Canadian Foodgrains Bank
A Christian Response to Hunger

Soil Testing Guidelines

AGRICULTURE & LIVELIHOODS GUIDANCE NOTE

APRIL 2020

AGRICULTURE & LIVELIHOODS CAPACITY DEVELOPMENT PROGRAM

Background

Soil infertility is a key constraint to improving crop production for small-scale farmers. Soils throughout Canadian Foodgrains Bank members' program areas are degraded and deficient in nutrients and organic matter. Soil testing measures the soil's health and nutrient holding capacity and provides a measure of nutrient status and health. It also serves as a basis for crop and land management decisions. Soil testing has been advocated by technical specialists, government extension agents and through radio messaging. As a result, there is a growing demand from farmers and project partners for information on soil testing strategies and services. Farmers want specific guidance on which fertility inputs are best for their fields, and how much they should apply.

Given the wide range of available soil testing options, it is important to identify which tests are most useful for a given project, and for what reason. Some tests are helpful in developing recommendations for how farmers manage crops. Other tests may not help with crop management decisions, but are useful in training farmers to think about soil health. Still others are helpful in monitoring and evaluation of the effects of a project on soil nutrients and soil health. This guide is designed to help farmers and partners decide what soil tests are most important and cost-effective for their context.

What are the main components of soil fertility?

Soil nutrients are used by plants in vastly different quantities. Nitrogen (N), Phosphorus (P) and Potassium (K) are used by plants in relatively large quantities, and thus are referred to as *macronutrients.* N, P and K are also the main components of synthetic fertilizers and major components of organic amendments like manure and compost. Thus, in addition to assuring healthy plant growth, optimizing their use can result in a greater return on investments of cash and/or labor for this costly input. Calcium (Ca), Magnesium (Mg) and Sulfur (S) are used by plants in lesser quantities and are referred to as *secondary nutrients*. These elements do not limit plant growth as commonly as macronutrients, and are much less common as components in fertilizers. *Micronutrients* (e.g. zinc, manganese) are used by plants in very small quantities, and their availability in soils is most commonly limited by soil pH rather than by their actual abundance in the soil.

Soil pH is a measure of the amount of acidity or alkalinity present in a soil, measured on a 0-14 scale, with *low* numbers indicating *high* acidity. Soil pH affects the availability of all soil nutrients—macro, secondary, and micro—so if soil is too acidic or alkaline, plants may not utilize nutrients even when they are present in the soil. Furthermore, nitrogen fixation in legumes is reduced in very acidic soils. Finally, some elements in the soil, such as aluminum, can become toxic if soils are not maintained in an optimum range. Taking all these factors into account, most crops perform best within a pH range of 5.5 to 8.0 (Figure 1). Given the many impacts of soil pH on soil chemistry, it is clearly in a farmer's best interest to try and manage soils within this range.

Another soil component which has broad impacts on soil fertility is soil organic matter (SOM). SOM serves as a slow-release source of most soil nutrients. It also acts as a storehouse for positively charged elements such as K, Ca and Mg, protecting them from leaching by excess water. Finally, SOM is the main fuel for

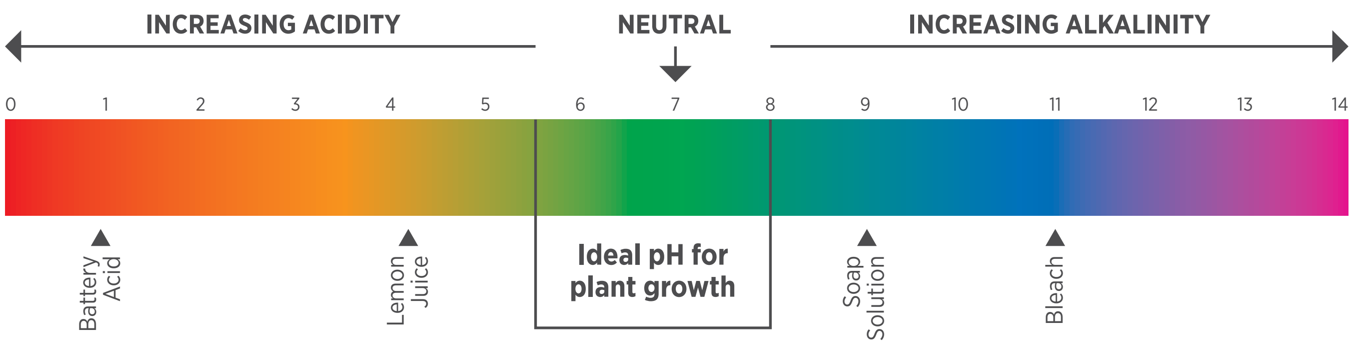


Figure 1. Ideal pH Range for plant growth.

soil microbial activity, which releases soluble soil nutrients and promotes good physical properties, good moisture retention and drainage of excess moisture.

Some of these soil components are more easily managed by farmers than others. Some can be measured locally, and others require expensive laboratory tests. Thus, a good soil testing strategy needs to answer several questions including:

1. Which factors may be affecting plant growth?
2. Which factors are within the management capacity of the farmers we are working with?
3. How costly is it to measure each factor?

The following pages attempt to summarize these complex questions in order to help farmers make better management decisions, to help project staff monitor how their interventions impact soil health and fertility, and to help everyone understand the importance of soil health in improving food security and environmental health.

Soil testing recommendations for crop management decisions

As noted above, some soil tests are not useful in making management decisions because the inputs they call for may be unavailable or too expensive for small-scale farmers to afford. Other tests may provide information that farmers can use to make changes that increase their productivity. Projects should focus on such testing when deciding how to advise farmers. The following guidelines summarize these issues:

- **Soil pH testing**, as noted above, is important because pH drives many of the processes which lead to good plant growth. In addition, farmers can often manage acid soils by using lime and/or wood ash in their fields. Soil pH testing using pH strips costs less than $0.15 per sample (see Appendix B), and thus individual small-scale farmers can generally afford to have their fields tested. Soil pH testing should be carried out every 3 or 4 years to monitor changes over time.
- **Complete soil nutrient tests should include pH, phosphorus (P), and potassium (K)**. Additional soil tests for Ca, Mg, and cation exchange capacity are sometimes included at no additional cost, but are less helpful since, as noted above, they aren't generally as limiting. ***Complete soil nutrient tests are generally too expensive (e.g. $25-50 per sample) for individual small-scale farmers to afford***. However, testing a range of soils in an area can help project staff develop general recommendations on which fertilizers are most important in the area, and what type and rates of fertilizer, compost and/or manure farmers should be using. For example, they might find that clay soils in the project area are generally low in P and therefore need P fertilizer or higher rates of manure. Or they

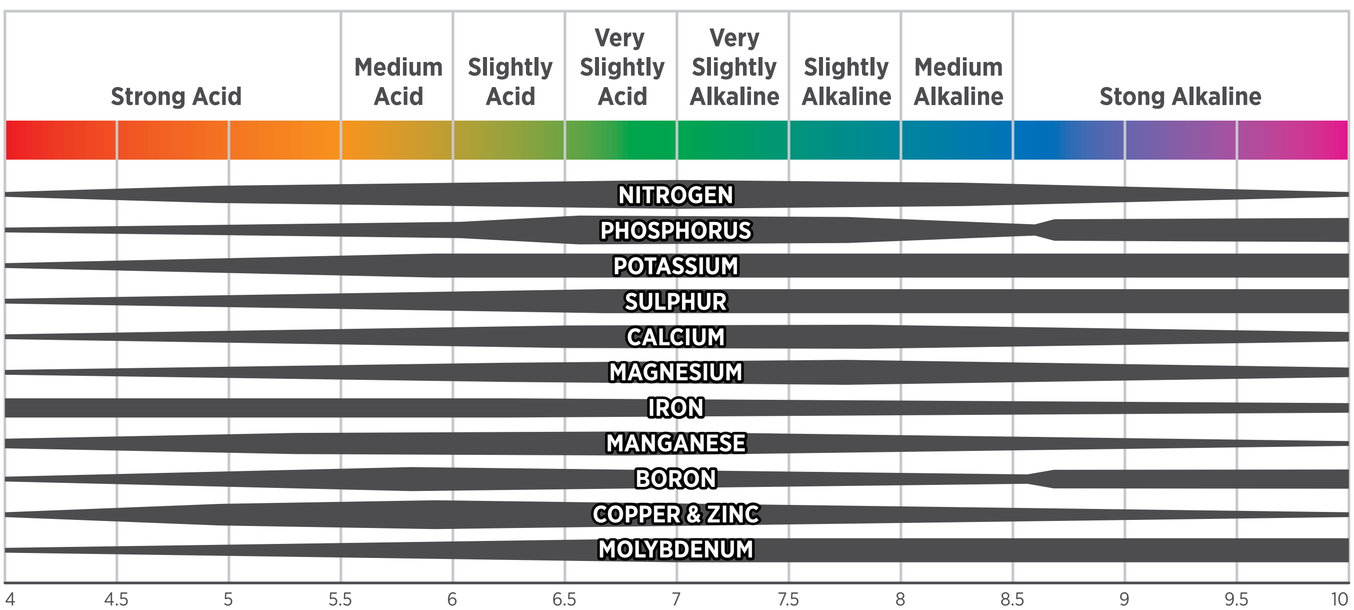


Figure 2. Nutrient availability as affected by soil pH (Roques, et al., 2013).

might find that the red soils in an area are highly acidic and therefore need ample doses of lime or wood ash. Over time, as soil quality improves, project staff may use soil testing to help farmers reduce inputs (compost, manure, fertilizer, lime or wood ash) without compromising yield, especially if they have been using large quantities of these materials.

- **Soil organic matter testing**, as noted above, provides many benefits for soil health and fertility, so the goal for most soils should be to *maximize* SOM levels. Testing for SOM doesn't generally help in making management decisions (farmers should *always* strive to increase SOM if they can!) However, documenting rising SOM levels, or higher SOM in project fields than in traditional fields, can motivate farmers to manage their soils well.
- **Nitrogen testing** is often expensive and the nitrogen content of the soil changes rapidly, especially with wet conditions. ***For this reason, nitrogen testing is not generally helpful in developing fertility recommendations***. Nitrogen rates are better determined based on the N demand of the current crop, any N contribution from the previous crop, history of manure and/or compost application, and recent weather (excess rain generally means less natural N available from the soil).
- **Micronutrient testing** is also expensive and the availability of most micronutrients is strongly influenced by soil pH (Figure 2). Furthermore, micronutrient fertilizers are rarely available for small scale farmers. ***For these reasons, it is generally better to focus on good soil pH management, and manure/compost which supply micronutrients, rather than to spend time and money on micronutrient testing***.
- **Soil texture** is *not* something farmers can change or influence. Laboratory analysis is expensive, and thus there is very little reason to include soil texture in a laboratory analysis. Hand texturing can be easily learned (see Appendix C) and is accurate enough for management decisions.

Soil testing methods for farmer education purposes

- **Crop growth and yield**, including understanding signs of nutrient deficiency in crops, are generally the most obvious and most convincing evidence of poor soil health or fertility. Such observations do not require expensive testing, and they should be encouraged and taught widely.
- **Increasing soil organic matter content** is the single most important strategy for improving soil health and crop production and should be central in any educational effort for small farmers. Organic matter improves soil moisture retention, soil structure, nutrient-holding capacity, biological activity, pH buffering, etc. It also helps plants utilize chemical fertilizers more efficiently. Because soil color and organic matter content are closely related, measuring changes in soil color using standardized color charts or by comparisons to control plots is an easy and relatively reliable way for farmers to discuss and monitor soil organic matter changes.
- **Soil infiltration and erosion demonstrations** using small plots or containers are very effective ways of demonstrating the impact of soil management and/or the differences between healthy and depleted soils (see Appendix D).
- **Soil health assessment tests**, as developed by the USDA or Cornell University, are a good starting place for encouraging farmers to think about improving their soils.

Soil testing recommendations for project monitoring and evaluation

- **Complete soil nutrient analyses** are useful to provide a baseline and to measure changes due to improved management practices. 30-40 fields should be randomly selected at the beginning of the project. Essential tests for a baseline include pH, buffer pH, P, K and organic matter. N, S and B (boron) are not appropriate indicators in a baseline because they are too mobile to be consistent over time.
- **Soil health assessment** tests, including soil color, structure, biological activity, etc., are also good parameters to monitor as part of a monitoring and evaluation strategy.
- **Soil texture** is *not* an appropriate measure as it is not affected by management practices.
- **Follow-up sampling for monitoring purposes** should be taken in the same fields as the baseline, ***at the same time of year***. A dry-season sample may be difficult to compare with a baseline sample taken during the wet season. Comparing results of the baseline with later years can be helpful, but it is even more helpful to compare project fields with an adjacent field that has not been managed with

recommended methods. Projects planning to use follow-up soil testing for monitoring and evaluation purposes should therefore budget for twice as many follow-up soil samples (60-80 fields) as they took in their baseline sample.

- **Detailed records should be kept** on soil and crop management practices for these monitoring and evaluation fields. This may reveal information that will guide the project's future recommendations. (e.g. the use of different kinds and thicknesses of mulch, different species of green manure cover crops, wood ash or lime applications, etc.)

Challenges in soil testing with small farmers:

- Commercial soil tests often include plant nutrient recommendations. These recommendations should be based on crop-response studies using varied fertilizer rates in varying conditions, and resulting in fertilizer recommendations based on soil types, crops and expected yield. However, in many environments, and for many crops, such research has never been conducted, especially in the countries where small-scale farmers reside. Thus, while broad fertility recommendations can be made for an area, specific rates for individual fields are not to be trusted.
- Crop response studies generally focus on mineral fertilizers and rarely study amendments such as manure or compost. This is due, in part, to the fact that the nutrient composition of these amendments varies greatly.
- Even when accurate soil tests and response data are available, small-scale farmers often have only limited access to fertilizers or soil amendments.
- Test results often do not state what laboratory methods were used to conduct the testing. Without this information it is sometimes difficult to interpret the results.
- Lower-cost forms of soil testing, such as near-infrared spectroscopy used by some commercial laboratories, need even more calibration than traditional laboratory methods, and in many cases, the data for adequate calibration is not available.

Appendix A: Soil testing procedures

Properly collected soil samples are a key to effective soil testing. Individual fields usually have a wide level of variation, and there is usually even more variation between fields or between different areas of a farm. In order to develop an effective soil fertility strategy, it is important to be aware of these differences and to test accordingly.

WHERE TO COLLECT SAMPLES

Before sampling, make a map of your land. Divide your map into individual areas, or management zones, with each one consisting of only one soil type or condition (slope, soil color, drainage or texture). If these areas are significant in size, sample each area separately. Zones which have been managed differently in the past may differ and should also be sampled separately. For example, in many homesteads, fields closer to houses receive higher rates of inputs than those further away. Most farmers know which parts of their farm are more or less productive, and this knowledge can be used to help guide how many different areas need to be sampled.

To ensure a representative sample, avoid taking cores from small areas where soil conditions may differ substantially from those in the rest of the field (e.g. field borders, under trees, wet spots, severely eroded areas or old household or kraal sites). In fields with permanent planting stations, one sample should be taken within the planting stations, and one sample from outside the planting stations.

Figure 3. Soil testing pattern for a field with 3 different management zones (Hardy, et al., 2002).

WHEN TO COLLECT SAMPLES

Collect and submit samples for laboratory testing in plenty of time before you plan to plant. Receiving test results may take time, and it is important to ensure there is adequate time to procure and apply any recommended inputs before planting. *If re-sampling a field, always sample during the same time of year as the previous sample.*

HOW TO COLLECT SAMPLES

Essential tools for collecting soil samples include a plastic bucket and a shovel, hoe or soil probe. If testing for micronutrients, do not use brass, bronze or galvanized tools because they can contaminate samples with metals. Clean the bucket and tools before collecting samples to prevent small amounts of materials like ash, compost or fertilizer from contaminating the sample and distorting test results.

The correct depth for a sample depends on previous field management. For cultivated row crops or vegetable gardens, sample to 15cm depth. Deep-rooted perennial crops should be sampled deeper. Collect soil at 15 to 20 staggered locations across a field and place them together in the bucket. Zigzag patterns help ensure that samples accurately reflect overall field conditions. Although a soil probe is ideal, samples can be collected with a shovel, hoe or soil probe as follows: remove any surface material/mulch present and then dig a hole 15cm deep. Now cut a 2-3cm thick slab of soil from the wall of the hole and carefully place it in the bucket. Mix the cores thoroughly and place 250-400ml of soil in a bag labeled with a permanent ink pen. Samples should be air dried, especially if testing for nitrogen. Paper bags speed this process. If thoroughly dried, however, plastic bags can be used for storage.

HOW OFTEN TO SAMPLE

Soil nutrients do not change rapidly in response to management practices. In most cases, it is adequate to sample every 3 or 4 years.

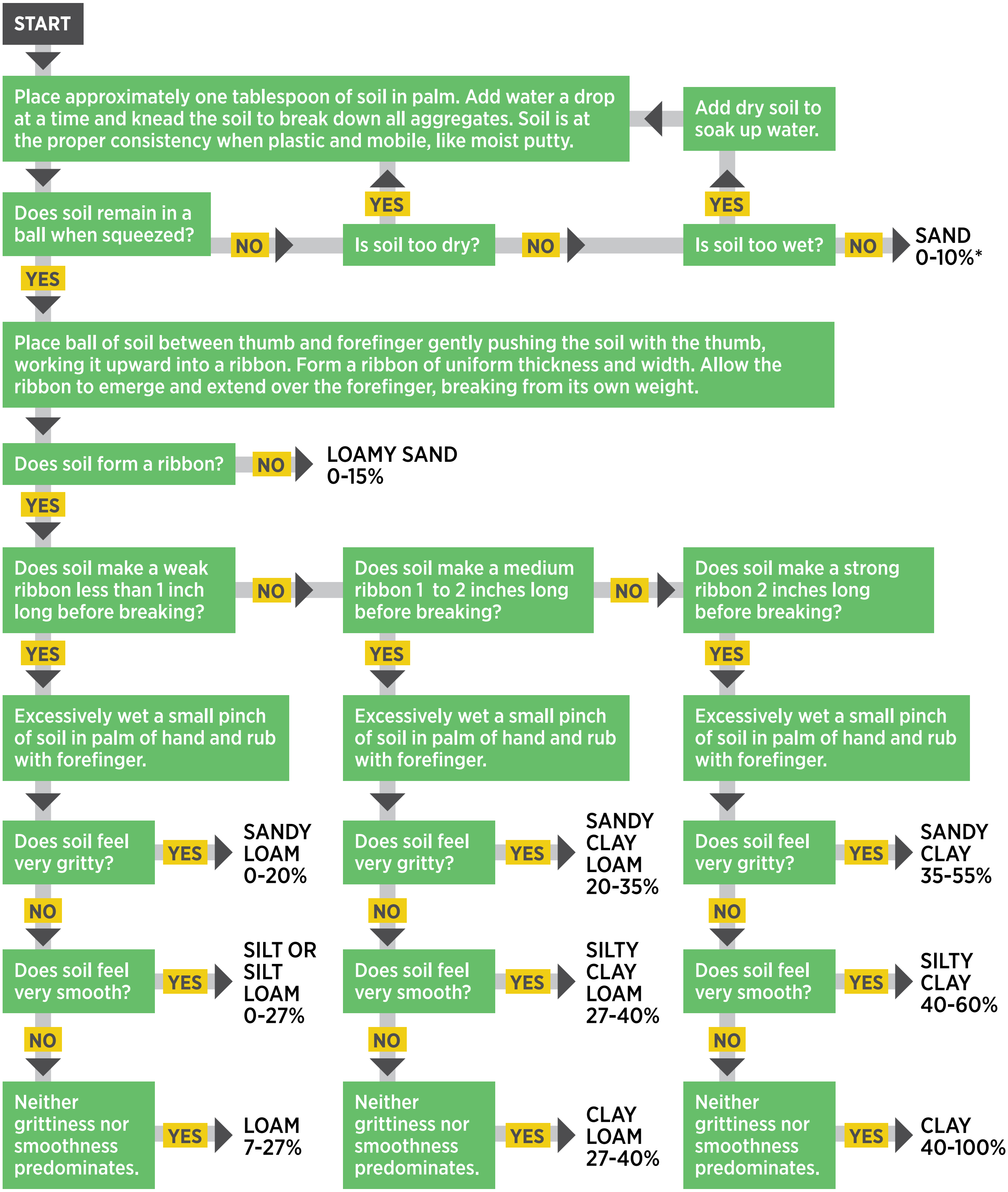
Appendix B: Measuring soil pH with pH strips

PH strips can be bought from medical supply or general laboratory supply stores. However, their accuracy and ease of reading ranges widely. Before promoting a particular brand of pH strip, it is best to test their accuracy by comparing them to a laboratory pH meter. Ordinary litmus paper only tells you whether the pH is above or below 7.0. The best strips we have found for soil sampling are paper pH strips manufactured by Kemphasol, India and available from laboratory supply stores in Kenya (and possibly other countries).

PROCEDURES

1. Sample soils using standard soil sampling procedures (see Appendix A).
2. Mark two 500ml water bottles with the tops cut off. Use a permanent marker to draw a line three cm from the bottom of each water bottle.
3. Fill one bottle to the line you just marked with well-mixed soil from the sample you just took.
4. Fill the second bottle to the line with distilled water (i.e. battery water from an automotive supply store).
5. Pour the water into the bottle with the soil sample and stir well until any soil clumps break apart and go into solution.
6. Place two layers of t-shirt material over the first bottle and pour the liquid from the second bottle through the cloth to filter it.
7. Allow the mixture to stand and settle for a few minutes.
8. Dip a pH indicator strip into the clear liquid for 15 seconds or however long the manufacturer recommends. If the liquid is strongly colored by the soil, immerse only a small part of the strip (5-8 mm) deep into the solution, and allow the liquid to wick up higher on the strip. Use the upper (cleaner) portion for pH reading.
9. Compare the final color of the strip to the color rating scale supplied with the strips.

Appendix C: Measuring soil texture



*Clay percentage range.

Figure 4. Soil texture by the feel method.

Appendix D: Water infiltration/erosion

DEMONSTRATION

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I. Create an experiment

A. Lay out the experiment (30 minutes)

1. *Measure two 1m x 1m plots and mark with wood stakes (or fill two cut-apart 20 litre containers with soil).*
2. *Spread mulch on one plot.*
3. *Fill the watering can with eight litres of water and sprinkle on the* ***unmulched*** *plot holding the can as high as possible so that it impacts the soil.*
    a) *Note any runoff water and soil from the plot.*
4. *Fill the watering can with eight litres of water and sprinkle on the* ***mulched*** *plot holding the can as high as possible in the same fashion.*
    a) *Note any runoff water and soil from the plot.*
    b) *Lift the mulch to examine the soil underneath.*

B. Discussion questions (30 minutes)

1. *What did you see in each plot?*
2. *What differences would you expect to see in the two plots if you return in two days? Why?*

Replace the mulch and leave the plots to dry out.

II. Follow-up (This activity should take place several hours or up to one day after watering the two plots. If this lesson is being done the same day as the lesson on planting with precision, you can facilitate that lesson now, then come back to complete this lesson at the end of the afternoon).

A. Field observations (30-45 minutes)

1. *Uncover the mulched plot.*
2. *Have participants feel differences in soil temperature in the two plots.*
3. *Turn soil in center of each plot with a shovel.*
4. *Give each participant a handful of soil from each plot.*
5. *Discussion questions:*
    a) *What changes do you see since we watered the two plots?*
    b) *What differences do you see between the two plots? Why?*
    c) *In which soil would you rather plant a crop?*
    d) *If we planted seed in each plot today, what difference would you expect to see in one week?*

Appendix E: Reference materials on soil testing, soil health and soil fertility management

Brady, N. C. 1974. *The Nature and Property of Soils*. Macmillan Publishing Co., Inc. New York.

Canadian Foodgrains Bank. 2017. *Soil Health Assessment Field Manual*.

Fairhurst, T. (ed.) (2012) *Handbook for Integrated Soil Fertility Management*. Africa Soil Health Consortium, Nairobi.

Magdoff, F. and H. van Es. 2009. *Building Soils for Better Crops*, 3rd Ed. Sustainable Agriculture Network.

McCauley, Ann, Clain Jones, and Jeff Jacobsen. 2009. *Plant Nutrient Functions and Deficiency and Toxicity Symptoms*, Nutrient Management Module No. 9. Montana State University Extension.

Moebius-Clune, B.N., *et al.* 2016. *Comprehensive Assessment of Soil Health - The Cornell Framework Manual* Edition 3.2, Cornell University, Geneva, NY.

USDA. *Soil Health for Educators.* Natural Resource Conservation Service, USDA.

Wichman, W. 2004. *World Fertilizer Manual*. International Fertilizer Association.

Youdeowei, A. F.O.C. Ezedinma, & O.C. Onazi. 1986. *Introduction to Tropical Agriculture*. Longman. pp. 58-79

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