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The 1983 growing season in Kentucky was a vivid reminder that water is éssential for good plant growth. And the water used by plants is taken from the reserve of water stored in soil.

The water content of a saturated soil can be separated into three classes: gravitational water, plant available water, and plant unavailable water. Gravitational water is that which will drain from soil during two or three days following significant rainfall amounts and in well-drained soils is not present in the soil long enough to be taken up by plants. Usually about 15 percent of the volume of soil in the surface foot of soil (1.8 inches) holds gravitational water. Plant unavailable water is held so tightly by the soil that plants cannot extract it fast enough for good growth. Plant unavailable water in most soils on which row crops are grown in Kentucky is approximately 15 percent of the volume of the surface foot of soil (1.8 inches).

Plant available water (PAW) of Kentucky soils averages about 20 percent of the volume in the surface foot of soil or about 2.4 inches. At depths below the top foot, there is proportionately less PAW per foot of soil. The pressures required to extract plant available water from soil range from 1 to 225 pounds per square inch. Soil water is not equally available to plants over this entire range. The less the pressure required to extract the water, the more available it is to plants.

For the most part, soil texture, structure, and organic matter determine the amount of PAW in soil. The texture of the plow layer (0-6 inches) of most row-cropped soils in Kentucky is silt loam and the organic matter does not vary very much. Structure varies more than texture or organic matter in these soils. In general, limestone derived soils have better structure than do soils derived from sandstone or shale.

Soil depth through which plant roots can freely grow determines the total volume of soil from which plants can extract water and is, therefore, the most important factor determining the amount of plant available water in most soils in Kentucky. Presence of compacted layers such as plow pans and genetic pans within the soil profile can severely limit the volume of soil from which plants extract water. Kentucky does not have an extensive acreage of soils with a rooting depth greater than 3 feet, and consequently many Kentucky soils used for row crop production do not contain nearly as much PAW as many soils in the upper corn belt. The table below shows the plant available water and the effective rooting depth of some important soil series in Kentucky that are frequently row cropped.

Soil Series	Effective Rooting Depth, Feet	Plant Available Water in Rooting Depth, Inches
Zanesville	3.0	5.5 to 6.0*
Calloway	3.0	5.5 to 6.0*
Grenada	3.0	5.5 to 6.0*
Crider	3.5	6.0 to 6.5
Pembroke	3.5	6.0 to 6.5
Huntington	7.0+	8.0 to 10.0+**
Maury	3.0	5.0 to 5.5
Shelbyville	3.5	5.5 to 6.0

* Can be 1 to 2 inches higher due to perched water table above the genetic pan.

** A permanent water table often exists in plant rooting depth especially along the Ohio River and other major streams. In such cases plant available water can exceed 10 or more inches.

Water Movement in Soil

Rainfall on the soil surface may either run off or percolate below the soil surface. Depending on the physical characteristics of the soil in the rooting depth and on the total amount of water that percolates into the soil, some water will be held which becomes available for plant transpiration. Some of the water in the rooting depth may be lost, as evaporation back to the atmosphere. Also, some water entering the soil may percolate beyond the rooting depth and be lost as plant available water. Transpired water plus that which evaporates back to the atmosphere is termed evapotranspired water.

The amount of evapotranspiration is determined by climatic conditions; primarily the amount of solar energy reaching the crop and/or soil surface, and temperature. Wind, relative humidity, slope, aspect (north or south facing slopes), and other factors affect evapotranspiration but to a much lesser extent than solar energy and temperature. Potential evapotranspiration is defined to be the maximum amount of water evaporated from leaf surfaces (transpired water) and/or the soil surface for the prevailing climatic conditions. As long as there is sufficient soil water to meet potential evapotranspiration, crops will not experience soil water stress.

A relative large amount of solar energy (heat) is required to evaporate water. In fact, it requires about 5.5 times as much heat energy to evaporate a pound of water as is required to increase the temperature of a pound of water from the freezing point to the boiling point. This is the primary reason why the air temperature is lower during summer months when rainfall equals or exceeds potential evapotranspiration than it is when rainfall is much below potential evapotranspiration during those same summer months. During June, July, and August when rainfall equals or exceeds potential evapotranspiration, a little more than 50% of the total solar radiation is used in evaporating water; about 10% goes into warming the surrounding air, soil, etc., and the remainder is reflected radiation or outgoing radiation. During these three summer months around 75 million BTU's of heat equivalents of total radiation are received per acre of land area during a typical day.

The average potential evapotranspiration (PET) and rainfall (R) during the growing season for the four climatic regions of Kentucky are given in the following table.

	Climatic Region							
Month	Western Ky.		Central Ky.		Bluegrass		Eastern Ky.	
	R	PET	R	PET	R	PET	R	PET
	inches							
May	4.33	3.90	3.93	4.04	4.11	3.64	4.35	3.07
June	3.95	5.51	4.19	5.37	4.19	4.97	4.42	4.13
July	3.97	6.27	4.97	6.33	4.66	5.64	4.39	4.49
Aug.	3.33	5.17	3.68	5.34	3.43	5.12	3.45	3.89
Sept.	3.19	3.73	3.13	3.69	2.95	3.66	3.04	2.88
Total	18.59	24.58	19.90	24.77	19.34	23.03	19.65	18.46
Ratio(PET:R)	0.76		0.80		0.84		1.06	

As can be seen in the above table, average PET of the Western Ky., Central Ky. and the Bluegrass climatic regions is greater than the average R during June, July, August and September, while PET in Eastern Kentucky is greater than R during August. During periods when PET is greater than R, PAW from the soil is being depleted. The smaller the average PET to R ratio, the greater the probability of drought. If the ratio is greater than 1, water stress will not occur; however, if for any extended period of time during July and August when the ratio is significantly lower than 1, crop yields will be reduced due to soil-water stress. Rainfall during the months of the growing season, especially July and August, varies much more than does potential evapotranspiration.

During periods of soil water stress (drought periods) actual evapotranspiration will be less than potential evapotranspiration due to lack of availability of soil water for transpiration by plants and/or evaporation of soil water.

Effect of Water Stress on Crops

In practically all soil types on which row crops are grown in Kentucky, the crop begins to experience mild water stress when approximately 20 to 25 percent of the plant available water has been depleted. Moderate water stress develops when an additional 25 to 20 percent has been depleted, and severe water stress develops as the remaining plant available water is used. Crops can grow under mild or the early stages of moderate water stress and show no visual symptoms such as wilting. When the crop is under severe water stress, wilting becomes evident from about 10 or 11 AM and lasts until 5 or 6 PM or longer.

The stage of crop growth when water stress occurs largely determines the effect on the yield. The critical stage of growth for corn and soybeans is the reproductive period and the grain filling period. The critical stage for tobacco is two weeks before and two weeks after topping. During these growth stages, yields can be reduced, even by mild water stress. Yields, of course, will be reduced more and more as the severity of and length of water stress increases during these critical periods. Yields are reduced in other growth stages due to water stress but not as severely as in the critical stage of growth.

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