SOIL-WATER-PLANT RELATIONSHIPS

Richard D. Black
Associate Professor
Extension Irrigation Engineer
Kansas State University

DeLynn R. Hay
Extension Specialist
Water Resources and Irrigation
Kansas State University

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Without soil and water, we'd have neither plant life nor growth. But too much or too little water can both decrease yields. Only with an adequate supply of moisture, and then, only with the nutrients and mechanical support of soils can we grow profitable crops.

Plants, soil and water are all tied together in a complex relationship. And while, even now, this relationship is not completely understood, we do know that it is the key to both higher yields and water conservation.

Soils contain solid mineral particles derived from the weathering of parent materials mixed with varying amounts of organic matter. Soils also contain various amounts of water and gases. But whatever the soil component, they all play an important part in plant growth.

The total volume of the soil is about half solid materials and half pore space. Organic matter will normally account for five percent of less of the soil volume. The mineral portion makes up another 45 percent of the volume. The remaining 50 percent, or pore space, is then available for air and water. But for good crop growth, it's essential to have a proper balance between soil air, soil water and soil solids.

The soil solids are divided into three major groups: sand, silt and clay. These groups or textual classes are based on particle size (See Table 1).

Particles larger than two millimeters or 1/12 inch are called gravel or stone which simply occupy space that can't be used to store water or nutrients.

On the other hand, clay, the smallest soil particle, is very active in cementing soil particles into groups and in holding plant nutrients and water.

Many of a soil's plastic properties are related to their clay content since many clay minerals expand and contract as water is added or removed.

The organic fraction of a soil is also important. Organic matter results from the slow, on-going decay and digestion of plant and animal residue in the soil. Organic matter consists of both solid particles and coatings on the soil particles. And it's present in all stages of breakdown.

The decomposition starts with plant and animal cell materials and continues until the materials are reduced to elemental compounds. As a consequence, the amount of soil organic matter at any one time depends on the supply of organic residue.

Soil organic matter is more active than clay minerals. It also holds more water and supplies more plant nutrients than an equivalent amount of clay. Organic matter helps cement together groups of soil particles as well as causes the dark color of most soils.

The term soil texture is used to describe the size of individual soil particles. The proportion of the different sized particles is the most important factor determining the soil's moisture holding capacity as well as other physical and chemical properties.

A textural classification system developed by the U.S. Department of Agriculture is shown in Figure 1. In addition to the classes of sand, silt and clay, there are loams - soils made up almost equally of sand, silt and clay. The loams are often called fine or coarse sandy loams, for example, if the sand in the loam is nearly all one size.

The textural name reflects the size of particles that dominate the soil's physical properties. The physical properties of clay mask the properties of silt and sand resulting in clay being part of the name for half of the textures shown.

The influence of soil texture on soil moisture is shown in Table II. The soil moistures in Table II are expressed as a depth in inches of water per foot of soil.

Table II gives typical moisture content for three soil textures at field capacity and permanent wilting point. It also give the moisture available for plant use.

Field capacity is the soil moisture content after free water has been drained by gravity. Most soils are at their capacity within a few hours to two to three days after a rain or irrigation.

The moisture above field capacity - or gravitational water - normally drains quickly and is of no value to plants. In fact, saturated conditions can actually prevent plant growth and development because of poor soil aeration.

The soil moisture below field capacity is removed by evaporation or by plant use - transpiration. As additional water is removed below field capacity, the force required to remove the water increases until plant roots can no longer withdraw water from the soil. The plant leaves then become permanently wilted. At this point, or the permanent wilting point, there's still water in the soil but it can't be recovered by plants.

The amount of water between the field capacity and the permanent wilting point is called available water - soil moisture that's usable for plant growth. Available water is the farmer's primary concern since the amount of water above field capacity or below the permanent wilting point generally is not available for plant growth. Table III gives available soil moisture capacity for some common Kansas soils.

As mentioned, it takes more force to remove water from the soil as the amount of soil moisture decreases. But the amount of force it takes also depends on soil texture. A set of typical soil-moisture-release curves is shown in Figure 2. Available soil moisture is released most easily from a sand. It takes the greatest effort to remove water from a clay - while the finer textured soils hold more water, they also hold it more tightly than coarser textured soils.

As soil moisture supplies drop, plants have a greater chance of going into stress. Most field crops are unaffected by soil moisture changes so long as at least half of the available soil moisture remains. However, yield reductions are possible if more than half of the available soil moisture is used.

But soil moisture is seldom constant. Rainfall and irrigation increase the supply while evaporation and transpiration reduce it. Short periods of excess or shortage seem to have little effect on most crops except at critical stages of growth.

The rate, amount and location of soil moisture use is controlled by plant population, stage of growth and weather. Small plants have small needs. They also remove moisture only to a shallow depth. A higher plant population, of course, means increased moisture use.

Larger plants generally have larger root systems and remove more water - also from a larger area and to a greater depth. The natural rooting depth of some common field crops is shown in Table IV.

Although different crops have different rooting habits, the water extraction patterns are very similar. Most of the roots are in the upper half of the root system and most of the water and nutrients are, therefore, absorbed from the upper soil zone.

If a typical root system is divided into quarters based on depth, 40 percent of the water will be removed by roots in the top quarter. Roots in the top half of the root zone will remove 70 percent. (See Table V).

A typical seasonal plant water-use curve is shown to represent all field crops in Figure 3. The water use curve reflects the crop's stage of growth and climatic conditions. Crop water requirements are small early in the season but grow to a peak at or near the start of the reproductive stage or when the plant starts flowering. Water use then usually remains high as the grain develops. But it drops during maturity.

Such non-seed crops as hay or sugar beets have seasonal moisture-use curves similar to seed crop curves. However, in the case of hay, the use curve resembles a set of saw teeth - moisture use drops sharply at each cutting then slowly increases with growth until the next cutting when the cycle starts all over again.

Moisture stress before and after the start of the reproductive stage reduces yields but stress during the early reproductive stage is even more critical. Early stress usually reduces plant size while late stress reduces filling of the seed. However, stress during the critical period prevents or drastically reduces pollination and results in reduced kernel formation. This is, therefore, the most important time to have adequate soil moisture supplies available.

The critical two-week period for corn starts just before tasseling and shooting of the silk. With milo the critical stage begins at the early boot stage and extends through flowering.

Low humidity, high temperatures and high winds all promote water loss. Anything that increases the evaporation potential of the air around the plant increases the loss of water through the plant.

Most adapted crop varieties can meet the normal water demands created by temperature, humidity and wind movement but combinations of all three frequently overtax the plant causing the leaves to wilt. And if soil moisture is low enough, the plant may not survive. An example of this is the dried leaves or dead plants a few rows deep on the windward side of the field.

Plant stress is also increased by salts dissolved in the soil moisture. Although crops differ in their ability to extract moisture in a salty solution, salts generally reduce the availability of soil moisture. This is one reason why irrigation water quality is important.

If irrigation water contains high amounts of salt, more water is needed. Salts in the soil moisture mean less water is available to the plants. The plant, therefore, needs more additional water. More water is also needed to flush the salt below the root zone. While some cereal crops tolerate quite salty conditions, the economically important crops in Kansas are mostly intermediate in their salt tolerance.

The soil must also be open to the free movement of air, water and root growth for optimum plant growth. Plant roots require oxygen and room to grow. Water cannot recharge the soil pores unless it can infiltrate and flow into the soil. And consequently, soil structure can play an important role, especially on the finer textured soils.

On the other hand, sandy soils are usually open and are easily maintained because of their single-grained structure. The individual particles are large enough for easy air, water and root penetration.

But this is not the case with many fine grained soils. With them, the spaces between the larger particles are filled with smaller particles leaving spaces too small for air and water movement. These soils depend on structures within the soil to provide this space - clusters or aggregates cemented together by clay minerals and organic matter.

The soil aggregates act as single particles which leave space open for water, air and roots. Unfortunately, soil aggregates vary in strength and many depend on organic materials to hold them together. The natural forces that cause soil aggregation can be either promoted or reduced by the farming practices used.

Organic matter is most frequently reduced when land is removed from native vegetation. In addition, tillage and traffic cause change. Tillage or traffic can severely compact wet soils. Excessive working also breaks down the soil aggregates. And like compaction, reduced soil aggregation restricts air and water movement while hindering root growth and development.

In summary, with basic knowledge of the soil-plant-water relationship, it's possible to better manage and conserve irrigation water. Some of the important factors to remember include:

1. Soil moisture holding capacity varies with soil texture. It's high for medium and fine textured soils but low for sandy soils. The structure of fine textured soils can be damaged if tilled or trafficked when too wet.

2. Plant roots can use only available soil moisture - or the moisture between field capacity and permanent wilting point. But plant growth and yields can be reduced if soil moisture in the root zone remains below 50 percent of the moisture holding capacity for a long period of time, especially during critical stages of growth.

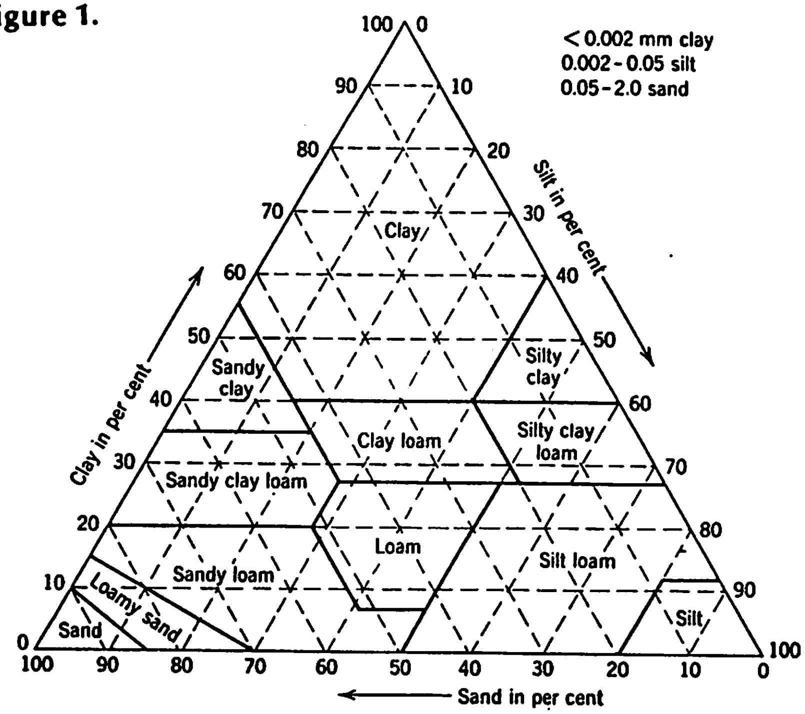
3. Although plant roots may grow to deep depths, most of the water and nutrients are taken form the upper half of the root zone. Plant stress and yield loss can occur even with adequate moisture in the lower half of the root zone.

4. Variations in soil moisture cause few problems if the soil isn't overly wet or overly dry for a long period of time and if the shortage doesn't occur at a critical stage of growth.

Table I. Soil Particle Size Limits, U.S. Department of Agriculture

Size	Name
2.0 mm	Stone or gravel
2.0 - 1.0 mm	Very coarse sand
1.0 - 0.5 mm	Coarse sand
0.5 - 0.25 mm	Medium sand
0.25 - 0.10 mm	Fine sand
0.10 - 0.05 mm	Very fine sand
0.05 mm - 0.002 mm	Silt
0.002 mm	Clay

Figure 1.



U. S. Department of Agriculture textural classification chart.

Table II. Typical soil moisture levels for three soil textures.

Texture	Soil Moisture		
	Field Capacity in./ft.	Permanent Wilting Point in./ft.	Available Moisture in./ft.
Sandy	1.2	0.2	1.0
Loamy	2.2	0.5	1.7
Clay	3.6	1.2	2.4

Table III. Available Moisture Holding Capacity of Some Common Kansas Soils.

Soil Type	Available Moisture Holding Capacity inches/foot of soil
Randall clay	2.40
Crete silt loam	2.28
Muir silt loam	2.28
Richfield silt loam	2.28
Colby loam	2.16
Bridgeport loam	2.16
Albiou sandy loam	1.80
Las Animas sandy loam	1.20
Ortello fine sandy loam	1.56
Pratt loamy fine sand	1.44
Dalhart loamy fine sand	0.84
Tavoli loamy fine sand	0.72

Figure 2. Typical Soil Moisture Release Curves

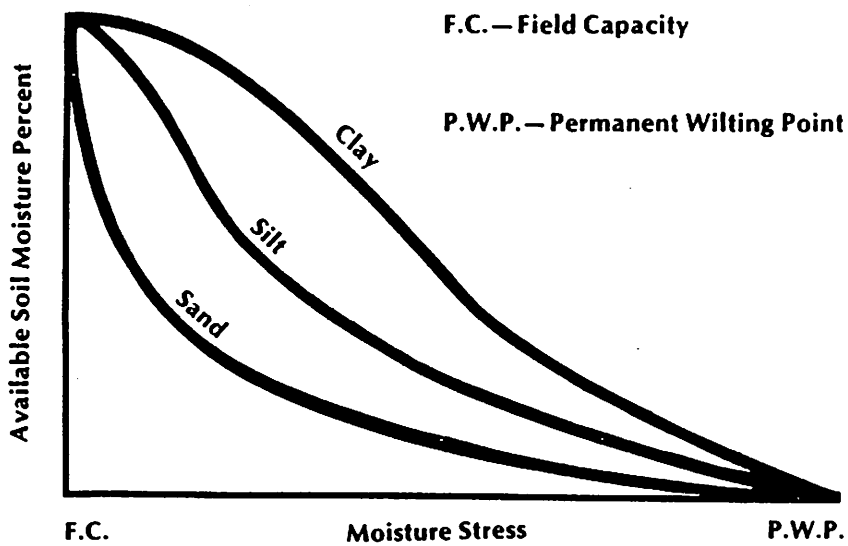


Figure 3. Typical Seasonal Water Use

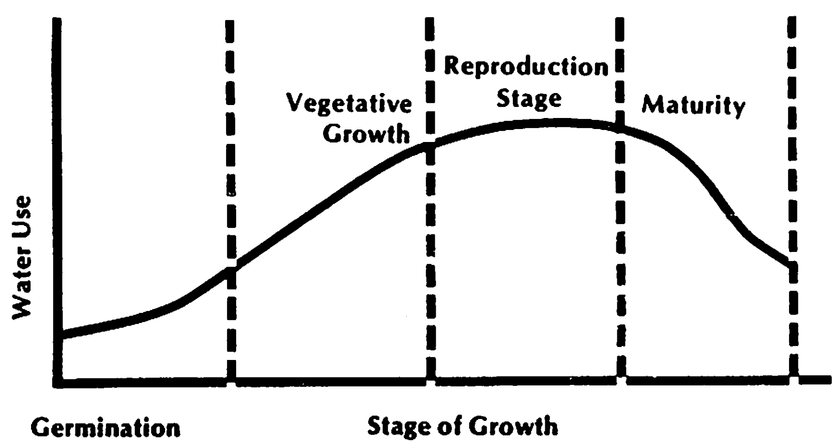


Table V. Typical Plant Soil Moisture Extraction Pattern

Portion of Root Zone	Moisture Extraction Percent
Top Quarter (¼)	40
Second Quarter	30
Third Quarter	20
Bottom Quarter	10

Table IV. Typical depth of crop root penetration and major feeder root zone depth.

Crop	Depth of Root Penetration feet	Major Root Zone Depth feet
Corn	4 - 6	2 - 3
Grain Sorghum	4.5 - 6	2 - 3
Alfalfa	6 - 10	3 - 4
Soybeans	5 - 6	2 - 3
Wheat	4 - 6	3
Sugar Beets	5 - 6	3