Infiltration

Infiltration is the downward entry of water into the soil. The velocity at which water enters the soil is infiltration rate. Infiltration rate is typically expressed in inches per hour. Water from rainfall or irrigation must first enter the soil for it to be of value.

Factors Affecting

Inherent - Infiltration rate is dependent on soil texture (percentage of sand, silt, and clay) and clay mineralogy. Water moves more quickly through the large pore spaces in a sandy soil than it does through the small pores of a clayey soil, especially if the clay is compacted and has little or no structure or aggregation (see Table 1).

Depending on the amount and type of clay minerals, many clayey soils develop shrinkage cracks as they dry, creating a direct conduit for water to enter the soil. These clay soils have high infiltration capacities as water moves into the shrinkage cracks, although at other times, when cracks are not present, their infiltration rate is characteristically slow.

Dynamic - A reflection of climate and landscape position, as well as management practices and crop demand, existing soil water content affects the ability of the soil to pull additional water into it. Pores and cracks are generally open in a dry soil. Many of them are filled in by water or swelled shut as the soil becomes wet, so infiltration rate is generally highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of dense clay.

Infiltration is affected by crop and land management practices that affect surface crusting, compaction, and soil organic matter. Without the protective benefits of vegetative or residue cover, bare soil is subjected to the direct impact and erosive forces of raindrops that dislodge soil particles. Dislodged soil particles fill in and block surface pores, contributing to the development of surface crusts that restrict water movement into the soil.

Compaction results from livestock and equipment traffic, especially on wet soils, and continuous plowing to the same depth, e.g. the creation of a plow pan below the tillage depth. Compacted or impervious soil layers have reduced pore space and restricted water movement through the soil profile.

A one inch layer of water is added to a six inch diameter ring to measure infiltration rate.

Soil organic matter affects infiltration through its positive affect on the development of stable soil aggregates, or crumbs. Highly aggregated soil has increased pore space and infiltration. Soils high in organic matter also provide good habitat for soil biota, such as earthworms, that through their burrowing activities, increase pore space and create continuous pores linking surface to subsurface soil layers.

Management that reduces soil cover, disrupts continuous poor space, compacts soil, or reduces soil organic matter negatively impacts infiltration. Since tillage negatively affects all of these properties, it plays an important role in a soil's infiltration rate.

Table 1. Steady infiltration rates for general soil texture groups in very deeply wetted soil. (Hillel, D. 1982. Introduction to soil physics. Academic Press, San Diego, CA)

Soil Type	Steady Infiltration Rate (in/hr)
Sands	> 0.8
Loams	0.2 - 0.4
Clays	0.04 - 0.2

Relationship to Soil Function

Infiltration is an indicator of the soil's ability to allow water movement into and through the soil profile. Soil temporarily stores water, making it available for root uptake, plant growth and habitat for soil organisms.

Problems with Poor Function

When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves downslope as runoff on sloping land or ponds on the surface of level land. When runoff occurs on bare or poorly vegetated soil, erosion takes place. Runoff carries nutrients, chemicals, and soil with it, resulting in decreased soil productivity, off-site sedimentation of water bodies and diminished water quality. Sedimentation decreases storage capacity of reservoirs and streams and can lead to flooding.

Restricted infiltration and ponding of water on the soil surface results in poor soil aeration, which leads to poor root function and plant growth, as well as reduced nutrient availability and cycling by soil organisms. Ponding and soil saturation decreases soil strength, destroys soil structure, increases detachment of soil particles, and makes soil more erodible. On the soil surface rather than in the soil profile, ponded water is subject to increased evaporation, which leads to decreased water available for plant growth.

A high infiltration rate is generally desirable for plant growth and the environment. In some cases, soils that have unrestricted water movement through their profile can contribute to environmental concerns if misapplied nutrients and chemicals reach groundwater and surface water resources via subsurface flow.

Conservation practices that lead to poor infiltration include:

- Incorporating, burning, or harvesting crop residues leaving soil bare and susceptible to erosion,
- Tillage methods and soil disturbance activities that disrupt surface connected pores and prevent accumulation of soil organic matter, and
- Equipment and livestock traffic, especially on wet soils, that cause compaction and reduced porosity.

Improving Infiltration

Several conservation practices help maintain or improve water infiltration into soil by increasing vegetative cover, managing crop residues, and increasing soil organic matter. Generally, these practices minimize soil disturbance and compaction, protect soil from erosion, and encourage the development of good soil structure and continuous pore space. As a short-term solution to poor infiltration, surface crusts can be disrupted with a rotary hoe or row cultivator and plow plans or other compacted layers can be broken using deep tillage.

Long-term solutions for maintaining or improving infiltration include practices that increase soil organic matter and aggregation, and reduce soil disturbance and compaction. High residue crops, such as corn and small grains, perennial sod, and cover crops protect the soil surface from erosion and increase soil organic matter when reduced tillage methods that maintain surface cover are used to plant the following crop. Application of animal manure also helps to increase soil organic matter. Increased organic matter results in increased aggregation and improved soil structure leading to improved infiltration rates. Conservation tillage, reduced soil disturbance, and reducing the number of trips across a field necessary to produce a crop help leave continuous pore spaces intact and minimize the opportunity for soil compaction.

Conservation practices resulting in infiltration rates favorable to soil function include:

- Conservation Crop Rotation
- Cover Crop
- Prescribed Grazing
- Residue and Tillage Management
- Waste Utilization

Measuring Infiltration

The Single Ring (Flooded/Ponded) Infiltrometer Method is described in the Soil Quality Test Kit Guide, Section I, Chapter 3, pp. 7 - 8. See Section II, Chapter 2, pp. 55 - 56 for interpretation of results.

Reference: Lowery B, Hickey WJ, Arshad MA, and Lal R. 1996. Soil water parameters and soil quality. In: Doran JW, Jones AJ, editors. Methods for assessing soil quality. Madison, WI. p 143-55.

Specialized equipment, shortcuts, tips:

To accurately assess infiltration and compare rates for different soils, the soils should be at similar moisture content when taking the measurement. It is recommended that measurements be taken at field capacity, defined as the water content of the soil root zone at which drainage (by gravity) becomes negligible. If the soil is already saturated, infiltration will not occur; wait for one or two days to allow for drying to measure infiltration rate.

Time needed: 60 minutes or more depending on soil conditions

3. Infiltration Test

The infiltration test is generally performed after the **first** respiration measurement. The same 6-inch diameter ring left in place from the soil respiration test can be used for the infiltration test. If soil respiration was not determined, follow the instructions in Step 1 of the soil respiration procedure (Chapter 2) for inserting the 6-inch diameter ring.

Materials needed to measure infiltration:

- **6-inch diameter ring (left in soil from respiration test)**
- **plastic wrap**
- **500 mL plastic bottle or graduated cylinder**
- **distilled water**
- **stopwatch or timer**

> **Did You Know?**
> Infiltration rate is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or to erosion from surface runoff on sloping fields.

Considerations: If the soil is saturated, infiltration will not occur. Wait for one or two days to allow for some drying. <u>Also, if the respiration test is not performed, make sure the sampling area is free of residue and weeds or that vegetation is trimmed to the soil surface before inserting the ring.</u>

1 Firm Soil

With the 6-inch diameter ring in place, use your finger to gently firm the soil surface **only** around the **inside edges** of the ring to prevent extra seepage. Minimize disturbance to the rest of the soil surface inside the ring.

2 Line Ring with Plastic Wrap

Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring as shown in **Figure 3.1.** This procedure prevents disturbance to the soil surface when adding water.

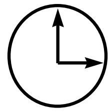
Figure 3.1

3 Add Water

- Fill the plastic bottle or graduated cylinder to the 444 mL mark with distilled water.

- Pour the 444 mL of water (1" of water) into the ring lined with plastic wrap as shown in **Figure 3.1.**

4 **Remove Wrap and Record Time**



- Remove the plastic wrap by gently pulling it out, leaving the water in the ring **(Figure 3.2)**. N**ote the time.**

- Record the amount of time (in minutes) it takes for the 1" of water to infiltrate the soil. Stop timing when the surface is just glistening.

Figure 3.2

- If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening **(Figure 3.3)**.

- Enter the amount of time in minutes on the Soil Data worksheet.

Figure 3.3

5 **Repeat Infiltration Test**

In the same ring, perform Steps 2, 3, & 4 with a second inch of water. On the Soil Data worksheet, enter the number of minutes elapsed for the second infiltration measurement. If soil moisture is at or near field capacity, the second test is not necessary.

[The moisture content of the soil will affect the rate of infiltration; therefore, two infiltration tests are usually performed (if soil is dry). The first inch of water wets the soil, and the second inch gives a better estimate of the infiltration rate of the soil.]

6 **Replace Lid**

If a second respiration measurement will be performed, set the lid loosely on the ring and leave it covered for preferably 16 to 24 hours (6-hour minimum) before beginning the second test (Chapter 2). (Remove lid and replace it before beginning the second soil respiration measurement).

> **!** **Reminder**: If you still need to perform the second respiration measurement, remember to loosely place the lid back on the ring before leaving the field.

2. Infiltration

Introduction

Infiltration is the process of water entering the soil. The rate at which water enters the soil is the infiltration rate, which is dependent on the soil type; soil structure, or amount of aggregation; and the soil water content (Lowery et al., 1996). The initial soil water content at time of measurement affects the ability of the soil to pull additional water into the soil. Therefore, the infiltration rate will be higher when the soil is dry than when it is wet. This factor is important when comparing infiltration measurements of different soils. The soils should have similar moisture content when taking the measurements.

Tillage will affect the infiltration rate. Immediately after tillage, improved infiltration may occur due to the loosening of surface crusts or compacted areas. Tillage fluffs up the soil. However, tillage further disrupts aggregates and soil structure, creating the potential for compaction, surface crusting, and loss of continuous surface connected pores. Compacted soils will have less pore space, resulting in lower infiltration rates. Soils that tend to form surface crusts, which seal the soil surface, can have severely reduced infiltration rates.

Interpretations

Since infiltration is affected by the initial water content at the time of measurement, it is important that the soil water content be similar when comparing infiltration rates from different sites. The infiltration test in the soil quality kit requires two 1-inch depths of water to be applied consecutively. Application of the first inch of water is used to wet the soil, and the second inch of water determines the infiltration rate. This procedure is an attempt to standardize the soils for differences in initial water content. Infiltration rates are best determined when the soil is at or near field capacity, usually 12 to 48 hours after the soil has been thoroughly wetted (i.e., soaking rain or irrigation).

The infiltration rate is sensitive to near-surface conditions and is subject to significant change with soil use, management, and time. It is affected by the development of plant roots, earthworm burrows, soil aggregation, and by overall increases in stable organic matter (Sarrantonio et al., 1996). Infiltration is rapid into large continuous pores in the surface. Infiltration is decreased when the size

Table 2. Steady infiltration rates for general soil texture groups in very deeply wetted soil (Hillel, 1982).

Soil type	Steady infiltration rate (inches per hour)
Sands	> 0.8
Sandy and silty soils	0.4 - 0.8
Loams	0.2 - 0.4
Clayey soils	0.04 - 0.2
Sodic clayey soils	< 0.04

or amount of pore space is reduced from conditions such as structure breakdown, pore clogging by lodged particles, or slower movement of deeper water as it reaches denser subsoils (Donahue et al., 1977).

Texture, or the percentage of sand, silt, and clay will affect the infiltration rate. Usually sandy soils will have rapid infiltration rates. Some typical values for steady infiltration rates (After long continuous wetting, the rate of infiltration becomes steady.) for general soil texture groups are shown in Table 2. However, the values in Table 2 can be considerably higher in well aggregated or cracked soils and during initial stages of wetting; these values can be lower if surface crusting occurs (Hillel, 1982). Soil structure greatly influences the movement of water into the soil.

Table 3 shows the infiltration rate in minutes per inch and inches per hour and the associated infiltration class. These classes are the soil permeability classes historically used in Soil Survey. Classes are estimated from soil properties and indicate a steady infiltration rate.

Table 3. Infiltration rates and classes.

Infiltration rate (minutes per inch)	Infiltration rate (inches per hour)	Infiltration class
< 3	> 20	Very rapid
3 to 10	6 to 20	Rapid
10 to 30	2 to 6	Moderately rapid
30 to 100	0.6 to 2	Moderate
100 to 300	0.2 to 0.6	Moderately slow
300 to 1,000	0.06 to 0.2	Slow
1,000 to 40,000	0.0015 to 0.06	Very slow
> 40,000	< 0.0015	Impermeable

References

Donahue, R.L., R.W. Miller, J.C. Shickluna. 1977. Soils: An introduction to soils and plant growth. Prentice Hill, Englewood, New Jersey.

Hillel, D. 1982. Introduction to soil physics. Academic Press, San Diego, CA.

Lowery, B., M.A. Arshad, R. Lal, and W.J. Hickey. 1996. Soil water parameters and soil quality. p.143-157. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, WI.