Soil Management Can Maximize Water Availability

NC STATE EXTENSION

SoilFacts

Introduction

Adequate water is critical for crops to reach their yield potential. In North Carolina, periods of insufficient rainfall occur frequently, causing drought conditions for many farms across the state. Although regular, adequate rainfall is important, the ability of the soil to absorb water and store it for plant use between rainfall events is also critical.

Soil physical properties determine how much water enters the soil and to what extent that water is stored. They also influence how well the soil will promote root growth and allow access to the stored water. Many of these factors can be influenced by the grower through soil management. Proper soil management will maximize the availability of water and provide the best opportunity for adequate water during periods of low rainfall.

Available Water Holding Capacity

Not all water that enters the soil is available to plants. A range of soil wetness conditions provides optimal water availability for crop growth. We call this range the *available water holding capacity* of the soil. The upper limit to this range is the amount of water in the soil a few days after a heavy, soaking rain, when soil has had adequate time for drainage and aeration. This upper limit is referred to as *field capacity*. Water entering the soil in excess of field capacity is not plant available because it either drains away too quickly for plant uptake, or if it remains during periods of soil saturation, limits exchange of oxygen and carbon dioxide from roots. Saturation also promotes loss of soil nitrogen via *denitrification* and limits the conversion of soil's organic nitrogen to plant available forms. Conversely, there is a lower limit of soil wetness, referred to as wilting point. At the *wilting point*, the amount of water remaining in the soil is held so tightly by the soil that the roots cannot extract any more—causing wilting of the plant.

Soil's Effect on Water Availability

Soil texture

Soil texture refers to the proportions of sand-, silt-, and clay-sized particles in a soil. Sand particles are the largest of these and tend to have larger spaces (pores) between particles. Clay particles are the smallest and also have the smaller pores between granules. The large pores between sand particles can allow rapid drainage through the soil, reducing water storage and making the water holding capacity of sands quite low (Figure 1). Clay soils drain more slowly but also may have low available water holding capacity because water is held too tightly between the small pores. Water held in these small pores is difficult for plant roots to extract. Loamy or medium-textured soils, such as a silt loam, tend to have the greatest available water holding capacity. They have both large pores for infiltration and drainage, and medium-sized pores to store water. Water stored in this textural class of soils can be extracted by plants. Textural influences on plant available water are generally inherent for a given soil and cannot be altered by management.

Bulk density and soil strength

Bulk density is a measurement of how tight the soil particles are in the soil. Recently tilled soils tend to have a lower bulk density compared to conditions before tillage. As soil settles after tillage or is compacted by equipment traffic during a field operation, its bulk density increases. Soil strength is a measure of the force required by a root to move through a soil and can be measured with a penetrometer. Generally, an increase in bulk density results in a corresponding increase in soil strength. High values for bulk density and soil strength often result in poor root growth. When root growth is impeded by high bulk density or high soil strength, the depth and length of roots are reduced. Roots cannot access water held in the soil beyond their physical location.

Soil structure

Healthy soils tend to have soil particles that are bonded together into clumps or groups. The arrangement of these aggregates in the soil, along with the gaps and fissures between them, are part of what constitute soil structure. Adequate organic matter is usually required for good soil structure in surface horizons. The spaces between aggregates are important pathways for water and roots to move through the soil profile.

Crusting

Raindrops striking bare soil can break the bonds holding aggregates together, allowing individual particles to mix and form a tightly knit, dense layer at the soil surface called a surface crust (Figure 2). Soils that contain enough silt and clay are susceptible to crusting. Crusts prevent water from infiltrating the soil. This water runs off the soil surface, promoting erosion, rather than entering the soil to become available for the plant. This scenario represents water that is wasted, from either precipitation or irrigation. Crusting also results in poor stand emergence as plants fight to break the crust that has formed.

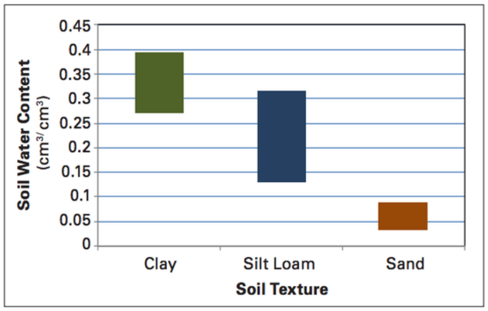

Figure 1. Water content of soil from field capacity (top of bar) to wilting point (bottom of bar).

Attribution: Adapted from Ratliff et al. (1983).

Figure 2. Crusting of the soil surface after planting can delay emergence and impair the plants' development. Crusting also limits water infiltration.

Attribution: Alan D. Meijer

Proper Soil Management to Maximize Water Availability

The previous section described how certain soil properties affect water availability. The good news is that appropriate soil management can improve soil physical properties so that soil water availability is maximized. Using optimum tillage or no tillage and managing equipment traffic patterns are two good practices.

Tillage

Tillage can affect soil water availability in a variety of ways. Certain tillage methods will create a better environment for water to enter the soil and be available to, or reached by, the plant roots.

Tillage methods that leave a relatively high amount of plant residue on the soil surface (no-till, striptill, cover-cropping) are beneficial because:

- Plant residues protect the soil surface from raindrop impact, preventing crusting.
- Plant residues slow the speed of water that does not infiltrate immediately, providing more time for the water to move downward and minimizing erosion.
- Plant residues prevent water evaporation, which can quickly deplete the water content of the soil near the surface.

- Decaying plant residue aids in the development of soil structure, which helps the soil absorb and hold water.

Deep tillage methods such as subsoiling can improve infiltration and root penetration because of the soil loosening that occurs deep in the soil profile. In-row subsoiling leaves plant residue on the soil surface.

- Conventional tillage methods that involve complete disruption of the soil surface (such as disking and bedding) can improve short-term infiltration by creating a porous surface immediately following tillage. However, a number of problems can arise from these methods:
    - Complete surface tillage, such as disking and cultivating, compacts soil at a depth just below where the disk blades reach. This traffic pan makes it harder for roots to penetrate and access water.
    - These tillage methods (Figure 3) leave bare soil exposed to rainfall at the surface. As discussed earlier, this can lead to problems with crusting, and thus, poor emergence, poor stand, decreased water infiltration, and loss of nutrients and topsoil due to runoff and erosion. Even without crusting, loose soil exposed at the surface is susceptible to erosion

Controlled Traffic

The acts of tilling, planting, spraying, and harvesting crops obviously require that equipment such as tractors and combines traffic the field. Tires cause compaction below the soil surface due to the weight and pressure applied at this soil/tire interface. Up to 85 percent of the soil surface can be trafficked in one season, leading to significant reductions in yield due to water stress caused by root-limiting conditions associated with compaction. [For more information on the effects of traffic on soil compaction, see *Managing Equipment Traffic to Limit Soil Compaction* (AG-439-72W)].

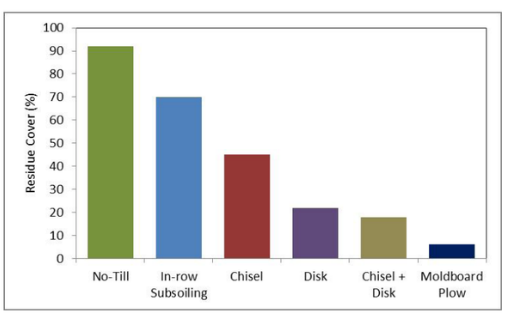

Figure 3. Percent ground covered with crop residue after tillage.

Attribution: Adapted from White et al. (2009)

Summary

While the inherent properties of soils may limit the amount of water absorbed or held for plants, proper management practices can provide benefits during periods of low rainfall or improve the efficiency of your irrigation program. Tillage practices that leave crop residues on the surface and increase organic matter are beneficial because they promote infiltration and water storage. Managing traffic in a way that keeps tire tracks limited to a few inter-row positions will keep compacted surface area to a minimum.

References

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