Colorado State University
EXTENSION

CMG GardenNotes #263

Understanding Irrigation Management Factors

Outline:

Poor watering practices lead to many common landscape problems, including iron chlorosis, low plant vigor, foliar diseases, root rots, and water pollution. On a community-wide basis, landscape irrigation typically uses twice the amount of water that the plants actually need.

Several complex factors work together in irrigation management, including the following:

- The soil's ***water-holding capacity*** (the quantity of water held by the soil)
- ***Evapotranspiration, ET,*** (a measurement of actual water use by the plant and lost from the soil by evaporation). ET is a factor of weather (temperature, wind, humidity, and solar radiation) and plant growth.
- Rooting depth.
- The plant's ability to extract water from the soil.
- The plant's water need.

Location of Soil Moisture

Following dry winters or summer droughts, soils may be dry in the top layers with moisture only in deeper layers. Following extended drought, it is possible that soils may be dry in deep layers and wet only in the top few inches following a light rain or irrigation.

Dry soils tend to resist wetting. Alternating irrigation applications with shutoffs to allow water to soak in (cycle and soak irrigation) may be necessary to wet a dry soil profile.

Irrigation management is basically applying the correct amount of water at the correct frequency to supply water needs of the plants. Additional water would be wasted as it would leach below the rooting zone.

Type of Soil

Soil texture, structure and organic matter content determine the water-holding capacity and water movement of a soil. Water coats the soil particles and organic matter, and is held in small pore space by cohesion (chemical forces by which water molecules stick together). Air fills the large pore space.

In large pore space, water readily moves downward by ***gravitational pull***. In small spore space, water moves slowly in all directions by ***capillary action***. Figure 1 illustrated water movement in a sandy soil with large pore space and clayey soil with small pore space. [Figure 1]

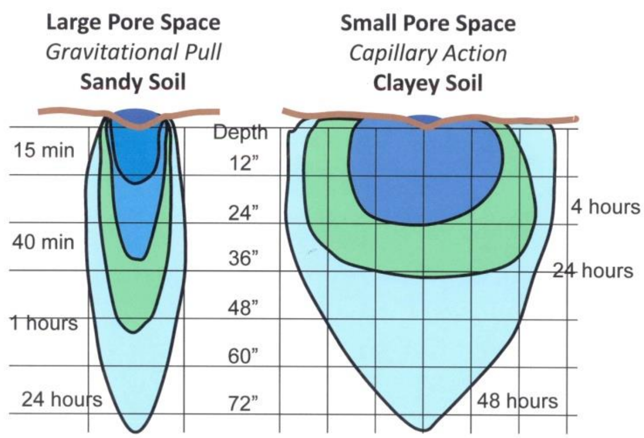

Figure 1. Comparative movement of water in sandy and clayey soils

<u>Sandy Soil</u> – Large pore space dominate sandy soil, giving it rapid drainage. Thus, surface runoff of irrigation water is generally not a concern with sandy soil. Water movement is primarily in a downward direction by gravitational pull in the large pore space with limited sideward and upward movement by capillary action in the small pore space. Thus, in drip irrigation the emitters must be placed closer together than in clayey soils.

Sandy soils have a low water-holding capacity due to the lack of small pore space. Organic matter, which holds ten times more water than sand, significantly improves the water-holding capacity of sandy soils.

As a point of clarification, plants on sandy soils do not use more water than plants on clayey soils. **With the limited water holding capacity, sandy soils simply need lighter and more frequent irrigations than clayey soils.** Water readily moves below the rooting zone when <u>too much</u> is applied at a time.

<u>Clayey Soil</u> – Small pore space dominates clayey soil, giving it high water-holding capacity. However, the lack of large pore space greatly limits water movement. Water is slow to infiltrate into clayey soil, often leading to surface run-off problems. Cycle and soak irrigation is appropriate on clayey soils to slow application rates and reduce surface runoff.

In clayey soils, soil *structure* (creating secondary large pore space) also directly influences water movement and soil oxygen levels. Compaction (a reduction in pore space) further limits water movement and reduces soil oxygen levels, resulting in a shallow rooting depth. The total water supply available to plants is reduced by the shallower rooting.

With higher water-holding capacity but limited drainage, clayey soils need heavier, but less frequent irrigations than sandy soils. Watering too often can aggravate low soil oxygen levels. Because water moves slowly in all directions by capillary action, drip emitters may be placed further apart than in sandy soils.

For additional discussion on texture, structure and pore space, refer to CMG GardenNotes #213, *Managing Soil Tilth*.

Water-Holding Capacity

The terms, *saturation*, *field capacity*, *wilting point*, and *available water* describe the amount of water held in a soil. [Figure 2]

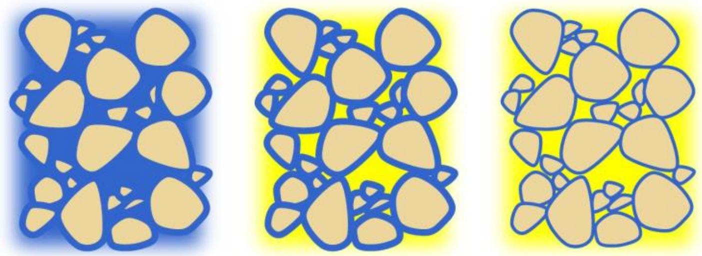

Figure 2. At ***saturation*** water fills the pore spaces. **At *field capacity*** air occupies the large pore spaces while water fills the small pore spaces. At the ***wilting point***, plants cannot extract additional water from the soil.

Saturation refers to the situation when water fills both the large and small pore spaces. With water replacing air in the large pore spaces, root functions temporarily stop (since roots require oxygen for water and nutrient uptake).

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 to die (due to root dieback). During summer flooding of the Mississippi River in Iowa and Illinois it was observed that healthy trees were somewhat tolerant of a short-term flooding period, whereas trees under stress or in a state of decline were very intolerant.

Field capacity refers to the situation when excess water has drained out by gravitational pull. Air occupies the large pore space. Water coats the soil particles and organic matter and fills the small pore space. A handful of soil at or above field capacity will glisten in the sunlight. In clayey and/or compacted soils, the lack of large pore space slows or prohibits water movement down through the soil profile, keeping soils above field capacity for a longer period of time 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; 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. Note from the illustration below that the amount of *available water* is low in a sandy soil. Loamy soils have the largest amount 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. [Figure 3]

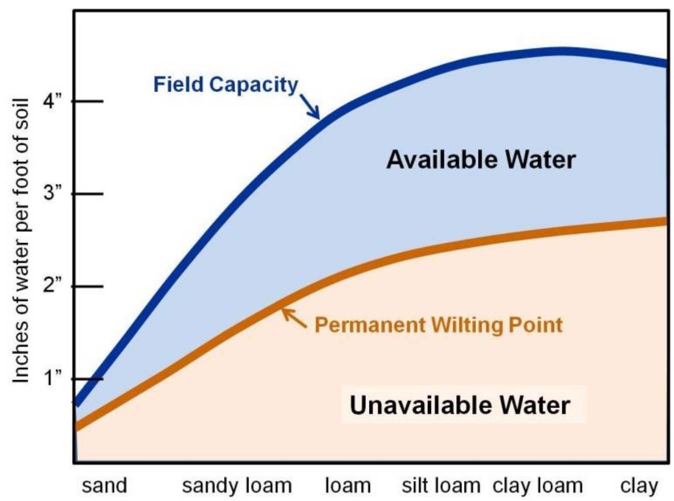

Figure 3. Relationship between soil texture and available water

Evapotranspiration, ET

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

On hot, dry, windy days, ET will be higher. On cool, humid days, ET will be lower. In the summer, ET changes significantly from day to day. To illustrate seasonal variations, the typical irrigation requirement for cool season turf in Colorado is given in Table 1. [Table 1]

Table 1.
Weekly Water Requirement for Cool Season Lawns in Colorado

Inches of water (irrigation and rain) per week

Late April	May	June	July	August	September	Early October
0.75"	1.0"	1.0"	1.5"	1.5"	1.0"	0.75"

Rooting Depth

Irrigation management should be taken into account the rooting depth, adding water to the actual root area. Root systems may be contained or spreading. Annual plants tend to have contained root systems, whereas woody trees and shrubs have more wide-reaching roots.

A newly planted annual flower or shallow-rooted plant cannot obtain water from deeper soil depths. Deep watering of these plants is wasteful.

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. [Figure 4]

A plant with deeper roots will need less frequent but heavier irrigation than the same plant with shallow roots. This, however, should not be interpreted as necessarily using less water. For example, turf-type fall fescue may root more deeply than Kentucky bluegrass (if soil oxygen levels allow). With deeper rooting, it requires less frequent irrigations, but irrigations must be heavier to recharge the rooting zone. Actual water-use rates of Kentucky bluegrass and tall fescue are similar.

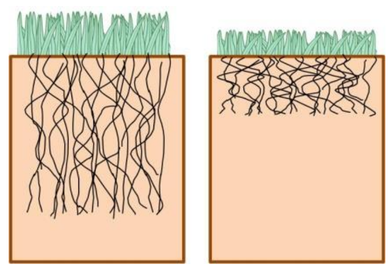

Figure 4. Plants with a deeper rooting systems reach a larger supply of water and can go longer between irrigations. With deeper rooting, irrigations will be less frequent but heavier to recharge the larger rooting zone. In compacted or clayey soils, low levels of soil oxygen limit rooting depth, thus reducing the supply of available water.

Irrigation: How Much? How Often?

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

These textbook figures make a good starting point for understanding 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 over-irrigated in the spring and fall by about 40%. This springtime over-irrigation is a primary contributing factor to iron chlorosis.

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”
<u>6-inch rooting depths</u>			
Inches of available water and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone.)	**0.25”**	**0.38”**	**0.5”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	1.8 days	2.7 days	3.6 days
Summer (at 1.5 inches/week)	1.2 days	1.8 days	2.4 days
<u>12-inch rooting depth</u>			
Inches of available water, and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone.)	**0.5”**	**0.75”**	**1”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	3.6 days	5.3 days	7.1 days
Summer (at 1.5 inches/week)	2.4 days	3.6 days	4.8 days
<u>24-inch rooting depth</u>			
Inches available water and **Inches of water to apply per irrigation** (Additional amounts would leach below the rooting zone.)	**1”**	**1.5”**	**2”**
Typical days between lawn irrigation			
Spring/Fall (at 1.0 inches/week)	7.1 days	10.7 days	14.2 days
Summer (at 1. 5 inches/week)	4.8 days	7.1days	9.5days

Fine-Tuning for the Site

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

On a typical July day, if the lawn is using an average of 0.20 inch per day, you can estimate the water-holding capacity and rooting depth by observing irrigation needs. For example:

- **<u>If the lawn will go five days on one-inch of water</u>**, and additional water won’t extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 1 inch. <u>One inch would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.</u> The ideal irrigation would be 1 inch of water every 5 days.

- <u>**If the lawn will go four days on 0.80 inch of water**</u>, and additional water won't extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 0.80 inch. <u>This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone.</u> The ideal irrigation would be 0.8 inches of water every 4 days.

- <u>**If the lawn will go two days on 0.40 inch of water**</u>, and additional water won't extend the interval between required irrigations, the water-holding capacity (for this soil and rooting depth) is 0.40 inch. <u>This would be the maximum amount of water to apply per irrigation, as additional amounts would leach below the rooting zone</u>. Irrigation options include the following: The ideal irrigation would be 0.4 inches of water every 2 days.

These textbooks figures don't take into account exposure, wind or irrigation system efficiency. They make a good start point, **but will need adjustments to fine-tune it to the specific site.** For example:

- In full shade (not under large trees), water use could be 30% lower.
- In unusually hot weather or in open, windy sites, water use could be 20% to over 50% higher.
- In the rooting area of large trees, water use could be 30% to 50% higher (as the tree is pulling water as well as the plants in the shade under the tree).

For examples, in the author's landscape, the front lawn (open site with constant summer wind) uses 20% more water than the normal ET. While the back lawn (sheltered from the wind by the house and wood fence) uses the normal ET.

So the trick for efficient irrigation is to start with the textbook numbers then fine tune them based on observation. **Based on actual observations for each zone, adjust the run time up/down in 10% increment to fine-tune the irrigation.**

These examples are based on typical July weather. <u>For cooler spring and fall seasons, the amount of water to apply generally remains the same, with a longer interval between irrigations.</u>

Other Factors Influencing Irrigation Management

Other factors also have a direct influence on the <u>actual</u> water-holding capacity and irrigation demands, for example:

- **Exposure** – The plant's exposures greatly influences water demand. Sun, heat and wind increase water demand. Shade decreases water demand. Water use for a lawn on a windy, southwest-facing slope could be double the water use of a lawn in full sun but sheltered from wind and extreme heat.

- **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%) 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 systems 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 generally need regular irrigation to establish.

  Confusion about plant water requirements can arise from changing needs as plants move through their life cycles. For example, newly planted trees are extremely intolerant of water stress. Established trees in good health are rather tolerant of short-term water stress. Older trees in decline are intolerant of water stress. General statements about the ability of trees to tolerate dry situations need to take into account life-cycle stages.

- **Water demand of a plant** – Plants vary greatly in the demand for water to 1) support growth, and 2) survive dry spells. (Note that the two are not necessarily related.)

- **Ability to extract water** – Plants vary in their ability to extract water from the soil. For most plants, the *available water* is about 50% 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%.

- **Drought mechanism** – A similar, <u>but unrelated</u>, issue is the plant's ability to survive on dry soil. Plants have evolved with a variety of drought mechanisms, for example:

  - Small leaves, waxy leaves, hairy leaves, and light-colored leaves are characteristics of many plants with lower water requirements.
  - Some plants, like cacti, have internal water storage supplies and waxy coatings.
  - Many plants, like impatiens, readily wilt as an internal water conservation measure.
  - Trees close the stomata in the leaves, shutting down photosynthesis, during water stress.
  - Some plants, like Kentucky bluegrass, can go dormant under water stress.
  - Kentucky bluegrass slows growth as soils begin to dry down. (Does your irrigation management capitalize on this dry-down, also reducing your mowing?)
  - Tall fescue is an example of plants that survive short-term dry soil conditions by rooting more deeply (if soil conditions allow) to reach a larger water supply. But tall fescue can't go dormant.

Tools to Evaluate Soil Moisture

Gardeners have a number of tools available to evaluate the amount of moisture in their soil.

Plant observation is a good guide to soil moisture. Look for color change and wilting. For example, Kentucky bluegrass will change from a blue-green to gray-blue with water stress. Footprints in the lawn that do not rebound within 60 minutes are another symptom to watch for. Use of an indicator plant in a perennial flower bed is also useful. Certain perennials such as *Ligularia stenocephala* 'The Rocket' and *Eupatorium rugosum* (White Snakeroot) often wilt before other perennial flowers, indicating irrigation will shortly be required.

The **hand feel method** used when digging in soil is more evidence of moisture content. Is the soil powder dry, medium moist or even muddy?

The ease with which a **probe** can be inserted can be telling. A screwdriver will punch into the soil more easily when wet than when dry. However, this can be very misleading, as a clayey soil may be difficult when wet and impossible when dry. A sandy soil may be easy when dry and easier when wet.

Soil moisture meters are available. A simple, houseplant water meter can be used outdoors. Although the exact number reading may give little information, the overall indication of wet or dry is useful. It will read on the wet side when the soil has high nutrients or salts, and on the dry side when the soil is low in nutrients and salt. Permanently buried soil moisture sensors are available to automatically activate irrigation systems when the soil has dried.

CMG GardenNotes on Irrigation Management

#260 Irrigation Management: References and Review Questions
#261 Colorado's Water Situation
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#264 Irrigation Equipment
#265 Methods to Schedule Home Lawn Irrigation
#266 Converting Inches to Minutes
#267 Watering Efficiently
#268 Home Lawn Irrigation Check-Up

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