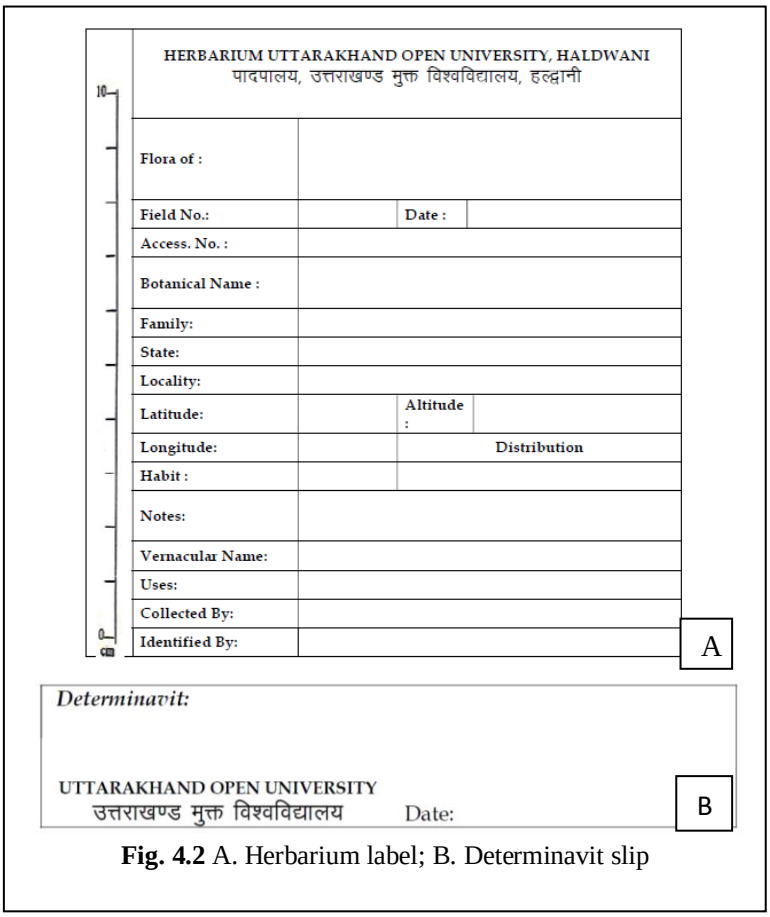
Fig. 4.1 Materials required: A. Secateurs; B. GPS; C. Field press, Blotters & straps; D. Vasculum; E. Field book

Field Equipments

- **Field Equipment & Tools**
  - * Trowel
  - * Clippers
  - * Field Bags
  - * Digger

* Forceps
* Manual Cover
* Light-Duty Bags
* GPS

- **Pressing**
  * Plant presses
  * Blotting sheets
  * Straps or ropes
  * Old newspaper
  * Polyurethane Foam
- **Mounting**
  * Mounting Sheets
  * Adhesives
  * Labels
  * Stitching material
- **Storage & Filing**
  * Genus Covers
  * Species Folders
  * Binding Tape
  * Wooden Cabinets
  * Compactors
  * Shelf Markers
  * Insect Traps
  * Humidity Indicators
  * Zip-lock Style Bags
  * Naphthalene Balls


HERBARIUM UTTARAKHAND OPEN UNIVERSITY, HALDWANI
पादपालय, उत्तराखण्ड मुक्त विश्वविद्यालय, हल्द्वानी

Flora of :			
Field No.:		Date :	
Access. No. :			
Botanical Name :			
Family:			
State:			
Locality:			
Latitude:		Altitude :	
Longitude:		Distribution	
Habit :			
Notes:			
Vernacular Name:			
Uses:			
Collected By:			
Identified By:			

A

Determinavit:

UTTARAKHAND OPEN UNIVERSITY
उत्तराखण्ड मुक्त विश्वविद्यालय Date:

B

Fig. 4.2 A. Herbarium label; B. Determinavit slip

4.5 TECHNIQUES IN COLLECTION

Making of herbarium involves survey, collection, drying, poisoning, mounting, stitching, labeling and deposition etc.

4.5.1 Survey

Plant survey and collection tours are conducted throughout the year so as to cover different season to different localities, altitudinal zones and forest types of targeted study area.

4.5.2 Collection

Angiospermic material must be chosen that should have leaves, inflorescence, flower and fruit etc. Size of the material depends upon the requirement and availability. Herbaceous small plant may be collected in 2-2, *i.e.,* with roots also, but in woody plants 4-6 twigs are sufficient. One should not collect diseased, infected or inappropriate plant material. The collection should be given a field number. The species should have at least 4-6 specimens with same field number. The habit, habitat, flower colour, locality interesting features etc. should be noted down in the field note book. Some tools are rather important while collecting up plants for herbarium: A small knife, scissors, thorn-proof gloves and a small handy spade could be of great help. The collected specimens should be put into a strong bag made of cloth or polythene, the function of these containers being to protect plants from damage during your collection visit. If your excursion takes place in summer time or lasts for two or more days, it is better to bring a folder of approximately "45x30"cm or more. The folder must be made of cardboard or some other strong stuff, e.g. aluminum, and it must contain some old newspapers (the more plants you collect the more newspapers you need). The folder can be covered with cloth and it should be closed with straps or belts, and a handle or shoulder-belt should be added for easy carrying.

4.5.3 Field Note

After specimen collection, a field record is noted in small pocket sized notebook. Date of collection, location (name of place or distance from definite point)), collection number, if possible, name of the specimen, and description of the floral parts that may change after drying are noted down. The good quality specimens also become worst if it does not have good field record. The range, latitude and longitude as well as ecology of the plant need to be noted down by GPS (Global Positioning System) and eyesight vision. Likewise specimen's microhabitat; means associated species should be mentioned, at least five species. Finally the distribution status of plant also needs to be mentioned, either the collected species is rare, frequent, common, locally common or occasional. Duplicate specimens of one species that are collected on the same date and same locality should be given the same collection number.

4.5.4 Taking Pictures

Taking color pictures of each plant in its natural environment is also something which could substantially enrich the quality of herbarium. In that way the dried specimen can be placed together with one or more photographs, which are very helpful for bulky plants like trees or bushes, which obviously cannot be entirely included in a herbarium. Also the habitat of a plant can be well described with a photograph, taking care not to be too distant from the nearby bushes or trees.

The suggested equipment is a 35 mm. single lens reflex camera, with a standard lens and a macro-lens, the latter very useful for close-ups of flowers and other specific features. Also a tripod can be very important if many close-ups have to be made, allowing the camera to remain steady. A tripod can also alleviate the need for a flash, which may be used when taking pictures

in low light, but has the disadvantage of giving quite unnatural looking images. The speed of print films can range from 64 - 100 ISO to 200 or 400 if pictures in the woods are planned.

Each photograph you take should be recorded in a note-book to provide further data for the classification and to include in the herbarium. Be careful that your camera and films are not damaged by rough handling and do not become wet.

4.5.5 Pressing

The specimens are kept gently within newspaper. Parts of flower are much carefully spread without overlapping in original shape. If the specimens are long, then it needs to be folded in V, N, W or Z shape.

Unnecessary overlapping of leaves and other parts must be avoided. Large leaf, if palmately compound, split in half lengthwise and one half is discarded. If pinnately compound, a branch is only kept. A few leaves may be turned over to show lower and upper view. If there is bulgy rhizome, needs to cut or dissect longitudinally by knife, so that moisture evaporates through there. Specimens should be of good quality with good field note. Collection numbers have also to be written in the flimsies (newspaper or blank newspaper). The standard size of the press is 30 x 45 cm.

If the specimen is gymnosperms, the specimen needs to dip in the glycerine before pressing. In case of flowers with gamopetalous corolla a few flowers should be pressed separately and some of these should be split open and spread. If flower is large, cotton padding is often helpful to dry quickly. The specimens thus kept inside flimsies, are covered on either side by blotters and then it is put in herbarium press. After press is filled or all the specimens are put in the press, the plant press is closed and pressure is applied by means of tightening the straps. Hard and dried fruits and cones need not to be preserved or pressed, but have to be kept in special boxes.

Fig. 4.3 Pressing of specimen in press board

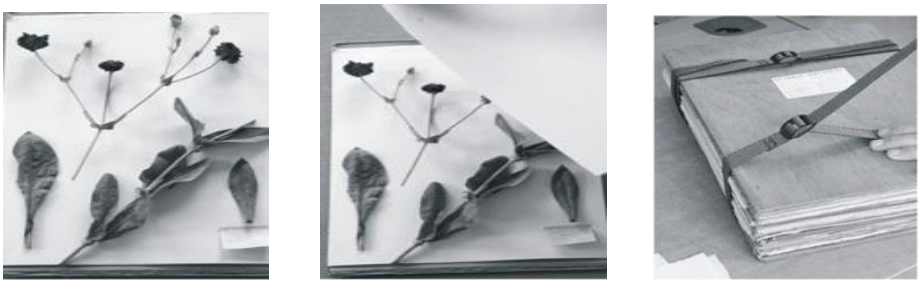


Fig. 4.4 Steps of pressing

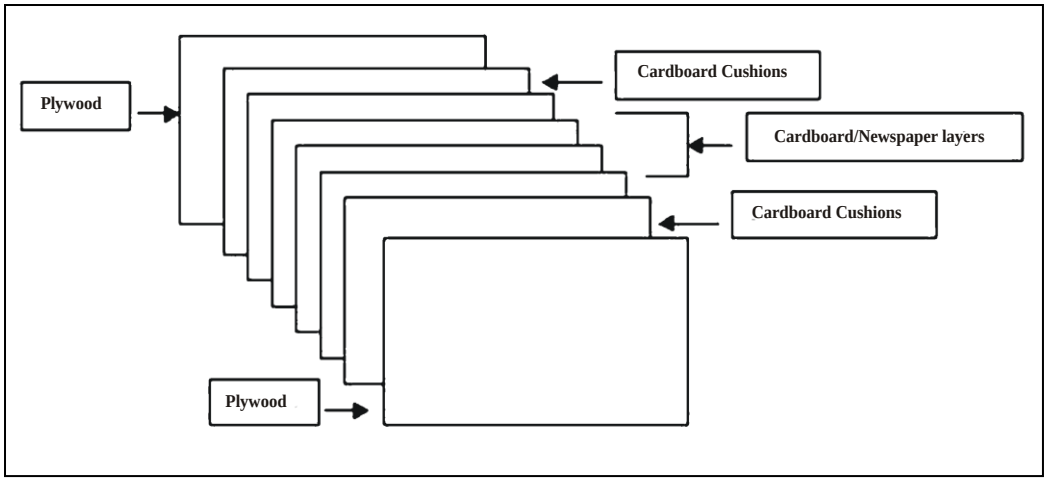


Fig. 4.5 Basic Structure of press

4.5.6 Drying

Drying techniques are of two types; those accomplished without heat, and those with the aid of artificial heat. Drying with the aid of artificial heat is the prevalent method. It is accomplished by means of heated dry air passing up and through the canal of the corrugate. Corrugates, often referred to as ventilators are used in presses when plants are dried by means of artificial heat. It is as sheet of pasteboard or thin aluminum metal, with fluted ducts. It provides air passages through the press for movement of dry heated air. The most common method of drying is without applying heat. Plants are placed in pressing papers between the blotters of the plant press. No corrugates are used. The press is locked up for about 24 hours. This is known as the sweating period. It is then opened, and as blotters are removed each pressing sheet is turned back, the specimens are examined, and parts rearranged as the situation demands.

After rearrangement the folder sheet is lifted on to a fresh dry blotter and covered by another dry blotter. The new pile of blotters and specimens is then locked up in the press and allowed to stand for another 24 to 36 hours, when the process of replacing wet blotters with dry ones is repeated. A third change of blotters follows usually after 2 to 3 days. Blotters must be changed 3-4 times; every wet blotter removed must be dried, usually by placing in the sun and reused. About a week is required for completion of drying. Dried specimens are packed with much care. Fungi as well as insects damage if proper care is not given till the permanent storage.

4.5.7 Poisoning

Precaution should be taken to protect herbarium specimens from damage by insect pests. The most destructive insects are herbarium beetle, cigarette beetle, booklice and silverfish. Insect repellants such as naphthalene ball or Para dichlorobenzene are sometimes placed in small quantities in herbarium cabinet. Although dangerous and hazardous to health, mercuric chloride is believed to be valuable because it provides long –term protection against insect attack. Besides the insect pest, the moulds and mildew are constant threat to material stored in damp condition or in areas of high humidity. Naphthalene and LPCP are believed to have fungicidal properties. However, thymol is quite effective as a fungicide.

4.5.8 Mounting

Mounting is the process by which a specimen is attached to a herbarium sheet and a label affixed at the lower right corner. Specimens are mounted on sheets of standard size herbarium paper (29 x 43 cm).

Most herbaria use a glue or paste to fasten specimens to the sheets. The specimen may be attached by various methods. A common method involves smearing a glass plate with a water-soluble paste, placing the specimen on the paste, and ten transferring the glued plant to the mounting sheet. Small paper envelopes called fragment packets are attached to the sheet to hold seeds, extra flowers, or any part of the specimen.

Fig. 4.6 Mounting of specimen

4.5.9 Label

Herbarium label is an important and essential part of permanent plant specimens. The size and shape of label may vary slightly but will usually be a rectangular and range between 10 x 15 cm (4 x 6 in.). The best position for the main label is generally thought to be the bottom right; this makes the label easier to read when kept in genus covers which open on the right hand side. Ideally a space should be left above the label to allow for the future attachment of determination slips. Generally herbarium label should contain the following information-

1. Heading- name of the institution in which the specimens originated /deposited.
2. Scientific name- Genus, specific epithet, author, or authors
3. Family-
4. Locality-
5. Range, latitude and longitude-
6. Habitat-
7. Date of collection-
8. Name of collector(s)-
9. Determined by-
10. Remarks-

4.5.10 Preservation of Specimens

Heating repellant and fumigants are used to check the attack of such destructive agents. The specimens may be treated by heating in a specially constructed cabinet at 60 ^{0}C for 6 hours,

which kills larvae, eggs etc. A common process is-Ethylene dichloride mixed with one part of CCl_4 (carbon tetrachloride) used for fumigation in closed chamber, which is effective process. DDT (Dichloro Diphenyl Trichloroethane) is an important insecticide and it is dusted.

4.6 INDEX HERBARIORUM (IH)

Index Herbariorum (IH) is the global, authoritative directory of herbaria (collections of preserved plant specimens) and their associated staff. Managed by the New York Botanical Garden since 1997, it formerly had six printed editions (1952–1974) under the International Association for Plant Taxonomy. Its importance lies in establishing a standardized and authoritative framework that facilitates scientific research, conservation, specimen exchange, and effective digitization efforts. By offering seamless access to expert contacts and comprehensive collection data, the IH acts as a vital infrastructure for biodiversity studies, enabling transparent documentation, cross-institutional collaboration, and informed decision-making in taxonomy, ecology, and conservation biology.

For the past three centuries, scientists have documented the earth's plant and fungal diversity through dried reference specimens maintained in collections known as herbaria. There are approximately 3,990 herbaria in the world today, with approximately 10,000 associated curators and biodiversity specialists. Collectively the world's herbaria contain an estimated 350,000,000 specimens that document the earth's vegetation for the past 400 years. *Index Herbariorum* is a guide to this crucial resource for biodiversity science and conservation.

The Index Herbariorum (IH) entry for a herbarium includes its physical location, Web address, contents (e.g., number and type of specimens), history, and names, contact information and areas of expertise of associated staff. Only those collections that are permanent scientific repositories are included in IH. New registrants must demonstrate that their collection is large (usually 5,000 specimens minimum), accessible to scientists, and actively managed. Each institution is assigned a permanent unique identifier in the form of a four to eight letter code, a practice that dates from the founding of IH in 1935.

The first six editions of Index Herbariorum were published by the International Association for Plant Taxonomy in the Netherlands (1952-1974). Dr. Patricia Holmgren, then Director of the New York Botanical Garden (NYBG), served as co-editor of edition 6, and subsequently became the senior editor of IH. She oversaw the compilation of hard copy volumes 7 and 8, and Dr. Noel Holmgren, a scientist on the NYBG staff, oversaw the development of the IH database, which became available on-line in 1997.

4.7 IMPORTANT HERBARIA OF INDIA

- In this para/section is given some of the **most important herbaria in India and international herbaria** in a tabular form (Table 4.1 & 4.2). These herbaria are essential

for national-level **plant taxonomy**, biodiversity documentation, and **conservation** initiatives.

Table 4.1: Some i**mportant herbaria of India**

Name of Herbarium	Acronym	Location	Year Founded	Specimen Holdings
Central National Herbarium	CAL	Sibpur (Howrah/Kolkata)	1795	~2 million
Forest Research Institute Herbarium	DD	Dehradun	mid-1800s	~350,000
National Botanical Research Institute (NBRI) Herbarium	LWG	Lucknow	1953	~260,000
Blatter Herbarium	BLAT	Mumbai	early 1900s	~200,000
Madras Herbarium (BSI Southern Centre)	MH	Coimbatore	1955	~264,000
FRC Herbarium (IFGTB)	FRC	Coimbatore	1911	~25,815
WII Herbarium	WII	Dehradun	1985	~18,000
Assam (Eastern Circle) Herbarium	ASSAM	Shillong	--	~3 million BSI holdings
Economic Botany Herbarium (BSIS)	BSIS	Kolkata	1897	~70,000
BSI Regional Herbaria	BSI	Across India	--	~3 million combined

Table 4.2: Some i**mportant international herbaria**

Herbarium (Acronym)	Acronym	Location	Year Founded	Specimen Holdings
Royal Botanic Gardens, Kew	K	London, UK	1852	~8,125,000
Muséum National d'Histoire Naturelle	P & PC	Paris, France	1635	~8,000,000
New York Botanical Garden	NY	New York, USA	1891	~7,921,000
Naturalis Biodiversity Center	L, Wag	Leiden, Netherlands	1829	~6,900,000
Missouri Botanical Garden	MO	St. Louis, USA	1859	~6,850,000

Conservatoire & Jardin Bot. de Genève	G	Geneva, Switzerland	1824	~6,000,000
Komarov Botanical Institute, RAS	LE	St.Petersburg, Russia	1823	~6,000,000
Naturhistorisches Museum Wien	W	Vienna, Austria	1807	~5,500,000
Natural History Museum	BM	London, UK	1753	~5,200,000
Smithsonian Institution	US	Washington, D.C., USA	1848	~5,100,000
Harvard University Herbaria	HUH2	Cambridge, USA	—	~5,000,500

4.8. STEPS FOR HERBARIUM PREPARATION

The preparation of a herbarium of forest vegetation from the local area involves systematic steps beginning with the selection of representative plant types such as herbs, shrubs, trees, and climbers to filing and storage of the specimens. The following steps are given here:

4.8.1 Selection of Plant Species

Identify and select targeted species such as herbs, shrubs, trees, and climbers from your locality. Always prefer specimens in flowering or fruiting stages for proper identification.

4.8.2 Collection of Specimens

Healthy specimens are collected, ensuring that flowers or fruits are present. Herbs are collected in whole, including roots; for shrubs and tree a healthy branch with leaves, flowers and fruits are collected. Climbers are collected with sufficient portion of the vine showing leaves and reproductive parts. Along with the collection process, record important data in a field notebook.

4.8.3 Field Note Preparation

For each collected specimens of r representative plant types, record the following:

- **Local Name**
- **Botanical Name**
- **Habitat** (e.g., forest floor, roadside, moist shady slope)
- **Phenology** (flowering/fruiting season)
- **Local Uses** (medicinal, fodder, fuel, etc.)

4.8.4 Pressing and Drying

Properly arrange the plant between blotting sheets or newspapers and kept the sheets in a plant press or between cardboard/plywood with pressure. The drying process involves keeping the press in a warm, well-ventilated area while replacing the blotting paper every day or every other day to prevent mold and ensure uniform drying. The pressing continues for about 7–10 days,

depending on the moisture content, until the specimens are completely dried, retaining their color and structure as close to the original as possible.

4.8.5 Mounting

Attach the dried specimen with glue or strips to a standard 29 x 41.5 cm herbarium sheet. Put any loose components (flowers or seeds) in an envelope made of paper on the same page.

4.8.6 Labeling

Labeling of plant samples like herbs, shrubs, trees, and climbers is an essential step in herbarium preparation. After the plant specimen is dried and mounted on a standard herbarium sheet, a label is affixed to the lower right-hand corner of the sheet. This label includes important details such as the **botanical name** (with author citation), **family**, **local name**, **habit** (herb, shrub, tree, or climber), **habitat** (e.g., forest floor, hill slope, roadside), **location of collection** (village, district, GPS if available), **collector's name and number**, and **date of collection**. It also includes **phenology** (flowering and fruiting time) and **local uses** (such as medicinal, fodder, or fuelwood). For example, *Quercus leucotrichophora* (Banj), found on hill slopes and mixed oak forests, which flowers from March to April and provides fuel wood, fodder, and aids in soil conservation.

4.8.7 Storage

Store herbarium sheets in dry, cool cabinets and fumigate occasionally to protect from insects. Use naphthalene balls or silica gel to reduce moisture and pests.

4.9 FUNCTIONS OF HERBARIUM

A modern Herbarium serves valuable functions or utility. The following are few important functions of a herbarium are:

1. It provides necessary information for verifying and identifying newly collected plants.
2. It is an invaluable conservatory of plant material and data.
3. It is storehouse of collections including the valuable type specimens. The herbaria greatly aid in all kinds of taxonomic researches.
4. Serves as a fundamental resource for identification of all plants of the world.
5. It serves as a source for collection of biodiversity. Most estimates on global biodiversity today are based on herbarium collection only.
6. It aids in biodiversity monitoring by carrying out security of herbarium collection to obtain quantitative baseline data on the distribution and abundance of keystone species is essential for all monitoring programmes.
7. It serves as a repository of voucher specimens on which various botanical researches are carried out.

8. Vast collection of a particular species in a herbarium aids in assessing the diversity or variations exhibited by a species in its distributional range helping in population biology studies.
9. It helps in development of computer database on plants and maintains active links to international networks of systematic resources and electronic database.
10. It provides research facilities to the students of taxonomic research.
11. It provides complete idea of vegetation and place of origin of plants.
12. The ecological, economical and ethnobotanical data may be obtained, and
13. It provides key for the preparation of modern system of classification.

4.10 LIST OF PLANT SPECIMENS FOR HERBARIUM PREPARATION OF FOREST VEGETATION

Here is a **detailed list of plant specimens each** for herbarium preparation of **forest vegetation** including **herbs, shrubs, trees, and climbers** from a typical **Himalayan forest locality** of Kumaun and Garhwal region of, Uttarakhand. Each specimen mentioning botanical name, local name, family, Habit, habitat, phenology and local uses (Table 4.3)

Table 4.3: Detailed list of plant specimens each for herbarium preparation of forest vegetation

S.N.	Botanical Name	Local Name	Family	Habit	Habitat	Phenology	Local Uses
1	*Viola odorata*	Banafsha	Violaceae	Herb	Moist forest floor	Feb–Apr	Cough, cold, expectorant
2	*Ocimum sanctum*	Tulsi	Lamiaceae	Herb	Edges of forests	All year	Religious, antimicrobial
3	*Swertia chirayita*	Chirayta	Gentianaceae	Herb	Forest clearings	Aug–Oct	Malaria, bitter tonic
4	*Centella asiatica*	Brahmi	Apiaceae	Herb	Wetlands, stream banks	Mar–Oct	Memory tonic, blood purifier
5	*Achyranthes aspera*	Apamarg	Amaranthaceae	Herb	Open forest, pathways	Aug–Nov	Piles, wounds
6	*Boerhavia diffusa*	Punarnava	Nyctaginaceae	Herb	Forest margins	July–Sept	Diuretic, liver tonic
7	*Urtica dioica*	Bichu Ghas	Urticaceae	Herb	Moist, shaded areas	Mar–Sept	Joint pain, green manure
8	*Allium stracheyi*	Ban Lasun	Amaryllidaceae	Herb	Rocky alpine areas	June–Aug	Edible leaves, spice
9	*Eclipta prostrata*	Bhringraj	Asteraceae	Herb	Wet forest edges	Aug–Nov	Hair tonic, liver tonic
10	*Cissampelos pareira*	Patha	Menispermaceae	Herb	Scrub forest understory	July–Oct	Fever, urinary issues
11	*Adhatoda vasica*	Bansa	Acanthaceae	Shrub	Forest margins	Jan–Mar	Cough and asthma
12	*Pyracantha crenulata*	Ghingaru	Rosaceae	Shrub	Dry slopes, forest edges	Mar–June	Fruits edible, fencing
13	*Berberis asiatica*	Kilmora	Berberidaceae	Shrub	Rocky hillsides	Apr–July	Edible berries, medicine
14	*Ziziphus mauritiana*	Ber	Rhamnaceae	Shrub	Dry deciduous forest	Mar–Apr	Fruits eaten raw or pickled
15	*Carissa carandas*	Karonda	Apocynaceae	Shrub	Dry rocky habitats	May–Aug	Fruits pickled, rich in vitamin C
16	*Woodfordia fruticosa*	Simaru	Lythraceae	Shrub	Dry deciduous forest	Mar–May	Flowers for fermenting tonics

17	*Lantana camara*	Lantana	Verbenaceae	Shrub	Degraded forest areas	All year	Fencing, soil cover (invasive)
18	*Justicia adhatoda*	Vasaka	Acanthaceae	Shrub	Forest edges	Winter-spring	Bronchodilator, leaf extract
S.N.	**Botanical Name**	**Local Name**	**Family**	**Habit**	**Habitat**	**Phenology**	**Local Uses**
19	*Lawsonia inermis*	Mehndi	Lythraceae	Shrub	Dry rocky land	Apr–Aug	Henna dye, skin coolant
20	*Vitex negundo*	Nirgundi	Lamiaceae	Shrub	Riverbanks, scrub areas	July–Sept	Joint pain, anti-inflammatory
21	*Quercus leucotrichophora*	Banj Oak	Fagaceae	Tree	Mid-elevation forests	Mar–Apr	Fodder, fuel wood, soil binder
22	*Rhododendron arboreum*	Buransh	Ericaceae	Tree	Subalpine forests	Feb–May	Flower juice, tonic
23	*Pinus roxburghii*	Chir Pine	Pinaceae	Tree	Dry hill forests	Mar–May	Resin, timber
24	*Toona ciliata*	Tun	Meliaceae	Tree	Moist deciduous forest	Mar–Apr	Timber, bark medicinal
25	*Ficus religiosa*	Peepal	Moraceae	Tree	Sacred places	All year	Religious, air purifier
26	*Ficus benghalensis*	Bargad	Moraceae	Tree	Large forest openings	Apr–July	Shade, spiritual, latex medicinal
27	*Phyllanthus emblica*	Amla	Phyllanthaceae	Tree	Deciduous forest	Nov–Feb	Edible fruit, immunity booster
28	*Terminalia bellirica*	Bahera	Combretaceae	Tree	Moist deciduous forest	Nov–Jan	Ayurvedic tonic ingredient
29	*Terminalia chebula*	Harad	Combretaceae	Tree	Hill slopes, forests	Oct–Feb	Digestive tonic, Triphala
30	*Bauhinia variegata*	Kachnar	Fabaceae	Tree	Forest edges, roadsides	Mar–May	Edible flowers, bark medicinal
31	*Tinospora cordifolia*	Giloy	Menispermaceae	Climber	Grows over trees	July–Sept	Fever, immunity booster
32	*Rubia cordifolia*	Majith	Rubiaceae	Climber	Forest floor climber	Aug–Nov	Dye, blood purifier
33	*Cuscuta reflexa*	Amarbel	Convolvulaceae	Climber	Parasitic on shrubs/trees	Aug–Oct	Liver ailments, skin

34	*Momordica charantia*	Karela	Cucurbitaceae	Climber	Fences, forest edges	July–Oct	Diabetic remedy, fruit
35	*Butea parviflora*	Palash Lata	Fabaceae	Climber	Forests	Mar–May	Decorative, rope-making
36	*Bauhinia vahlii*	Malu	Fabaceae	Climber	Forests	Aug–Nov	Edible buds, rope and mats

4.11 PRCTICAL EXERCISE

4.11.1 Practical-01

Objective: To understand and apply the step-by-step method of preparing herbarium specimens for forest vegetation, including herbs, shrubs, trees, and climbers, with examples from your locality.

Aim: To systematically prepare, preserve, and document herbarium specimens of forest vegetation to aid in identification, study, and conservation efforts.

Exercise: Learners will visit the nearby forest areas to collect the plant samples for preparing a herbarium. Each learner will collect 10–20 samples of plants specimens including herbs, shrubs, trees, and climbers and noted detailed observation data such as:

Step I: Observation and Collection

- Select plant specimens from nearby forest areas (herb, shrub, climber, or tree)
- Collect multiple parts such as leaves. Flowers, fruits, seeds, bark, stem if possible
- Record data in the field such as

-Date of collection

-Accurate location (with GPS if possible)

-Habitat description (e.g., forest type, elevation)

-Phenology (flowering or fruiting stage)

-Local uses or ethnobotanical importance

Step II: Preparation

- **Pressing and drying:** As per given above methods. Attach a label with all the recorded data: botanical name, family, habitat, phenology, uses, collection date, and collector's name.

Step III: Documentation and Storage

- **Label and catalog:** Prepare a proper label and assign a unique identification number. Store the herbarium sheet in a protective folder or cabinet away from pests and moisture.

Step IV: Example

Task: Search and record an example of a forest plant species from your area, including:

- Botanical name: ----------
- Family: ----------
- Habitat: ----------
- Phenology: ----------
- Local uses: ----------

4.12 SUMMARY

The process of creating a complete herbarium of forest vegetation, which includes trees, shrubs, climbers, and herbs, starts with frequent field trips, particularly during flowering and fruiting seasons, and the use of the appropriate equipment (secateurs, trowel, tags, plastic bags, notebook, camera). Using hardboard or corrugated layers, gather healthy specimens with representative components (roots, stems, leaves, flowers, and fruits), remove soil, tag them, and, in a plant press, press them flat between blotting papers or newspapers. To ensure even drying, replace the moist sheets every 24 to 48 hours. After the specimens are completely dry, mount them using archival adhesive, linen tape, or stitching on typical herbarium sheets (about 41 by 29 cm). . Label each specimen clearly at the lower right corner with botanical name, family, collector's name and date, precise locality with altitude, habitat description, phenological stage, and any local or ethnobotanical uses; then seal, freeze or fumigate the sheets to prevent pest damage, and store them taxonomically in cabinets or folders. For instance, the *Myrica esculenta* of the Myricaceae**,** a small tree/shrub growing in temperate Himalayan forests at 1000–2500 m, flowers in **spring**, fruits in **summer**, and is widely valued locally for its edible "kaphal" berries—a culturally significant fruit in Uttarakhand.

4.13 SELF-ASSESSMENT QUESTIONS

4.13.1 Questions Based on Knowledge

a) Give a **list** of essential tools used during field collection of herbarium specimens.
b) Name the fields that must appear on a herbarium label.
c) What is the standard size of a herbarium sheet?

4.13.2 **Skill-Based Questions**

a) Explain why pressing specimens in a V, N, W or Z shape fold is done.
b) Describe why acid-free paper and archival materials are used for mounting.
c) Explain the importance of phenology and local uses on herbarium labels.

4.13.3 Applications and Analysis Based Questions

a) Given a plant with delicate flowers, how would you arrange and dry it in the press correctly?
b) Provide an outline of label data for a climber from your locality.
c) Analyze why early improper drying or overlapping of parts can lead to specimen degradation.
d) Why is it important to collect specimens at different phenological stages?
e) How can a herbarium contribute to research in the field of plant based research?

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- *https://sweetgum.nybg.orgsweetgum.nybg.org*

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4.16 TERMINAL QUESTIONS

4.16.1 Short Answer Questions

1. What is a herbarium?
2. What are the necessary tools and materials when collecting forest plants in the field?

3. What post-drying preservation techniques are applied to prevent against mold and insect damage?
4. How may photographs and field notes improve the herbarium record?
5. What features define a "good" specimen in a herbarium?

4.16.2 Long Answer Questions

1. Describe the step-by-step method of herbarium preparation for forest vegetation, including herbs, shrubs, trees, and climbers. Provide a local example strengthen what you say, highlighting the plant's name, family, habitat, phenology, and local uses.
2. Explain the significance of documenting local forest vegetation through herbarium preparation. Describe any two plant specimens each from herb, shrub, tree, and climber categories with their botanical name, family, habitat, phenology, and uses.
3. Discuss the importance of habitat and phenology data in herbarium work. Choose one plant each from herb, shrub, tree, and climber categories and explain how this information is vital for ecological and ethnobotanical research.

UNIT-5- PREPARATION OF A FIELD DIARY AND OBSERVATIONS

Contents:

5.1 INTRODUCTION

A field diary is an in-depth, first-hand record of observations and experience made while conducting fieldwork. It is designed to document the researcher's subjective ideas, observations, and developing questions in addition to objective data like the date, time, location, weather, setting, and participant behaviors. It becomes an accurate gadget for further analysis, pattern recognition, and study validation when data and interpretations are recorded independently and according to a reliable format. A well-kept field diary is more than just a record; it serves as a link between analytical interpretation and firsthand experiences, conserving the diversity of the "field" in a way that encourages both in-depth scientific research and individual understanding.

When preparing a field diary for daily observations of forest species and plantation of timber or industrial species, start by selecting a sturdy, full-size notebook that is weatherproof. Date each entry and record the exact time and location (with GPS coordinates or descriptive landmarks). Start each daily entry with weather conditions (temperature, cloud cover, wind), followed by a detailed habit and habitat description: note whether a plant is a tree, shrub, herb, or climber, along with its local and botanical names. Record phenological stage (e.g., flowering, fruiting), any distinctive features or interactions (such as insect visits), and include brief sketches or photographs. For planted timber and industrial species, add notes on planting date, spacing, growth measurements, health assessments, and management activities like weeding, mulching, or pest control. At the end of each day, expand on your field notes in a formal diary entry organize observations into a clear, chronological narrative that captures patterns, changes, and emerging questions. This structured yet reflective diary approach not only ensures accurate, scientific data collection but also produce a rich, living record of forest biodiversity, phenology, and plantation dynamics for future study and management.

5.2 OBJECTIVES

After reading this unit, learners will be able to:

- Prepare a field dairy and record daily observation of forestry species, plantation sites, and activities accurately
- Understand the characteristics of different local NTFP species and the importance of proper plantation techniques.
- Apply observations to evaluate the health, growth, and success of plantation efforts.
- Analyze or examine patterns in growth, survival rates, and environmental factors affecting plantation success.
- Develop improved strategies for future plantations based on analyzed data.

5.3 FIELD DIARY

A "field diary" is a record or logbook or schedule that is kept by individuals working in various fields, particularly in research, exploration, or data collection in the field. Therefore, the Field diary is the basic document which contains all the data collected. During study or fieldwork, it is used to document observations, notes, data, and other pertinent information. Field diaries are frequently used to record activities, discoveries, and experiences during fieldwork in anthropology, geology, biology, scientific research, environmental studies, and many other fields. It is required that facts and interpretations be written independently, and that conversations be recorded in the local tongues. There are two types of field notes to be observation.

i) Taking notes on the spot

ii) Writing detailed diary

5.4 PURPOSES OF FIELD DIARIES

The following important uses of field diaries are given below:

- The primary purposes of field diaries are to systematically record observations, activities, and reflections made during fieldwork,
- Serving as a valuable tool for data collection, monitoring, and analysis. Field diaries help maintain a chronological account of species behavior, environmental conditions, and field management practices,
- Enabling accurate and consistent documentation over time.
- Field diaries support research by providing a reliable source of firsthand information, essential for drawing conclusions, preparing reports, and validating findings.
- They also aid in decision-making by capturing both objective data and personal insights that highlight challenges, successes, and areas for improvement.
- Additionally, field diaries enhance learning and professional development by encouraging critical thinking, reflective observation, and deeper engagement with the natural environment.

5.5. STEPS FOR PREPARING & MAINTAINING A FIELD DIARY

Preparing a field diary is an important skill, especially for researchers, scientists, explorers, and professionals working in various fields. Here are some steps to help you prepare and maintain a field diary effectively:

- **Selecting the Correct Notebook or Digital Tool:** Select a notebook that is durable, weather-resistant, and easy to carry. Alternatively, you can use digital tools like tablets or smart phones with note-taking apps.

- **Include Essential Information:** Your diary should begin with a title page that contains the name of the project, your name, the date, and any other pertinent identifying information.
- Number the pages of your diary for easy reference.
- **Set a Consistent Format:** Establish a consistent format for your entries. For handwritten diaries, use clear, legible handwriting. For digital diaries, choose a readable font and formatting style.
- **Date and Time Stamp:** Begin each entry with the date and time (if necessary). This helps establish a timeline for your activities and observations.
- **Detailed Descriptions:** Write detailed accounts of your actions, your observations, and any noteworthy occurrences. Add pertinent information about the area, the weather, and other environmental changes.
- **Use Sketches and Diagrams:** Provide maps, diagrams, or sketches to help explain what you're seeing, if appropriate. You can enhance your written descriptions with these visual tools.
- **Record Data:** If you are collecting data, be sure that you accurately document it. Effective data organization involves the use of tables, charts, or bullet points.
- **Reflect and Analyze:** Give your experiences and observations some thought. Include your observations, questions, and interpretations. This aids in your interpretation of your results.
- **Be Honest and Objective:** Keep or maintain objectivity in your diary. Record both positive and negative observations, and avoid injecting personal biases or opinions.
- **Use Clear Language:** Write in clear and simple language. Avoid terminology or technical terms that may be unclear to others who read your diary.
- **Review and Edit:** Make sure your entries are correct and well-structured by reviewing and editing them on a regular basis. Your diary will be more valuable for examination later on if you do this.
- **Protect Your Diary:** Protect your field diary from harm, theft, and loss. When use digital diaries make regular backups of your data.
- **Share and Collaborate:** If you are working with a team, share applicable portions of your diary with your colleagues to facilitate collaboration and cross-referencing.
- **Maintain Consistency:** Ideally, you should update your diary at the end of each field session or day.
- **Document Sources:** When you consult literature or refer to outside sources, be sure to cite your sources.

5.6 DAILY FIELD DIARY

A daily field diary is an arranged, day-to-day record maintained during fieldwork to document observations, activities, environmental conditions, and thoughts. It is a vital tool to collecting data and monitoring changes over time in field-based research in forestry, ecology, agriculture, and other fields. There are some important key features of a daily field diary are given here:

5.6.1 Key Features of a daily field diary: The daily field diary includes the following key features such as

i) It is the regular and chronological documentation of details such as date, time, and location of the field visit.

ii) It records unbiased observations about plant species, their life cycles, physical characteristics, and habitat.

iii) The diary also notes environmental conditions like weather, soil type, and moisture levels**.**

iv) It also provides details of field activities like sample collection, weeding, pruning, and planting.

v) Sometimes, it may also be included reflective notes, in which the observer documents personal thoughts, difficulties encountered, or suggestions for additional research, may also be included.

In general, a daily field diary facilitates long-term monitoring, provides reliable data collecting, and is an invaluable resource for plant sciences, forestry and environmental studies research, analysis, and decision-making.

5.6.2 Importance of a daily field diary:

A daily field diary is of great importance in field-based studies such as

i) Daily field diary provides a reliable and systematic record of day-to-day observations, environmental conditions, and field activities.

ii) It helps ensure accuracy and continuity in data collection by capturing vital information such as species observed, growth measurements, plantation progress, weather conditions, and management practices.

iii) The diary supports effective monitoring of forestry or ecological projects by documenting changes over time, identifying problems like pest infestations or nutrient deficiencies, and assisting in timely decision-making.

iv) It provides a valuable reference for research, analysis, report writing, and future planning.

In order to better understand, conserve, and manage natural resources sustainably, field workers, researchers, and forestry professionals can preserve crucial information by keeping a daily field diary.

5.7 FIELD DIARY FOR DOCUMENTATION OF RESEARCH WORK

A field diary is the most helpful tool for a process documenter. The documenter uses a field diary to record his or her observations and thoughts in an arranged manner. Recording observations and impressions enables a researcher to pick up clues about how the system is operating.

A field diary ought to help the researcher in understanding the social and physical environment of the system. It needs to aid in describing the who, what, where, when, how, and why. who alludes to the subjects or system under study. What is relevant to the data collected? Important information regarding the observation is provided by the questions of why, where, when, and how.

Although there is no specific format for writing a field diary, entries should be made every day in chronological sequence to prevent forgetfulness from causing material to be lost or altered. The crucial issue is that observations are routinely documented in a diary.

When learners observing forestry species and plantations of timber and industrial species like ***Poplar*** and ***Eucalyptus***, two main types of field notes are typically maintained:

5.7.1 Descriptive or Observational Notes of a Field Diary:

Descriptive or observational notes are a fundamental part of a field diary. These notes are truthful, objective, and detailed records of what the observer sees, hear, and experiences during fieldwork, without any personal interpretation or analysis.

Additionally, the researcher observes individuals, small groups, ethnic families, communities, and government organizations. Observations can be made of situations and human actions, including actors between farmers between farmers and government agencies and between different government agencies.

In the context of forestry and plantation studies**, Descriptive notes may include:**

- Date and time of observation,
- Location (GPS coordinates, forest compartment, etc.),
- Plant species observed **(local name, botanical name),**

- Growth stage **(seedling, sapling, mature tree),**
- Size measurements **(height, girth, DBH),**
- Spacing and plantation layout,
- Physical condition of plants **(leaf color, wilting, pest/disease signs),**
- Soil type and moisture,
- Weather conditions **during observation,**
- Management activities **(pruning, weeding, irrigation).**

5.7.1.1 Example of a Descriptive Note (Field Diary Entry):

- Date: ---------- *(visit date)*
- Time: ----------*(Field diary entry time)*
- Location: ---------- *(visit place/area/locality)*
- Species Observed: *Eucalyptus tereticornis (Safeda)*
- Age: *2.5 years*
- Spacing: *3 x 3 meters*
- Average Height: *5.5 m*
- DBH: *7.2 cm*
- Soil*: Sandy loam, well-drained*
- Weather*: Partly cloudy, 26°C*
- Observation: *All trees healthy. Green leaves with no visible pest damage. Weed growth observed at base. Drip irrigation functional.*

5.7.1.2Key Features of Descriptive Field Notes: The important key features of descriptive or observational notes of a field diary are following, these are:

- Descriptive field notes are objective, factual, and detailed records of observations without bias or opinion.
- They include detailed specific information about species, site conditions, weather, and activities.
- These notes are written in a systematic and chronological manner, capturing essential details such as the date, time, and exact location of the observation
- Only factual or what is directly observed is written, no guesses or interpretations.

5.7.1.3 Purpose of Descriptive Notes:

- To document real-time observations systematically.
- To support long-term monitoring of forest growth and health.
- To provide evidence-based records for research, analysis, or management planning.
- They serve as the basis of scientific analysis, helping scientists and forest managers in making rational decisions based on current field data.
- Descriptive notes provide the reliability and validity of the field record by emphasizing neutrality, accuracy, and clarity, qualities that are critical for long-term ecological studies, reporting, and research.

5.7.2 Reflective or Impressions Notes of a Field Diary:

Reflective field notes, also known as impression field notes, are a kind of field diary entry in which the observer documents their own feelings, ideas, interpretations, and revelations derived from their fieldwork. Reflective notes, as opposed to descriptive notes, which are strictly factual, go beyond what is seen to investigate the meaning of those observations, the reasons behind particular circumstances, or the observer's own response to the field scenario.These impressions help provide context to the observed data and often offer insights into species performance, habitat suitability, and overall forest health.

For example:

i) A field researcher may feel that a particular patch of Sal or Teak forest appears less vigorous due to poor soil conditions or competition from invasive species like Lantana. They might note that Poplar plantations seem stressed in drier areas, indicating a need to check site selection. Emotional reactions, such as the aesthetic beauty of a well-managed forest or the satisfaction of witnessing natural regeneration, also form part of these reflections.

ii) *Eucalyptus* shows healthy growth, likely due to timely monsoon. However, signs of termite activity observed at the base of 3 trees—monitoring required. Consider applying neem-based biopesticide in nearby plantations.

Additionally, challenges faced during fieldwork, such as accessibility issues or weather-related disruptions, may be recorded along with suggestions for future management or research. These subjective impressions add depth to the field diary and support more informed and reflective forest conservation and management practices.

5.7.2.1 Key Features of Reflective Field Notes:

- Reflective field notes are characterized by their personal, interpretive, and analytical nature, capturing the observer's thoughts, insights, and emotional responses during fieldwork.
- Reflective notes explore into the meaning behind observations, explore possible explanations for patterns or issues noticed in the field, and often raise questions for further investigation.
- These notes may include reflections on the effectiveness of forest management practices.
- They also provide space to document challenges faced, ethical considerations, and suggestions for improvement.
- Reflective field notes help enhance critical thinking, support adaptive planning, and add depth to the field diary by linking observations with interpretation.

5.7.2.2 Purpose of Reflective Notes:

- To deepen understanding of field observations
- To guide future actions or research
- To capture the human experience of fieldwork
- To support critical thinking and learning from the field

Reflective notes add valuable context to descriptive observations and help turn field data into meaningful ecological or management insights.

5.8 FIELD NOTE BOOK (FIELD DIARY) FORMAT

Here is a Field Note Book (Field Diary) format for documenting forestry species and plantation of timber and industrial species such as *Poplar*, *Eucalyptus*, *Teak*, etc. This format ensures systematic and comprehensive field data collection useful for herbarium preparation, monitoring plantation health, and scientific documentation.

1. Entry Number: *(Sequential number for each field entry)*

2. Date of Observation/Collection: *(DD/MM/YYYY)*

3. Time of Visit: *(HH:MM AM/PM)*

4. Collector's Name: *(Name of the person making the entry)*

5. Location: *-Forest Division:*

-Range/Block/Compartment:

-Village (if applicable):

*-GPS Coordinates / Altitude***:**

6. Local Name of Species: *(e.g., Safeda, Safaida)*

7. Botanical Name: (e.g., *Eucalyptus tereticornis*)

8. Family: *(e.g., Myrtaceae)*

9. Type of Species / Habit: *(Tree / Shrub / Herb / Climber)*

10. Plantation Type (if applicable):

- *Species planted:*
- *Year of planting:*
- *Spacing:*
- *Number of plants:*
- *Method of planting:*

11. Phenological Stage: *(Vegetative / Flowering / Fruiting)*

12. Habitat Description: *(Natural forest, degraded land, plantation site, roadside, riverbank, etc.)*

13. Soil and Moisture Condition: *(Sandy / Loamy / Clayey; Dry / Moist / Wet)*

14. Associated Species: *(Other trees or vegetation growing in the area)*

15. Field Description of the Plant:

- *Height:*
- *Girth / DBH (Diameter at Breast Height):*
- *Bark texture & color:*
- *Leaf shape, size, and arrangement:*
- *Flower/fruit color and shape:*
- *Any special features (e.g., latex, aroma, thorns, resin, etc.)*

16. Uses / Local Knowledge (if available):

(Timber, fuel wood, fodder, medicinal, industrial, etc.)

17. Management Practices Observed:

(Pruning, thinning, irrigation, weeding, fertilization, etc.)

18. Health Status / Observations:

(Healthy / Pest infected / Disease symptoms / Mortality rate)

19. Reflective Comments / Suggestions:

(Observer's impression, site suitability, scope of improvement, etc.)

20. Herbarium Sample Collected:

(Yes / No – If yes, Collection Number: _____)

5.9 LIST OF SOME FORESTRY SPECIES WITH LOCAL NAME AND THEIR COMMON USES

In this para/section given a list (table 5.1) of some important forest species with their botanical name, local name, family and their uses. These species will be helpful in preparing field dairy when learners visit forest areas.

Table 5.1 List of some important forest species

S. N.	Botanical Name of Forest species	Local Name	Family	Common uses
1.	*Bauhinia variegate* L.	Kachnar	Caesalpiniaceae	Fodder, Fuel, Timber, Medicine
2.	*Boehmeria rugulosa* Wedd.	Gethi	Urticaceae	Fuel wood, fodder, wooden pot
3.	*Bombax ceiba*L.	Semal	Bombacaceae	Fuel, Fibre, Timber, Medicine
4.	*Cassia fistula*L.	Amaltas	Fabaceae	Ornamental, Herbal medicine
5.	*Celtis australi s*L.	Kharik	Cannabaceae	Fodder, Fuel, Agricultural tools
6.	*Cupressus torulosa* D.Don	*Surai*	Cupressaceae	Industrial, Timber, Ornamental
7.	*Debregeasia longifolia* Wedd	Tushar	Urticaceae	Fodder, Fibre
8.	*Excoecaria acerifolia* Didr.	Dudhil	Euphorbiaceae	Ornamental, Medicinal
9.	*Eucalyptus tereticornis* Smt.	Safeda	Myrtaceae	Timber, Firewood, Pulpwood
10.	*Ficus palmata* Forssk.	Bedu	Moraceae	Edible fruits, Fodder, Medicinal
11.	*Ficus roxburghii* Wall.	Timil	Moraceae	Fodder, Fuel, Fruit
12.	*Grewia optiva* J.R.Drumm.ex Burret	Bhemal	Tiliaceae	Fodder, Fibre, Timber
13.	*Juglans regia* L.	Akhrot	Juglandaceae	Fruit, Timber
14.	*Lyonia ovalifolia* Wall. Drude	Angyar	Ericaceae	Fuel
15.	*Morus alba*L.	Sehtoot	Moraceae	Fodder, Fruit, Fibre, Fuel
16.	*Melia azedarach*L.	Betain	Meliaceae	Fuel, Timber, Fodder
17.	*Myrica esculenta* D.Don	Kafal	Myricaceae	Edible fruits, Dye, Fuelwood
18.	*Picea smithiana (Wall.)Boiss.*	Spruce	Pinaceae	Ornamental, Timber
19.	*Pinus roxburghii* Sarg.	Chir	Pinaceae	Timber, fuel
20.	*Prunus cerasoides* D.Don	Padam	Rosaceae	Fuel, Timber

21.	*Pyrus pashia* L.	Mehal	Rosaceae	Edible fruits, Fuel, Fodder
22.	*Quercus leucotrichophora* A. Camus	Banjoak	Fagaceae	Fodder, Fuel, Timber
23.	*Q. glauca*Thunb.	Falyat	Fagaceae	Fodder, Fuel, Timber
24.	*Q. semecarpifolia*	Kharsu	Fagaceae	Fodder,Fuel, Timber
25.	*Q. floribunda*	Tilonj	Fagaceae	Fodder,Fuel, Timber
26.	*Rhododendron arboretum* Sm.	Buransh	Ericaceae	Juice, Fuel, Ornamental
27.	*Shorea robusta* Roth	Sal	Dipterocarpaceae	Timber,Fodder, Seedoil
28.	*Syzygium cumini*(L.) Skeels.	Jamun	Myrtaceae	Fruit
29.	*Toona ciliata* M. Roem.	Toon	Meliaceae	Fuel,Timber

5.10 SUMMARY

Preparing a field diary is an essential practice for documenting daily observations in vegetation related fieldwork, especially when monitoring natural forest species and plantations of timber and industrial species such as *Poplar*, *Eucalyptus*, *Sal*, *Teak etc*. The field diary acts as a structured account of site visits, documenting facts about the species observed, the location, the habitat, the phenological stages, and the condition of the plantation. It includes both descriptive notes (factual details like plant height, growth condition, and management practices) and reflective notes (personal impressions, site suitability, challenges faced, and suggestions for improvement). Daily field observations aid in monitoring plant growth, identifying early warning indicators of pest or disease outbreaks, and assess the effectiveness of silvicultural interventions. This systematic documentation provides reliable, first-hand data that can be examined over time, supporting scientific study, plantation management, and ecological monitoring. Eventually, a well-kept field diary or note book improves decision-making and helps ensure that forestry resources are managed sustainably.

5.11 SELF ASSESSMENT QUESTIONS

5.11.1Questions Based on Knowledge

d) What is a field diary and why is it important in forestry research and plantation management?
e) Define the basic components of a field diary entry for timber species.
f) Name any five forest tree species commonly used in plantation forestry in India.

5.11.2 Skill-Based Questions

d) Explain how to format and structure a field diary entry for observing *Poplar* plantation over a one-week period.

e) Illustrate a sample page of a field diary showing observations on *Eucalyptus* from plantation establishment to one-month growth.

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5.13 SUGGESTED READINGS

- Manuals and Guidelines from ICFRE (Indian Council of Forestry Research and Education) *Visit: https://icfre.gov.in***.**
- Forest Working Plans and Field Diaries from State Forest Departments (e.g., Uttarakhand, Himachal Pradesh, Madhya Pradesh)
- Herbarium and Field Note Training Materials from Forest Research Institutes**.**
- UNEP and FAO Field Manuals on plantation and forest monitoring, *Visit: http://www.fao.org/forestry*

5.14 TERMINAL QUESTIONS

5.14.1 Short Answer Type Questions

1. Define a field diary and state its importance and purpose in forestry and plantation work.
2. List any four components that must be recorded in your daily field diary entry.
3. Mention two common problems faced during plantation and how they were noted in the field diary.

5.14.2 Long Answer Type Questions

1. Describe the format of a field diary used for recording daily observations in forestry
2. Explain the step-by-step process of preparing a field diary for the plantation of timber species. Highlight how you record morphological, phenological, and ecological observations with a suitable example.
3. Create a model field diary entry format for timber species plantations. Include columns/sections for date, species, botanical name, soil type, irrigation status, phenological stage, plant health, and remarks.
4. Describe any field visit conducted by you to observe a forest plantation. Include your complete field diary record of that day and analyze one major problem observed during the plantation.

UNIT-6- STUDY OF FOREST VEGETATION QUANTITATIVELY FOR CHARACTERISTICS, VIZ, IVI AND SPECIES DIVERSITY INDICES USING STANDARD SIZE AND NUMBER OF QUADRATES IN TWO DIFFERENT FORESTS

Contents:

6.1 OBJECTIVES

After reading this unit, the learners will be able to calculate the:

- Density, frequency and abundance of forest vegetation
- Relative density, Relative frequency and Relative abundance
- Importance value index (IVI) and diversity of vegetation
- The main objective of this exercise is to study the quantitatively characteristics of two different forests by using quadrate method

6.2 INTRODUCTION

The study of plant community structure is called plant sociology or phytosociology and this study is important for understanding the functioning of the community (Singh and Singh 2010). The phytosociological study incorporates mainly the description of the vegetation of the terrain because it provides detailed information about composition of vegetation communities and also the functional aspect. It is assumed that the dominating plant species actually determine the structure of a community (Behura et al. 2015; Odum 1971) and the structure of a vegetational unit depends upon the species composition and their relative number.

As introduced by Raunkiaer (1934) frequency indicates the distribution and dispersion of a species in a community. Abundance and density represent the numerical strength of the species in the community. Abundance with frequency gives an idea of distribution pattern, while the density represents the number of individuals of the species in any unit area.

For ecological study of a region, a quantitative evaluation of its vegetation is a prerequisite. The present chapter deals with the structure and composition of vegetation types in the selected two (Forest type 1 of hill region and Forest type 2 of Plane region) different forests systems.

6.3 METHODOLOGY

The composition of tree and herb species is recorded in different forests of different altitudinal range (Hill and Plane region). The tree and sapling will be analyzed by using randomly placing 10 quadrats of 10 × 10 m size in each forest. Circumference at breast height (CBH i.e., 1.37 m above the ground) of all the trees and saplings in each quadrats would be measured and recorded individually. Within each of these quadrats, a sub-quadrat of 1 x 1 m will take for herb species. The design use for sampling of trees and herbs is presented in Fig. 6.1.

The tree vegetation will categorized into seedling (having girth class <10 cm), sapling (with girth class 10.1-30 cm.) and tree (with girth class ≥ 30.1 cm). The vegetational data will quantitatively analyzed for density, frequency and abundance according to the formula as given by Curtis and Mc Intosh (1950).

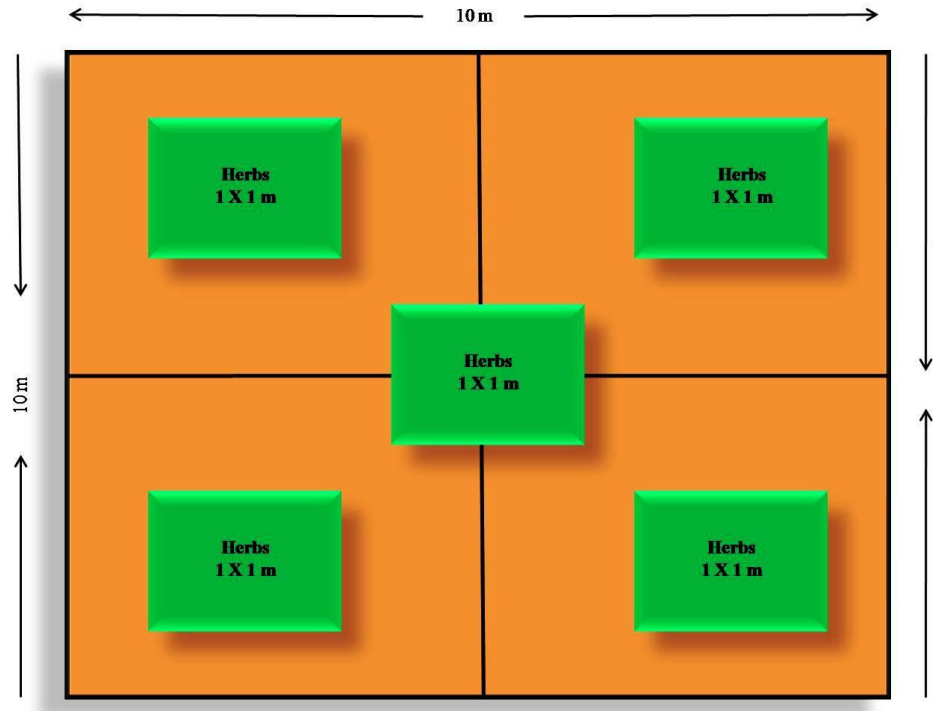

Fig. 6.1: Schematic representation of different quadrates studied (Source: Padalia 2017)

Density is expressed as the number of individuals per unit area (eg. Trees/ha) and calculated as:

$$\text{Density (individuals per unit area)} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}$$

Frequency is the degree of dispersion of a species in a forest. Individuals of some species are sparsely distributed while others are found in clumps.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100$$

Abundance is simply the number of individuals of a species. It refers actually to the density of population in those quadrats in which a given species occurs. It is expressed as tree per unit area.

$$\text{Abundance} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats in which species occurred}}$$

Mean Basal Area: Basal area is the cross sectional area of the tree stem at breast height (1.37m). It is regarded as an index of dominance. The tree basal area is expressed as: The basal area and total basal area of tree species were calculated by

$$\text{Mean basal area of woody species} = \frac{\text{Circumference at breast height (C.B.H)}^2}{4\,\pi}$$

Relative frequency (%), relative density (%) and relative basal area (%) will calculate according to Curtis (1959).

$$\text{Relative Density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Number of occuence of the species}}{\text{Total Number of occurence of all species}} \times 100$$

$$\text{Relative Basal Area (RBA)} = \frac{\text{Mean basal area of individual species}}{\text{Total mean basal area of all species}} \times 100$$

Importance Value Index (IVI): The calculation of the Importance Value Index (IVI) of the tree species (tree and sapling) is done by computing the relative density, relative frequency and relative basal area (Curtis 1959).

Importance Value Index (IVI) = RD + RF + RBA

Provenance value: For herb species and tree seedling, Provenance value (PV) index is calculated by summing up the value of relative frequency and relative density instead of computing IVI.

Provenance value (PV) = RD + RF

6.4 DIVERSITY MEASUREMENTS

The diversity index (H') was computed by using Shannon- Wiener's index (Shannon and Weaver (1949) and concentration of dominance by Simpson's index (Simpson 1949).

Shannon- Weiner's Index: Diversity is measured as the number of species occurring within an area of a given size (Huston 1994). It therefore, measures the richness of a potentially interactive

assemblage of species. Diversity Index was calculated by using Shannon-Weiner's index (Shannon-Weaver 1949).

$$H' = - 3.3219 [\log_{10} N - (\sum Ni \log_{10} Ni/N)]$$

Where,

Ni = The total density of species

N = The total density of all species.

The factor 3.3219 was used to convert the index value to $\log_2$.

Concentration of dominance (Cd) (Simpson's Index): Simpson (1949) proposed for the first time a widely used index, which varies inversely with species heterogeneity, and in fact measures the concentration of dominance (Cd) and was calculated as:

$$Cd = \left(\sum \frac{Ni}{N}\right)^2$$

Where,

Ni = total number of individuals of a species.

N = total number of individuals of all species.

6.5 QUANTITATIVE ANALYSIS OF DIFFERENT FORESTS

Let us suppose we are analyzing the diversity measurement of the two different vegetatively composed forests of hill region (Forest type 1) and plane region (Forest type 2) of Uttarakhand.

Table 6.1: Tree vegetation composition for Forest type 1 (hill region):

Species	Total number of quadrats studied										D	F	A
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
Species A	2	1				3				1	0.70	40	1.75
Species B			1	1			2				0.40	30	1.33
Species C					2			1	2		0.50	30	1.67
Species D	3		2				3			3	1.10	40	2.75
Species E		1						1			0.20	20	1.00
Total											**2.90**	**160**	

Q1-10= quadrats from 1 to 10; D= Density (trees/ 100 m^2); F= Frequency (%); A= Abundance (trees/ 100 m^2)

For Species A:

Density = $\frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}} = \frac{2+1+3+1}{10} = 0.70$

Frequency = $\frac{\text{Number of quadrats in which species occurred}}{\text{Total number of quadrats studied}} \times 100 = \frac{4}{10} = 40$

Abundance = $\frac{\text{Total number of individuals}}{\text{Number of quadrats in which species occurred}} = \frac{7}{4} = 1.75$

For Species B:

Density = $\frac{1+1+2}{10} = 0.4,$ Frequency = $\frac{3}{10} \times 100 = 30,$ Abundance = $\frac{4}{3} = 1.33$

For Species C:

Density = $\frac{2+2+1}{10} = 0.5,$ Frequency = $\frac{3}{10} \times 100 = 30,$ Abundance = $\frac{5}{3} = 1.66$

For Species D:

Density = $\frac{3+2+3+3}{10} = 1.10,$ Frequency = $\frac{4}{10} \times 100 = 40,$ Abundance = $\frac{11}{4} = 2.75$

For Species E:

Density = $\frac{1+1}{10} = 0.20,$ Frequency = $\frac{2}{10} \times 100 = 20,$ Abundance = $\frac{2}{2} = 1.00$

The total density of the forest is 2.90 trees/ 100m^2 in which Species D showed the highest tree density (1.1 trees/ 100 m^2) as compared to other species. Species A and D have the frequently distributed species (40 %) among all while Species D have the highest abundance.

Table 6.2: Tree vegetation composition for Forest type 2 (plane region):

Species	Total number of quadrats studied										D	F	A
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
Species F	2	1			3			2			0.80	40	2.00
Species G			3	1		1			1	1	0.70	50	1.40
Species H							2				0.20	10	2.00

Species I	1	1	1	1	1	1	2	0.80	70	1.14
Species J		3	1			1		0.50	30	1.67
Total								**3.00**	**200**	

Q1-10= quadrats from 1 to 10; D= Density (trees/ 100 m^2); F= Frequency (%); A= Abundance (trees/ 100 m^2)

For Species F:

Density = $\frac{2+1+3+2}{10} = 0.80$, Frequency = $\frac{4}{10} \times 100 = 40$, Abundance = $\frac{8}{4} = 2.00$

Similarly, by applying the formula, we will calculate the density, frequency and abundance of all the species occurred in Forest type 2 of plane region (Table 6.2.). The total density of the forest is 3.00 trees/100 m^{-2} in which Species F and I showed the highest tree density (0.80 trees/ 100m^2) as compared to other species. Species I is the most frequently occurred species (70 %) among all. The maximum abundance was reported for Species F and H in this forest.

Table 6.3: Circumference or diameter (cm) at breast height of different individuals of tree species in Forest type 1 (hill region):

Species	Total number of quadrats studied										Total cbh	Average cbh	MBA
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
Species A	220	110			330			240			900	225.00	4030.65
Species B			123	144		185			210	240	902	180.40	2591.09
Species C							220				220	220.00	3853.50
Species D	450	120		298		114	125	114		210	1431	204.43	3327.31
Species E		385			178				125		688	229.33	4187.40
Total													**17989.97**

Q1-10= Quadrats from 1 to 10; cbh= Circumference At Breast Height, MBA= Mean Basal Area (cm^2/ individual)

For species A:

Mean basal area $= \frac{\text{Circumference at breast height (C.B.H)}^2}{4\pi} = \frac{(225)^2}{12.56} = 4030.65$

For species B:

Mean basal area $= \frac{(180.40)^2}{12.56} = 2591.09$

For species C:

Mean basal area $= \frac{(220)^2}{12.56} = 3853.50$

For species D:

Mean basal area $= \frac{(204.43)^2}{12.56} = 3327.31$

For species E:

Mean basal area $= \frac{(229.33)^2}{12.56} = 4187.40$

The total basal area of all the species is 17989.97 cm^2 / individual. Species E represent the highest mean basal area among all the species.

Table 6.4: Circumference or diameter (cm) at breast height of different individuals of tree species in Forest type 2 (Plane region):

Species	Total number of quadrats studied										Total cbh	Average cbh	MBA
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
Species F	240	360			380			280			1260	315.00	7900.08
Species G			452	758		456			789	258	2713	542.60	23440.67
Species H							400				400	400.00	12738.85
Species I	485	184		486		163	467	254		124	2163	309.00	7601.99
Species J		245			546				253		1044	348.00	9642.04
Total													**61323.63**

Q1-10= Quadrats from 1 to 10; cbh= Circumference at Breast Height, MBA= Mean Basal Area (cm^2/ individual)

For species F:

Mean basal area $= \frac{(315)^2}{12.56}$ = 7900.08

Likewise, we will calculate the Mean Basal Area for all the remaining species of the forest. From the table 6.4, we can conclude that the total basal area of all the species is 61323.63 cm^2 / individual. Species G represent the highest mean basal area among all the species.

Table 6.5: Tree vegetation composition for Forest type 1 (hill region):

Species	D	F	MBA	RD	RF	RBA	IVI
Species A	0.7	40	4030.65	24.14	25	22.40	71.54
Species B	0.4	30	2591.09	13.79	18.75	14.40	46.95
Species C	0.5	30	3853.5	17.24	18.75	21.42	57.41
Species D	1.1	40	3327.31	37.93	25	18.50	81.43
Species E	0.2	20	4187.4	6.90	12.5	23.28	42.67
Total	**2.9**	**160**	**17989.95**				

D= Density (ind/ 100 m^2); F= Frequency (%); MBA= Mean Basal Area (cm^2/ individual); RD= Relative density (%); RF= Relative frequency (%); RBA= Relative Basal Area (%); IVI= Importance Value Index

For Species A:

$$\text{Relative Density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Total number of individuals of all species}} \times 100 = \frac{0.7}{2.90} \times 100 = 24.14$$

$$\text{Relative Frequency (RF)} = \frac{\text{Number of occuence of the species}}{\text{Total Number of occurence of all species}} \times 100 = \frac{40}{160} \times 100 = 25$$

$$\text{Relative Basal Area (RBA)} = \frac{\text{Mean basal area of individual species}}{\text{Total mean basal area of all species}} \times 100 = \frac{4030.65}{17989.95} \times 100 = 22.40$$

So, Importance Value Index (IVI) = RD + RF + RBA = 24.14 +25 +22.40 = 71.54

For Species B:

RD = $\frac{0.4}{2.90} = 13.79$, RF = $\frac{30}{160} \times 100 = 18.75$, RBA = $\frac{2591.09}{17989.95} = 14.40$, IVI= 46.95

For Species C:

RD = $\frac{0.5}{2.90} = 17.24$, RF = $\frac{30}{160} \times 100 = 18.75$, RBA = $\frac{3853.50}{17989.95} = 21.42$, IVI= 57.41

For Species D:

RD = $\frac{1.1}{2.90} = 37.93$, RF = $\frac{40}{160} \times 100 = 25$, RBA = $\frac{3327.31}{17989.95} = 18.50$, IVI= 81.43

For Species E:

RD = $\frac{0.2}{2.90} = 6.90$, RF = $\frac{20}{160} \times 100 = 12.50$, RBA = $\frac{4187.40}{17989.95} = 23.28$, IVI= 42.67

Table 6.6: Tree vegetation composition for Forest type 2 (Plane region):

Species	D	F	MBA	RD	RF	RBA	IVI
Species F	0.8	40	7900.08	26.67	20	12.88	59.55

Species G	0.7	50	23440.67	23.33	25	38.22	86.56
Species H	0.2	10	12738.85	6.67	5	20.77	32.44
Species I	0.8	70	7601.99	26.67	35	12.40	74.06
Species J	0.5	30	9642.04	16.67	15	15.72	47.39
Total	**3.00**	**200.00**	**61323.63**				

D= Density (ind/ 100 m^2); F= Frequency (%); MBA= Mean Basal Area (cm^2/ individual); RD= Relative density (%); RF= Relative frequency (%); RBA= Relative Basal Area (%); IVI= Importance Value Index

For Species F:

RD = $\frac{0.80}{3.00} = 26.67$, RF = $\frac{40}{200} \times 100 = 20$, RBA = $\frac{7900.08}{61323.63} = 12.88$, IVI = 59.55

Herb species: For herbs, Provenance value (PV) was calculated by summing up the values of relative frequency and relative density similarly as computed for the tree species.

6.6 FOREST DIVERSITY

Species diversity is a function of the number of species present in a given area and the distribution of individuals among the species. Let us suppose we are analyzing the diversity of the two different vegetatively composed forests of hill region (Forest type 1) and plane region (Forest type 2) of Uttarakhand.

Table 6.7: Tree vegetation composition for Forest type 1 (hill region):

Species	D	Ni/N	log Ni/n	H'	cd
Species A	0.70	0.2413	-0.6173	0.4949	0.058
Species B	0.40	0.1379	-0.8603	0.3942	0.019
Species C	0.50	0.1724	-0.7634	0.4372	0.030
Species D	1.10	0.3793	-0.4210	0.5305	0.144
Species E	0.20	0.0689	-1.1613	0.2660	0.005
Total	2.90			**2.12303**	**0.256**

For Species A:

H' = $-3.3219\ [\log_{10} N - (\sum Ni \log_{10} Ni/N)]$ $= -3.3219 \times \frac{0.70}{2.90} \times log\ \frac{0.70}{2.90} = 0.4949$

Cd = $\left(\sum \frac{Ni}{N}\right)^2 = \left(\sum \frac{0.70}{2.90}\right)^2 = 0.058$

The total diversity of the forest can be calculated by adding the diversity and concentration of dominance of individual plant species. Therefore, it is concluded from the table 6.7 that the total diversity and cd of the forest type 1 of hill region is 2.123 and 0.256, respectively.

Table 6.8: Tree vegetation composition for Forest type 2 (Plane region):

Species	D	Ni/N	log Ni/n	H'	cd
Species F	0.80	0.266667	-0.57403	0.50852	0.071
Species G	0.70	0.233333	-0.63202	0.4899	0.054
Species H	0.20	0.066667	-1.17609	0.26047	0.004
Species I	0.80	0.266667	-0.57403	0.50852	0.071
Species J	0.50	0.166667	-0.77815	0.43084	0.028
Total	3.00			**2.19823**	**0.229**

For Species F:

H' = $-3.3219 \times \frac{0.80}{3.00} \times log \frac{0.80}{3.00}$ = 0.5085 cd= $\left(\sum \frac{0.80}{3.00}\right)^2 = 0.071$

The total plant diversity of Forest type 2 in Plane region is recorded as 2.1982 and the concentration of dominance is 0.229.

6.7 SUMMARY

The study of groups of plant species that are typically found together is called phytosociology, also known as phytocoenology or simply plant sociology. The objective of phytosociology is to empirically define the vegetative environment of a certain location. A certain community of plants is seen as a social unit; it is the result of specific past and present circumstances and can only exist when such circumstances are satisfied. The goal of phytosociology is to create an adequate empirical model of vegetation utilizing combinations of plant species that define discrete vegetation units.

6.8 GLOSSARY

Environment: The biotic and abiotic surroundings of an organism or population, and the chemical interactions between these factors that influence their survival, development, and evolution. An environment can vary in scale from microscopic to global.

Quadrat: A rectangular plot of land extensively studied for its ecology.

Species diversity: It is the number of different species that are represented in a given community (a dataset).

Density: Plant density is simply the number of individuals per unit ground area.

Frequency: Frequency is the number of times a plant species occurs in a given number of quadrats.

Abundance: Plant abundance is often described by the cover, i.e. the relative area covered by different plant species in a quadrat.

Relative density: Relative density, or specific gravity, *is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material*.

Relative frequency: Relative Frequency is *a proportion or percentage which is calculated with the help of given frequency*.

Mean basal area: It is the average amount of an area (usually an acre) occupied by tree stems.

6.9 SELF-ASSESSMENT QUESTIONS

6.9.1 Multiple Choice Questions

1. If the total 20 tree were occurred in 10 quadrats, the density (trees/ 100 m^2) will be
   (a). 2 (b). 0.2
   (c) 2000 (d) 20000
2. If a tree species is found in only 2 quadrants out of total 10 quadrants, then the frequency will be
   (a). 2000 (b). 200
   (c). 20 (d). 2
3. If the total 30 tree were found in only 2 quadrants out of total 10 quadrants, then the abandance will be
   (a). 15 (b). 3
   (b). 20 (d). 30

6.9.2 True and False

1. phytosociology study is important for understanding the functioning of the community.
2. The dominating plant species actually determine the structure of a community.
3. vegetational unit depends upon the species composition and their relative number.
4. Abundance with frequency gives an idea of distribution pattern, while the density represents the number of individuals of the species in any unit area.
5. The formula of frequency is: $\frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}$

6.9.3 Fill in the blanks

1. The study of plant community structure is called plant _____
2. The phytosociological mainly the description of the _____ of the terrain.
3. As introduced by _____ frequency indicates the distribution and dispersion of a species in a community.
4. Importance Value Index (IVI) = RD + RF + _____
5. _____ is measured as the number of species occurring within an area of a given size

Answer Keys:

6.9.1: 1.(a); 2.(c); 3.(a)

6.9.2: 1. True; 2. True; 3. True; 4. True; 5. False

6.9.3: 1. Phytosociology; 2. Vegetation; 3. Raunkiaer; 4. RBA; 5. Diversity

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6.12 ACKNOWLEDGEMENT

The author of the unit is greatly indebted to Dr. Beena Tewari Fulara, Assistant Professor (AC), Department of Forestry, School of Earth and Environmental Sciences, Uttarakhand Open University, Haldwani for their constant help during the writing of the unit.

6.13 TERMINAL QUESTIONS

6.13.1 Short answer type questions

1. What do you understand by tree density?
2. Write the formula of frequency.
3. What do you understand by diversity?
4. Define the quadrate in one line.

5. How will you calculate the Importance Value Index (IVI) for a species?

6.13.2 Long answer type questions

1. Calculate the tree density, frequency, abundance, relative density, relative frequency, mean basal area, IVI and diversity of the given forest ecosystem. (the given values in the table are the cbh of the tree species).

Species	Total number of quadrats studied									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Species A	215	474			854		754	874		
Species B			785	989		785			254	445
Species C		265			1245		879			
Species D	245	254	455	298		114	125	2545		210
Species E		785			254				854	

BLOCK-3-ETHNOBOTANY

UNIT-1 PREPARATION OF THE HERBARIUM OF MEDICINALLY IMPORTANT PLANTS

1.1 BACKGROUND

Medicinal plants have played a vital role in traditional healthcare systems for centuries and continue to be a rich resource for modern drug development. The proper identification and documentation of these plants are essential for their conservation, sustainable use, and scientific study. One of the most effective and scientific methods for this purpose is the preparation of a **Herbarium**— a systematically organized collection of dried and pressed plant specimens mounted on sheets and labeled with essential data such as botanical name, local name, family, habitat, medicinal uses, and locality.

A herbarium of medicinally important plants serves as a permanent botanical record and is an essential tool for researchers, students, herbal practitioners, and conservationists. Preparing a herbarium involves field collection, plant identification, pressing, drying, mounting, and labeling of plant materials, along with the documentation of relevant ethnobotanical data. Herbarium not only preserves plant specimens for long-term study but also supports learning across taxonomy, pharmacognosy, conservation, and traditional medicine and acts as a reference for researchers, students, and practitioners of traditional and modern medicine

This unit aims to develop knowledge, skills, and values in learners by engaging them in both theoretical and hands-on processes of herbarium preparation, especially focusing on medicinally important plants.

1.2 OBJECTIVES

After reading this unit learners will be able to -

- Recall the definition and purpose of a herbarium.
- List the materials and tools used in herbarium preparation.
- Identify common medicinal plants by their local and botanical names
- Explain the importance of preserving medicinal plant specimens and describe the steps involved in the preparation of herbarium sheets.
- Discuss the role of herbarium in ethnobotanical research.
- Demonstrate the correct method of plant collection, pressing, and drying and use proper techniques to mount and label specimens according to herbarium standards.
- Differentiate between various types of herbarium specimens based on plant parts or habitat.

1.3 INTRODUCTION

A **herbarium** is a systematically arranged collection of dried and preserved plant specimens mounted on sheets and labeled with critical information such as botanical name, local name, common name, English name, family, habit, habitat, and medicinal and ethnobotanicl uses. These preserved specimens serve as a permanent botanical record for taxonomic reference, research, education, and conservation.

When focused on **medicinally important plants,** herbarium preparation contributes significantly to preserving traditional knowledge, assisting in accurate plant identification for pharmacological research, and supporting sustainable medicinal plant use. In this pera of unit, we explore in detail the methods of herbarium preparation specifically for plants of medicinal important.

1.4 SIGNIFICANCE OF MEDICINALLY IMPORTANT PLANTS HERBARIA

Medicinal plant herbaria serve as valuable scientific and cultural resources. They play a crucial role in bridging indigenous or traditional knowledge and modern science. They ensure that valuable medicinal plant resources are conserved, correctly identified, ethically used, and scientifically studied for the benefit of present and future generations. The significance of such herbaria lies in their multifaceted role in supporting both traditional and modern healthcare systems, especially in biodiversity-rich regions. Here some significance of medicinal plant herbaria is given below:

i. **Conservation of medicinal plant knowledge**

Plant specimens and related indeginous knowledge are permanently preserved in herbaria. They help to preserve intangible cultural heritage, which is frequently passed down orally and in danger of disappearing, by documenting the traditional uses of plants by indigenous populations.

ii. Correct identification of Plants

Misidentification of medicinal plants may result in treatments that are dangerous or ineffective. By using voucher specimens, herbaria enable accurate identification and authentication. Reliability in medicinal research is ensured by the inclusion of botanical data, local names, and specifics of the plant portion utilized in each herbarium specimen.

iii. Research and drug discovery

Medicinal herbaria offer reference material for phytochemical, pharmacological, and other plant based research**.** New bioactive chemicals may be discovered by returning to specimens for secondary metabolite analysis.

iv. Conservation and biodiversity assessment

Medicinal plant herbaria provide data on **species distribution, habitat preference, and phenology,** which are essential for assessing the conservation status. They support *in-situ* and *ex-situ*

conservation initiatives and aid in the identification of medicinal plants that are threatened or endangered.

v. Plant based education and training

Medicinal plant collections are vital teaching resources for courses in Botany, Pharmacy, Ayurveda, Traditional medicine, Biodiversity and other plant based education. Through practical application, they teach students about plant classification, therapeutic qualities, and ethnobotanical significance.

vi. Legal and ethical reference

Herbaria are reference collections used in bioprospecting and intellectual property rights (IPR) agreements. Voucher specimens can be used to verify the origin of plant material in scientific articles and patent applications.

vii. Resource for sustainable utilization

Through documenting traditional uses and abundance of species, herbaria help **plan** sustainable harvesting and cultivation of medicinal plants. . They help herbalists and local communities promote the ethical and safe use of therapeutic plants.

1.5 TOOLS FOR HERBARIUM

The tools used in making herbarium are given in the unit-4 of block-2 of Forest Ecology.

1.6 STEPS FOR PREPARATION OF THE HERBARIUM OF MEDICINALLY IMPORTANT PLANTS

Step 1: Collection of Specimens

- Collect healthy, disease-free, and mature plant parts such as leaves, flowers, stems, roots if necessary. For medicinal plants, make sure to include the part used medicinally.
- Record field data in a notebook:
    - Local name
    - Botanical name (if known)
    - Family
    - Location (with GPS or landmarks)
    - Habitat (forest, roadside, field, etc.)
    - Habit (Herb, shrub, tree, climber etc.)
    - Medicinal uses (as told by locals or documented)

Step 2: Pressing and Drying

- Collected plant specimen kept between newspaper sheets and arrange plant parts properly (leaves spread, flowers visible).

- Place the newspaper inside cardboard and press it between two wooden boards or tighten with straps or place under weight.
- Change newspapers daily for 3–7 days until specimens are fully dry.

Step 3: Mounting the Specimen

- Take a clean standard size of herbarium sheet and neatly glue the dried specimen on the sheet using gum. Ensure all parts are securely attached and aesthetically arranged.

Step 4: Labeling

- Affix a label on the bottom right corner of the sheet and include botanical name, local name, family, location, date of collection, collector's name, habit and habitat, part used and medicinal use

Step 5: Storage

- Store herbarium sheets in dry, cool cabinets and fumigate occasionally to protect from insects. Use naphthalene balls or silica gel to reduce moisture and pests.

1.7 PRECAUTIONS DURING HERBARIUM PREPARATION

When preparing a herbarium, it's important to follow certain precautions to make sure safety and the preservation of plant specimens. The following important safety measures are:

- **Using sharp instruments carefully:** When gathering or preparing specimens, use scissors, knives, or cutters carefully to prevent cuts or injury.
- **Protective things:** Put on gloves to protect your skin from allergies or plant sap. Use a mask if working with dusty or mold-prone specimens.
- Preservatives and chemicals like as alcohol or herbicide sprays should be handled in well-ventilated places, and safety precautions should be taken to prevent overexposure to chemicals.
- **Correct disposal:** To avoid contaminating the environment, dispose of any chemical waste appropriately.
- **Labeling Accuracy:** To avoid future confusion and misidentification, make sure labels are applied accurately.
- **Drying Precautions:** To reduce the risk of fire and the growth of mold, keep specimens away from open flames and make sure there is adequate ventilation.
- **Handling with Care:** Take care when mounting and pressing specimens to avoid damage, and store them appropriately to keep pests out.
- Hands should be cleaned after handling specimens, particularly if they are from unidentified or possibly allergic species.

By using these safety measures, you can guarantee high-quality herbarium specimens.

1.8 USES AND APPLICATIONS OF MEDICINALLY IMPORTANT HERBARIUM

Medicinally important herbarium specimens play a vital role in various fields by facilitating correct plant identification and authentication, which is essential for ensuring the safe and effective use of herbal medicines. They are useful tools for studying phytochemicals, helping scientists to extract and examine the active ingredients that give treatments their benefits. These specimens supply baseline data for researching the characteristics, effectiveness, and safety of medicinal plants. Additionally, herbarium collections contribute to conservation efforts by documenting plant diversity and **preservation of indigenous knowledge** and traditional healthcare systems.

1.9 MAJOR MEDICINAL PLANT HERBARIA IN INDIA

In this para/section given a detailed list of major medicinal plant herbaria in India, including their location, affiliated organization, and key functions. These institutions preserve valuable specimens and support the documentation, authentication, and research on medicinal plants.

Table 1: Detailed list of Major Medicinal Plant Herbaria in India

S. N.	Name of Herbarium	Location	Affiliation	Key Features
1	**National Herbarium of Medicinal Plants (NHMP)-** a section within the Raw Materials Herbarium Museum (RHMD)	New, Delhi	CSIR-NISCAIR, (National Institute of Science Communication and Information Resources)	Contains more than 8,000 verified examples of MPs that are employed in traditional medicinal systems like as Siddha, Unani, and Ayurveda.
2	**Herbarium of Central Council for Research in Ayurvedic Sciences (CCRAS)**	New Delhi	Ministry of AYUSH, Govt. of India	Includes voucher specimens of plants used in Ayurvedic formulations; supports drug standardization and plant authentication.
3	**FRLHT-TDU Medicinal Plant Herbarium**	Bengaluru, Karnataka	FRLHT– TDU	One of the richest ethnobotanical herbaria; houses 7,000+ medicinal plant specimens, including local health traditions.
4	**CSIR-National Botanical Research Institute (NBRI)**	Lucknow, Uttar Pradesh	CSIR	Botanical and medicinal plant herbarium with over 1,00,000 specimens
5	**Janaki Ammal Herbarium (BSI Central National Herbarium - CNH)**	Indian Botanic Garden, Howrah, West Bengal	Botanical Survey of India (BSI),	One of the largest and oldest herbaria; includes medicinal plants with national-level representation and reference.

6	**Regional Centres of BSI**	Dehradun, Pune, Shillong, Port Blair, Allahabad, etc.	Botanical Survey of India	Each regional herbarium documents local medicinal flora; used for biodiversity and conservation studies.
7	**Herbal Garden and Herbarium – National Medicinal Plants Board (NMPB)**	New Delhi	Ministry of AYUSH	Supports cultivation, conservation, and documentation of medicinal plants across India.
8	**Tropical Botanic Garden and Research Institute (TBGRI)**	Thiruvananthapuram, Kerala	Kerala State Council for Science, Technology and Environment	Over 50,000 specimens; focus on ethnobotany and indigenous medicinal plant research.
9	**Herbarium of Arya Vaidya Sala**	Kottakkal, Kerala	Arya Vaidya Sala, Kottakkal	used for medicine manufacturing.
10	**Herbarium of Regional Ayurveda Research Institutes (RARIs)**	Across India (e.g., Itanagar, Gangtok, Vijayawada)	CCRAS, Ministry of AYUSH	Each center maintains local medicinal plant herbaria to support region-specific Ayurvedic research and validation.

1.10 COMMON MEDICINAL PLANTS PRESERVED IN INDIAN HERBARIA

Here is a detailed list of 50 common medicinal plants preserved in Indian herbaria, along with their botanical names, common names, families, parts used, and medicinal uses are given in tabular form (Table 2).

Table 2: Some common medicinal plants preserved in Indian Herbaria

S. N.	Botanical Name	Common Name	Family	Parts Used	Medicinal Uses
1	*Adhatoda vasica*	Vasaka	Acanthaceae	Leaves	Bronchitis, asthma
2	*Aegle marmelos*	Bael	Rutaceae	Fruit, leaves	Diarrhea, digestion
3	*Aloe vera*	Ghrit Kumari	Asphodelaceae	Leaf gel	Skin, digestion
4	*Andrographis paniculata*	Kalmegh	Acanthaceae	Leaves	Liver health, fever
5	*Asparagus racemosus*	Shatavari	Asparagaceae	Root	Female tonic
6	*Azadirachta indica*	Neem	Meliaceae	Leaves, bark	Skin, diabetes
7	*Bacopa monnieri*	Brahmi	Plantaginaceae	Whole plant	Brain tonic
8	*Boerhavia diffusa*	Punarnava	Nyctaginaceae	Root	Diuretic, edema
9	*Calotropis gigantea*	Akanda	Apocynaceae	Leaves, latex	Rheumatism
10	*Cassia angustifolia*	Senna	Fabaceae	Leaves, pods	Laxative
11	*Centella asiatica*	Gotu Kola	Apiaceae	Leaves	Memory, wounds
12	*Cissampelos pareira*	Patha	Menispermaceae	Root	Diuretic, fever
13	*Clerodendrum serratum*	Bharangi	Lamiaceae	Root, leaf	Asthma, cough

14	*Coleus forskohlii*	Patharchur	Lamiaceae	Root	Heart health
15	*Coriandrum sativum*	Dhania	Apiaceae	Seeds	Digestion
16	*Curcuma longa*	Turmeric	Zingiberaceae	Rhizome	Anti-inflammatory
17	*Cuscuta reflexa*	Amarbel	Convolvulaceae	Stem	Liver tonic
18	*Cymbopogon citratus*	Lemongrass	Poaceae	Leaves	Fever, stress
19	*Datura metel*	Dhatura	Solanaceae	Leaves, seeds	Asthma, pain relief
20	*Delonix regia*	Gulmohar	Fabaceae	Flowers, leaves	Inflammation
21	*Eclipta alba*	Bhringraj	Asteraceae	Whole plant	Hair tonic, liver
22	*Emblica ribes*	Vidanga	Myrsinaceae	Fruit	Anthelmintic
23	*Ficus benghalensis*	Banyan	Moraceae	Bark, aerial roots	Diabetes
24	*Ficus religiosa*	Peepal	Moraceae	Bark, leaves	Asthma, diabetes
25	*Holarrhena antidysenterica*	Kutaj	Apocynaceae	Bark	Dysentery
26	*Justicia adhatoda*	Adusa	Acanthaceae	Leaves	Bronchitis
27	*Lawsonia inermis*	Mehndi	Lythraceae	Leaves	Skin, hair
28	*Mentha arvensis*	Pudina	Lamiaceae	Leaves	Cooling, digestion
29	*Mimosa pudica*	Lajjalu	Fabaceae	Root, leaves	Piles, wounds
30	*Moringa oleifera*	Drumstick	Moringaceae	Leaves, pods	Nutrition, detox
31	*Myristica fragrans*	Jaiphal (Nutmeg)	Myristicaceae	Seed	Digestive, stimulant
32	*Nigella sativa*	Kalonji	Ranunculaceae	Seeds	Immunity, digestion
33	*Ocimum gratissimum*	Ram Tulsi	Lamiaceae	Leaves	Cough, fever
34	*Ocimum tenuiflorum*	Tulsi	Lamiaceae	Leaves	Cough, cold, fever
35	*Phyllanthus emblica*	Amla	Phyllanthaceae	Fruit	Vitamin C, digestion
36	*Piper longum*	Long Pepper	Piperaceae	Fruit	Respiratory issues
37	*Piper nigrum*	Black Pepper	Piperaceae	Fruit	Digestion, cough
38	*Punica granatum*	Pomegranate	Lythraceae	Fruit rind	Diarrhea, antioxidant
39	*Rauvolfia serpentina*	Sarpagandha	Apocynaceae	Root	Hypertension
40	*Solanum nigrum*	Makoy	Solanaceae	Whole plant	Liver, ulcers
41	*Syzygium cumini*	Jamun	Myrtaceae	Seed	Diabetes
42	*Tamarindus indica*	Imli	Fabaceae	Pulp, bark	Digestion, laxative
43	*Terminalia arjuna*	Arjuna	Combretaceae	Bark	Heart tonic
44	*Terminalia bellirica*	Baheda	Combretaceae	Fruit	Respiratory issues
45	*Terminalia chebula*	Haritaki	Combretaceae	Fruit	Digestion, laxative
46	*Tinospora cordifolia*	Giloy	Menispermaceae	Stem	Immunity, fever
47	*Tribulus terrestris*	Gokhru	Zygophyllaceae	Fruits	Urinary tonic
48	*Trigonella foenum-graecum*	Methi	Fabaceae	Seeds	Diabetes, lactation
49	*Withania somnifera*	Ashwagandha	Solanaceae	Root	Stress relief, immunity
50	*Zingiber officinale*	Ginger	Zingiberaceae	Rhizome	Nausea, inflammation

1.11 PRCTICAL EXERCISE

1.11.1 Practical-01

Objective: To collect medicinal plants or plant parts from natural habitats.

Aim: Medicinal plants are used for a variety of purposes. Approximately 90% of medicinal plant products or raw drugs are collected from the wild source. Many of these plant parts cannot be clearly and easily identified especially dried bark, tubers, roots etc. Lerners will be able to properly identify plants and raw pharmaceuticals with the use of these collected from natural forests.

Exercise: Learners will visit the nearby forest areas to collect the plant samples and plant produce or raw material of herbal drugs. Each learners will collect 10–20 samples of plants or plant parts and with proper labeling for identification and demonstration. All the information of collected material will be presented in tabular form in the practical notebook as follows.

S.N.	Botanical Name of Plants	Local/Common Name	Family	Habit	Collection area	Medicinal Uses
1.						
2.						
3.						
4.						
5.						

1.11.2 Practical-02

Objective: To be familiar with the preparation of herbarium specimens of the medicinal plants species.

Aim: The plant species with the medicinal and ethno-medicinal values collected from the field. After that correct identification, naming and to be preserved for longer periods in the herbarium. So, to understand the procedures and methods followed in the process of herbarium preparation from the collection of specimen's upto the process of mounting on the herbarium sheets before storing.

Material Required: Secateurs, Knife, Plant press, Plastic bags, Field book, Hand lens, Herbarium sheets, herbarium press, old news papers, pencil/marker, thread etc.

Exercise: Each student has to collect 10-20 plant species with the medicinal or ethnomedicinal values from your local surrounding area. Prepare the herbarium specimens for each collected species.

S. N.	Botanical Name of Plants	Local/Common Name	Family
1			
2			
3			
4			
5			

1.11.2 Practical-03

Objective: To visit botanical garden or herbal garden or medicinal plant repositories for identification of medicinally important plants with ethnobotanical notes.

Aim: To identify the plants accurately based on their morphological characteristics is essential to understand ethnobotanical plants.

Exercise: Learners will identify the medicinal plants with ethnobotanical notes on the basis of morphological characters. These characters may be their habit, leaf, stem, bark, flower, fruit, seed, odour etc. These characters are not truly on taxonomic basis but unique identification characters for the general understanding and differentiation. Learners will also be familiar with the local uses of these plants. Arrange photographs of important plants with herbarium preparation of these plants.

List the plants you have identified (Place----------; Date----------)

S.N.	Botanical Name of Plants	Local/Common Name	Family	Habit	Major Identification Features
1.					
2.					
3.					
4.					
5.					

1.12 SUMMARY

Plant specimens with medicinal uses must be systematically collected, preserved, and documented for the purpose to build up a herbarium of medicinally significant plants. Plants are carefully collected during their flowering or fruiting stages to ensure correct identification, then pressed and dried using blotting sheets or newspapers to retain their natural form and colour. After that dried specimens are mounted on standard size herbarium sheets and labeled with necessary information such as botanical name, local/common name, family, collection location, date, and indigenous or local medicinal uses. These labeled sheets are then stored in controlled conditions to prevent damage from pests or humidity. This herbarium serves as a very important

reference for botanists and researchers, supporting the study, conservation, and sustainable use of medicinal plant biodiversity.

1.13 SELF-ASSESSMENT QUESTIONS

1.13.1 Questions Based on Knowledge

g) What is a herbarium and what are its main uses?
h) Why is it important to collect plants at the correct stage of growth?
i) Name any five medicinally important plants commonly used in traditional medicine systems.

1.13.2 Skill-Based Questions

f) Describe the step-by-step process for preparing a herbarium specimen.
g) How do you prevent fungal growth or decay during the drying process of specimen?
h) What tools and materials are required for collecting and pressing plant specimens?

1.13.3 Applications and Analysis Based Questions

f) Choose one plant from your local herbal garden or herbarium or herbarium sheet and explain its medicinal uses.
g) What safety measures need to be followed when collecting potentially harmful medicinal plants?
h) How can a herbarium contribute to research in the field of plant based research?

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1.16 TERMINAL QUESTIONS

1.16.1 Short Answer Questions

6. What is a herbarium?
7. What is the standard size of a herbarium sheet?
8. Mention two materials used for pressing plant specimens.
9. Name any five medicinal plant commonly found in your surroundings.
10. Which plant part is used in *Withania somnifera* (Ashwagandha) for medicinal purposes?

1.16.2 Long Answer Questions

4. Describe the complete process of herbarium preparation.
5. Identify the medicinal plant specimen provided and prepare a mock herbarium label with the following details:
    - Botanical name
    - Family
    - Local name
    - Medicinal use
    - Location and date of collection
    - Collector's name
    - Medicinal uses
6. What difficulties did you face when preparing the herbarium, and how did you resolve them?

UNIT-2 MAKE A LIST OF PLANTS USED BY VILLAGERS AND ON THE BASIS OF THEIR LOCAL USE, PLACE THEM IN DIVERSE ETHNIC GROUP

Content

2.1 OBJECTIVES

The main objective of this unit is to study about the tribes of Uttarakhand and uses of medicinal plants used by local people. After going through this unit student will be able to-

- Know about the indigenous uses of plants
- how ethnic group used plants as a medicine

2.2 INTRODUCTION

Himalaya has always been a treasure trove of medicinal phyto-diversity and a source of numerous ethnobotanical features for tribes and ethnic communities. Indigenous people traditionally utilised different kinds of plants as medicines for their well- being. Many of these plants were chosen practically over generations, and the experiment is still in progress. The word indigenous refers to "systems generated by internal initiative within a local community itself."

India has had a rich tribal population since time immemorial, and their traditional knowledge system deals with many important features and health issues of tribal populations. The tribal people are cured using their traditional knowledge and awareness of nature, as well as local practitioners and their own herbal homework. The use of herbal medicines by tribal societies is influenced by diverse socio-cultural practises, religious beliefs, traditional ability support, and traditional medicine men's services. Because they live in remote places, these people have a close relationship with their environment and ecosystem, and they rely on it for primary health care.

Indigenous knowledge is usually considered as informal knowledge exists in local societies as compared to formal knowledge developed by modern universities and research institutions.
Mountain communities in the Himalayan region have depended primarily on natural resources, including biodiversity. Indigenous knowledge on protecting environmental balance in various mountain ecosystems would be extremely valuable for scientists and planners working to enhance conditions for biodiversity conservation in mountain systems.

Ethnic groups who are either native to the area or have moved from other areas of the country but are now living in the Garhwal Himalaya foothills and have their own indigenous health care system. Plant species are used in the health care system in Uttarakhand by local residents and ethnic groups such as the Buksa, Bhotiyas, Jaunsari, Tharu, and Raji tribe.

2.3 MAKE A LIST OF PLANTS USED BY VILLAGERS AND ON THE BASIS OF THEIR LOCAL USE, PLACE THEM IN DIVERSE ETHNIC GROUP

Local people depend primarily on medicinal plants, as they are good sources for resources used in primary health care. People utilise medicinal plants for treating various ailments based on traditional knowledge passed down from generation to generation. There are five major ethnic groups in Uttarakhand state: Bhotia, Jaunsari, Raji, Tharu, and Buksa. Tribal people of this region have different cultures, traditions, dialects, and customs yet rely on the forest for basic necessities like as food, fruits, edible roots, leaves, medicinally essential plants, and so on. Their primary health care system is based on traditional medical knowledge and medicinal herbs. The two main objectives are to study about the medicinal uses of plants. Firstly, indigenous medicinal plant applications by local people or villagers, and secondarily, medicinal plants utilised by the tribal people in Uttarakhand.

2.3.1 Objective: Make a list of some common medicinal plants and study about their morphological description.

Exercise: Students will study the use of ethnomedicinal plants and practice in the villages by common people with the help of literature.

1-*Azadirachta indica* A . Juss.,

Family : Meliaceae
Vernacular name : Neem, Margosa' or 'Indian Lilac'
Plant parts used : Whole parts (flowers, leaves, fruits, bark, gum, seeds)
Description : Neem is a medium-sized tree that grows to a height of 15 to 30 m and has a large circular crown 10-20 m in diameter. It is primarily evergreen, but sheds its leaves during the dry season. Neem has a deep taproot. In older trees, the bark becomes grey, fissured, and flaky. In humid climates, aged trees release a sticky foetid sap. At maturity, the leaves are alternate, petiolated, clustered at the ends of the branches, unequally pinnate, glabrous, and a dark glossy green. Flowers are abundant, fragrant, white, and borne in huge clusters. When unripe, neem fruits are long drupes that are smooth and green with white milky liquid, getting yellow to brown when mature.

Medicinal uses : In joint pain, diabetes, piles, constipation, wound, earache, ringworm, pyarrhoea, eczema, cuts, otorrhoea, fever, boil, blood purifier, dentifrice, hair problem, stomach worms, pimple, itching, louse, increase eye sight, deafness, syphilis, obesity, palate disease.

2- *Bacopa monnieri* (L.) Pennell.,
Synonyms: *Herpestis monnieria* (L.) H.B. and K.

Family : Scrophulariaceae
Vernacular name: Brahmi
Plant parts used: Entire plant
Description: *Bacopa monnieri* is a non-aromatic herb. Leaves of this plant are succulent, oblong, and thick. The leaves are oblanceolate and are arranged oppositely on the stem. Flowers are small, actinomorphic and white, with four to five petals. It can even grow in slightly brackish conditions. Cuttings are commonly used for propagation.
Medicinal uses: In acidity, cough, fever, blood purifier, epilepsy, hoarseness, brain related problem, insanity, cooling effect.

3-*Bambusa arundinacea* Willd.,
Family : Bambusaceae
Vernacular name : Bans
Plant parts used : Stem
Description : It is a tall, bright-green spiny bamboo species that grows in thickets of many densely branched, closely growing culms. It grows naturally in the forests of the arid zones and reaches a height of 10-35 m. Bamboo that is thorny, abrorescent, or shrubby in size.
Medicinal uses: In cough, bone fracture.

4-*Berberis aristata* DC.,
Family : Berberidaceae
Vernacular name : Kingore, Daruhaldi
Plant parts used : Root bark
Description : *Berberis aristata* is an erect spiky shrub that grows to a height of 2 to 3 m (6.6 to 9.8 ft). It is a woody plant with yellow to brown bark on the outside and deep yellow from the inside. The bark is covered with three-branched thorns that are modified leaves and can be removed in longitudinal strips by hand. The leaves are long and broad, grouped in tufts of five to eight. The leaves are simple and pinnately venated. The leaves are serrated and leathery in texture, with many small indentations along the margin of the leaf.
Medicinal uses: In jaundice, diarrhoea, stomachic related problem, conjunctivitis, eye pain, high blood pressure, as tonic.

5-*Boerhavia diffusa Linn.,*
Family : Nyctaginaceae
Vernacular name : Punarrnava or Patharchitta
Plant parts used : All parts of plant
Description : *Boerhavia diffusa* is a annual herbaceous plant. It is a weed that can be found all throughout India. The plant is distinguished by its hairy stems and triangular or lanceolate leaves. The leaves are placed in opposite directions on the stalk and are

covered in small white or light-colored hairs. The plant produces small, five-petaled flowers that are often pink, crimson, or purple in colour. The flowers are followed by small, spherical, brown or black seeds covered within a papery, three-lobed fruit. *Boerhavia diffusa* grows in sunny, dry situations and can tolerate a wide range of soil conditions. It commonly occurs in disturbed soils, such as along roadsides and in abandoned fields.

Medicianl uses: In bleeding piles, flatulence, jaundice, catarract, dog bite, boil, stone problem, gonorrhoea, stomachic related problem, ophthalmia, watering in eyes, nightblindness, swelling of hand and feet, high blood pressure, urine suppression, easy delivery.

***6-Calotropis procera* (Aiton) Drya.A.f.,**

Family : Asclepiadaceae

Vernacular name : Aak

Plant parts used : Whole

Description : *Calotropis procera*, generally referred to as small crownflower or huge milkweed, is a milkweed. It is an erect shrub or small tree that grows 2-6 m tall. It is a big shrub with waxy stems and leaves that produce milky sap. It has a 3-4 m deep taproot and a secondary root system with woody lateral roots that can quickly generate adventitious shoots when the plant is injured. Its naturally large greyish-green leaves borne in pairs and are stem-clasping. Its flowers have five petals that are white with purplish-coloured tips and a purplish crown-like centre. Its fruit is a large (8-12 cm long) bladdery 'pod' that is greyish-green in colour. When mature, this fruit splits apart to release multiple seeds, each topped with a tuft of long, white, silky hairs.

Medicinal uses: In mouth bubbles, headache, earache, cough, toothache, asthma, dog bite, scorpion sting, boil, whooping cough, ulcer, leucoderma, black spot of face, as tonic.

7- *Carica papaya* Linn.,

Family : Caricaceae

Vernacular name : Papita

Plant parts used : Milky juice of fruit

Description : Carica papaya is an evergreen, tree-like herb that grows 2-10 m tall, is normally unbranched but can become branched because of injury, and contains white latex in all parts. Stem is hollow, cylindrical, and 10-30 cm in diameter, with visible leaf scars and spongy-fibrous tissue. Has a large rooting system. Leaves are spirally arranged and clustered near the trunk's tip. Flowers are produced along the trunk from the leaf axil and are tiny, golden, funnel-shaped, solitary or grouped. Fruit develops in the leaf axil towards the trunk. Seeds are many, tiny, black, and spherical, with a gelatinous aril covering them. Small latex vessels extend throughout the tree and are especially abundant in fruit that has grown to full size but has not yet begun to ripen.

Medicinal uses : In arthritis, piles, constipation, mouth bubbles, jaundice, acidity, ringworm, eczema, catarract, asthma, scorpion sting, tuberculosis, throat infection, stone problem, dyspepsia, insect bite, swelling of hand and feet, appetizer, unconsciousness.

8-*Citrus aurantifolia* (Christmann) Swingle,

Family : Rutaceae
Vernacular name : Kagzi nimbu
Plant parts used : Fruit, peel and juice
Description : *Citrus aurantifolia* is a small perennial evergreen shrubby tree in the Rutaceae family known for its sour fruit. Lime trees can grow to be 5m (16 ft) tall. The lime tree has sharp spines and is unevenly branching. The tree's leaves are elliptical in shape, with small rounded teeth around the edges. The leaves can grow to be 4-8 cm long. The tree bears small, cupped white flowers and spherical or egg-shaped yellowish-green fruit. It can produce fruit for many years.

Medicinal uses: In lumbago, dysentery, constipation, headache, vomiting, flatulence, migrain, earache, cough, colic pain, dentifrice, insect bite, eye sty, epistaxis, heart related problem, giddiness, insomnia, external allergy, obesity.

9- *Coriandrum sativum* Linn.,

Family : Apiaceae
Vernacular name : Dhaniya
Plant parts used : Seed and leaves
Description : Coriander is a small annual herb that grows to about 50 cm in height, is branched, and fragrant. The leaves vary in shape, being widely lobed near the plant's base and slender and feathery higher up the flowering stems. The flowers are borne in small umbels that are white or very pale pink in colour, and are asymmetrical, with the petals pointing away from the centre of the umbel being longer than those pointing towards it. The fruit is a spherical, dry schizocarp with a diameter of 3-5 mm.

Medicinal uses: In rheumatism, vomiting, flatulence, gonorrhoea, cold, swelling of hand and feet, deafness, hidden injury.

10-*Curcuma domestica* Valeton,

Synonyms : *Curcuma longa* Linn.,
Family : Zingiberaceae
Vernacular name : Haldi or Kanchini
Plant parts used : Root
Description : Turmeric is a rhizomatous herb that grows underground. The shrub can reach a height of 3-5 feet and has little yellow flowers that produce seeds. It has oblong, pointed leaves and funnel-shaped yellow flowers that grow from big bracts. Primary rhizomes are ovate or pear-shaped, oblong, pyriform, or cylindrical, usually short-

branched. Turmeric rhizomes are referred to as 'bulb' or 'round' turmeric. Turmeric roots contain a substance called curcumin, which gives them their yellow colour.

Medicinal uses: In wound, leucorrhoea, ringworm, pyarrhoea, toothache, cataract, cuts, otorrhoea, itching, cancer, hidden injury, urinary trouble.

11-*Ficus benghalensis* Linn.,

Family : Moraceae

Vernacular name : Bar

Plant parts used : Aerial roots, leaves, buds, fruits and latex

Description : It is an evergreen tree with a radius of 15-35 metres and a height of 15-35 metres. Aerial roots are seen hanging from the tree and provide support to the branches when they touch the ground. The tree bark is thick and oval, measuring 4-6 inches long. The leaves are 10-20 cm long and there are numerous aerial roots. The plant's leaves are large, oval, and glossy. If the leaves are broken, a white milky fluid pours out. The fruits are spongy, round, and red. The male and female flowers are surrounded by axillary, sessile, red fruits. In the summer, new delicate buds appear alongside the fruits.

Medicinal uses: In diabetes, bleeding piles, wound, cough, toothache, cataract, burn, fever, cholera, dentifrice, pimple, goiter, giddiness, urine suppression, unconciousness, black spots on face.

12-*Ficus religiosa* Linn.,

Family : Moraceae

Vernacular name : Peepal

Plant parts used : Bark, shoot, Leaves and Fruit.

Description : *Ficus religiosa* is a 20-meter-tall, irregularly-shaped evergreen or deciduous tree with wide-spreading branches and no aerial roots from the branches. It's an epiphytic plant. The trunk has a regular shape and is often covered with low buttresses. The bark is smooth and greyish with brownish flecks, flaking in irregular spherical flakes. Leaves are alternate, spirally arranged, and broadly oval, glossy, coriaceous (leathery), dark green leaves with unique tail-like tips that are pink when young. Petiole is long and thin. Galls on the leaves. Flowers are axillary sessile and unisexual. Figs in pairs, round, flat-topped green, axillary, sessile, smooth, maturing to purple with red spots.

Medicinal uses : In rheumatism, mouth bubbles**,** wound, headache, vomiting, jaundice, earache, cough, asthma, stomach ache, burns, otorrhoea, fever, dentifrice, gonorrhoea, debility, cold, cramp, deafness, epistaxis, heart related problem, hiccup, chilblain.

13-*Ocimum tenuiflorum* Linn.,

Family : Lamiaceae

Vernacular name : Tulsi

Plant parts used : Whole plant

Description : Holy basil is an erect, tiny annual or short-lived perennial shrub that grows up to 1 metre (3.3 feet) tall. The stems are hairy and have simple toothed or whole leaves oppositely along the stem. The leaves are green or purple, simple, petioled, and have an ovate blade. Depending on the type, the fragrant leaves are green or purple. The small purple or white tubular flowers are borne in terminal spikes and have green or purple sepals. The fruits are nutlets with many seeds.

Medicinal uses : In gout, constipation, vomiting, flatulence, jaundice, earache, ringworm, snake bite, cough, toothache, asthma, apepsy, colic pain, fever, scorpion sting, malaria, stone problem, stomach worms, cold, insect bite, bowel complaints, liver problem, urine suppression, stress, hiccup, teething of a child, rib pain, small-pox, ear swelling, cholestrol.

14-*Phyllanthus emblica* Linn.,

Synonyms : *Emblica officinalis* Gaertn

Family : Euphorbiaceae

Vernacular name : Amla

Plant parts used : Fruit

Description : Amla is commonly referred to as an Indian Gooseberry. The deciduous plant is small to medium in size. It can grow to a height of 8-18 m. It has a crooked trunk and branches that extend out. The leaves are simple, subsessile, and densely set along branchlets; they are light green, resembling pinnate leaves, and have a lemony fragrance. The flowers are greenish-yellow in colour. The fruit is almost spherical, pale greenish-yellow in colour, appears smooth and solid. Its wood has a rough texture. When exposed to direct sunlight or extreme heat, it wraps and splits.

Medicinal use: In knee pain, piles, constipation, wound, flatulence, pyarrhoea, cough, burn, stomachic related problem, cold, eye pain, stammering, babbling, epistaxis, heart related problem.

15-*Raphanus sativus* Linn.,

Family : Brassicaceae

Vernacular name : Muli

Plant parts used : Root and leaves

Description : Radishes are annual or biennial crops that grow flowering stems up to 50 cm tall, as well as a tall herb. Grown for their globular, tapering, or cylindrical swelling tap roots. The colour of the root skin varies from white to pink, red, purple, yellow, and green, and finally black, although the flesh is usually white. Anthocyanins give the roots their colour. The basal leaves can grow to be up to 7" long, with round roots up to 2.5 cm in diameter or more slender, long roots up to 7 cm in length. The leaves are arranged in a rosette pattern. The upper and central stems end in floral racemes. The blooming season occurs during the summer and lasts around 1-12 months. Each flower is replaced by a silique, which contains 2-3 seeds.

The seeds are oval in shape, somewhat flattened, and reddish brown. The fruits are tiny pods that are edible when young.

Medicinal uses: In jaundice, earache, cough, scorpion sting, stone problem, itching, insect bite, brain related problem.

16- *Ricinus communis* Linn.,

Family : Euphorbiaceae

Vernacular name : Arand

Plant parts used : seed

Description : The castor plant is a 5.5m tall glabrous evergreen shrub or small tree cultivated in tropical and temperate regions for its seeds which is rich in oil. It has deep tap roots and large lateral roots. The stem and branches contain prominent nodes, ring-like scars, and glands that commonly appear at nodes. The shoots are generally glaucous, green, or red. The leaves are borne on petioles and are spirally arranged. The inflorescence is a 40 cm long erect terminal panicle that becomes lateral as the plants grow new branches. The flowers are unisexual and regular. The fruits are spiny or smooth, ellipsoid to globose, and brown in colour. The seeds are compressed and ellipsoid, with a brittle, mottled, shiny seedcoat and a distinct caruncle at the base.

Medicinal uses: In arthritis, knee pain, rheumatic swelling, wounds, headache, eczema, burn, boil, stomach worms, black spots of face.

17- *Syzygium cumini* (Linn.) Skeels.

Family : Myrtaceae

Vernacular name : Jamun

Plant parts used : Bark and fruit

Description : Jambolan, also known as Java Plum, is a medium-sized tropical evergreen deciduous tree that grows to a height of 10-30 m. The bark is hard and dark grey at the base of the tree, becoming lighter grey and smoother higher up. The smooth, opposite, shiny, leathery, and round leaves have a turpentine-like smell. The flowers are fragrant and tiny, pink or almost white in colour. *Syzygium cumini* trees flower from March to April. When ripe, the fruits are oval and green to black, with dark purple flesh. It has a big seed. The fruits appear in May or June and resemble big berries; the fruit of Syzygium species is described as "drupaceous."

Medicinal uses: In diabetes, dysentry, vomiting, leucorrhoea, pyarrhoea, catarract, burn, otorrhoea, dentifrice, diarrhoea, stomachic related problem, liver problem, polyeuria, problem of nervous system, naval dislocation.

18-*Tinospora cordifolia* (Willd) Hook.f. and Thomson,

Family : Menispermaceae
Vernacular name : Giloy
Plant parts used : Entire plant
Description : It is a large, deciduous, widely spread, gregarious glabrous climbing vine with multiple elongated twining branches. The leaves are simple, alternating, and exstipulate, with long roundish and pulvinate petioles. Heart-leaved moonseed gets its name from its heart-shaped leaves and reddish fruit. Flowers are unisexual, small and occur when the plant is leafless, and are greenish-yellow on axillary and terminal racemes. The fruit is an ovoid, succulent drupe with a single seed that is glossy and red in colour. The seed is fleshy and curved. Flowering occurs in May-June, with fruits occurring in September-October.
Medicinal uses: In fever, rheumatism, gonorrhoea, cough, malaria, stomachic related problem, debility, appetizer, cooling effect.

19-*Trigonella foenum-graecum* Linn.,
Family Fabaceae
Vernacular name : Methi
Plant parts used : Seed
Description : Fenugreek is an aromatic herb that grows as an annual plant. It is an erect, smooth, herbaceous plant that can grow to be 40-80 cm tall. It has tap roots. Its stems are erect, up to 50 cm tall, and occasionally branched. The leaves are light green in colour, alternating, compound and trifoliolate. The leaflets are oval in shape and up to 5 cm long, with a hairy lower face. The flowers are papillonaceous, white, lemon-yellow, or purplish blue in colour, and are borne in leaf axils. The fruits are straight or sickle-like pods, long, thin, and pointed, with 10-20 seeds. The seeds are long, oblong or square in shape, green-olive or brownish in colour, and have a strong and spicy the aroma.
Medicinal uses: In rheumatism, arthritis, asthma, fever, stomach worms, cold, bowel complaints, heart related problem, polyeuria.

20- *Zingiber officinale* Roscoe.,
Family : Zingiberaceae
Vernacular name : Saunth or Adarak
Plant parts used : Rhizome
Description : Ginger is a flowering plant with tuberous rhizome. It is a herbaceous perennial which grows annual pseudostems (false stems constructed of the rolled bases of leaves) which rises two or three feet in height, bearing narrow leaf blades. The leaves are 15 to 30 cm long, elongate, alternate in two vertical rows, and grow from sheaths that enwrap the stem. The inflorescences have flowers with pale yellow petals and purple margins that grow directly from the rhizome on separate branches. The fruits are red, three-part capsules bearing small black seeds.

Medicinal uses: In rheumatism, dysentry, headache, flatulence, earache, toothache, colic pain, cold, hoarseness, hiccup, and appetizer.

2.3.2 MEDICINAL PLANTS USED BY TRIBES OF THE UTTARAKHAND

Medicinal plants and methods for using them vary from community to community depending on the tribal community's location and the availability of medicinal plants in the surrounding area. The five major tribes of Uttarakhand are the Tharus, Jaunsaris, Buksas, Bhotiyas, and Rajis.

Objective: To study about the indigenous uses of plants by the tribes of Uttarakhand.

Exercise: Study about the use of ethnomedicinal plants by the tribes of Uttarakhand with the help of literature. Make a list of ethnobotanical plants, their uses, and the ethnic groups linked with particular practice.

1-THARU TRIBE: The Tharu tribe is indigenous to the tarai region of India and Nepal. Tharus reside in India from Uttarakhand to northwestern UP and the Bihar region. The majority of Tharus are forest dwellers who depend on the forest for their daily needs. The Tharu tribe is Uttarakhand's largest primitive tribe, living interiorly in the forest and maintaining a close bond with their surroundings. Agriculture is the main occupation of the Tharu people. They usually live in tarai region of Uttarakhand.

Table 2.1: Plants used by Tharu Tribe for indigenous medicinal uses with their botanical name, local name and diseases

FAMILY	BOTANICAL NAME	LOCAL NAME	DISEASE CURED	PU
Euphorbiaccae	*Acalypha indica* L.	Kuphi	Ear Problem	LF
Amaranthaceae	*Achyranthes aspera* L	Chattisa/Chircita	Boils	LF,RT
Rutaeae	*Aegle marmelos* (L.) Corea	Bel	Cholera	FR
Mimosaceae	*Albizia lebbeck* (L.) Benth	Siris	Boils	LF
Lilaceae	*Allium sativum* L.	Lehsun	Diarrhoea	BU
Apocynaceae	*Alstonia scholaris* (L.) R.Br	Chitwan	Cholera	BRK
Lamiaceae	*Anisomeles indica* (L.) Kuntze	Basingo	Gastric complaints	LF
Annonaceae	*Annona squamosa* L.	Sitaphal	Boils	LF
Papaveraceae	*Argemone maxicana* L.	Pili kantiya	Digestive disorder	SD
Euphorbiaccae	*Balioselia retusa (permum momnatum* (Willd) Mull-Arg	Danti/Vanchura	Asthama	LF

Acanthaceae	*Barleria prionitis* L.	Pila bansa	Skin ailment	LF
Basellaceae	*Basella rubra* L.	Poy	Cold and cough	LF
Bombacaceae	*Bombax ceiba* L.	Semal	Burns	RT
Euphorbiaccae	*Bridelia retusa* (L.) Sprengel	Khaja	Abdominal pain	RT
Euphorbiaccae	*Bryophyllum pinnatum* (Lam) Oxen	Patharchut	Headache	LF
Asteraceae	*Caesulia axillaris* Roxb	Gorghanta	Cuts	FLW
Fabaceae	*Cajanus cajan* (L.) Huth	Arhar	Cholera	LF
Asclepidiaceae	*Calotropis procera* (L.) Dryander	Aankha	Boils	LF,FLW
Cannabinaceae	*Cannabis sativa L.*	Bhang	Dysentery	LF
Caesalpiniaceae	*Cassia tora* L.	Kasonji	Cold and Cough	LF
Menispermaceae	*Cissampelos pareira* L.	Madrachi	Bodyache	LF
Verbenaceae	*Clerodendrum viscosum* Ventenat	Bhatar	Cuts	LF
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	Kanduri	Cholera	LF
Cucurbitaceae	*Cucumis sativus* L.	Kheera	Fever	LF

Abbreviation: Lf-leaf, RT-root, FRT-fruit, BRK-bark, SD-seed, FLW- flower, PU-parts used. (**Source:** Sharma *et al* 2011, "Medicinal plant used for primary health care by Tharu tribe of Udham singh nagar"; international journal Med. Arom. Plants.)

2-BHOTIA TRIBE: The Bhotiya live primarily in Kumaon and Garhwal regions of the Uttarakhand state. They tend to reside in the river valleys of Uttarakhand. They are known by multiple names, including Shauka, Johaari, Daarmi, Tolcha, Marchha, and Jaad. They generally prefer to reside in river valleys where they can engage in some agricultural practices and conduct trade through the crossings formed by these rivers. They are the most advanced tribal society in Uttarakhand. Because of weather conditions and trade requirements, Bhotiyas live a semi-nomadic life.

Table 2.2: Plants used by Bhotia Tribe for indigenous medicinal uses with their botanical name, local name and diseases

BOTANICAL NAME	**LOCAL NAME**	**FAMILY**	**USES**
Aconitum heterophyllum Wall.	Atees	Ranunculaceae	Half tablespoon ground dry root is taken with boiled water during fever.

			Root is also chewed and sucked twice a day to control abdominal pain and vomiting.
Acorus calamus L.	Gurbach	Araceae	Dry root boiled with mustard oil is applied on the sprain region
Allium cepa L.	Piyaj	Liliaceae	Water extract of crushed/ground onion is given to control vomiting
Allium sativum L.	Lehsun	Liliaceae	Till (*Sesamum indicum L)* oil heated with spilled bulbs of garlic after cooling is poured in to the ear to reduce earache.
Allium stracheyi Baker.	Jambu	Liliaceae	A clean cloth dipped into leaf decoction is applied on wound
Brassica campestris L.	Sarsoun	Brassicaceae	Hot mustard oil is applied on the burns
Bergenia ligulata (Wall) Engl.	Pashanbhed	Saxifragaceae	Dry rhizome is chewed to remove kidney stone
Capsium annum L.	Mirch	Solanaceae	Paste is applied on the part of the body bitten by dog.
Carum carvi L.	Thoya or kala jeera	Apiaceae	Fried powdered seeds are taken with boiled water to relieve from indigestion.
Morus alba L.	Shahtoot	Moraceae	Fruit juice is taken against cough and cold.
Myristica fragrans Houtt.	Jayphal	Myristicaceae	Fruit paste is applied on neck or chest to get relief from cough.
Psidium guajava L.	Amrood	Myrtaceae	Leaves are chewed to get relief from blisters in mouth.
Punica granatum L.	Anar	Lythraceae	Leaves are boiled in half litre of water with ten rose leaves till the extract is reduced to half of its volume. Filtered extract with some butter is given for curing epilepsy / hysteria.
Rosa sp.	Gulab	Rosaceae	Leaf paste is applied on boils and ulcers. Juice extracted from leaves of red rose is taken against urine infection of children.
Saussurea obvallata Wall.	Brahmakamal	Asteraceae	Seed oil is applied on the head twice a day as a remedy for headache and mental problems. Flower is also cooked with taga misri and taken against urine tracts infection.

(Source: Prasanna k Samal ,*et al* 2010, "Indigenous medical practices of Bhotia tribal community in Indian central Himalaya", Indian Journal of Traditional Knowledge Pp,140-144)

3-Jaunsari Tribe: The Jaunsaris are Uttarakhand's second largest ethnic community. They have spread among over 365 villages. This area is also known as Jaunsar-Bawar. It is located in remote mountain regions of the Dehradun district. They speak Jaunsari, a dialect of Western Pahari. The Jaunsaris economy is entirely dependent on agriculture and other industries like as animal husbandry. With the advancement of education, more people are finding work in government and non-government organisations.

Table 2.3: Plants used by Jaunsari Tribe for indigenous medicinal uses with their botanical name, local name, parts used and diseases

BOTANICAL NAME	FAMILY	VERNACULAR NAME	AILMENTS	PARTS USED
Abrus precatorius Linn.	Fabaceae	Ratti	Fever, asthma, chest pain, tuberculosis.	Leaf, seed and root decoction.
Aconitum atrox (Buehl) Mukherjee	Ranunculaceae	Meetha Bish	Rheumatism, neuralgia, paralysis, puerperal fever	Rhizome paste fried in *Ghee* is externally used.
Aegle marmelos Correa	Rutaceae	Bel	Diarrhoea	Leaf paste and fruit decoction.
Anemone polyanthes D Don	Ranunculaceae	Ratanjot	Food poisoning.	Seed decoction.
Berberis chitria Lindl.	Berberidaceae	Kingore/Chotar	Jaundice, eye disorders (ophthalmia).	Fruit, bark and root.
Bergenia ciliata (Haw.) Sternb.	Saxifragaceae	Silphara	Kidney stone, Sores, Swellings	Root decoction, Leaf
Centella asiatica (L.) Urban	Apiaceae	Brahmi	Mental disorder, skin disease, blood purifier, diuretic.	Plant extract, leaf paste.
Emblica officinalis Gaertn.	Euphorbiaceae	Amla	Stomach problem.	Fruit extract.
Evolvulus alsinoides L.	Convolvulaceae	Sankhpushpi	Cough,cold, asthma, bronchitis.	Plant and flower extracts.
Nardostachys jatamansi DC.	Valerianaceae	Jatamasi	Epilepsy, Hysteria.	Rhizome.
Rauvolfia	Apocynaceae	Sarpgandha	Fever, anxiety,	Roots.

serpentina Benth.			epilepsy, intestinal & nervous disorders.	
Syzygium cumini (L.) Skeels	Myrtaceae	Jamun	Diabetes.	Fruit and bark.
Terminalia bellirica Roxb.	Combretaceae	Bahera	Stomach problem.	Fruit extract.
Withania somnifera Dunal	Solanaceae	Ashwagandha	Urinary disorders, fever, Insomnia.	Leaf juice Root powder.
Zanthoxylum armatum DC.	Rutaceae	Timru	Toothache, Tooth decay.	Fruit-powder, Stem bark.

(Source: G.C.S. Negi et al,"Ethnomedicinal plant resources of Jaunasri tribeof Garhwal Himalaya, Uttranchal, Indian Journal of Traditional Knowledege , July 2006)

4- RAJI TRIBE: The Raji are Uttarakhand's smallest tribal community. They are concentrated around Ascot in southern Pithoragarh. The Rajis are also known as Vanrawats or Ban Rajis. Raji tribals live in the dense and remote forest of this region. They rely on forest goods for their survival. Long ago, their main source of income was hunting wild beasts and storing forest items. Their traditional occupation, however, was the making of wooden vessels. They are on the edge of extinction.

Table 2.4: Plants used by Raji Tribe for indigenous medicinal uses with their botanical name, local name, parts used and diseases

BOTANICAL NAME	FAMILY	VERNACULAR NAME	AILMENTS	PARTS USED
Adhatoda vasica Nees (*Justicia adhatoda* L.)	Acanthaceae	Vasa	common cold and bronchitis	Decoction of flowers and leaves is given
Barleria cristata L.	Acanthaceae	Kala-bansa	dermatitis	Leaf paste
Dicliptera bupleuroides Nees	Acanthaceae	Kuthi	dysentery	Seeds or whole plant decoction is useful
Achyranthes bidentata Blume	Achyranthacea e	Apamarga	mouth blisters	Root paste
Rhus parviflora Roxb.	Anacardiaceae	Samak Dana	Cholera and Stomachache.	Decoction of bark and leaves is given at short period of intervals
Acorus calamus L.	Araceae	Vach	cough, fever, coryza	Leaves and flower decoction juice is given

Arisaema flavum (Forssk.) Schott	Araceae	Bang	Antidote	Wounds are washed with decoction of rhizomes. Rhizome paste with water is applied on body part stung by snake or scorpion
Calotropis procera (Aiton) R. Br.	Asclepidaceae	Aak	Migraine, Abortifacient	Powder of dried leaves, whole plant
Asparagus adscendens Roxb	Asparagaceae	Kairuwa	Ophthalmic disease	To cure redness in eyes, root is crushed slightly and used as eye pencil thrice a day
Artemisia nilagirica (C.B. Clarke) Pamp.	Asteraceae	Pati	intestinal worm	Freshly and washed roots/leaf are dipped overnight in cold water and taken orally for 5-6 days before meal
Bidens bipinnata L.	Asteraceae	Arka-jhar	itching feet	Leaves crushed and juice rubbed on itching feet during rainy season
Taraxacum officinale Weber.	Asteraceae	Dudhi	Blisters	Decoction of inflorescence is taken orally to cure
Berberis aristata DC.	Berberiadaceae	Kilmora	redness and infection in eyes	Root juice mixed with water is dropped in eyes
Bombex cieba L.	Bombacaceae	Semal	Fractured Bone	Poultice made through bark is plastered on fractured bones
Cynoglossum zeylanicum (Vahl ex Hornem.) Thunb. ex Lehm.	Boraginaceae	Chitkuri	Wounds	Whole plant is grounded and make into paste to heal
Bauhinia vahlii Wight and Arnott	Caesalpiniaceae	Malu	Skin irruption	Stem bark is pasted and applied
Cassia fistula L.	Caesalpiniaceae	Amaltas	stomachache due to worms	Fresh stem bark is warmed on gentle

				fire and juice extracted from it is given
Mesua ferrea L.	Clusiaceae	Nagkesar	Antidote Sores, wounds and Rheumatism	Root paste is given orally as antidote against Snake bite. The seed oil is considered for healing purpose
Dioscorea bulbifera L.	Dioscoreaceae	Gethi	cough	Tubers are roasted in hot ash and given with salt
Euphorbia hirta L.	Euphorbiaceae	Dudhi	toothache	Latex of plant is dropped on the root of tooth
Gossypium arboreum L.	Malvaceae	Kapas	fractured bone	Seeds are pasted and applied for bone setting
Ficus palmata Forssk.	Moraceae	Beru	boils, cuts and wounds	Milky Latex is applied
Ficus religiosa L.	Moraceae	Peepal	cuts, wounds and skin diseases	Bark grounded with turmeric powder is applied externally
Boerhaavia diffusa var. *hirsuta* Kuntze		Punernava	cataract problem	Leaf juice of plant mixed with goat's milk is dropped in eyes
Cynodon dactylon (L.) Pers.	Poaceae	Doob	nasal bleeding	Entire above ground parts are crushed with water. Two to three drops of this extract are poured in the nostril
Rubia cordifolia L.	Rubiaceae	Manjith	acne and dark spots on face	Whole plant pulp rubbed with honey
Zanthoxylum armatum DC.	Rutaceae	Timoor	bad breath and pyorrhea	Stem twig is used to brush the teeth
Solanum nigrum L.	Solanaceae	Gewain, Makoi	Fever and Jaundice	Juice of whole plant is administrated orally
Vitex negundo L.	Verbenaceae	Nirgundi	Syphilis	Leaves are pounded with rice and water made into a syrup, given to patient

(Source: Bhatt et al., "Indigenous uses of medicinal plants by the Vanraji tribes of Kumaun Himalaya", India Journal of Medicinal Plant Research, Oct, 2013)

5-BUKSA TRIBE: Buksa, also known as Bhoksa, are located in the Kumaon division, with the majority of the people residing in Nainital district in the Ramnagar to Dineshpur strip, with some also residing in Kotdwar-bhabar of Pauri Garhwal. However, the majority of Boksa live in the Western Terai region, primarily in Gadarpur, Bajpur, Kashipur, and Ramnagar. Their economy depends mainly on agriculture. Other from that, they work as labourers and rely on forest products.

TABLE 2.5: Plants used by Buksha Tribe for indigenous medicinal uses with their botanical name, local name, parts used and diseases

BOTANICAL NAME	FAMILY	VERNACULAR NAME	AILMENTS	PARTS USED
Cassia fistula Linn.,	Caesalpiniaceae	Amaltas	Constipation	fruit pulp
Pinus roxburghii Sargent	Pinaceae	Chir	Rheumatism	seed oil
Justicia adhatoda L.,	Acanthaceae	Kala bansha	Cough	root and leaves
Lycium barbarum Linn.,	Solanaceae	Charchita	Asthma	whole plant
Leucas cephalotes (Roth.)Sprengel,	Lamiaceae	Guma	Toothache	flower
Carica papaya Linn.,	Caricaceae	Papita	Scorpion sting	latex
Ficus religiosa Linn.,	Moraceae	Peepal	Debility	fruit
Cuscuta reflexa Roxb.,	Convolvulaceae	Aakashbel	Epistaxis (Bleeding from nose)	creeper
Butea monosperma (Lam.)Kuntze,	Fabaceae	Dhak	Urine suppression (Anuria)	flower
Michelia champaca L.,	Magnoliaceae	Champa	Fever	Stem and bark powder
Lannea coromandelica A.Rich.,	Anacardiaceae	Jhigan	Sprain	leaves paste
Colocasia esculenta (Linn.)Schott	Araceae	Ghuiya	Constipation	corm juice
Grewia optiva	Tiliaceae	Bhiunl	Hair problems	stem bark

J.R.Drummond ex Burret.,				
Rhododendron arboreum Smith.,	Ericaceae	Burans	Jaundice	fresh juice flower
Pyrus communis Linn	Rosaceae	Nashpati	Whooping cough	roasted seed powder
Litchi chinensis Lam.,	Sapindaceae	Litchi	Insect bite	seed paste
Ficus hispida Linn.f.,	Moraceae	Katumbar or Ghogsa	Leprosy	leaf paste and latex

(Source: Thesis)

2.4- SUMMARY

Ethnobotany is a part of ethnobiology that studies the past and present interactions between human civilizations and the plants, animals, and other species in their environment. After significant studies, we now know that ethnobotany is an emerging area. Because of its broad scope, it is an informative area of study that has increased the interest of botanists, chemists, socialists, and others. With the support of ethnobotanical studies, it is now possible to conserve and sustain biodiversity and indigenous culture. In this unit, we discussed indigenous plant applications and compiled a list of several common medicinal plants, describing their morphology, ethnomedicinal plant use, and practice in the villages by common people. The indigenous applications of plants by the tribes of Uttarakhand, primarily the Raji, Tharu, Jaunsari, Boksha, and Bhotiyas, were also discussed.

2.5- GLOSSARY

Purgative: an agent that causes evacuation of bowels.
Sedative: soothes or allays irritability
Vermifuge: A drug which kills or causes explusion of intestinal worms
Epistaxis: It refers to minor bleeding from the blood vessels of the nose. Epistaxis is defined as nose bleeding in general.
Blister: A blister is a painful skin ailment in which fluid fills a gap between skin layers.

2.6- REFERENCES

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2.7-SUGGESTED READINGS

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- Ethnobotany by Vinay Sharma & Afroz Alam published by Rastogi publication, Meerut
- Compendium of Indian Folk Medicine and Ethnobotany Vartika Jain and S K Jain, 2016. Deep Publications, New Delhi, India.

2.8-TERMINAL QUESTIONS

1-What is the occupation of Buksha?
2-What Tharu do for their livelihood?
3-Discuss any five medicinal plants mentioned in your syllabus.
4- Discuss in brief about the Raj tribe.
5- Write a short note on Jaunsari tribe and mention any five plants which are used by jaunsari tribe for medicinal purposes.

UNIT-3- ECONOMIC POTENTIAL OF PHYTOMEDICINE AND ITS ROLE IN MODERN MEDICAL SYSTEM

Contents:

3.1 OBJECTIVES

After reading this topic, learners will be able to answer the:

- What is phytomedicines?
- Explain the potential of phytomedicine,
- Define the role of phytomedicine in modern medical system,
- Discuss the importance of phytomedicinal plants and their secondary metabolites

3.2 INTRODUCTION

The term "phytomedicines" refers to the use of crude drugs, an essential oil, an extract, or a part of it for therapeutic uses and quite often complex mixtures of compounds that generally occur in low (variable) concentrations. They are products that contain plant metabolites as their pharmacologically active compounds. The most widely used phytomedicines are made from plant extracts that have been extracted from dried plants using solvents, maceration, or percolation. The extracts also can be utilised as powdered or liquid formulations. Water and alcohol are the two solvents that are frequently used for extraction. In some cases, fractions that are formed via partitioning with liquids of increasing polarity and often contain higher concentrations of the active principles are used.

In India around 20,000 medicinal plant species have been recorded recently but more than 500 traditional communities use about 800 plant species for curing different diseases (Kamboj, 2000). Because plant-derived medication has no side effects, it is currently the first line of primary healthcare for 80% of the world's population. About 25% of pharmaceutical prescriptions in the United States currently contain at least one chemical derived from plants, making plants significant suppliers of medication. On the basis of traditional knowledge gathered from various sources, around 121 medicinal products were developed in the last century.

Therefore, phytomedicine or herbal medicine also known as phytotherapy, is a branch of alternative medicine that uses plant-based materials, such as herbs, plant parts (leaves, roots, flowers, bark etc.), and plant extracts, for therapeutic purposes. It has been practiced for centuries in various cultures around the world and continues to be used today as a complementary or alternative approach to conventional medicine. The active compounds found in plants, such as alkaloids, flavonoids, and terpenes, can have pharmacological effects on the human body. These natural compounds are used to create herbal remedies, teas, tinctures, capsules, and other forms of plant-based medicines.

Some examples of phytomedicine include:

Echinacea: A herb used to treat respiratory infections and improve the immune system.

Ginseng: It is thought to increase energy, enhance cognitive function, and lessen stress.

St. John's Wort: Used as a herbal treatment for mild to moderate depression and anxiety.

Aloe vera: Applied to treat skin diseases including burns and sores.

Turmeric: Known for its anti-inflammatory and antioxidant properties, it is frequently used to treat joint pain and other inflammatory diseases.

Chamomile: A peaceful and soothing substance that is frequently ingested as a tea to encourage relaxation and aid in sleep.

The use of phytomedicine should be done with caution and under the supervision of a trained healthcare professional, despite the fact that it can be useful for some medical disorders. Herbal medicines' effectiveness and safety might differ greatly, and there may be interactions with prescription drugs or potential side effects. To learn more about the effectiveness and safety of different herbal remedies, scientific study is also being conducted. Always get medical advice before beginning a new treatment plan, especially if you have underlying health issues or are using other medications.

Numerous procedures and therapies are included in phytomedicine, such as:

Aromatherapy: The application of plant-based essential oils for therapeutic purposes such pain reduction, stress release, and relaxation.

Dietary Supplements: Herbal supplements, which come in a variety of forms, are frequently used to enhance overall health or treat particular health issues.

Herbal Remedies or Plant-Based Remedies: The use of particular plants or plant parts such as leaves, roots, petals, etc. to cure a variety of medical ailments. These treatments are available in a variety of preparations, such as teas, tinctures, pills, and topical applications.

Holistic Approach: Phytomedicine often takes a holistic approach to health, taking into account not only the specific symptoms but also the overall well-being of the individual. Along with herbal remedies, it may also include nutritional and lifestyle recommendations.

Naturopathy: Naturopathic practitioners often included herbal medicine into their treatment strategy, alongside other natural therapies.

Natural Compounds: Various natural substances with potential therapeutic qualities can be found in plants such as alkaloids, flavonoids, terpenes, and phenolic compounds. These compounds can have various biological effects on the human body.

Potential Benefits and Risks: Phytomedicine have a wide range of potential health benefits, from managing minor ailments to supporting the treatment of chronic diseases. However, like any form of medicine, there can be risks and side effects associated with the use of herbal remedies, and it's important to consult with a qualified healthcare professional before using them, especially in conjunction with other medications.

Traditional Medicine Systems: Many traditional medical systems, such as Traditional Chinese Medicine (TCM) and Ayurveda, heavily rely on herbal medicines as part of their treatment protocols.

Scientific Validation: In recent years, there has been increasing interest in scientifically evaluating the safety and efficacy of plant-based remedies. Some herbal treatments have been found to have pharmacological effects and are used alongside conventional medicine.

Scientific Research: Scientific studies have been done on a few plant-based medicines to determine their safety and efficacy. As a result, standardised and regulated herbal supplements and medications have been created in various nations.

Traditional Knowledge: Numerous civilizations have created their own traditional plant-based medical systems based on the usage of plants that are readily available in their area. In many cases, these systems rely on accumulated information that has been passed down through the centuries.

It's crucial to remember that, phytomedicine has been used for centuries and some herbal remedies have shown therapeutic benefits, the efficacy and safety of specific herbal treatments can vary widely. Additionally, interactions between herbal remedies and conventional medications can occur, so it's essential to consult with a healthcare professional, preferably one knowledgeable in herbal medicine, before starting any herbal treatment.

3.3 POTENTIAL OF PHYTOMEDICINE

Phyto-medicine, also known as herbal medicine or botanical medicine, involves the use of plants and plant extracts for medicinal purposes. This traditional form of medicine has been practiced for thousands of years in various cultures around the world. In recent times, there has been a resurgence of interest in phytomedicine due to its potential economic and medical benefits. Here are some details about the economic potential of phyto-medicine and its role in the modern medical system:

1. Natural and Holistic Approach: A holistic approach to health is used in phytomedicine, which emphasises the well-being of the whole person. It frequently promotes dietary changes and lifestyle modifications, which may enhance long-term health.

2. Rich Biodiversity: Many regions of the world, particularly tropical and subtropical areas, are home to a wide variety of plant species with potential medicinal properties. This biodiversity provides a vast resource for the development of new pharmaceuticals and health products.

3. Pharmaceutical Industry: Phyto-medicines serve as a source of inspiration for the pharmaceutical industry. Plant compounds have been the basis for the development of numerous drugs, including aspirin (from *Willow* bark), quinine (from *Cinchona* bark), and morphine (from *Opium*-poppy). Pharmaceutical companies are continually exploring plant extracts for the discovery of new medicines.

4. Alternative and Complementary Medicine: Phyto-medicines are often used as complementary or alternative treatments for various health conditions. This has created a growing market for herbal supplements, teas, and other natural products, contributing to the economic growth of the herbal products industry.

5. Cultural and Traditional Practices: In many cultures, traditional herbal remedies continue to be widely used alongside modern medicine. This provides economic opportunities for those who grow, harvest, process, and sell medicinal plants.

6. Bioprospecting: Bioprospecting involves the systematic search for bioactive compounds in plants, and it has the potential to yield valuable discoveries. Pharmaceutical and biotechnology companies invest in bioprospecting to find new drugs or therapeutic agents.

7. Research and Development: Scientific research into the efficacy and safety of phyto-medicines is ongoing. This research generates jobs in the fields of botany, pharmacology, and clinical research, contributing to the economy.

8. Nutraceuticals: Many phyto-medicines are also used in the production of nutraceuticals—products that combine elements of nutrition and pharmaceuticals. These products often target specific health conditions and have a growing market.

9. Sustainable and Eco-Friendly Agricultural Practices: The cultivation of medicinal plants can promote sustainable agricultural practices. This can include organic farming methods, which are environmentally friendly and can generate income for farmers.

10. Safety Profile: When used responsibly and under the guidance of knowledgeable practitioners, many herbal remedies have a relatively low risk of adverse effects compared to some synthetic pharmaceutical drugs. However, it's essential to use them correctly and be aware of potential interactions with other medications.

11. Rich Source of Bioactive Compounds: Plants contain a wide array of bioactive compounds, such as alkaloids, flavonoids, polyphenols, and essential oils, which can have therapeutic properties. These compounds can be isolated and studied for their potential pharmacological effects.

12. Global Trade: The global trade in herbal medicines and medicinal plants is substantial. Export and import of these products contribute to international trade and can benefit countries with rich herbal traditions.

13. Integration into Modern Medicine: Some phyto-medicines are being integrated into modern medical systems. For example, herbal supplements are sometimes recommended by healthcare professionals to complement conventional treatments.

Although, phytomedicine has many potential applications, it is crucial to use caution and recognise its limitations. Not all herbal treatments are safe or effective for every individual or conditions. The effectiveness and safety of particular plants are still being studied, and while taking herbal remedies, especially for serious medical illnesses, it is essential to follow the

advice of experienced healthcare specialists. Additionally, local variations in regulatory oversight and quality control of herbal products highlight the significance of sourcing products from reliable suppliers.

3.4 ROLE IN MODERN MEDICAL SYSTEM

Numerous compounds found in plants, referred to as phytochemicals, have been shown to have anti-cancer, anti-metabolic, and anti-degenerative effects. For both humans and animals, these chemical-based natural sources are of utmost importance. A potential use for these chemical components is to combine herbal formulations with phytomedicine, in which one or more herbs are provided in specific amounts to provide benefits for cosmetic purposes, help in disease diagnosis, and lessen disease severity. Due to their rapid therapeutic effect, they were also utilised as antibiotics or analgesics, and their application in allopathic medicine is rapidly growing.

Many of people are still using phytomedicine because of the fewer side effects and achieved popularity as compared to synthetic drugs. Pharmacology is another word for a therapeutic plant's functions and how it interacts with the body. They include alkaloids, anthraquinones, anthocyanins, cardiac glycosides, coumarins, cyanogenic glycosides, glucosilinates, flavonoids, phenols, saponins, and tannins. Essential oils, which are highly significant in medical botany, are produced by several phytochemicals that are taken from plants. These oils are extremely complex substances that could include 100 or more different components. Resin and gums are closely connected to essential oils, which have potent antibacterial properties. Therefore, there is a need to study and conserve the flora of our world and its important phytochemicals.

Numerous examples demonstrate how phytomedicine, or herbal medicine, contributes in diverse ways to modern medical systems. The following are some of the main functions of herbal medicine in the modern medical system:

Antimicrobial Effects: *Tea tree oil* has natural antimicrobial properties and is used externally to treat bacterial and fungal diseases of the skin like acne and fungal infections (Carson et al., 2006).

Antioxidant Properties: *Green tea* contains catechins, which have high properties, Green tea extracts are used for their potential in reducing the risk of chronic diseases like cancer and cardiovascular disease (Arab and Il'Yasova, 2014).

Complementary and Integrative Medicine: By offering more therapeutic alternatives, phytomedicine augments conventional medicine. For example, St. John's wort (*Hypericum perforatum*) is used alongside prescription medications in some cases of mild to moderate depression (Linde et al., 2008). Its usefulness in elevating mood has been supported by some studies.

Cancer Supportive Care: Some herbal supplements, including Ginger and Turmeric, may reduce chemotherapy-related nausea and enhance the general health of cancer patients. *Curcumin*, a compound in turmeric, is under investigation for its potential anticancer properties.

Digestive Health: *Peppermint oil* is used to improve symptoms of irritable bowel syndrome (IBS) by relaxing the muscles of the gastrointestinal tract. According to Khanna et al. (2014), *Ginger* is another herb that helps with nausea and indigestion.

Immune Support: *Echinacea* is a well-known herb utilised to boost immunity, reduce the severity and length of the common cold, and support the immune system. It is available in a number of forms, such as capsules, teas, and tinctures (Shah et al., 2007).

Mental Health and Relaxation: *Lavender* is well known for its soothing and relaxing effects. It's essential oil is used in aromatherapy and relaxation practices to reduce anxiety and promote better sleep.

Pain Management: Herbal remedies are effective for pain relief. According to Mason et al. (2004), *Capsaicin*, a compound produced from chilli peppers, is applied topically to treat pain caused on by neuropathy and osteoarthritis.

Respiratory Health: In order to treat respiratory symptoms like cough and congestion, herbal remedies like *Eucalyptus* and *Peppermint* are frequently employed (Kehrl et al., 2004). Cough drops and throat lozenges frequently contain menthol from peppermint.

Skin Conditions: Due to its hydrating and anti-inflammatory qualities, *Aloe vera* gel is frequently used to treat sunburn and numerous skin conditions. (Surjushe et al., 2008) It is also utilised in cosmetic items.

Traditional Medicine Systems: Herbal medicines play a significant role in traditional systems like Traditional Chinese Medicine (TCM) and Ayurveda. For instance, TCM uses herbs like ginseng and astragalus for a variety of health issues.

Wound Healing: Marigold (*Calendula*) is well known for its wound-healing therapeutic properties. It is used as an external ointments and creams to promote the healing of minor cuts, burns, and skin irritations (Preethi and Kuttan, 2009).

These instances highlight the various functions of phytomedicine in modern medical systems, from curing particular medical disorders to enhancing general health. But it's crucial to use herbal treatments under the supervision of medical specialists and with an awareness of any possible drug interactions or underlying health issues.

3.5 SOME EXAMPLES OF PHYTOMEDICINAL PLANTS

In this section we will discuss some examples of phytomedicinal plants, along with details of their traditional and modern uses, as well as any scientific evidence supporting their effectiveness:

3.5.1 ASTRAGALUS *(Astragalus membranaceus* Fisch. ex Bunge.)

Description: *Astragalus membranaceus* Fisch. ex Bunge., commonly known as Astragalus or Milk vetch, is a perennial flowering plant native to regions of China, Mongolia, and Korea. It is a member of the Fabaceae family of legumes and is distinguished by its unusual root system and tiny, pea-like blooms. The root of the astragalus plant is mainly used for its potential medicinal properties.

Traditional Use: *Astragalus* has a long history of use in traditional Chinese medicine (TCM) and other traditional healing systems. It was traditionally used as:

- **Adaptogen:** *Astragalus* was identified as an adaptogen, because it helps the body cope with stress and stay in equilibrium.
- **Energy and Vitality:** It was employed to increase stamina, fight weariness, and increase energy levels.
- **Immune Support:** It was used to strengthen the entire immune system and increase resistance to infections. It was known as an immune system tonic.
- **Respiratory Health:** It was applied to respiratory problems such colds, coughing, and allergies.

Modern Use: *Astragalus* is predominantly employed in modern herbal medicine and nutritional supplements for its potential health advantages, which include:

- **Adaptogenic Effects:** It is also used in modern medical system as an adaptogen since it helps the body adjust to stress and enhances general wellbeing.
- **Anti-Inflammatory**: *Astragalus* contains compounds with anti-inflammatory properties and may be used to reduce inflammation and reduce conditions associated with chronic inflammation.
- **Antioxidant Effects:** It's have antioxidant properties that help protect cells from oxidative stress.
- **Energy and Stamina:** *Astragalus* is a well-liked supplement for people seeking improved vitality because of its well-known history for having the ability to boost physical stamina and energy levels.
- **Heart Health:** *Astragalus* useful for the heart and blood vessels, including decreasing blood pressure and enhancing cardiac function.
- **Immune Support:** It is still widely known and recognized for its immune-boosting properties. It is used to boost immunity and lower the risk of infections, particularly during the cold and flu seasons.

- **Dosage:** Different dosages of *Astragalus* supplements may be recommended, depending on the product and intended use. Typical dosages may be ranged from 500 mg to 3,000 mg per day, which may divide into multiple doses. It's important to follow the recommended dosage on the product label or consult with a healthcare provider for personalized guidance.

Precautions: *Astragalus* is usually regarded as safe, when it is used as recommended dosages; however modest side effects including digestive discomfort are possible.

3.5.2 ECHINACEA (*Echinacea purpurea* (L.) Moench)

Description: *Echinacea purpurea* (L.) Moench, commonly known as purple coneflower, is a perennial herb characterized by its distinctive purple petals and cone-shaped central disk. It is a native of North America and belonging to the Asteraceae family. Echinacea is frequently found in gardens and other natural locations and is renowned for its therapeutic benefits.

Traditional Use: Native American groups, especially the Plains Indians, have a long history of using *Echinacea* and have made use of numerous plant parts for therapeutic purposes. *Echinacea* has a long history of use in:

- **Immune Support:** *Echinacea* preparations were utilised by Native Americans to strengthen the immune system and aid the body in battling illnesses.
- **Respiratory Health:** It was also used to treat respiratory conditions such sore throats, colds, and coughs.
- **Wound Healing:** *Echinacea* poultices were applied to wounds and insect bites to aid in healing and reduce inflammation.

Modern Use: In modern herbal medicine, *Echinacea* has grown in popularity and is used for a number of suggested health advantages, including:

- **Antioxidant Effects:** Used as antioxidant, that helps protect cells from oxidative stress.
- **Anti-Inflammatory:** It can be used to treat inflammation-related illnesses like arthritis and may help reduce inflammation.
- **Cold and Flu Relief:** When cold or flu symptoms first appear, people frequently use *Echinacea* supplements, extracts, and herbal teas to relieve their symptoms and strengthen their body's defenses.
- **Immune Support:** It is widely known for its immune-boosting properties. It is frequently used to reduce the severity and period of colds and upper respiratory infections.
- **Wound Healing:** Echinacea products applied topically are used to speed up the healing of wounds, particularly small cuts and skin irritations.

Dosage: Depending on the product and intended application, different echinacea supplement dosages may be advised. Usually, dosages are divided into many doses of 300 mg to 1,000 mg per day for immune support and cold relief.

Precautions: *Echinacea* is normally considered as safe, when it is used for short-term, but long-term use should only be undertaken with a healthcare professional's advice. Mild side effects like digestive discomfort or allergic responses can occur in some people. If negative responses happen, stop using. Autoimmune problem sufferers shouldn't consume *Echinacea* since it may stimulate the immune system and accelerate autoimmune conditions.

3.5.3 GINKGO (*Ginkgo biloba* L.)

Description: *Ginkgo biloba* L., frequently known as Ginkgo belongs to family Ginkgoaceae, has a long history that dates back hundreds of millions of years. It is one of the oldest tree species on Earth. It is a special kind of tree that has no immediate living relatives and is frequently referred to as a "Living Fossil." Ginkgo trees can reach heights of quite a few feet and are distinguished by their characteristic fan-shaped leaves.

Traditional Use: *Ginkgo biloba* L. has a long history of use in Traditional Chinese Medicine (TCM), where it is referred to as “Yinxing” or “Silver Apricot.” Ginkgo tree seeds have historically been 233tilized for a number of therapeutic uses. Ginkgo has been used to cure ailments like bronchitis and asthma as well as to improve cognitive function.

Modern Use: *Ginkgo biloba* L. is predominantly utilised as a dietary supplement in the modern world. Flavonoids and terpenoids are among the many bioactive substances present in the standardised extract of ginkgo leaves. It is well known for its possible health advantages, including:

- **Antioxidant Effects:** Ginkgo extract contains antioxidants that aid in preventing free radical-induced oxidative cell damage. The general health and longevity may be affected by this.
- **Cognitive function**: It is frequently used to support cognitive performance. It is a popular option among older persons for addressing age-related cognitive decline because some studies indicate that it may improve memory, concentration, and overall mental clarity.
- **Eye diseases:** According to certain studies, ginkgo biloba may improve eye health and aid in the treatment of diseases including glaucoma and age-related macular degeneration (AMD).
- It is said to enhance blood flow, particularly to the extremities. It might help treat problems like intermittent claudication, which causes leg pain from inadequate circulation.

Dosage: Depending on the particular supplement and desired application, different *Ginkgo biloba* dosages may be advised. An average daily dosage for cognitive support is usually divided

into two or three doses and varies from 120 mg to 240 mg. It's crucial to adhere to the directions on the product label or get advice from a healthcare provider for specific recommendations.

Precautions: *Ginkgo biloba* supplements should be used with carefulness by those who are taking blood-thinning drugs (anticoagulants) or who have bleeding disorders since they may increase the risk of bleeding.

It's important to let your healthcare provider know about any supplements you're taking because it may interfere with specific drugs. Therefore, the efficacy of *Ginkgo biloba* can differ from person to person, and the scientific evidence supporting its advantages is still under investigation. Before beginning any new dietary supplement, it is advisable to speak with a healthcare provider, especially if you have certain health issues or are using other medications.

3.5.4 GINSENG (*Panax ginseng* C.A. Mey.)

Description: Eastern Asia, especially China and Korea, is home to the perennial plant known as *Panax ginseng* C.A. Mey., often called Asian ginseng or Korean ginseng. Traditional Chinese Medicine (TCM) has employed this herb for millennia due to the possible health benefits it may have. It is one of the most well-known and popular herbal treatments. Ginseng is distinguished by its thick root and complex leaves. It is frequently referred to as a "adaptogen" because of its capacity to assist the body in adjusting to stress.

Traditional Use: Ginseng has been used traditionally for a very long time, particularly in Chinese and Korean herbal medicine. Historically, it served a variety of functions, such as:

- **Cognitive Function:** Ginseng has long been used in traditional medicine to enhance cognition and ability to think clearly.
- **Energy and Vitality:** Ginseng has been used for centuries to increase vitality, stamina, and energy levels.
- **Immune Support:** Ginseng was frequently used as a cure for colds and the flu because it was thought to enhance the immune system.
- **Stress and Adaptation:** It was regarded as an adaptogen, assisting the body in adjusting to both physical and mental pressures.

Modern Use: Ginseng is still widely used in modern herbal medicine and nutritional supplements due to its possible health advantages, which include:

- **Anti-Inflammatory:** Ginseng is considered to have anti-inflammatory properties and can be utilised to treat inflammation-related diseases.
- **Cognitive Function:** The potential benefits of Ginseng for supporting cognitive function, increasing mental clarity, and boosting memory are being investigated.

- **Immune Support:** It is a common choice during the cold and flu season since some research indicate that it may have immune-boosting qualities.
- **Energy and Stamina:** It is frequently taken to increase energy levels, improve physical endurance, and combat fatigue.
- **Stress Adaptation:** Ginseng is still regarded as an adaptogen and is utilised to increase resilience, fatigue reduction, and the body's ability to cope with stress.

Dosage: The recommended dosage of Ginseng supplements can vary depending on the product and its content. Typical daily doses might range from 100 mg to 400 mg, depending on the purpose for which it is used It's crucial to adhere to the suggested dosage listed on the product label or seek out specific advice from a healthcare professional.

Precautions: Ginseng is usually thought of as safe when taken at the appropriate doses, but in some people, it may have unwanted effects including insomnia, nervousness, or digestive trouble. It should be used carefully by people who have high blood pressure because it may raise or lower blood pressure. Ginseng's efficacy can vary from person to person, and there is still work to be done in the field of science to determine whether it has any health advantages. As with any dietary supplement, it's best to speak with a doctor before using ginseng, especially if you have any health issues or are already on medication. Therefore, it's important to let your doctor know if you're taking any other medications since ginseng and some medicines may interfere.

3.5.5 MILK THISTLE (*Silybum marianum* (L.) Gaertn.)

Description: Milk thistle, botaniclly known as *Silybum marianum* (L.) Gaertn. is a flowering plant belonging to the family (Asteraceae). It is a native of the Mediterranean region and is distinguished by its prickly leaves and striking purple flower heads. The seeds and other aerial portions of the plant are exploited for their possible therapeutic effects.

Traditional Use: Traditional herbal therapy has traditionally used milk thistle, particularly for the liver-healing properties. In the past, it was employed for:

- **Digestive Tonic:** It is used as a digestive tonic to treat indigestion and enhance general digestive health.
- **Gallbladder Health:** Milk thistle has been utilised to prevent gallbladder problems and support gallbladder function.
- **Liver Health:** Traditional it is used to promoting liver health and treating a number of liver-related ailments, such as cirrhosis, jaundice, and hepatitis.

Modern Use: Milk thistle is predominantly utilised in modern herbal medicine and dietary supplements for its putative liver-protective effects and other health advantages, such as:

Liver Support: Hepatoprotective (liver-protective) properties of milk thistle are well known. It is used to support liver health, particularly in situations of liver disorders, liver damage brought on by alcohol, and exposure to pollutants.

Detoxification: It helps the liver remove unwanted compounds from the body and aid in detoxification.

Antioxidant Properties: Milk thistle contains antioxidant properties, such as *Silymarin*, which help protect liver cells and other tissues from oxidative damage caused by free radicals.

Cholesterol Control: It enhances cardiovascular health by lowering cholesterol levels.

Skin Health: It is used to relieve skin diseases such as psoriasis.

Dosage: Depending on the product and purpose of use, different dosages of milk thistle supplements may be advised. Standardised milk thistle extract is typically taken in daily doses of 200 mg to 600 mg. It's crucial to adhere to the suggested dosage listed on the product label or seek the advice of a healthcare professional for more specific instructions.

Precautions:

Milk thistle is generally considered safe when used at suggested doses. Although side effects are uncommon, they could occasionally cause minor stomach pain. Individuals with allergies to plants in the Asteraceae family (like ragweed, marigolds, and daisies) may be at an increased risk of allergic reactions to milk thistle. People who are allergic to members of the Asteraceae family of plants (such as marigolds, and daisies) may be more susceptible to allergic reactions to milk thistle.

There are various health applications of milk thistle, especially liver support. Before using milk thistle, like with any dietary supplement, it is best to speak with a healthcare provider, especially if you have certain health problems or are taking other drugs.

3.5.6 ST. JOHN'S WORT (*Hypericum perforatum* L.)

Description: St. John's Wort is a blooming plant with bright yellow blooms and perforated leaves that is indigenous to Europe and some regions of Asia. Its scientific name is *Hypericum perforatum* L. It is a hardy and resilient plant that has been used for potential medical use for many years. The plant is known as "St. John's Wort" because it typically blooms and is harvested on June 24, the feast day of St. John the Baptist.

Traditional Use: Traditional herbal medicine has long used St. John's Wort, primarily for its mood-lifting abilities. It was usually applied to:

- **Mood Disorders:** It was used to treat mild to moderate depression and anxiety symptoms.

- **Nerve Pain:** It was used to treat sciatica and neuralgia as well as other types of nerve pain and discomfort.
- **Wound Healing:** St. John's Wort oil or ointment was applied topically to facilitate wound healing, lower inflammation, and ease skin irritations.

Modern Use: St. John's wort is predominantly utilised in modern herbal medicine and dietary supplements for its potential antidepressant effects and other health advantages, such as:

- **Depression and Anxiety:** It is generally known that St. John's Wort has the ability to reduce the signs and symptoms of mild to moderate anxiety and depression. Serotonin and other neurotransmitters, such as them, are thought to be increased in the brain, which may affect how it functions.
- **Mood Regulation:** It is a well-liked natural therapy for people who experience mood swings because it might aid to enhance mood and mental well-being.
- **Nerve Pain:** For the treatment of sciatica and other nerve-related pain problems, St. John's wort may be used.
- **Applied Uses**: Skin irritations, sunburns, and small wounds can all be treated topically using St. John's Wort oil or ointments.

Dosage: Different dosages of St. John's Wort supplement may be advised depending on the product and purpose of use . The usual daily dosages, divided into several doses, vary from 300 mg to 900 mg. It's critical to adhere to the suggested dosage listed on the product label or seek the advice of a healthcare professional for more specific instructions.

Precautions: Several medications, including as antidepressants, anticoagulants, and birth control pills, can react with St. John's Wort and may reduce the effectiveness of those drugs. Any supplements you use must be disclosed to your healthcare provider. It may cause photosensitivity in some individuals, making the skin more sensitive to sunlight. Adequate sun protection is recommended while using St. John's Wort. It is generally considered safe when used at recommended doses, but it may cause side effects such as gastrointestinal upset, fatigue, and dry mouth.

3.5.7 TURMERIC (*Curcuma longa* L.)

Description: The *Curcuma longa* L. plant, which is a member of the ginger family (Zingiberaceae), produces turmeric, an energetic yellow-orange spice. Turmeric, a plant native to South Asia, is widely farmed and has been used in food, medicine, and culture for a very long time. It is renowned for its unusual colour and earthy, slightly bitter flavour.

Traditional Use: Since ancient times, turmeric has played a significant role in both Ayurvedic and Traditional Chinese Medicine (TCM). The following are some of the traditional uses for it:

- **Anti-inflammatory:** Turmeric has been used for a very long time to treat a variety of inflammatory diseases.
- **Digestive support:** It was used to treat digestive discomfort, such as indigestion and bloating, in traditional medicine.
- **Wound Healing:** Turmeric paste was applied to wounds and cuts to help healing and reduce the risk of infection.
- **Antioxidant:** It was acknowledged for its antioxidant qualities and capacity to reduce oxidative stress.

Modern Use: *Curcumin*, a bioactive component of turmeric, is highly valued in contemporary culture. The following are some of the potential health advantages of *Curcumin*:

- **Anti-Inflammatory:** *Curcumin* is a potent anti-inflammatory agent and may help reduce inflammation in diseases like inflammatory bowel disease and arthritis.
- **Antioxidant:** The anti-oxidant qualities of *Curcumin* assist in protecting cells from oxidative damage carried on by free radicals. It has potential to avoid chronic diseases.
- **Brain Health:** *Curcumin* may boost cognitive function, lower the risk of neurodegenerative illnesses, and have neuroprotective qualities.
- **Cardiovascular Health:** *Curcumin* is useful to heart health by improving factors such as blood pressure, cholesterol levels, and reducing the risk of atherosclerosis.
- **Cancer Prevention:** According to some study, *Curcumin* may have anticancer characteristics and may be investigated as an additional therapy for the treatment of cancer.
- **Digestive Health:** As a digestive aid, turmeric is thought to lessen gastric discomfort and swelling.
- **Pain Relief:** Supplements containing turmeric and *Curcumin* are frequently used to treat headaches, sore muscles, and joint discomfort.

Dosage: Depending on the product and its content, different amounts of turmeric or curcumin supplements may be taken. *Curcumin* is often taken in daily doses of 500 mg to 2,000 mg for general health and wellbeing. However, it's crucial to adhere to the suggested dosage listed on the product label or get advice from a healthcare professional for more specific instructions.

Precautions: The use of turmeric and curcumin as cooking spices is usually regarded as safe. However, some people may experience digestive issues when taking supplements at large doses. Supplements containing turmeric should be used with caution by those who are using blood thinners or who have bleeding disorders since they may increase the risk of bleeding.

The potential health advantages of turmeric and *Curcumin* are still being studied in depth by scientists, who have conducted a lot of research on them. As with any nutritional supplement, it

Astragalus membranaceus

Echinacea purpurea

Source: https://healthroots.in/astragalus-membranaceus) and https://www.missouriplants.com/Echinacea_purpurea_page.html

Ginkgo biloba

Ginseng (*Panax ginseng*)

Source: https://www.tradeindia.com/products/panax-ginseng-p-e-1108482.html

***Silybum marianum* (Milk-thistle)**

Source: https://pixers.uk/posters/silybum-marianum-milk-thistle-41352992 and
https://www.istockphoto.com/photo/st-johns-wort-isolated-on-white-background

Curcuma longa

Source: https://ntbg.org/database/plants/detail/Curcuma-longa

is best to consult with your physician before using turmeric or curcumin, especially if you have any medical issues or are taking other drugs.

These instances highlight the wide variety of phytomedicinal plants and their conventional use. Although these plants have a history of use and some scientific evidence to support their benefits, it's important to note that individual responses may vary, so it's best to consult with a healthcare provider before using them as a supplement, especially if you have underlying medical conditions or are taking medications. The efficacy and safety of herbal products might also be impacted by the quality and preparation of those products.

3.6 EXPERIMENTAL PROCEDURE OF PHYTOMEDICINAL PLANTS

While phyto-medicine holds significant economic potential and plays a role in modern healthcare, it's important to ensure that the use of herbal remedies is based on scientific evidence and safety assessments. Collaboration between traditional knowledge, modern science, and regulatory agencies is essential to harness the full potential of phyto-medicines while ensuring their safety and efficacy in the modern medical system.

3.6.1 EXERCISE-1: ALPHA-AMYLASE INHIBITION ASSAY

The Alpha-Amylase and Alpha-Glucosidase Inhibition Assays are commonly used to evaluate the potential anti-diabetic activity of compounds by assessing their ability to inhibit enzymes involved in carbohydrate digestion. Here's an experimental procedure for conducting these assays:

MATERIALS AND REAGENTS:

- Alpha-amylase enzyme (from a commercial source)
- Alpha-glucosidase enzyme (from a commercial source)
- Substrate solution for alpha-amylase assay (e.g., starch solution)
- Substrate solution for alpha-glucosidase assay (e.g., p-nitrophenyl-α-D-glucopyranoside, PNPG)
- Test compounds or extracts dissolved in an appropriate solvent
- Buffer solution (e.g., phosphate buffer, pH 6.9)
- Dimethyl sulfoxide (DMSO) or other suitable solvent for dissolving test compounds
- Acarbose (a positive control)
- Microplates (96-well)

- Microplate reader

PROCEDURE: ALPHA-AMYLASE INHIBITION ASSAY

1. Prepare the alpha-amylase enzyme solution by diluting it with the buffer solution to achieve a suitable enzyme concentration.

2. Set up a series of test wells in a microplate:

- Blank (buffer only)
- Control (enzyme + substrate without a test compound)
- Test wells (enzyme + substrate with varying concentrations of test compounds)
- Positive control (enzyme + substrate with acarbose)

3. Add the alpha-amylase enzyme solution to the appropriate wells.

4. Incubate the microplate at a suitable temperature (e.g., 37°C) for a specified time (typically 10-30 minutes).

5. After incubation, add the substrate solution (starch solution) to each well.

6. Incubate the microplate again for a specified time to allow the enzyme to digest the substrate.

7. Stop the reaction by adding a stopping solution (e.g., iodine solution) to all wells.

8. Measure the absorbance at a specific wavelength (e.g., 540 nm) using a microplate reader.

9. Calculate the percentage inhibition of alpha-amylase activity by comparing the absorbance of test wells to that of the control wells.

ALPHA-GLUCOSIDASE INHIBITION ASSAY:

1. Prepare the alpha-glucosidase enzyme solution by diluting it with the buffer solution to achieve a suitable enzyme concentration.

Set up a series of test wells in a microplate:

- Blank (buffer only)
- Control (enzyme + substrate without a test compound)
- Test wells (enzyme + substrate with varying concentrations of test compounds)
- Positive control (enzyme + substrate with acarbose)

3. Add the alpha-glucosidase enzyme solution to the appropriate wells.

4. Incubate the microplate at a suitable temperature (e.g., 37°C) for a specified time (typically 10-30 minutes).

5. After incubation, add the substrate solution (PNPG solution) to each well.

6. Incubate the microplate again for a specified time to allow the enzyme to hydrolyze the substrate.

7. Stop the reaction by adding a stopping solution (e.g., sodium carbonate solution) to all wells.

8. Measure the absorbance at a specific wavelength (e.g., 405 nm) using a microplate reader.

9. Calculate the percentage inhibition of alpha-glucosidase activity by comparing the absorbance of test wells to that of the control wells.

DATA ANALYSIS:

- Plot dose-response curves for the test compounds and positive control.
- Calculate the IC50 values (concentration at which enzyme activity is inhibited by 50%) for each compound.
- Interpret the results to assess the anti-diabetic potential of the test compounds based on their inhibitory activity on alpha-amylase and alpha-glucosidase enzymes.
- Remember to use appropriate controls, replicate experiments, and validate your assay conditions to ensure reliable results.

3.6.2 EXERCISE-2: *IN-VITRO* FREE RADICAL SCAVENGING ACTIVITY ASSAY

In-vitro free radical scavenging activity assay is an accepted mechanism for screening the antioxidant activity using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, which is a widely used method to assess the antioxidant potential of compounds or extracts

MATERIALS AND REAGENTS:

- DPPH (2,2-diphenyl-1-picrylhydrazyl) powder
- Test compounds or extracts
- Solvents (methanol or ethanol) for sample preparation
- Ascorbic acid (vitamin C) as a positive control
- Microplate reader or spectrophotometer
- 96-well microplate
- Pipettes and tips
- Clear plastic wrap or aluminum foil
- Vortex mixer or shaker

- Centrifuge (optional)
- Distilled water

PROCEDURE:

1. Sample Preparation:
    - Prepare stock solutions of your test compounds or extracts in an appropriate solvent (e.g., methanol or ethanol). The concentration of the stock solution may vary based on your expected antioxidant activity.
2. DPPH Solution Preparation:
    - Prepare a 0.1 mM DPPH solution by dissolving DPPH powder in methanol or ethanol. Keep this solution protected from light.
3. Sample Dilution:
    - Dilute your test compounds or extracts to the desired concentrations in the same solvent used for the stock solutions.
4. Negative Control:
    - Prepare a negative control by adding the same volume of solvent used for sample dilution (without the test compound) to a separate microplate well.
5. Positive Control:
    - Prepare a positive control by adding ascorbic acid to a separate microplate well at a known concentration.
6. Reaction Mixtures:
    - In a clear 96-well microplate, add 180-200 µL of the DPPH solution to each well.
    - Add 20-50 µL of your test compound or extract (at various concentrations) to separate wells. Ensure that the final volume in each well is the same.
    - Include blank wells containing only the solvent used for sample dilution to account for any solvent-induced color changes.
7. Mixing and Incubation:
    - Mix the contents of each well thoroughly using a vortex mixer or by gently shaking the plate.
    - Cover the microplate with clear plastic wrap or aluminum foil to protect it from light.
    - Incubate the microplate in the dark at room temperature for a specific duration (e.g., 30 minutes to 2 hours, depending on the kinetics of your reaction).

8. Measurement:

- After the incubation period, measure the absorbance of each well at the appropriate wavelength (usually around 517 nm) using a microplate reader or spectrophotometer.

9. Data Analysis:

- Calculate the percentage inhibition of DPPH radicals by comparing the absorbance of your test samples to that of the negative control and positive control, using the following formula:

10. Antioxidant Activity:

- Higher percentage inhibition indicates stronger antioxidant activity. You can plot a dose-response curve to determine the IC50 (the concentration at which 50% of DPPH radicals are scavenged) if you have tested multiple concentrations.

11. Repeat and Validate:

- Conduct replicate experiments to ensure the reproducibility of your results.

This assay provides a measure of the ability of your test compound or extract to scavenge free radicals. A lower IC50 value indicates stronger antioxidant activity. It's important to use appropriate positive controls, and ensure that all reagents are handled carefully to prevent exposure to light, as DPPH is light-sensitive.

3.7 SUMMARY

Phytomedicine or herbal medicine also known as phytotherapy, is a branch of alternative medicine that uses plant-based materials, such as herbs, plant parts (leaves, roots, flowers, bark etc.), and plant extracts, for therapeutic purposes. It has been practiced for centuries in various cultures around the world and continues to be used today as a complementary or alternative approach to conventional medicine. The active compounds found in plants, such as alkaloids, flavonoids, and terpenes, can have pharmacological effects on the human body. These natural compounds are used to create herbal remedies, teas, tinctures, capsules, and other forms of plant-based medicines.Some examples of phytomedicine such as ***Echinacea*** (a herb used to treat respiratory infections and improve the immune system), ***Ginseng*** **(**enhance energy, cognitive function, and lessen stress), **St. John's Wort (**used in depression and anxiety), ***Aloe vera*** (applied to treat skin diseases like burns and sores), ***Turmeric*** (anti-inflammatory and antioxidant properties), ***Chamomile:*** (encourage relaxation and aid in sleep).

In recent times, there has been a resurgence of interest in phytomedicine due to its potential economic and medical benefits. In this unit, the economic potential of phytomedicine and its role in various aspects in the modern medical system is described. These are often used as a holistic and natural approach to health, rich biodiversity, phrmceutical industries, alternative and

complementary medicine, cultural and traditional practices, bioprospecting, research and development, nutraceuticals, modern medicine, global trade sustainable and eco-friendly agricultural practices etc.

Although, phytomedicine has many potential applications, it is crucial to use caution and recognise its limitations. Not all herbal treatments are safe or effective for every individual or conditions. The effectiveness and safety of particular plants are still being studied, and while taking herbal remedies, especially for serious medical illnesses, it is essential to follow the advice of experienced healthcare specialists. Additionally, local variations in regulatory oversight and quality control of herbal products highlight the significance of sourcing products from reliable suppliers.

3.8 SELF ASSESSMENT QUESTIONS

3.8.1 Multiple Choice Questions

1. What is the primary source of Phytomedicine?

a) Minerals and vitamins b) Plant extracts and compounds

c) Animal-derived substances d) Synthetic chemicals

2. Which of the following best describes the economic potential of Phytomedicine?

a) Limited and only applicable in traditional medicine

b) Significant, with growing global demand for natural remedies

c) Negligible due to concerns about plant conservation

d) Restricted to a few developed countries

3. In which medical system is Phytomedicine often a central component?

a) Allopathy b) Homeopathy

c) Naturopathy d) Traditional Chinese Medicine (TCM)

4. What is the role of Phytomedicine in modern medicine?

a) It is used as a primary treatment for all medical conditions.

b) It has no role in modern medicine.

c) It is only used in underdeveloped countries.

d) It is primarily used as a complementary therapy alongside conventional medicine.

5. Which of the following is NOT a potential benefit of Phytomedicine in healthcare?

a) Enhanced genetic modification of plants for higher yields

b) Reduced side effects compared to synthetic drugs

c) Cost-effectiveness in healthcare systems

d) Preservation of indigenous knowledge and biodiversity

Answer key

3.8.1: 1.(b); 2.(b); 3.(d); 4.(d); 5.(a)

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3.11 TERMINAL QUESTIONS

3.11.1 Short Answer Type Questions

1. What is phytomedicine?
2. Write a short note on role of phytomedicine.
3. Describe any two phytomedicinal plants with their scientific evidence.

3.11.2 Long Answer Type Questions

1. Give a general account on potential of phytomedicine
2. What is the role of traditional medicine systems in promoting the use of phytomedicine?

3. How do modern scientific advancements impact the development of phytomedicines?
4. How does phytomedicine differ from conventional medicine? What are some examples of commonly used phytomedicines?

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