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COMPUTER MANAGEMENT OF TRICKLE IRRIGATION SYSTEMS[1]

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Abstract. **Good irrigation management practices are critical for the efficient use of energy and water resources in agriculture. This paper describes a software package that includes: 1) computer-aided irrigation scheduling, 2) computer-aided field uniformity information manipulation, 3) an expert emulation program for diagnosis and treatment of slime clogging problems, and 4) real time control software for the operation of trickle irrigation systems. This package of programs was developed to aid in the management of trickle irrigation systems. They enable the user to monitor uniformity changes due to both gradual and sudden changes in the hydraulic behavior of trickle systems. This will enable the system operator to detect or anticipate the need for maintenance or repair. This software also aids the user in scheduling of trickle irrigation to satisfy water use demands of the crop. Also, programs for computer control of trickle irrigation systems have been developed that enable the irrigation system manager to operate the system using a low cost micro-computer. These programs will run on most microcomputers and are available to the public.**

The implementation of irrigation technology involves three steps: design, installation and management. Design is the process by which a set of techniques and principles are used to define an irrigation system in sufficient detail for its physical realization. Installation consists of the physical realization of an irrigation system according to design specifications. Finally, management consists of the use of the irrigation system to maintain high yield while optimizing associated resources by maintaining high efficiencies. These resources are water, energy and all chemical products applied through the irrigation system.

An important part of irrigation system management is maintenance, which consists of the actions that must be undertaken to keep the system running at top efficiency and that will prolong the life of the system. If design, installation and management (scheduling, operation and maintenance) of the irrigation system are not well executed, the efficiency of the system will decrease. If an irrigation system has been properly designed and installed, the success of the system will depend upon its management, that is how well irrigations are scheduled and how well the system is operated and maintained.

A package of microcomputer software was developed for trickle irrigation management under Florida conditions. The remainder of this paper discusses the basic principles underlying the software development and capabilities offered.

Irrigation Scheduling Software

Irrigation management strategies attempt to maintain within the active crop root zone a region of sufficient size and soil water content that it insures adequate water supply for the crop. Under most irrigation systems moisture fluctuates between irrigation applications. The magnitude of soil moisture fluctuations are related to the irrigation system type. For example, with overhead sprinkler irrigation systems the entire soil surface is covered by precipitation and irrigation at infrequent time intervals. On the other hand, with trickle irrigation systems water is applied to a fraction of the soil surface at frequent time intervals and precipitation occurs over the entire surface at infrequent intervals. In management of irrigation systems that produce full coverage, such as overhead irrigation, the concept of irrigation depth or volume of water applied per unit area is often used. Instead, volume of water applied will be used here.

Scheduling trickle irrigation systems can be achieved by maintaining a soil water budget. As opposed to full coverage irrigation systems, two distinct root zones must be budgeted: 1) that wetted by the emitter and, 2) a non-irrigated root zone. (Fig. 1). Fig. 2 shows the water flow paths through a typical crop root zone. By definition, all irrigation water goes to the irrigated zone only. However precipitation may replenish both the irrigated and the non-irrigated zones. Water may exit the root zone as deep percolation if precipitation or irrigation exceed the available storage volume. Also, water exits from the soil surface as evaporation and from the root volume profile as water absorption for evapotranspiration.

To perform a two zone budget of the water stored in the soil, it was necessary to estimate how much of the

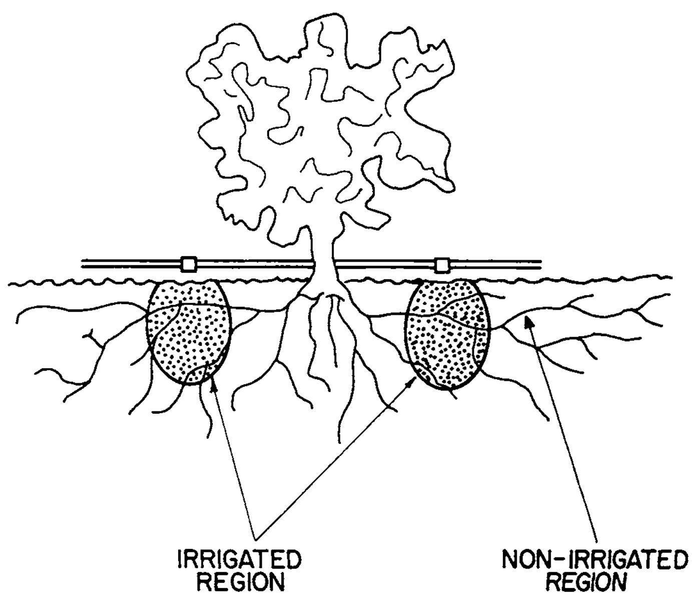

Fig. 1. Soil moisture regions under a trickle irrigated crop.

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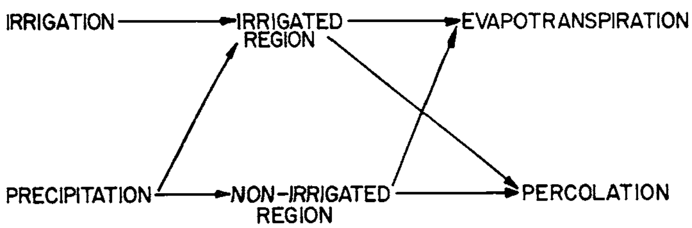

Fig. 2. Paths of water flow in a trickle irrigated crop.

total water used by the crop is being taken from the irrigated region and how much is being taken from the non-irrigated region. This was done using a soil water uptake partition coefficient, P.

$$P = \frac{V_i}{V_{ni}} \quad (1)$$

Where V_i is the water volume absorbed by the root system and evaporated from the irrigated region, and V_{ni} the water volume absorbed by the root system and evaporated from the non-irrigated region. The sum of V_i and V_{ni} is the total soil water volume extraction caused by evapotranspiration from the root zone.

Using the electric analog model developed by Gardner (5) and the root activity coefficient presented by Hillel (6), a partition ratio can be calculated as:

$$P = C\frac{K_i}{K_{ni}}\frac{A_i}{A_{ni}}\frac{VS_i}{VS_{ni}} \quad (2)$$

where K is the average hydraulic conductivity, A is a root activity coefficient, VS is the volume of the crop root zone and the subscripts i and ni refer to the irrigated and non-irrigated regions, respectively. C is a correction coefficient that accounts for nonuniformity in the distribution of roots and soil water in each of the regions. In our work, C was assumed to be 1 due to lack of better knowledge at this time.

Given the total volume of water extracted from the soil, which can be estimated by any adequate evapotranspiration equation (7, 9), the extraction from the irrigated and the non-irrigated regions can be approximated by:

$$V_i = \frac{V_{tot}}{1 + P} \quad (3)$$

$$V_{ni} \frac{V_{tot}}{1 + 1/P} \quad (4)$$

where V_{tot} is the total soil water extraction caused by evapotranspiration, and other factors as previously defined.

Equations 1 through 4 can be used to keep a water budget of each of the regions in the root zone. Estimating the partition coefficient from equation 2 requires that the hydraulic properties of the soil be known as well as the size of the effective root zone and the irrigated region. Under field conditions this can be done with any degree of certainty only by direct observation. This requires the user to measure the extent of the wetted region in the field. Typically, in sands the wetted area at the surface provides a good indication of this wetted region.

Upon estimation of the extraction from each region, the water budget can then be carried out for each region as described by Choate and Harrison (2) at regular short time intervals. In order to carry out the water budget, precipitation and soil-water holding capacity data are needed in addition to those data previously discussed. The computations required for water budgeting can easily be carried out by a computer. The computer can also be used for the maintenance of historical data on managing a given irrigation system.

The water budget method described above will work well provided that the *actual size* of the root zone and of the irrigated region are not overestimated. Any underestimation of the size of either of these volumes will act as a safety factor in estimating the available water for crop use at any time.

Maintenance Software

One of the major problems in trickle irrigation systems is the change of emitter discharge with time. Changes may be due to aging of the components, and to physical and biological clogging of the irrigation system. Physical clogging results from solid particles in the system or in the irrigation water and is easily controlled by a well-designed filtration system. On the other hand, biological clogging is more complex both in its dynamics and the management actions that are needed for its control. Because of this, a program that addresses biological problems alone was developed. Also, a second program was developed that addresses all causes of changes in uniformity.

Biological clogging. Clogging of trickle irrigation systems with algae and bacterial sludges is a common problem in Florida. Chemical water treatment is necessary in order to prevent biological growths. At the present time sodium hypochlorite is the only form of chlorine that has an approved EPA label for use as a biocide in trickle irrigation systems in Florida. Software that diagnoses and prescribes water treatment with sodium hypochlorite to reduce clogging problems has been developed based on the research done by Ford (3, 4). This program requires data from a chemical analysis of the irrigation water and information concerning the characteristics of the water source and the irrigation system.

Field uniformity. Under most conditions, field uniformity of a trickle irrigation system will vary slowly with time. In order to ascertain the state of the irrigation system with respect to hydraulic uniformity it is necessary to periodically sample the emitter discharges and to keep historical records in such a way that gradual changes in uniformity can be detected and remedial actions can be taken before lack of uniformity causes a decrease in efficiency of the irrigation system.

The basic procedure for uniformity estimations developed by Bralts and Kesner (1) and applied by Smajstrla et al. (8) has been included in our trickle irrigation management software. This software is used: 1) to estimate the field uniformity coefficient and its statistical confidence interval from field samples and, 2) to create and maintain a set of files of the field uniformity coefficient as it varies with time. Utilities are included that will display the uniformity data in tabular or graphical form. Any number of irrigation subunits can be handled by the program. The data in these files can be manipulated through a series of functions that allow the user to obtain information about the state of the irrigation system and tendencies for future estimates. Graphical display of these data allow the impacts of maintenance actions, or lack of actions, on the uniformity of the irrigation system to be clearly shown.

Irrigation System Operation Software

A digital computer controlled system for irrigation was developed by Zazueta et al. (10). This software was developed around low cost, "off-the-shelf" components. All of these components are available from department stores, irrigation supply stores, consumer electronic stores or mail order houses. The central component is a home computer that is used as a dedicated controller. The system developed by the authors functions in 3 modes: 1) manual control, in which the user can turn devices on and off from the keyboard of the computer, 2) timer control, in which the user specifies an irrigation schedule and the computer takes over all irrigation and chemical injection tasks, and 3) an automatic mode in which the computer senses the soil-water status and irrigates when it reaches a critical level.

This system was installed and tested in greenhouses (11) and will be tested for the operation of citrus trickle irrigation systems. The results of this study will be presented in a future paper.

Summary

Computer software has been developed to be used as an aid in trickle irrigation system management. This software (available through: IFAS Software Communication and Distribution, Florida Cooperative Extension Service, GO22 McCarty Hall, University of Florida, Gainesville, FL 32611) has been designed to run on any MS-DOS or CP/M based computer and is available to the public on a variety of disk formats.

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EFFECTS OF TRICKLE IRRIGATION METHODS AND AMOUNTS OF WATER APPLIED ON CITRUS YIELDS[1,2]

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Additional index words. drip irrigation, spray irrigation.

Abstract. **A 5-yr study of the production of 'Valencia' orange [Citrus sinensis (L.) Osb.] in response to amount of water applied and method of trickle irrigation was conducted. Irrigation scheduling was based on 100%, 50% and 25% of potential evapotranspiration calculated from pan evaporation, with irrigation delays following rainfall. Citrus yield was not influenced by the amount of irrigation applied, indicating that all treatments provided sufficient water to avoid yield-limiting stress. Yields were strongly related to irrigation method, with the spray irrigation systems which covered 28%-51% of the area under the tree canopy increasing yields by 65% as compared to the non-irrigated control. Drip irrigation systems which irrigated 5%-10% of the canopy area increased yields 41%-44%. Rainfall distributions also strongly influenced yields of both the irrigated and non-irrigated treatments. Yields of all treatments were greatest when rainfall distributions in the months of April-October were above average.**

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[2]The excellent work of the late J. Mostella Myers in the design, installation and data collection for the early years of this research is greatfully acknowledged.

Trickle irrigation has become an increasingly popular method of irrigation of citrus in Florida (3). This has occurred because trickle irrigation systems are relatively low in cost (4), and their use results in sufficient yield increases that they are cost-effective (4, 5). There is also the ability to obtain a measure of freeze protection when under-tree spray emitters are operated during some freezing conditions (1, 2, 7, 8).

This work was initiated to study the effects of trickle irrigation on citrus yields for the sandy soils and humid climatic conditions of Florida. Trickle systems used for citrus irrigation in Florida are commonly of two general types: 1) point-source drip types, and 2) low flow rate spray types. Drip systems generally operate at lower flow rates per tree irrigated than spray systems, thus resulting in lower system costs. However, as compared to drip emitters, spray emitters are capable of irrigating a much larger fraction of a tree root zone per emitter because of the very limited lateral movement of water from trickle emitters in typical Florida deep sandy soils.

Our objectives were specifically to quantify yield increases resulting from trickle irrigation of citrus under climatic, soil, and grove management conditions typical of the central ridge citrus production area of Florida, and to quantify yield differences which might occur due to the amount of irrigation water applied or to the type of trickle irrigation system used. Fruit quality responses and responses to fertigation are presented in a companion paper (6).

Materials and Methods

Trickle irrigation systems were installed in a mature 'Valencia' orange grove on rough lemon rootstock (*Citrus*