Nova Scotia Agriculture and Fisheries | Nova Scotia Agricultural College | Horticulture NS Nova Scotia

factsheet

# Fundamental Aspects of Soil-Water-Plant Relationships

## Introduction

Soils are fundamental to agricultural production because they supply many of the essential plant requirements for plant growth including:

- Water
- Nutrients
- Anchorage
- Oxygen for roots
- Moderated temperature

Soil physical properties are those characteristics that can generally be seen or felt. They influence the movement of water and hence the growth of most plant species. Thus, soil productivity, crop growth and the success of a farm often depends on soil physical characteristics.

## Soil Texture

Soil texture (Figure 1) is the proportion of the three sizes of soil particles: sand (0.05 to 2.0 mm diameter), silt (0.002 to 0.05 mm diameter) and clay (< 0.002 mm diameter). Soil texture influences such attributes as water and nutrient holding capacity, aeration, water infiltration and ease of root penetration (Table 1). The effects of texture are often generalized since a multitude of other factors affect the soil. For example, water tends to drain more rapidly through coarse soils than through fine soils. No soils in Nova Scotia have a clay content greater than 30-35 %.

After rain or snowmelt, coarse soils usually dry quicker than fine soils. This allows farmers earlier access to fields with coarser textured soils. As coarse soils dry out quickly, they require frequent rainfall or irrigation to maintain an adequate supply of plant available water.

Medium soils are considered ideal for crop production. Medium (loamy) soils are not too sticky when wet and are easy to work. They have good moisture holding capacity but excess water usually drains freely if organic matter and structure are maintained. Medium soils exhibit the benefits of both fine and coarse soils without their drawbacks.

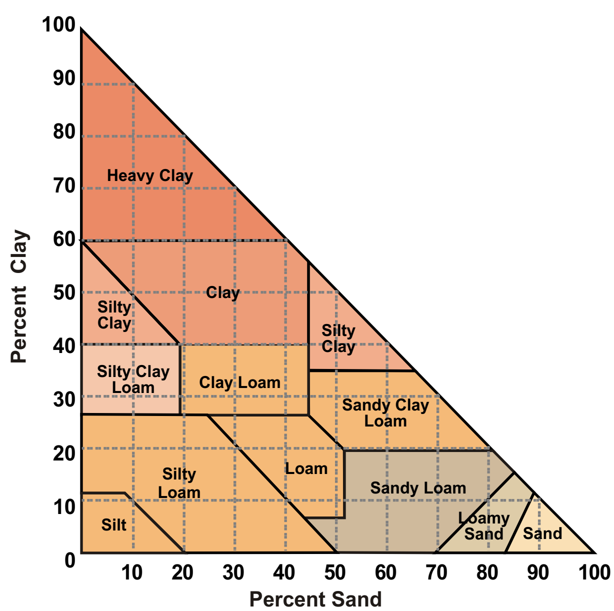


**Figure 1** Soil Texture Triangle

**Table 1** Generalized Influence of Soil Particles on Some Soil Attributes.

| | Rating Associated with Soil Particle | | |
|---|---|---|---|
| **Attribute** | **Sand** | **Silt** | **Clay** |
| Water Holding Capacity | Low | Medium to High | High |
| Aeration | Good | Medium | Poor |
| Drainage Rate | High | Slow to Medium | Very Slow |
| Soil Organic Matter Level | Low | Medium to High | High to Medium |
| Decomposition of Organic Matter | Rapid | Medium | Slow |
| Warm-Up in Spring | Rapid | Moderate | Slow |
| Compactability | Low | Medium | High |
| Susceptibility to Wind Erosion | Moderate | High | Low |
| Susceptibility to Water Erosion | Low | High | Low if aggregated High if not |
| Shrink-Swell Potential | Very Low | Low | Moderate to Very High |
| Suitability for Tillage after Rain | Good | Medium | Poor |
| Ability to Store Plant Nutrients | Poor | Medium to High | High |

There are several methods of measuring soil texture, including laboratory procedures which are expensive. A simple test however, that can be performed on site is the ribbon or "feel" method (Table 2). This test is based on the feel of a dampened soil and how easily it can be molded. The procedure can be useful after one has practised enough to "get a feel" for it.

**Table 2** The "Feel" Method For Determining Soil Texture Class

**Soil Texture Assessment Tests**

**Moist Cast Test:**
Compress some moist soil by squeezing it in your hand. If the soil holds together (ie: forms a cast), test the strength of the cast by tossing it from hand to hand. The more durable it is, the higher the clay content.

**Ribbon Test:**
Moist soil is rolled into a cylindrical shape and then squeezed out between the thumb and forefinger to form the longest and thinnest ribbon possible. Clay forms the longest, thinnest ribbons.

**Feel Tests:**
***Graininess Test*** - Soil is rubbed between the thumb and forefinger to assess the sand percentage, where sand has a grainy feel. Silt, on the other hand, feels slippery.
***Stickiness Test*** - Soil is moistened and compressed between the thumb and forefinger. The degree of stickiness is determined by noting how strongly it adheres to the thumb and forefinger upon release of pressure, and how much it stretches.

**Shine Test:**
A small amount of moderately dry soil is rolled into a ball and rubbed once or twice against a hard, smooth object such as a knife blade or thumbnail. A shine on the ball indicates clay in the soil.

| Texture | Moist Cast Test | Ribbon Test | Feel Test | Shine Test |
|---|---|---|---|---|
| **Sand** | No Cast | None | Very grainy | No shine |
| **Loamy Sand** | Very Weak Cast | None | Very grainy | No shine |
| **Sandy Loam** | Weak Cast | None | Grainy | No shine |
| **Silt Loam** | Weak Cast | Flakes (rather than ribbons) | Slippery, slightly grainy, slightly sticky | No shine |
| **Loam** | Moderate Cast | Thick, short (< 1 cm) | Soft and smooth, slightly grainy, slightly sticky | No shine |
| **Sand Clay Loam** | Strong Cast | Thick, short (< 3 cm) | Grainy, slightly to moderately sticky | Slight shine |
| **Clay Loam** | Strong Cast | Thin, barely supports own weight | Moderately grainy, sticky | Slight shine |
| **Silty Clay** | Very Strong Cast | Thin, long (5 – 7 cm), holds own weight | Smooth, very sticky | Moderate shine |
| **Clay** | Very Strong Cast | Very thin, very long | Smooth, very sticky | Very shiny |

## Soil Structure

Soil structure is the arrangement of sand, silt and clay particles into aggregates or peds. Aggregates are granules composed of many soil particles held together. A ped is an aggregate that is formed by natural processes. While a clod is an aggregate formed by man-made means such as plowing. Structure influences the movement of water through a soil (permeability). Well aggregated soils contain large, continuous pores that promote good air and water movement and provide for effective root growth.

## Soil Density

Soil density is its mass per unit volume. There are two common density measurements for soil,which include particle density and bulk density.

Particle density is the density of the solid soil particles and does not include pore (air and water) spaces. Most mineral soils have a particle density of approximately 2.65 g/cm$^3$, which is often used as a standard particle density in soil calculations.

The bulk density is the density of a volume of soil as it exists naturally, including pore spaces and organic material. It is normally expressed on a dry weight basis, with values ranging from 1.0 g/cm$^3$ to 1.8 g/cm$^3$ for mineral soils. An ideal seedbed is about 1.3 g/cm$^3$. Some NS subsoils have bulk densities in excess of 2.0 g/cc.

The bulk density of mineral soils depend primarily on the amount of pore space. Bulk density values indicate whether a soil layer is too compacted to allow root penetration or if it is effective for adequate aeration of the root zone.

## Soil Porosity

Soil porosity is a measure of the soil volume that holds air and water. It is normally expressed as a percentage (%).
Bulk density (BD) can be used to calculate a soil porosity (%) as follows:

$$Porosity\ (\%) = 100 - (\frac{BD}{2.65} * 100)$$

Assuming a particle density of 2.65 g/cm$^3$, a soil with a bulk density of 1.3 g/cm$^3$ contains about 50% pore space. Soils with less than 20% pore space provide little room for air, water or plant roots and are too compacted to farm.

Permeability is the ease with which air, water and roots move through soil. Permeability cannot be directly measured, but the movement of water can be.

## Water Movement in Soil

Infiltration is the entry of water into the soil after rain or snowmelt. After the soil profile becomes wetted, the subsequent movement of additional water downward through the soil is called percolation. Hydraulic conductivity is a measurement of this rate of water movement, usually expressed in centimetres per hour (cm/h). Rates are extremely variable, ranging from nearly zero to more than 15 cm/h. "Moderate" values are in the 0.5 to 5.0 cm/h range.

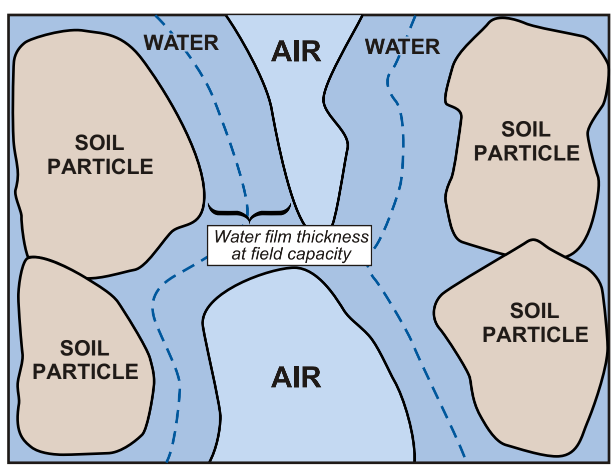


**Figure 2** Cross Section of a Soil at Field Capacity

Factors that control hydraulic conductivity include soil texture, structure, density and porosity. Additionally, the amount of water in the soil and depth to impervious layers can also influence the hydraulic conductivity. Usually one soil horizon must become saturated before water will move to the next soil horizon. Therefore, maintaining good soil structure is critical to ensure free water movement.

## Soil as a Water Reservoir

All living things require water. Soil acts as a water reservoir that supplies water for plant growth and microbial activity. Soil water occurs in pore spaces and is also held as films on the surface of soil particles (Figure 2).

Some of the water in the soil is available for plant use while other water is not. Gravitational water exists in large pores and drains freely from the soil. It is mostly unavailable to plants, simply because it moves out of reach of plant roots so quickly. If gravitational water is prevented from draining, the soil becomes poorly aerated and plant roots die from a lack of oxygen. Capillary water is held in smaller pores and is generally available to plants. Hygroscopic water is held so tightly by soil particles that plants are unable to absorb it.

The strength at which soils hold water is measured in kiloPascals (kPa). There are two physical limits that determine the amount of plant available water, field capacity (-33 kPa) and permanent wilting point (-1500 kPa).

Another way to measure field capacity is to measure the amount of water a soil holds after being thoroughly wetted and allowed to drain freely for three days. This is the upper limit of available water. As the water content decreases, it becomes increasingly difficult for crops to use the water that is left and the plants begin to wilt. The permanent wilting point is where plants essentially die of thirst.

Field capacity is dependent on soil porosity since more pores provide for more space to store water. As well, pore size distribution is just as important because large pores can hold only air, while medium and small pores can hold either air or water.

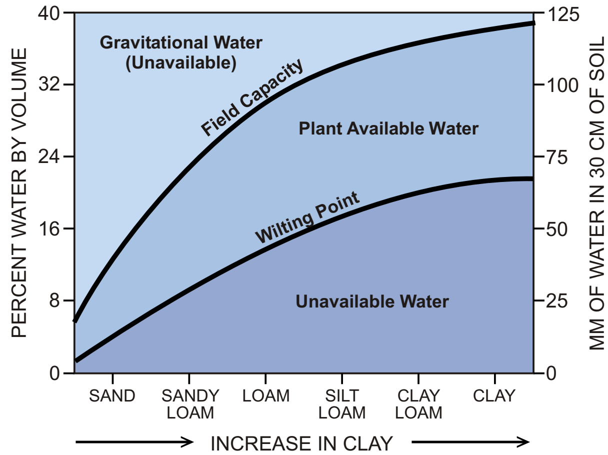


**Figure 3** Influence of Texture on the Moisture Retention Characteristics of a Well-Structured Soil

The permanent wilting point is directly related to the surface area of the soil solids. Clay has the smallest soil particles, therefore these soils have the highest surface area per unit of volume. This means that, as the clay content increases, more water is held which is unavailable to plants.

Medium textured soils, particularly those with a high silt content, hold the most plant available water. Soils high in clay tend to have both a high field capacity and a high permanent wilting point resulting in an intermediate amount of water available to plants. Soils high in sand have the lowest plant available water because they have low field capacities (Figure 3).

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