3. Soil Sampling and Processing

While the main focus of this manual is to present an easy-to-use methodology for soil testing and, to a lesser extent, for plant analysis, their related aspects are worthy of due emphasis. Therefore, a brief description of such aspects follows.

While much attention is given to laboratory procedures, the process of obtaining soil for analysis, i.e., soil sampling, is often ignored or poorly considered. A good sampling plan should provide a measure of the average fertility level of a field and a measure of how variable it is. If a sample is not representative of the field or is incorrectly taken, the resulting analytical data are meaningless, or at best, difficult to interpret. The error in field sampling is generally much greater than that due to chemical analysis. Therefore, obtaining a representative soil sample from a field is the most important step for making a meaningful soil analysis.

3.1. Soil Sampling

A soil sample should be composed of several sub-samples representing a seemingly uniform area or field with similar cropping and management history. There is no universally accepted numbers of sub-samples for different field situations. However, the following points can serve as guidelines:

Composite Sampling

- At ICARDA, eight sub-samples are taken per hectare (ha) in a diagonal pattern for obtaining one composite sample.
- Other plans range from 5 to 25 borings or sub-samples per composite sample, with sample units varying from 2 to 8 ha.
- Fewer sub-samples are needed where little or no fertilizer has been used. Sampling areas are often traversed in a zigzag pattern to provide a uniform distribution of sampling sites. Some of these methods are represented in Figure 2 and 3.
- Correspondingly, more sub-samples are needed where fertility is variable due to hand broadcasting of fertilizers and/or with cropping-livestock systems. Indeed, banding of fertilizer poses serious problems for reliable sampling.
- Thus, the number of sub-samples taken by farmers should be realistic, considering the particular field situation.

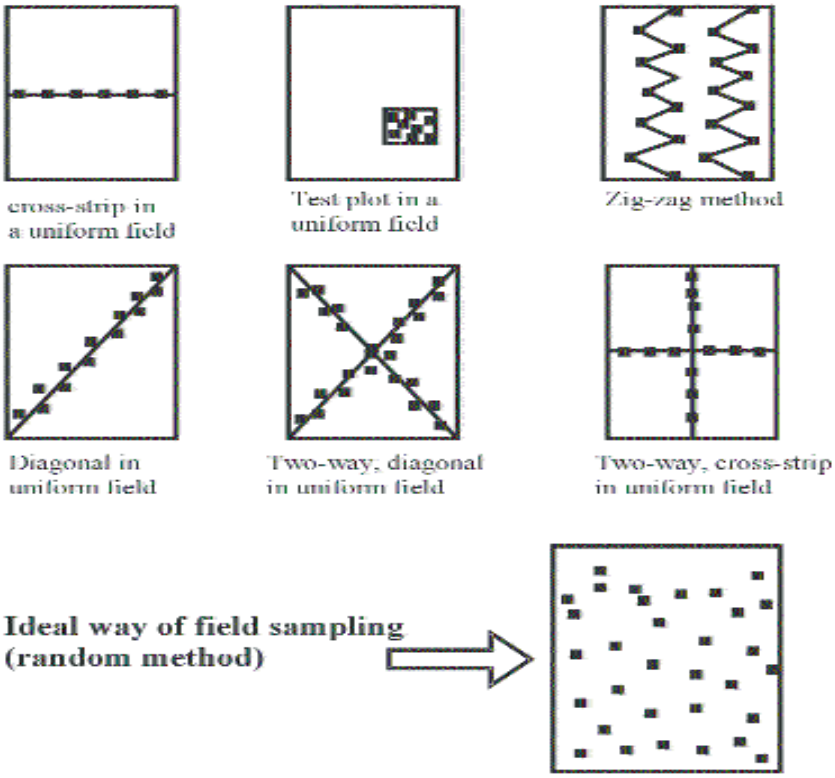


Figure 2. Some suggested methods for soil sampling; each dot represents a sample point, with formation of a sample pattern within the fielded

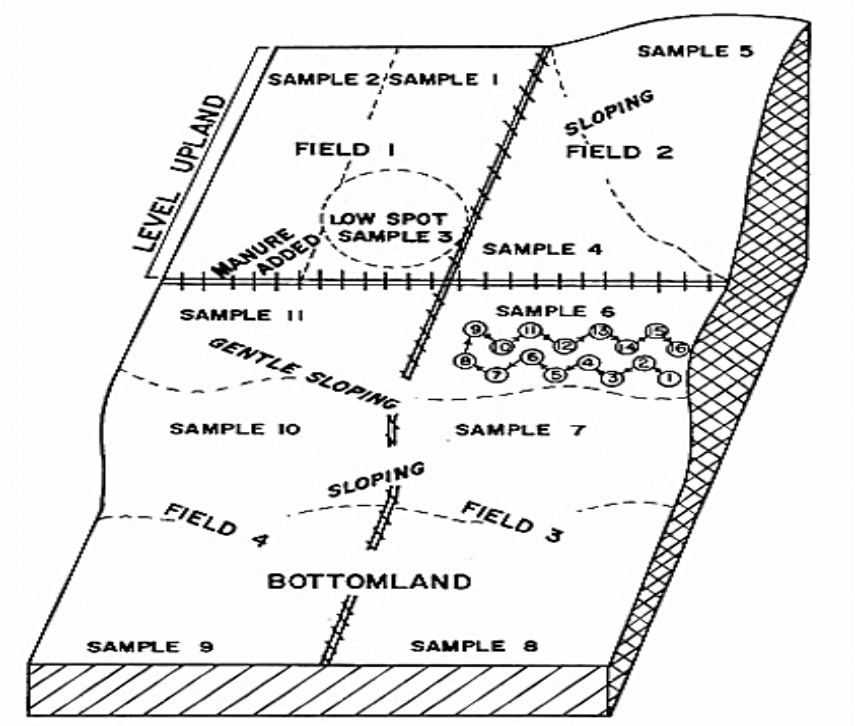


Figure 3. Sampling pattern for fertility test in a non-uniform land (sample numbers refer to composite sample; Tarzi, 1984)

Sampling Time

- Soil samples can be taken any time that soil conditions permit, but sampling directly after fertilization or amendment application should be avoided.
- Samples taken during the crop growth period will help in knowing the nutrient status of the soil in which plants are actively taking up nutrients.
- In the WANA region, it is recommended that sampling be carried out in autumn (before planting) if fertilization is intended at planting.
- It is important to sample at similar times year after year for comparing analysis at regular time intervals.

Sampling Depth

- For most purposes, soil sampling is done to a depth of about 20-cm. Available P, NO_3-N, and micronutrients in such samples are related to crop growth, and nutrient uptake.
- In some cases, especially in irrigated areas, sampling to a depth of 60-100 cm is desirable, especially for monitoring nitrate (NO_3-N) leaching.
- Depth-wise soil samples should also be taken where there is a concern about B toxicity.

Soil profile

Sampling Tools

- A uniform slice should be taken from the surface to the depth of insertion of the tool; the same volume of soil should be obtained in each sub-sample.
- Augers generally meet these requirements. In areas where the topsoil is dry, e.g., during summer, topsoil sampling can be done by a metal ring, by digging out the soil inside the ring, because it is almost impossible to sample dry topsoil with an auger.
- Soil samples for micronutrient analysis should be taken using a stainless steel auger, or at least ungalvanized auger (because galvanized coating is zinc oxide).
- Researchers generally use augers for field sampling. Farmers or Extension Agents can use shovels or trowels, with almost the same result.

Soil sampling tool: Auger

- If you do not have sampling tools, use a spade as follows:

- Dig a V-shaped hole 15 to 20 cm deep. Then take a fine thick slice from the smooth side (see Figure 4).

- Trim the sides leaving a fine strip then dump this strip into a clean bucket. Break the clods, and mix thoroughly. Remove large rocks, pieces of sod, earthworms, etc. Put the soil into the sample container and label the box clearly.

- For a moist soil, the tube auger or spade is considered satisfactory. For harder soil, a screw auger may be more convenient.

Figure 4. Soil sampling tool: Spade

Instructions for Field Processing

- Disturbed soil samples should be put in plastic bags (tags and markers are required), or aluminum or stainless steel boxes
- Depending on the subsequent analysis samples may be kept cool until laboratory analysis.
- Bags should be examined for cleanliness as well as for strength.
- Soil samples can be transported to the laboratory in cardboard boxes or sacks.
- All information about samples is recorded, and each sample is given a laboratory number.
- Sketch your field. Diagram it the way you sampled it. Be sure sampled areas are labeled the same as sample containers. (This is so you have a record of which recommendations apply to which areas – do not rely on your memory).
- Information sheet should be clearly written with copying pencil. Fill out the information sheets. The more information you can provide with each sample, the better your recommendation will be.
- Do not sample unusual area, like unevenly fertilized, old channel, old bunds, area near the tree, and site of previous compost piles and other unrepresentative sites.
- Avoid any type of contamination at all stages. Soil samples should never be kept in the store along with fertilizer materials and detergents. Contamination is likely when the soil samples are spread out to dry in the vicinity of stored fertilizers or on floor where fertilizers were stored previously.
- Collect samples from the middle of the rows, when crops have been planted in rows, so as to avoid the area where fertilizer has been band-placed.

3.2. Preparation Laboratory Processing

Handling in the laboratory

- As soon as the samples are received at the soil preparation facility, they should be checked with the accompanying information list (including sample number, depth, and date of sampling should be written on the bag from outside, and on a sample card placed inside the bag). Information regarding samples should be entered in a register and *each sample be given a laboratory number*.
- The soil-fresh sample received in the laboratory should be analyzed directly after sampling for determination of nitrate, nitrite and ammonium. ***These samples should not be dried, and the results are expressed on oven-dry basis by separately estimating moisture content in the samples*.** If short-term storage is unavoidable, this must be done in a fridge at temperature close to 0 °C (but not below zero!). Lag time between field sampling and analysis must be minimized. Otherwise, storage time will inevitably introduce an additional factor influencing analysis results.

Drying of the soil samples

- The soil-fresh samples received in the laboratory should be dried in wooden or enameled trays. The trays can be numbered or a plastic tag could be attached, and care should be taken to maintain the identity of each sample at all stages of preparation.
- During drying, the soils are allowed to dry in the air. Alternatively, the trays may be placed in racks in a hot air cabinet (the temperature should not exceed 35 °C and humidity should be between 30 and 60 %). In general, excessive oven-drying of the soil affects the availability of most of the nutrients present in the sample, and should be avoided.

Ovens

- Only air-drying is recommended for some of the nutrients present in the sample. Such as, drying has negligible effect on total N content but the NH_4 and NO_3 content in the soil changes with time and temperature. The microbial biomass is also significantly affected by drying at high temperature.

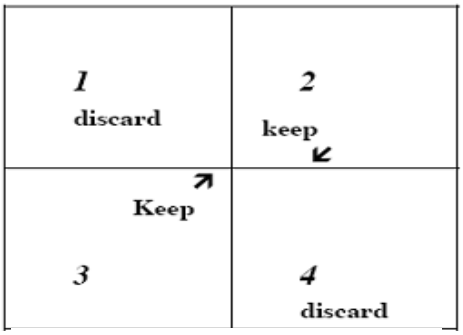
Preparation of soil samples

- After drying, the samples are ground with a wooden pestle and mortar in preparation room (which is separate from the main laboratory), and clods and large aggregates are crushed and mixed. Remember that:
- Pebbles, concretions, and stones should not be broken during grinding.
- Care should be taken not to break the individual soil particles during the grinding process.
- The entire sample should be passed through the sieve, except for concretions and pebbles of more than 2-mm.
- The purpose of grinding is to reduce heterogeneity and to provide maximum surface area for physical and chemical reactions. Various devices are used for crushing and grinding soils. However, choice of equipment depends on:
  - Amount of sample to be crushed or ground
  - Degree of fineness to be attained
  - Contamination that can be tolerated
  - The analysis in question

- After grinding, the soil is screened through a 2-mm sieve. The coarse portion on the sieve should be returned to the mortar for further grinding (except for concretions, pebbles, and organic residues). Repeat sieving and grinding till all aggregate particles are fine enough to pass the 2-mm sieve.
- It is necessary to reduce the size of the large sample for ease of storage and handling. To achieve this goal, a random method of sub-sampling is essential. Sample splitting can be performed with a mechanical sample splitter, such as a **Riffle-type Sample Splitter**, by which the sample is divided in half by a series of chutes. This process can be repeated as many times as necessary.
- Another way for reduction of sample size is by **quartering**. The sample is spread uniformly over a plastic or paper sheet and divided into four equal portions. For example, portions 2 and 3 are collected and thoroughly mixed, whereas the remainder is discarded.
- Following the drying and preparing processes, half of the amounts of the dried soil sub-sample are placed in a clean container and then transferee into the soil testing laboratory for the requested analysis, the rest should be stored in cardboard boxes in a store room.
- Remember, if the soil is to be analyzed for trace elements, containers made of copper (Cu), zinc (Zn) and brass must be avoided during grinding and handling. Sieves of different sizes can be obtained in stainless steel. Aluminum or plastic sieves are useful alternative for general purposes.

Riffle-type soil samples splitter (sample dividers)

Soil grinder



Reduction of soil sample size

4. Soil Physical Analysis

Soil physical measurements are numerous, depending on the objective of the study for agricultural purposes. These measurements generally includes soil water purpose on the content, infiltration and hydraulic conductivity, evapotranspiration, heat, temperature, reflectivity, porosity, particle size, bulk density, aggregate stability, and particle size distribution.

Soil moisture is routinely measured on field-moist samples, since all physical analyses are expressed on oven-dry basis (16-18 hours drying at 105 ^{o}C). As texture (e.g., whether sandy or clay) is quite important in relation to nutrient behavior, particle size distribution is often carried out, especially if more precision is needed than provided by the qualitative physical "feel" approach for determining texture.

4.1. Soil Moisture Content

As water is the most limiting factor in the arid to semi-arid areas, soil moisture determination is of major significance. ***Soil moisture influences crop growth not only by affecting nutrient availability, but also nutrient transformations and soil biological behavior****. Therefore, at ICARDA soil moisture is routinely measured in most field trials. While it can be assessed in the field by the neutron probe, the gravimetric approach is more flexible, as samples can be readily taken from any soil situation. All analyses in the laboratory are related to an air- or oven-dry basis, and therefore must consider the actual soil moisture content* (Sparks et al., 1966).

Apparatus

Electric oven with thermostat

Desiccator

Procedure

1. Weigh 10 g air-dry soil (< 2-mm) into a previously dried (105 °C) and weighed metal can with lid.
2. Dry in an oven, with the lid unfitted, at 105 °C overnight (normally for 24 hours).
3. Next day, when the soil has dried, remove the container from the oven, using tongs; fit the lid, cool in a desiccator for at least 30 minutes and re-weigh.

Calculation

$$\boldsymbol{Soil\ Moisture}\ (\theta) = \frac{\boldsymbol{wet\ soil}\ (\boldsymbol{g}) - \boldsymbol{dry\ soil}(\boldsymbol{g})}{\boldsymbol{dry\ soil}\ (\boldsymbol{g})}$$

$$\boldsymbol{Dry\ Soil}\ (\boldsymbol{g}) = \frac{\mathbf{1}}{\mathbf{1} + \frac{\boldsymbol{\theta}}{\mathbf{100}}} \times \boldsymbol{Wet\ soil}$$

$$\boldsymbol{Moisture\ Factor} = \frac{\boldsymbol{Wet\ soil}(\boldsymbol{g})}{\boldsymbol{Dry\ soil}\ (\boldsymbol{g})}\ \boldsymbol{or}\ \frac{\mathbf{100} + \%\,\boldsymbol{\theta}}{\mathbf{100}}$$

Technical Remarks

1. The wet soil sample should be kept loosely in the container.
2. Care should be taken to avoid over-heating of the soil sample by maintaining the oven temperature at 105-110 °C.
3. Dry soil sample should not be left uncovered before weighing.
4. To determine the moisture content of litter and humus samples, dry samples at 70 °C for 48 h.
5. Moisture content in air-dry is called hygroscopic moisture. It varies from less than 0.2% for sand to more than 8% for similar with leaf litter/OM, depending upon the relative humidity in the storage area, and fineness of soil particles. Samples should be air-dried prior to moisture content determination.
6. Moisture content values reproducible to within ± 0.5 % can be achieved.
7. The oven is monitored periodically to ensure that temperature fluctuation does not exceed 5 ^{o}C.
8. The water content at field capacity, wilting point, and the hygroscopic coefficient are all based on the oven-dry reference mass. The percentage of water held under each of these conditions can therefore be used to define the following and other forms of soil water. Each of these forms of water can be calculated from the appropriate soil mass.

$$Hygroscopic\ water\ (\%) = Hygroscopic\ coefficient$$

$$Capillary\ water\ (\%) = Field\ capacity - Hygroscopic\ coefficient$$

$$Available\ water\ (\%) = Field\ capacity - Wilting\ point$$

$$Unavailable\ water\ (\%) = Wilting\ point$$

$$Gravitational\ water\ (\%) = Water\ content - Field\ capacity$$

4.2. Water Holding Capacity

The water-holding capacity *(WHC) is defined as the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water has materially ceased. Stage of field capacity is attained in the field after 24 to 72 hours of saturation; this is the upper limit of plant-available soil moisture. We must distinguish between* ***soil water content****, (the percent water on an oven-dry weight basis), and* ***the soil water potential*** *(the energy status of water in the soil), which is usually expressed in pressure units (Pascal or bar). However, as indeed we are dealing with a tension – a negative pressure - units are usually considered to be negative.*

Apparatus

Polythene sheets	Funnel (glass or plastic)
Spade	Tubing (to attach to bottom of funnel)
Soil auger	Clamp (to secure tubing)
Moisture boxes/cans	Filter paper (to line funnel)
Balance	Beakers (250-mL)
Oven	Graduated cylinder
Ring stand	Stirring rod (long)

Procedure

A. Field Processing

1. Select a uniform plot measuring (5 m x 5 m) and make a flat and horizontal area.
2. Remove any loose material from the surface (weeds, pebbles, etc.).
3. Make bunds around the plot.
4. Fill sufficient water in the plot to completely saturate the soil.
5. Cover the plot area with a polythene sheet to check evaporation.
6. Take soil sample from the centre of the plot from the desired layer, starting after 24 h of saturation and determine moisture content daily till the values of successive days are nearly equal.
7. Record the weight of the oven-dry soil.
8. Repeat above on next day and so on till a constant oven-dry soil value is reached.

B. Laboratory Processing

1. Thoroughly air-dry compost and soil samples.
2. Attach and clamp tubing to bottom of funnel and attach funnel to ring stand.
3. Place filter paper in funnel.
4. Fill funnel with the 100 mL sample – do not compact.
5. Measure out 100 mL of water using the graduated cylinder.
6. Gradually add water to the sample until covered. Record the amount of water added.
7. Stir gently and let sit until sample is fully saturated.
8. Release the clamp and collect excess water in the graduated cylinder (water drained, mL).
9. Record the amount of water in the cylinder.
10. Calculate how much water was retained in the 100-mL sample of compost, soil or compost/ soil mixture and then calculate the water-holding capacity.

Calculations

$$\frac{\boldsymbol{Water\ retained\ (mL)}}{\boldsymbol{100\ mL\ sample}} = \boldsymbol{Water\ added\ (mL)} - \boldsymbol{Water\ drained\ (mL)}$$

$$\boldsymbol{Water\ Holding\ Capacity\ (mL\ /L)} = \frac{\boldsymbol{Water\ retained\ (mL)}}{\boldsymbol{100\ mL\ sample}} \times \mathbf{10}$$

Note

Water-holding capacity is expressed as the amount of water retained per liter of soil, so the next step is to multiply by 10 to convert from the 100 mL sample to the full liter.

Technical Remarks

1. Estimates of soil WHC, wilting point and texture can be made from the saturated moisture content. The method is generally reproducible within ± 12%, dependent on the soil textural class.
2. Plot the daily readings on a graph paper. The lowest reading is taken as the value of field capacity of the soil.