IRRIGATION SCHEDULING AND USE OF "SCHEDULER" PLANT STRESS MONITOR [1]

by
Larry K. Hiller [2]

Abstract

The basic objective of irrigation scheduling is to increase irrigation efficiency by balancing the quantity of water applied with the amount that the crop actually uses. Methods of irrigation scheduling are generally classified into three categories: soil, meteorological, and plant based. The soil and climate based methods are the most commonly used for estimating crop water needs, but these are indirect measurements. Recent advancements in infrared thermometry have led to the use of remote sensing techniques to measure crop canopy temperatures and the development of a crop water stress index (CWSI) for purposes of irrigation scheduling. This presentation will discuss these various methods and approaches to irrigation scheduling as well as our first-year evaluation of a new crop water stress monitor called the "Scheduler".

The primary reason for irrigating crops is often to supplement that water available from natural sources such as rainfall, dew and groundwater. Irrigation scheduling involves water (irrigation) management in the broadest sense. Questions pertaining to irrigation and water management generally involve the following: "Do I need to irrigate?", "How should I irrigate?", "When do I irrigate?", "How much do I apply?". The answers to the last two questions is the subject of irrigation scheduling. We are readily aware of the problems associated with too little water, but we must also remember that there are about as many problems that result from too much water.

The principle objective of irrigation scheduling is to increase the irrigation efficiency by balancing the amount of water applied with the amount of crop water use. Improving irrigation efficiency is important for at least three major reasons: conserve water resources, conserve energy, and reduce the potential of leaching contaminants (nitrates, pesticides, etc.) into groundwater supplies. A vital factor to growers would also be the increased net dollar returns from improved crop yields and quality and lower production costs. The water balance involves the supply of water to meet the demand for water.

---

1 Paper presented at the 27th Annual Washington State Potato Conference & Trade Fair, February 2-4, 1988, Moses Lake, Wa. 98837.

2 Department of Horticulture & Landscape Architecture, Washington State University, Pullman, Wa. 99164-6414.

This Presentation is part of the Proceedings of the 1988 Washington State Potato Conference & Trade Fair.

This demand includes a small but real amount used in plant growth processes called CONSUMPTIVE USE and a larger, more easily measured amount from evaporation (primarily from the soil) and transpiration (plant). These last two are often combined and called EVAPOTRANSPIRATION.

The fundamental principles of irrigation scheduling involve the plant - soil - atmosphere (climate) relationships, which can be summarized simply that the plant needs water, the soil stores and provides the water, and the atmosphere provides the energy by which the plant will withdraw water from the soil. This driving force is the differential in water potential from the soil (low tension) through the plant to the atmosphere (high tension). Thus, the estimation of irrigation schedules--timings and amounts of water to apply--involves a complex interaction of these soil, plant and climatic factors.

One important factor is the soil water availability. Various forces hold water in the spaces between soil particles. These forces, called the matric potential, vary from zero in saturated soils to several bars of pressure in dry soil. The upper limit of water available to plants is referred to as Field Capacity. The lower limit is often called Permanent Wilting Point. The water in between is considered Available Water (AW) or Available Soil Moisture (ASM). The amount, or percentage of water in a given volume of soil, will vary with soil type. As water is removed from the soil, the soil matric forces increase and it becomes increasingly more difficult for the plant to remove (ie, take up) water from the soil.

Many plant factors (root growth, root health, plant vigor, plant nutrient balance, etc.) influence the water relations of a crop, but the process which basically helps or allows the plant to take water from the soil is called transpiration. This process of transpiration changes the water potential (ie, tension or suction levels) in a plant such that they are higher (more suction) at the leaf than at the root, allowing water uptake and movement up the plant to occur. This is also a cooling mechanism for plants which will be discussed later. About 99% of the water taken up by plants is transpired. This water is converted from the liquid to vapor phase within the leaf and moves into the atmosphere through leaf pores called stomates. This process generally occurs whenever the stomates are open which is normally during the day. Stomates close at night or whenever water flow into the plant decreases and leaf water content decreases to a point causing the stomates to close. This results in reduced transpiration and decreased cooling of the plant (leaf temperatures increase); but also carbon dioxide uptake is decreased which results in lower photosynthesis and ultimately a reduction in growth and yield and/or quality.

The atmosphere provides the differential in tension needed by the plant to withdraw water from the soil. If soil water is not limiting and the stomata are fully open, then conditions in the atmosphere will control the rate of transpiration. The most important atmospheric factors affecting this process include humidity of the air surrounding the plant, temperature and relative humidity of the air carried to the plant by the wind, and net solar radiation.

The lower the relative humidity of the air around the plant will increase the transpiration, all other factors constant. As wind removes the layer of water vapor around the leaf, transpiration will increase or decrease depending on the temperature and humidity of the replacement air. Radiation influences transpiration in two ways. Net solar energy will increase leaf temperature which increases transpiration up to a limit, and light triggers the opening of stomates.

These basic concepts and principles of the soil-plant-atmospheric relationships are important as we consider the methods of measuring and estimating crop water use and requirements, which in turn are the basis for determining irrigation requirements. The methods of determining irrigation scheduling are generally categorized as soil based, plant based, and climatological based.

The soil based methods involve a determination of the current water content of soil, comparing that to a predetermined minimum water content, and irrigating to replenish and maintain the soil water content above this minimum level. These soil based indicators also provide data for estimating the amount of water to apply per irrigation. Soil based methods include feel and appearance of a soil sample, oven dry (gravimetric) measure, gypsum blocks and other types of resistance-block measures, tensiometers, and neutron probe. Various other kinds of soil moisture meters are being developed. The correct use, sensitivity, and accuracy of these methods depend on various factors.

The meteorological, or atmospheric, based methods largely involve the determination or estimation of evapotranspiration (ET). These are often the basis of the "water budget" technique which is used in computer programs today. These methods either provide a direct measure of the ET or an estimated and calculated ET. The direct measure approach involves isolating a portion of the crop from its surroundings and measuring the ET. This is done by the use of lysimeters or above-ground plant chambers to enclose a portion of the vegetated area. These are used primarily for research and not for routine field measurements. The calculation approach involves various equations to compute the crop ET. The methods (calculations) differ in the data requirements and level of sophistication but usually involve relative humidity, solar radiation, wind, and air temperature data. Examples of this method include the Penman equation and the pan evaporation method. The accuracy or precision of these methods is largely dependent on the number of factors and variables used in determining the ET and if a crop coefficient is incorporated for the type of crop (foliage canopy) and changes in water requirements throughout the growing season.

Plant based methods are considered by some researchers to be the most direct method for irrigation scheduling since the primary objective is to supply plants with water when they need it. Normally it is necessary to relate plant parameters to soil water content (ie, soil water measurements) to determine the amount of water to apply. Plant methods include change in foliage color, leaf changes, leaf water potentials, stomata conductance, leaf temperature, etc.

One problem with the change in foliage color is that yield and quality is often affected long before color changes are observed. Other problems with plant methods has been that they are time consuming and often tedious, many samples are required for reliability and accuracy, they are often plant destructive, and have not been readily usable under most field situations.

The one plant method which has received renewed interest recently is leaf temperature because of its known relationship with plant moisture status. The advent of infrared thermometry has made possible fairly large scale measurements with relative ease. This is the basis of a new instrument called the "SCHEDULER" recently placed on the market. This instrument measures and records simultaneously the relative humidity of the air, net solar radiation, plant canopy temperature, and air temperature. A microcomputer calculates from this information a Crop Water Stress Index (CWSI). This index value relates to established baseline values for the specific crop as determined for various vapor pressure deficits. The CWSI has been shown to directly relate to the plant water status (ie, water potential or content), thus providing a direct indication of the plant stress level and need for irrigation. The baseline information has been developed for a number of crops other than potatoes. We evaluated this instrument on potatoes in 1987 experiments and plan to continue this work in 1988.