Chapter 3
Soil Fertility Evaluation
The proper rate of plant nutrient is determined by knowing the nutrient requirement of the crop and the nutrient supplying power of soil.

Hence, the evaluation of soil fertility becomes important.

Soil fertility evaluation is essential for balanced nutrition of the crops.
Soil fertility evaluation:

Know the nutrient supplying power of soil to the crop.

Advantage of fertility evaluation:

• It helps in maintenance and improving soil productivity.
• Soil fertility evaluation is the key for adequate and balanced fertilization in crop production.

• Balance nutrient supply / Balanced fertilization:

   It refers to the application of essential plant nutrients in right amounts and proportions using correct methods and time of application suited for specific soil-crop-climatic situations.
Techniques are commonly employed to assess the soil fertility are

1. Soil testing

2. Analysis of tissues from plant growing on the soil

3. Biological tests in which the growth of higher plants or certain micro-organisms is used as a measure of soil fertility

4. Nutrient deficiency symptoms of plant
1. Soil testing:
• Soil testing is the chemical analysis that provides a guideline for addition of amendments or fertilizer to soils.
• The primary advantage of soil testing is determining the nutrients status of the soil before the crop is planted as compared to the plant analysis.

Objectives of Soil testing:
• Soil fertility evaluation for making fertilizer recommendation
• Prediction of likely crop response to applied nutrient
• Classification of soil into different fertility groups for preparing soil fertility maps of a given area
• Assessment of the type and degree of soil related problems like salinity, sodicity, acidity etc., and suggesting appropriate reclamation / amelioration measures
Steps involved in soil analysis

i. Sampling
ii. preparation of samples
iii. Analytical procedure
iv. Calibration and interpretation of the results
v. Fertilizer recommendation

1. Sampling:
Soil sampling is perhaps the most vital step for any analysis. Because a very small fraction of the huge soil mass of a field is used for analysis and converted in hectare basis. So it becomes extremely important to get a truly representative soil sample from the field.

2. Preparation of sample:
Drying, grinding and sieving according to the need of analytical procedure
3. Analytical procedure:

A suitable method is one which satisfies the following three criteria.

(i) It should be fairly rapid so that the test results can be obtained in a reasonably short period.

(ii) It should give accurate and reproducible results of a given Samples with least interferences during estimation.

(iii) It should have high predictability i.e., a significant relationship of test values with the crop performance.
Following chemical methods are widely used for determination of different nutrients

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Methods</th>
<th>Merits and demerits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total N</td>
<td>Kjeldahl method</td>
<td>• This method is time consuming, lengthy and costly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Rate of mineralization of N varies with the soil</td>
</tr>
<tr>
<td>Organic C</td>
<td>Walkley and Black</td>
<td>• This method is simple and rapid</td>
</tr>
<tr>
<td></td>
<td>method</td>
<td>• Based on C:N ratio which is varied (7.7 to 11.7)</td>
</tr>
<tr>
<td>Available N</td>
<td>Alkaline-KMnO$_4$</td>
<td>• Extract part of organic and mineral N</td>
</tr>
</tbody>
</table>
| Available P$_2$O$_5$ | Olsen's method for alkaline soils | • High efficiency of HCO$_3$ ion to remove P from Ca, Al and Fe  
• Reduce the activity of Ca  
• Used in slightly acidic, neutral and alkaline soil |
|-------------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                    | Bray's method for acid soils    | • High efficiency of F ion in dissolving P  
• Useful in acidic or slightly calcareous soils |
| Available K$_2$O   | NH$_4$OAc extratetable          | • Higher efficiency of extraction as compared to salt solution  
• Inefficiency to remove part of non exchangeable K, which is considered to be available to some extent |
Available S

<table>
<thead>
<tr>
<th></th>
<th>0.15% CaCl$_2$ extractable</th>
<th>Extract water soluble S and adsorbed S</th>
</tr>
</thead>
</table>

Heat soluble S

<table>
<thead>
<tr>
<th></th>
<th>Heat soluble - extract WS + organic S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time consuming and lengthy procedure</td>
</tr>
</tbody>
</table>

Available Micronutrients

<table>
<thead>
<tr>
<th></th>
<th>DTPA extractable</th>
<th>Extract complexed, chelated and adsorbed form of Fe, Mn, Zn, Cu</th>
</tr>
</thead>
</table>
4. Calibration and interpretation of the results:

- For the calibration of the soil test data, soils are grouped in to high, medium and low category.
- For categorization of soil, the particular nutrient are selected and the test crop is grown with varying doses of particular nutrient and basal dose of other nutrients.
- Plot soil test values against the percentage yield to calculate the relationship between soil test values and per cent yield response.

\[
\text{Percent yield} = \frac{\text{Crop yield with adequate nutrient} - \text{Yield of control without addition of particular nutrient under study}}{\text{Crop yield with adequate nutrient}} \times 100
\]
### Critical level of nutrients in soil:

<table>
<thead>
<tr>
<th>SN</th>
<th>Nutrients</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Alkaline KMnO₄-N (kg/ha)</td>
<td>&lt;250</td>
<td>250-500</td>
<td>&gt;500</td>
</tr>
<tr>
<td>2.</td>
<td>Olsen-P₂O₅ (kg/ha),</td>
<td>&lt;28</td>
<td>28-56</td>
<td>&gt;56</td>
</tr>
<tr>
<td>3.</td>
<td>Neutral N NH₄OAc-K₂O</td>
<td>&lt;140</td>
<td>140-280</td>
<td>&gt;280</td>
</tr>
<tr>
<td>4.</td>
<td>0.15% CaCl₂ –S (mg/kg)</td>
<td>&lt;10</td>
<td>10-20</td>
<td>&gt;20</td>
</tr>
<tr>
<td>5.</td>
<td>DTPA extractable Fe (mg/kg)</td>
<td>&lt;5</td>
<td>5-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>6.</td>
<td>DTPA extractable Mn (mg/kg)</td>
<td>&lt;5</td>
<td>5-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>7.</td>
<td>DTPA extractable Zn (mg/kg)</td>
<td>&lt;0.5</td>
<td>0.5-1.0</td>
<td>&gt;1.0</td>
</tr>
<tr>
<td>8.</td>
<td>DTPA extractable Cu (mg/kg)</td>
<td>&lt;0.2</td>
<td>0.2-0.4</td>
<td>&gt;0.4</td>
</tr>
<tr>
<td>9.</td>
<td>Hot water soluble B (mg/kg)</td>
<td>&lt;0.1</td>
<td>0.1-0.5</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>10.</td>
<td>NH₄OAc soluble Mo (mg/kg)</td>
<td>&lt;0.05</td>
<td>0.05-0.1</td>
<td>&gt;0.1</td>
</tr>
</tbody>
</table>
This classification indicated that

- low class of soil would respond to added fertilizer means add 25% more fertilizer than recommended dose.
- Medium class soil may or may not respond to added fertilizer, add recommended dose of fertilizer.
- High status soils do not respond to added fertilizer, add 25% less recommended dose.
2. Plant Testing:

1. Analysis of tissues from plant growing on the soil

Plant tissue analysis is the determination of the concentration of an element in a plant sample taken from a particular portion of a crop at a certain time or stage of morphological development.

The plant analysis has been used as a diagnostic tool or complementary to soil testing because

(i) In many situations, the total or even the available content of an element in soil fails to correlate with the plant tissue concentration or the growth and yield of crop due to many reasons including the physico chemical properties of the soils and the root growth patterns.

(ii) On the other hand, the concentration of an element in the plant tissue is positively correlated with the plant health. Therefore, the plant analysis has been used as a diagnostic tool to determine the nutritional cause of plant disorders/diseases.
Following steps (procedure) are included in plant analysis

i. The collection of the representative plant parts at the specific growth stage,

ii. Washing, drying and grinding of plant tissue,

iii. Oxidation of the powdered plant samples to solubilize the elements,

iv. Estimation of different elements,

v. Interpretation of the status of nutrients with respect to deficiency / Sufficiency / toxicity on the basis of known critical concentrations,
Plant analysis applications:

- Diagnosis of nutrient deficiencies, toxicities or imbalances
- Measurement of the quantity of nutrients removed by a crop to replace them in order to maintain soil fertility
- Estimating overall nutritional status of the region or soil types
- Monitoring the effectiveness of the fertilizer practices adopted
- Estimation of nutrient levels in the diets available to the livestock
Collection and Preparation of plant samples

1. Collect the representative plant parts at the specific growth stage because nutrient content in plant vary with growth stage and it reflect the nutrient concentrations at particular growth stage.

2. Collect the recently matured fully expanded leaves just before the onset of the reproductive stage and put in perforated paper bags.

3. The plant samples are often contaminated with dust, dirt and residues of the sprays, etc. so it need to be washed first under a running tap water followed by rinsing with dilute HCl (0.001N), distilled water and finally in deionized water.

4. The washed samples are dried in a hot air oven at 60±5°C for a period of 48 hours and ground in a stainless steel mill to pass through a sieve of 40/60 mesh.
Oxidation of plant material

• The main objective of oxidation is to destroy the organic components in the plant material to release the elements from their combinations.

• The plant materials can be oxidized by two methods

  (i) Dry ashing at a controlled high temperature (500ºC) in a muffle furnace

  (ii) Wet digestion in an acid or a mixture of two or more acids.
i) Dry-ashing:

(a) The powdered plant materials are taken in silica crucibles and ashed in a muffle furnace at 500$^\circ$C for 3-4 hours.

(b) Temperature is an important consideration in dry ashing because Nitrogen and sulphur, being highly volatile, lost during dry ashing even at 500$^\circ$C and at higher temperatures(above 500$^\circ$C ) elements like K may also be lost.

(c) The ash is dissolved in 2 ml of 6 N HCl, heated on a hot plate to near dryness and again dissolved in 10 ml 0.01N HCl or 20% aquaregia before making up the final volume with distilled water.

(d) These extracts may contain different amounts of insoluble materials, mainly silica, depending upon the plant species.

(e) Keep these extracts for some time to settle down insoluble materials and separate by filtration before estimation of different elements.

(f) All elements, except N and S, can be estimated from these extracts by suitable techniques.

(g) The results obtained by this method are quite satisfactory and comparable to those obtained by wet digestion procedures.

(h) Moreover, B can only be determined by dry ashing since it is volatilized during wet digestion with di-or triacid mixtures.
## ii) Wet Digestion:

Wet oxidation digestion reagents and their applicability

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Reagents</th>
<th>Applicability</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H$_2$SO$_4$/HNO$_3$</td>
<td>Vegetable origin</td>
<td>Most commonly used</td>
</tr>
<tr>
<td>2</td>
<td>H$_2$SO$_4$/H$_2$O$_2$</td>
<td>Vegetable origin</td>
<td>Not very common</td>
</tr>
<tr>
<td>3</td>
<td>HNO$_3$</td>
<td>Biological origin</td>
<td>Easily purified reagent, short digestion time, temperature 350 °C</td>
</tr>
<tr>
<td>4</td>
<td>H$_2$SO$_4$/HClO$_4$</td>
<td>Biological origin</td>
<td>Suitable only for small samples, danger of explosion</td>
</tr>
<tr>
<td>5</td>
<td>HNO$_3$/HClO$_4$</td>
<td>Protein, carbohydrate (no fat)</td>
<td>Less explosive</td>
</tr>
<tr>
<td>6</td>
<td>HNO$_3$/HClO$_4$/H$_2$SO$_4$</td>
<td>Universal (also fat)</td>
<td>No danger with exact temperature control</td>
</tr>
</tbody>
</table>
Generally $\text{HNO}_3$, $\text{HClO}_4$ and $\text{H}_2\text{SO}_4$ acids are used in wet digestion method.

These acids are used either singly or in combinations of two or three acids, e.g. $\text{HNO}_3$ and $\text{HClO}_4$ (10:4 ratio), $\text{HClO}_4$ and $\text{H}_2\text{SO}_4$ (4:1 ratio) and $\text{HNO}_3$ and $\text{H}_2\text{SO}_4$ (10:1 ratio) or a triple acid is a mixture of $\text{HNO}_3$, $\text{HClO}_4$ and $\text{H}_2\text{SO}_4$ (in 10:4:1 ratio).

The powdered plant samples are dissolved in these suitable di-acids or tri-acids mixture using hot plate at nearly 350$^\circ$C till clear the content.

Cool the content and add some distilled water, filter and make desired volume.

This filtration can be used for estimation of different elements.
Rapid tissue tests:

- Tissue tests are rapid and essentially qualitative.
- The nutrients are absorbed by roots and transported to those plant parts where they are needed.
- The concentration of cell sap is usually a good indication of how well the plant is supplied at the time of testing.
- The plant parts, usually leaves, are removed and plant sap is extracted.
- The plant sap is usually tested for nitrate, phosphorus, and potassium by colorimetric tests.
DRIS approach

• Recently Diagnosis Recommendation Integration System (DRIS) is suggested for fertilizer recommendation.

• In this approach, generally plant samples are collected from farmer's fields.

• These plant samples are analyzed for nutrient content and they are expressed as ratios of nutrients with others.

• The nutrients whose ratios are not optimum for high yields are supplemented by top dressing.

• This approach is generally suitable for long duration crops, but now a days it is being tested for short duration crops like soybean, wheat etc. also.
3. Biological tests:

- In biological test, the growth of higher plants or certain micro-organisms are used as a measure of soil fertility.
- The biological methods consist of raising a crop or a microbial culture in a field or in a soil sample and estimating its fertility from the volume \((\text{yield/mass})\) of crop or microbial count.
- These methods can used for direct estimates of soil fertility,
- These methods are time consuming and therefore, not well adapted to the practice of soil testing.
1. Field tests:

(i) The field plot technique essentially measures the crop response to nutrients.

(ii) In these tests, specific treatments are selected and randomly assigned to an area of land which is representative of the conditions.

(iii) Several replications are used to obtain more reliable results and to account for variation in soil.

(iv) Field experiments are essential in establishing the equation used to provide fertilizer recommendation, Maximum profitability, and minimize environment impact of nutrient use.
2. Pot culture tests:

- The pot culture test utilizes small quantities of soil to quantify the nutrient supplying power of a soil.

- Selected treatments are applied to the soils and a crop is planted and evaluated.

- Crop response to the treatments can be than determined by measuring total plant yield and nutrient content.
3. Laboratory tests

(a) Neubauer seedling Method:
• The Neubauer seedling technique is based on the uptake of nutrient by growing a large number of plants on a small amount of soil.
• The seedlings (plants) exhaust the available nutrient supply within short time.
• The total nutrients removed are quantified and tables are established to give the minimum values of nutrients available for satisfactory yield of various crops.

(b) Microbial methods:
• In the absence of nutrients, certain microorganisms exhibit behaviour similar to that of higher plants.
• For example, growth of Azotobacter or Aspergillus niger reflects nutrient deficiency in the soil.
• The soil is rated from very deficient to not deficient in the respective elements, depending on the amount of colony growth.
• In comparison with other methods that utilize higher plants, microbiological methods are rapid, simple and require little space.
• These laboratory tests are not in common use in India.
4. Nutrient deficiency symptoms of plant

1. The plant requires seventeen essential nutrients for their optimum growth and development.
2. It is good tool to detect deficiencies of nutrient in the field.
3. When a plant nutrient is below critical concentration in plant, it shows deficiency symptoms.
4. These symptoms are nutrient specific and show different patterns in crops.

Limitations:

• The visual symptoms may be caused by more than one nutrient.
• Deficiency symptoms may be due to an excess quantity of another.
• Deficiency symptoms in the field may be due to disease or insect damage which can produce certain micronutrient deficiencies.
• Nutrient deficiency symptoms are observed only after the crop has already suffered an irreversible loss.
Clear Deficiency indicator plants:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Nutrient deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>Mg, Mn and Cu deficiencies</td>
</tr>
<tr>
<td>Wheat and barley</td>
<td>Mg, Cu and some times Mn deficiencies</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>B and Mn deficiencies</td>
</tr>
<tr>
<td>Maize</td>
<td>N, P, K, Mg, Fe, Mn and Zn deficiencies</td>
</tr>
<tr>
<td>Potatoes</td>
<td>K, Mg and Mn deficiencies</td>
</tr>
<tr>
<td>Rape</td>
<td>N, P and Mg deficiencies</td>
</tr>
<tr>
<td><em>Brassica</em> species</td>
<td>K and Mg deficiencies</td>
</tr>
<tr>
<td>grass</td>
<td>Fe and Mn deficiencies</td>
</tr>
<tr>
<td>Celery and sunflower</td>
<td>B deficiency</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>B and Mo deficiencies</td>
</tr>
<tr>
<td>Flax</td>
<td>Zn deficiency</td>
</tr>
</tbody>
</table>
Clear Toxicity indicator plants:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Nutrient toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>B, Mn and Al toxicities</td>
</tr>
<tr>
<td>Cucumber</td>
<td>N and P excess</td>
</tr>
<tr>
<td>Sugar beets</td>
<td>Cu excess</td>
</tr>
</tbody>
</table>