Water Use and Irrigation Management of Agronomic Crops[1]

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To obtain maximum yields from agronomic crops, plants should remain relatively free of water stress. Although different crops may vary in their responses to water deficits at different growth stages, the amount of water used by a crop is closely associated with final vegetative and grain yield.

Maximum yields of agronomic crops can be achieved by avoiding stress, with water deficit often causing the greatest impact on yield. Although different crops may vary in their responses to water deficits at different growth stages, most crops have their highest water requirements and water-stress sensitivity during late vegetative and early reproductive phases of growth.

Evapotranspiration (ET)

Evapotranspiration (ET) is a term used to describe the water loss from land on which vegetation is growing. The evaporation component (evapo-) of ET is the process by which water in the soil is changed to the vapor state and moved into the atmosphere. This is the same evaporation process that results in water being lost from the surface of a lake or an ocean.

The second component of ET (-transpiration) refers to the vaporization and loss of water from the leaves of a crop through the small pores, or stomata, in the leaf. Although this is also an "evaporation process," it is termed transpiration because the evaporated water has been taken up by the plant roots from the soil, moved up through the plant stem, and evaporated from the plant leaves.

If the amount of water which is evaporated from the soil surface (the *evapo*- part) is added to the amount of water which is transpired from the leaves above the soil surface (the -*transpiration* part), the resulting amount is the total amount of water loss to the atmosphere, or ET. Thus, ET is composed of evaporation from the soil plus transpiration from plant leaves. Values of ET for a crop are usually expressed as the amount of water lost to the atmosphere (inches, cm, mm) per unit of time (hour, day, week, month, season, or year).

At planting time, ET rates consist only of evaporation of water from the soil surface. As the crop emerges and begins to develop leaf area, an increasingly larger portion of ET results from transpiration from the crop's leaves. When leaves completely shade the soil surface (canopy coverage), ET consists largely of transpiration. Actually, during most of the growing season of typical agronomic crops, transpiration is responsible for the largest portion of the water loss from the field. Even during early crop development when the soil surface is exposed to direct sunlight, evaporation is

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small if the soil surface is dry. Clearly, the largest seasonal requirement for water in most field crop situations is to supply transpirational needs and not for evaporation from the soil surface.

Seasonal ET

Calculated seasonal ET values for several agronomic crops range from about 15” (38 cm) for tobacco to approximately 49” (124 cm) for sugarcane (Tables 1 and 2). For most agronomic crops that produce leaf canopies that fully cover the soil surface, variations in the amounts of water required for ET are primarily dependent on the time of season during which the crop is grown, the water stress imposed on the crop, and the length of the growing season. Net irrigation requirements (NIR) (see equation below) necessary to satisfy the ET needs in 80% of crop years are also given in Tables 1 and 2. For example, in 8 of 10 years for corn, 12” (25 cm) of irrigation water supplementing rainfall would provide adequate water to meet the ET demand of 25” (64 cm). Since ET is quite responsive to many weather variables including radiation, temperature, humidity, and wind speed and also to numerous crop characteristics, values of both ET and NIR will vary from season to season. Data reported in Table 1 must only be considered as values representing average environmental and crop conditions. Also, the NIR values given in Tables 1 and 2 do not consider irrigation efficiency. See the section on “Efficient Irrigation Management” for further information.

Sensitive Crop Growth Stages for Water Deficits

Severe water stress at any crop developmental stage will usually result in some growth and yield reduction. However, certain stages of growth are sensitive to even mild water stress. Knowledge of these particularly sensitive growth stages and ET rates during these growth periods can be helpful when deciding whether to irrigate or delay for a few days in anticipation of rainfall.

Table 3 gives a summary of crop growth stages that are most sensitive to water stress, the approximate days after planting at which the critical stages occur, and the expected maximum daily water use rates during the indicated periods. Days after planting and daily water use rates are only to be used as general guidelines since dates of planting, variety, plant population, and numerous environmental factors will cause the actual values to vary. The ET estimates given, however, are representative of a typical crop planted at a recommended date and population on a relatively clear day during the indicated crop growth stage. Generally, the ET requirements during the most sensitive growth stages are similar for the various crops and range between 0.20” and 0.28” (0.51 to 0.71 cm) per day. While replacing ET losses is the goal of most irrigation scheduling tools, obtaining correct ET values for individual fields can be challenging. To aid in irrigation scheduling, there are instruments available that measure soil moisture levels as well as plant stress so that irrigation for individual fields can be timed to meet the needs of the plant before stress occurs. Tools used to determine soil moisture can be found here. Information on how to avoid over-irrigation on sandy soils can be found here.

For grain crops, yield is determined by both the total number of seeds produced and by the weight of each seed. Thus, any stress which causes a reduction in either the number of seeds produced or the weight of the seed will result in yield reductions. Growth stages that are most sensitive to water stress are usually the growth stages during which either seed numbers or seed weights are established (Table 1). Crop yield is generally reduced less by water stress occurring during the vegetative stage than during the reproductive stage of growth for most crops.

Some crops, including corn, sorghum, and small grains, have relatively short periods of growth during which seed numbers are determined, and severe water stress at this growth stage may be quite detrimental to grain yield. Conversely, crops such as soybeans, cotton, and peanuts bloom over an extended period of time in which the crop can set seed or bolls and are not as severely affected by short term stresses. For a crop such as tobacco, where leaf production is most important, water stresses during most growth stages can be detrimental to yield.

Water deficits may also affect crop management and production other than the direct effect on plant growth. The efficacy of many herbicides and other pesticides depends on soil moisture. Plants under moisture stress may not respond to foliar applied chemicals or fertilizer, or, in some cases, may be damaged by chemical burns. Nutrient utilization and fertilization practices are influenced by soil moisture status. Application of pesticides must consider irrigation applications and moisture stress in the crop.

Efficient Irrigation Management

The most sensitive growth stages for most crops coincide with time intervals during which the crop is also utilizing the most water (Table 3). The most important irrigation management decisions must be made when the crop is using large amounts of water and when the crop may progress from being well-watered to severely stressed in a period of a few days. This emphasizes the importance of designing an irrigation system so that it will be able to apply amounts and rates sufficient to supply maximum ET demands. Furthermore, all of the water applied does not become available for ET. Some water is unavoidably lost during the delivery to the crop. In Florida, most agronomic crops are irrigated by sprinkler irrigation systems. Sprinkler systems deliver water with approximate efficiencies of 70 to 75%, depending on the system and environmental conditions. Therefore, for an irrigation system with 75% efficiency, if 1" (2.5 cm) of water is pumped, only 0.75" (1.9 cm) reaches the soil surface and is available for ET. To ensure 1" (2.5 cm) of water is actually available to the crop, 1.33" (1.0 ÷ 0.75) must be applied. Therefore, amounts of water actually applied must be increased above the ET requirements (presented above) to allow for the delivery losses. Irrigation efficiency can be improved by use of low pressure systems and by irrigating at night. However, most pivots cover enough acreage that they must be run continuously during critical, dry periods. Sprinkler system efficiencies can be evaluated for free in Florida by contacting the Mobile Irrigation Lab.

Although the preceding paragraphs have referred to critical crop growth stages, this does not suggest that stress at other periods will not reduce yields. The critical growth periods only imply that added attention should be given to irrigation management decisions during those stages.

Some general guidelines for irrigation management of several agronomic crops are given in the following paragraphs. On coarse-textured soils dominating much of Florida, more frequent irrigations with smaller amounts of water (1" or less) allow for more efficient storage of rainfall that may occur shortly after irrigation. The goal of efficient irrigation management should be to minimize the loss of water to runoff, deep percolation, and evaporation, and to maximize water used for crop transpiration. Efficient irrigation requires careful management and is attainable if an understanding of water use and stress responses of the crop is applied. Water in amounts and rates sufficient to supply maximum ET demands. Furthermore, all of the water applied does not become available for ET. Some water is unavoidably lost during the delivery to the crop. In Florida, most agronomic crops are irrigated by sprinkler irrigation systems. Sprinkler systems deliver water with approximate efficiencies of 70 to 75%, depending on the system and environmental conditions. Therefore, for an irrigation system with 75% efficiency, if 1" (2.5 cm) of water is pumped, only 0.75" (1.9 cm) reaches the soil surface and is available for ET. To ensure 1" (2.5 cm) of water is actually available to the crop, 1.33" (1.0 ÷ 0.75) must be applied. Therefore, amounts of water actually applied must be increased above the ET requirements (presented above) to allow for the delivery losses. Irrigation efficiency can be improved by use of low pressure systems and by irrigating at night. However, most pivots cover enough acreage that they must be run continuously during critical, dry periods.

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Corn, Tobacco, and Peanuts

Research has indicated that corn and tobacco, two of the more sensitive crops to water stress, can be effectively irrigated on sandy soils with the aid of tensiometers or other types of moisture monitoring equipment placed at various depths including 6" (15 cm) deep in the crop root zone. For tensiometers, when the soil moisture tension at that depth approaches 20 to 25 centibars, irrigation water should be applied. It is well documented that corn is extremely sensitive to water stresses during silking and tasseling, but research also indicates that 2 weeks of midday wilting during early vegetative growth can reduce yields by as much as 10% to 15%. Additional tensiometers placed at 12" (30 cm) and 18" (45 cm) depths will help determine the amount of water to apply without leaching nutrients through the soil profile.

Irrigation of peanuts with tensiometers installed at the 12" (30 cm) depth and using an irrigation trigger of 30 centibars has also proven effective. A peanut irrigation threshold of 40 centibars has been effective on heavier soils in the western panhandle. Tensiometers allow the manager to apply irrigation water before crop stress symptoms become visible.

If tensiometers are not utilized, an accounting method can also be quite effective. Accounting methods are more practical for determining when to irrigate with overhead sprinklers than are tensiometers and other moisture-sensing devices placed in the soil. Accounting methods are much like keeping a bank account ledger, in that records of rainfall and irrigation are maintained and water use by the crop is estimated. Estimated weekly water use by corn (Figure 1) and peanut (Figure 2) can help managers decide how much irrigation is needed to replace water use by these crops. Water use estimates can also be based on the experience of the irrigation manager, but may become difficult when several systems at various locations must be monitored. Use of weather instruments can improve the reliability of water use estimates and can be coupled with computer programs that are available to quickly provide reliable irrigation recommendations. In general, when using the accounting method, irrigation should begin when 50 percent of the available water in the root zone is depleted. Estimates of the water-holding capacity of the soil and changes in the rooting depth as the crop grows must be estimated, if not actually measured.

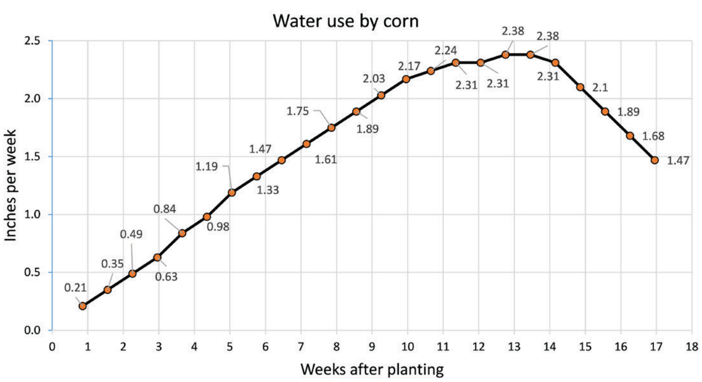

Figure 1. Estimated weekly water use by corn.
Credits: Wes Porter, UGA

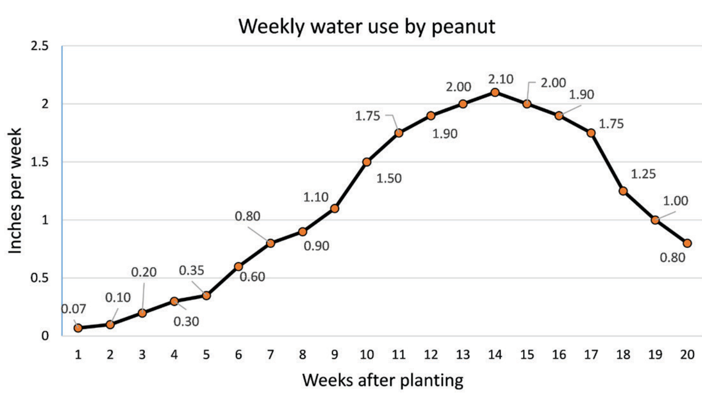

Figure 2. Estimated weekly water use by peanut.
Credits: UGA. 2017. "2017 Peanut Update." University of Georgia, accessed Nov. 2, 2017. http://www.gapeanuts.com/growerinfo/2017_ugapeanutupdate.pdf

Estimates are based on soil type and are available from soil surveys and other references. In general, sandy soils contain less than an inch of available water per foot of depth, while soils that contain significant levels of clay or organic matter can hold well over an inch of available water per foot of depth. The rooting depth of the crop varies with species, age of plant, and soil properties. More detailed information on irrigation scheduling can be found in UF/IFAS Extension Bulleting 249, *Basic Irrigation Scheduling in Florida* ().

Soybeans

The appearance of midday wilt appears to be a reasonable indicator for applying water for soybean during reproductive growth. However, research results have indicated that 2 weeks of midday wilting during vegetative growth resulted in only small (2% to 5%) yield reductions. Thus, it appears that some water stress can be tolerated by soybean during vegetative growth without significantly reducing yields, but more liberal applications of irrigation water are necessary from early pod-set to maturity. As new varieties of higher-yielding soybean come on the market, moisture stress can result in higher yield losses.

Sugarcane

There are two factors to consider in reviewing the water requirements of sugarcane; one is the actual amount of water required to produce the sugarcane, the other is the management of the water table in the cane field.

Approximately 80% of all sugarcane grown for commercial sugar production in Florida is grown on organic soils in which the water table should be maintained at a certain level to reduce soil subsidence. A water table depth of 24" (61 cm) or greater is usually maintained on well-decomposed organic soils. According to a seven-year study conducted at the UF/IFAS Everglades Research and Education Center, a water table of 30" (76 cm) resulted in the best sugar tonnage per acre, but a water table of 15" (38 cm) reduced production only 5%. The rate of subsidence with a 20" (51 cm) water table for example, is less than half of the rate for soil with a 36" (91 cm) water table.

A higher water table maintained to reduce subsidence will require more water for irrigation during the dry season and more pumping for drainage during the wet season.

The actual amount of water required to produce 2.2 lb (1 kg) of cane ranged from 196 lb (89 kg) for plant cane (freshly planted sugarcane) to 260 lb (118 kg) for ratoon cane (sugarcane that was harvested and allowed to grow back). The water use efficiency for the ratoon cane is less than that for the plant cane. The water required to produce 2.2 lb (1 kg) of sugar ranged from 1,948 lb (884 kg) in plant cane to 2,485 lb (1115 kg) in ratoon cane. More information on water management for Florida sugarcane is available here.

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Table 1. Seasonal evapotranspiration and net irrigation requirements for several agronomic crops.[1]

Crop	Seasonal ET (in.)	NIR-80
Corn	25	12
Grain Sorghum	20	6
Peanuts	22	7
Soybeans	23	7
Small Grains	20	9
Tobacco	15	7

[1] From Rogers and Harrison, Water Resources Council Report No. 5 as calculated from US Soil Conservation Service, Technical Release No. 21.

Table 2. Consumptive use, or ET (Evapotranspiration), of sugarcane for Everglades area of Florida.

Month	ET	NIR-80
January	1.4	0.5
February	1.1	0.5
March	2.5	0.9
April	3.4	1.8
May	4.8	1.7
June	6.0	1.2
July	6.5	1.6
August	6.7	1.7
September	5.1	0.7
October	5.2	2.2
November	3.2	1.7
December	2.6	1.5
Total	49.5	17.9

NIR-80 = Net irrigation at 80% rainfall probability. Divide by irrigation efficiency for gross irrigation requirements. For sugarcane, seepage irrigation is used and the efficiency is 30 to 50%.

Table 3. Sensitive growth stages, dates of occurrence, and maximum daily water use required of several agronomic crops.

Crop	Sensitive Growth Stage[1]	Approx. Days After Planting	Expected Maximum Water Use Requirements During Critical Growth Stage[2] (in/day)
Tobacco	2 to 3 week period near flowering[3]	50–65	0.22–0.25
Corn	Tasseling and silking	65–75	0.22–0.28
Sorghum	Early boot through bloom	45–70	0.20–0.25
Peanuts	Mid-flowering through completion of pod set	45–90	0.22
Soybeans	Early to late bean fill	50–100	0.20–0.25
Cotton	Bloom period	45–90	0.20–0.25

[1] Growth stage at which yield is most sensitive to water stress.
[2] Value should only be used as estimates for maximum rates since many environmental factors affect water use. The range in values given for a particular crop represents values obtained from different experiments or changes associated with crop development during the critical period.
[3] Represents maximum water use period. Data are limited for growth stage sensitivities.