Colorado MASTER GARDENER

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Soil Water Holding Capacity and Irrigation Management

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Outline. . .

Colorado State University Cooperative Extension

Putting Knowledge to Work

Poor watering practices lead to many common landscape problems including iron chlorosis, low plant vigor, foliar diseases, root rots, and water pollution. Gardeners who water by dragging the hose tend to over water by about 10 percent while those who have a automatic sprinkler system tend to over water by an average of 30 to 40 percent.

It's ironic that the automatic sprinkler system, installed to make life easier and save water actually uses more water due to poor design, maintenance, and management. The convenience of *set it and forget it* has caused people to pay less attention to the needs of their yards. However, with a little time to learn how to precisely manage the irrigation system, we will conserve water, save money and improve the health of a lawn and garden.

Several complex factors work together in irrigation management.

- The soil's **water holding capacity** (i.e., the quantity of water held by the soil);
- **Evapotranspiration, ET;**
- Rooting depth; and
- The plant's ability to extract water from the soil.

Water Holding Capacity

Soil texture and structure (actually the pore space created by soil texture and structure) primarily determine a soil's ability to hold water. Water coats the soil particles and organic matter and is held in the small pore spaces by cohesion (the chemical forces by which water molecules stick together). Air fills the large pore spaces.

Water readily moves downward by gravitational pull through the large pore spaces. In small pore spaces, water moves slowly in all directions by capillary action.

For additional discussion on texture, structure and pore space, refer to the fact sheet 7.722, *Managing Soil Tilth*.

The terms, saturation, field capacity, wilting point, and available water describe the amount of water in a soil.

Saturation refers to the situation when the soil's pore spaces are filled with water. With water replacing air in the large pore spaces, root functions temporarily stop since roots require oxygen for water and nutrient up-take.

Prolonged periods without root oxygen will cause most plants to wilt (due to a lack of water uptake), to show general symptoms of stress, to decline (due to a lack of root function and possible root dieback), and to die. During summer flooding of the Mississippi River in Iowa and Illinois it was observed that healthy trees were somewhat tolerant of a flooding period, while trees under stress or in a state of decline were very intolerant.

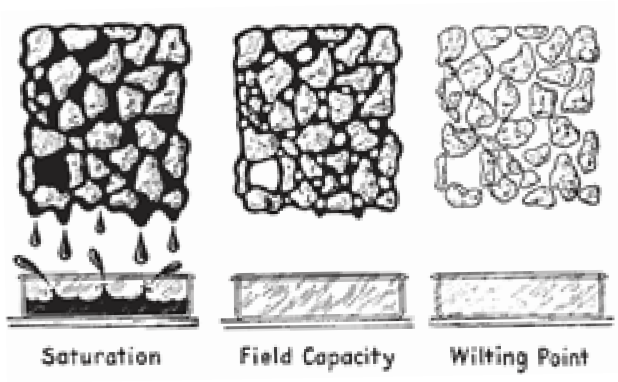

Figure 1. At saturation water fills the pore spaces. At field capacity air occupies the large pore spaces while water fills the smaller pore spaces. At the wilting point, plants cannot extract additional water from the soil.

Field capacity refers to the situation when excess water has drained out due to gravitational pull. Air occupies the large pore spaces; and water coats the soil particles and organic matter, and fills the small pore spaces. A handful of soil at or above field capacity will glisten in the sunlight. In clayey or compacted soils, the lack of large pore space slows or prohibits water movement through the soil profile, keeping soils above field capacity and limiting plant growth.

Permanent wilting point refers to the situation when a plant wilts beyond recovery due to a lack of water in the soil. At this point the soil feels dry to the touch. However, it still holds about half of its water, but the plant just does not have the ability to extract it. Plants vary in their ability to extract water from the soil.

Available water is the amount of the water held in a soil between field capacity and the permanent wilting point. This represents the quantity of water available or usable by the plant.

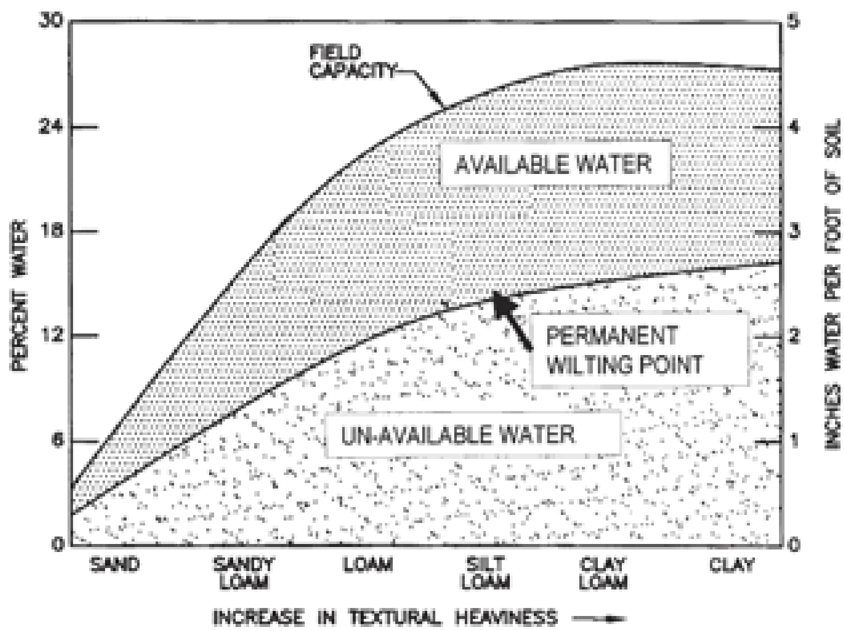

Figure 2. Relationship between soil texture and available water. The amount of available water is low in a sandy soil. Loamy soils have the largest quantity of available water. In clayey soils, the amount of available water decreases slightly as capillary action holds the water so tightly that plants cannot extract it.

Evapotranspiration (ET)

Evapotranspiration, ET is the rate a crop uses water for transpiration plus evaporation from the soil surface. Primary influences on ET include weather factors (solar radiation, temperature, wind, and humidity) and the stage of plant growth.

On hot or windy days, ET will be higher; on cool, humid days, ET will be lower. To illustrate seasonal variations, the typical evapotranspiration rates for cool season grass (ET) along Colorado's Front Range are found in Table 1.

Table 1. Typical ET for cool season turf along Colorado's Front Range.

	April	May	June	July	August	September	October
Per month	3.88"	4.93"	6.04"	6.52"	5.47"	4.01"	2.76"
Per day	0.13"	0.16"	0.20"	0.21"	0.18"	0.13"	0.09"

Source: Northern Colorado Water Conversancy District.

Local ET data is available on the web at www.coloradoet.org, or from many local water providers.

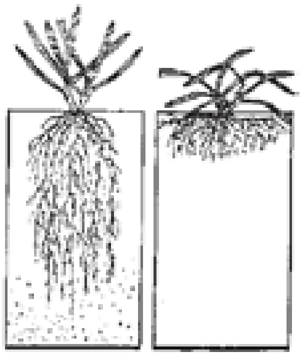

Figure 3. Plants with a deeper rooting system reach a larger supply of water and can go longer between irrigations. In compacted or clayey soils, low levels of soil oxygen limit rooting depth, reducing the supply of available water.

Rooting Depth

Rooting depth is another primary factor influencing irrigation management. Roots only grow where there are adequate levels of soil oxygen. In clayey or compacted soils, where a lack of large pore space restricts oxygen levels, roots will be shallow. Plants with a shallow rooting depth simply have a smaller profile of soil water to use.

Plants Ability to Extract Water

Plants vary in their ability to extract water from the soil. For most plants, the available water is about 50 percent of the soil's total water supply before reaching the permanent wilting point. Onions are an example of a crop that can only extract about 40 percent.

A similar, but unrelated, issue is the plant's ability to survive on dry soil (drought mechanism). Many plants, like impatiens, readily wilt as an internal water conservation measure. Some plants, like cacti, have an internal water storage supply and a waxy coating. Trees close the stomata in the leaves, shutting down photosynthesis, during water stress.

Some plants, like Kentucky bluegrass, can go dormant under water stress. Tall fescue is an example of plants that survive short-term dry soil conditions by rooting deeper (if soil conditions allow) reaching a larger water supply. But tall fescue can't go dormant.

Irrigation: How Much? How Often?

Table 2 illustrates the relationship of the soil water holding capacity, ET, and rooting depth.

Table 2. Irrigation summary of a textbook soil.

	Soil Type		
	Sandy	**Sandy Loam**	**Loamy & Clayey**
Available water per foot of soil	0.5"	0.75"	1"
6 inch rooting depths			
Inches of available water, and			
Inches of water to apply per irrigation	0.25"	0.38"	0.5"
(Additional amounts would leach below the rooting zone.)			
Typical days between lawn irrigation*			
April (at 0.13" per day average)	2 days	3 days	4 days
June (at 0.20" per day average)	1 day	2 days	2½ days
12 inch rooting depth			
Inches of available water, and			
Inches of water to apply per irrigation	0.5"	0.75"	1"
(Additional amounts would leach below the rooting zone.)			
Typical days between lawn irrigation*			
April (at 0.13" per day average)	4 days	6 days	8 days
June (at 0.20" per day average)	2½ days	4 days	5 days
24 inch rooting depth			
Inches available water and			
Inches of water to apply per irrigation*	1"	1.5"	2"
(Additional amounts would leach below the rooting zone.)			
Typical days between lawn irrigation			
April (at 0.13" per day average)	8 days	11½ days	15 days
June (at 0.20" per day average)	5 days	7½ days	10 days

*Based on historical ET for a cool season lawn.

These textbook figures are a good starting point to understand irrigation management. Most automatic sprinkler systems are set to keep the lawn green in the summer. (i.e., set for the higher summer water need). Without seasonal adjustments on the irrigation controller the lawn will be overirrigated in the spring and fall by about 40 percent. This springtime overirrigation is a primary contributing factor to iron chlorosis.

Other Factors

The following factors also have a direct influence on the water holding capacity and irrigation demands:

- **Soil organic matter content** – Since organic matter holds over ten times more water than sand, a sandy soil with good organic content (around 4 to 5 percent) will hold more water than indicated in the table above. Over time, clayey soils with good organic content may have an improved soil structure, supporting a deeper rooting depth.
- **Previous irrigation pattern** – Plants adjust rooting depth (to the extent that soil oxygen levels allow) to where soil water is available. Frequent irrigation eliminates the need for plants to develop a deep rooting system. A shallow rooting system makes the plant less resilient to hot, dry weather.
- **Stage of growth** – The stage of growth also influences ET. Water needs increase as a plant grows in size during the season, and peaks during flowering and fruit development.
  Compared to the rooting system of a mature plant, newly planted or seeded crops don't have the root system to explore a large volume of soil for water. Recently planted and seeded crops will require frequent, light irrigations. In our dry climate, even *xeric* plants need regular irrigation to establish.
- **Water demand of a plant** – Plants vary greatly in the demand for water to: 1) support growth; and 2) survive dry spells (note the two are not necessarily related).

Fine-Tuning

The textbook figures are a good starting point to understand irrigation management. When coupled with careful observations a gardener can quickly fine-tune his irrigation schedule to the site-specific irrigation demands.

To the observant gardener, the lawn tells you when it needs watering. The color has a subtle change from bluish-green to grayish-blue and footprints are still visible an hour or more later. The observant gardener can use these indicators to understand the water management for the site.

Look at the historical ET for the summer. On a typical June and July day, if the lawn is using 0.20 inches ET per day, you can estimate the water holding capacity and rooting depth by observing irrigation needs.

For example:

- IF the lawn will go 5 days on 1 inch of water, and additional water won't extend the interval between required irrigation, the water holding capacity (for this soil and rooting depth) is 1 inch. One inch would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.

Irrigation options include the following:

- Water every 5 days applying 1 inch of water, OR
- Water every 4 days applying 0.8 inches of water, OR
- Water every 3 days applying 0.6 inches of water,
- And so forth.

- IF the lawn will go 4 days on 0.80 inches of water, and additional water won't extend the interval between required irrigation, the water holding

Since sprinklers don't deliver water uniformly, as you fine-tune the irrigation management don't be surprised to start seeing dry spots. This is what you're looking for. It indicates that you have it just about right.

capacity (for this soil and rooting depth) is 0.80 inches. This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.

Irrigation options include the following:

- Water every 4 days applying 0.8 inch of water, OR
- Water every 3 days applying 0.6 inches of water, OR
- Water every 2 days applying 0.4 inches of water,
- And so forth.

- IF the lawn will go 2 days on 0.40 inches of water, and additional water won't extend the interval between required irrigation, the water holding capacity (for this soil and rooting depth) is 0.40 inches. This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.

Irrigation options include the following:

- Water every 2 days applying 0.4 inch of water, OR
- Water every day applying 0.2 inches of water.

The above examples are based on the typical June and July weather. For cooler spring and fall seasons, the amount of water to apply generally remains the same, with a longer interval between irrigations.

For additional details on scheduling irrigation refer to the fact sheet 7.758, Irrigation Management: Methods to Schedule Irrigation.

For details on how to convert inches of water to minutes, refer to the fact sheet 7.757, Irrigation Management: Converting Inches to Minutes.

Normal Irrigation Requirements

Table 3 illustrates how the normal irrigation requirement for cool season lawns (Kentucky bluegrass, tall fescue, and perennial ryegrass lawns) changes through the season. Contact your city or local water supplier for local data. Most gardeners have the irrigation controller set for summer applications, resulting in overwatering in the spring and fall by about 40 percent. In many parts of the state actual ET data is available from local water providers or on the Web at www.coloradoet.org.

Table 3. Typical cool season turfgrass water requirements in inches of water.*

Inches Per Week	April	May	June	July	August	September	October
Northern Front Range[1]	0.9"	1.1"	1.4"	1.5"	1.2"	0.9"	0.6"
	7/8"	1 1/8"	1 3/8"	1 1/2"	1 1/4"	7/8"	5/8"
Colorado Springs[2]	1/2"	3/4"	1 1/4"	1 1/2"	1 3/8"	7/8"	3/8"

[1]Figures for Northern Colorado Front Range based on historical ET.

[2]Figures from Colorado Springs Utilities at www.csu.org/xeric.howto/resetmonthly.html

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