Developing a Water-Conserving and Drought Resistant Soil

Summary

- **Organic matter works effectively in all soil types by aggregating soil particles and creating a range of soil pore sizes.**
- **Soil water retention and availability depend on soil pore size.**
- **Tillage is as important and necessary as organic matter in developing water-conserving soils.**
- **For every 1% increase in soil organic matter, plant available water increases by 0.44, 0.34, 0.26 inches per foot of soil for silt loams, silty clay loams, and sands, respectively.**
- **Irrigation intervals can be increased by at least one day.**
- **Number of season total irrigations decreased from 48 to 36.**

Soil organic matter (SOM) is a key element in developing a soil that promotes drought resistant plants. In an urban landscape, drought frequently leads to watering restrictions. A poorly-prepared landscape will suffer more than its counterparts having added SOM. In clay soils, organic soil amendments improve soil infiltration and reduce soil compaction, thus creating larger pore spaces for plant root growth. SOM also helps decreases pore sizes in sands to promote increased water retention and availability in the soil.

Soil texture primarily drives soil water-holding capacity and availability to plants. Certain combinations of soil pore and particle sizes are essential to maximizing soil water holding capacity and plant water availability.

Plant Available Water and Soil Texture

Plant water availability depends on two soil water parameters, field capacity (FC) and permanent wilting point (PWP). Field capacity occurs when soil water ceases to drain freely. The soil water remaining is held in the soil by adhesion to soil particles. Permanent wilting point occurs when plants can no longer extract water from the soil. The remaining soil water is so tightly bound by the soil particles that the plant root is not able to overcome the forces of attraction of water to soil. Plant available water (PAW) is the difference between FC and PWP.

Sands have the largest soil particles and have the least amount of total pore space, but very high levels of macropores (very large soil pores). Sands also have the least water-holding capacity and plant available water. This leads to rapid downward movement of water with gravity, as soil water retention is a function of pore size and adhesion to soil particles and is minimal for macropores and large particles.

Clay soils are dominated by micropores and tiny soil particles. Clayey soils, however, have the most pore space and can retain more water than sands or loams. While it may seem that clays would have more plant available water than loamy or sandy soils, it is not necessarily so. Micropores in combination with the tiny charged clay soil particles cause the soil water to be so tightly bound by the soil particles that plants are unable to extract as much of the soil moisture. Drainage in clay soils occurs more slowly than sands or loams because of the micropores and can be a limiting factor for plant health.

Loamy soils have the best combination of pore sizes and soil particle sizes for plant available water than clayey or sandy soils. Loamy soils have a larger capacity for plant available water than sandy or clayey soils. Because of the combination of large, medium, and small pore sizes, loams are also well-drained soils.

A drought resistant soil maximizes the plant available water for that soil texture. The best way to do that is to first create a deep soil with no barriers for plant root growth, and second, to make sure the soil has a mixture of pore and particle sizes. It is very difficult to change soil texture to a more favorable plant available water capacity by adding more sand, clay, or silt, but relatively small amounts of organic matter can effectively modify soil water-holding capacity and plant available water.

Organic matter works in all soil types primarily by aggregating soil particles. In sands, the aggregation produces more medium sized pores that retain more water. In clay soils, the tiny clay particles are aggregated together to create a broader range of pore sizes that allow better aeration and better drainage. Decreasing the influence of the tiny charged clay particles and micropores allows more soil water to be available to the plant.

Soil organic matter and tillage

Tillage is also an important and necessary component in developing a drought resistant soil. Most municipalities require tillage to certain depths as well as SOM amendments in all new developments. Even without additional SOM, tillage can help loosen soils and break up compacted soil layers that can inhibit root growth and soil water drainage. A deep root zone is a first line of defense against drought.

Tillage should break up soil layers, which requires a drier soil and possibly more powerful equipment. This is most problematic for clay soils. While it is easier to till clay soils when they are moister, this can exacerbate drainage problems by creating a compacted and even sealed layer at the base of the tillage depth. Drainage into this layer will not occur until the upper layer has filled with water. This can affect plant health by limiting air in the root zone. It also restricts the effective rooting zone depth, as roots cannot readily penetrate severely compacted soil layers. More frequent irrigations are then necessary to maintain the health of the plants.

Organic matter must be thoroughly incorporated into the soil. Because SOM can change the water-holding and drainage capabilities of the soil, it is important to till the soil properly and incorporate the OM so that drainage discontinuities do not develop at the tillage depth.

Soil organic matter and water-holding capacity

What magnitude of increased PAW can be expected in soils with added SOM? While soils are highly variable, some generalities can be presented. In the silt loam soil (Figure 1), increasing soil organic matter by 1% increased PAW by 3.7%. Plant available water for the sand increased 2.2% with a 1% increase in SOM. PAW in the silty clay loam increased 2.8%.

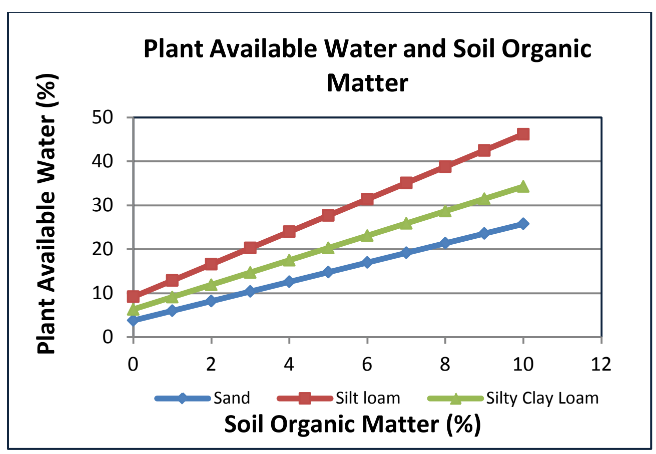

Figure 1. The contribution of soil organic matter to plant available water in three soil types. (Adapted from Hudson (1994).

Translating PAW in % to inches of available water showed that for every 1% increase in SOM, sand PAW (in) increased 0.26 inches per foot, silty clay loam PAW increased by 0.34 inches per foot, and silty loam PAW increased by 0.44 inches per foot (Adapted from Hudson (1994).

Implications for irrigation scheduling

Irrigation scheduling depends on 1) plant water requirements and 2) plant available soil water. One benefit of increasing SOM is decreasing the number of irrigations necessary to maintain turf.

In a clay loam soil, an increase in plant available water from 1.92 inches per foot to 2.28 inches per foot decreased the number of irrigations from 48 to 36 from May through October, based on 2011 weather and turf ET values. The turf irrigations were managed for the top 6" of the soil profile at 50% Managed Allowable Depletion and took into account rainfall and turf ET at 80% of ETo. Mean time between irrigations increased from 4 days to 5 days. Less frequent irrigation increases the possibility of capturing in-season rainfall for plant benefit, decreasing reliance upon supplemental irrigations.

Values for the soil available water capacity were taken from "Ranges of AWC in Relation to Soil Texture and Organic Matter" (http://www.mo10.nrcs.usda.gov/references/guides/properties/awcrange.html).

The Conservation Gardens

According to NRCS SSURGO soil maps, the Nunn Clay Loam soil in the Conservation Gardens has a native organic matter content of 2.29%. Organic matter varies with cropping sequence and can be highly variable. Soil test results (all from the same laboratory as Conservation Garden results) in Northern Water's adjacent agricultural fields showed that OM ranged from 1.4 to 2.0 over a 2 year period. Conservation Gardens test results indicated a range of soil OM from 3% to 4.4% in the 0, 3, and 6 CY/1000 sq ft treatments in the Soil Preparation plots in 2010, several years after compost incorporation. Since the Gardens were developed from a former agricultural field, taking the un-amended SOM in the 1.4 to 2.0% range is realistic. Therefore the Conservation Gardens plots, all amended with at least 3 cu yds/1000 sq ft of OM, likely have an increased plant available water content of around 0.3-0.35 inches per foot of soil.

Summary

A drought resistant soil is one that has been loosened by tillage and the addition of high quality organic matter, thus providing the best possible environment for root growth, soil water holding capacity, and drought defense. Because municipal outdoor watering restrictions typically limit the number of days per week available to a homeowner for lawn watering, the ability to stretch the time between irrigations means a less-stressed lawn that can maintain its health through challenging conditions.

References

Hudson, Berman D. 1994. Soil organic matter and available water capacity. J. Soil and Water Cons. 49(2) 189-194.

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Authored by Mary J. Hattendorf, Water Management and Conservation Specialist, Northern Water. February, 2012.