Irrigation Scheduling Research using Variable-Rate Pivot and Switched-Sprinkler Linear Systems

Calvin Perry , James Hook , Kerry Harrison , Craig Bednarz [1 2 1 2]
Biological & Agricultural Engineering [1]
Crop & Soil Science [2]
The University of Georgia
Tifton GA 31793
perrycd@tifton.uga.edu

INTRODUCTION

Irrigation scheduling is critical to optimizing water application for maximum crop yield while conserving water. The University of Georgia is conducting research into several methods for improving the scheduling of irrigation of cotton, peanut, and corn.
The methods include

- expert system software (IrrigatorPro)
- simplified evaporation pan (UGA EASYPan)
- soil moisture sensor triggers
- growth stage
- remote sensing data (NDVI)
- checkbook
- fixed schedule

However, a ongoing challenge with field irrigation research has been designing studies that create irrigation conditions that are found in growers fields while allowing statistically valid replicates for comparisons among irrigation treatments.

Often irrigation studies are conducted with high pressure, high angle impact sprinklers in solid set permanent or portable arrangement. Solid set sprinkler systems are difficult to use in designs where multiple replicates of treatments are randomly arranged. Multiple laterals or multiple sprinkler heads are needed, and switching among treatments may involve reconfiguration by hand. If irrigation scheduling is conducted on plots irrigated with solid set sprinklers at instantaneous application rates far lower than occurs on growers' center pivot systems (CP), the period of leaf wetting and infiltration into the soil are lengthened. While valuable information may be gained, the resultant conclusions on application depth variables or application timing may not be representative of modern sprinkler irrigation that is predominantly applied with low pressure nozzles on center pivot systems.

Many irrigation researchers have attempted to use CP or linear-move systems (LM) to replicate irrigation conditions found in grower fields. While these can clearly repeat those field conditions, applying variable treatments that compare several irrigation depths applied at one time or compare application amounts at different times based on various scheduling techniques becomes prohibitively expensive. Achieving even a minimal of three replicates of four treatments could require that a single CP be divided into 12 pie-shaped segments. The whole pivot is in use while only 12 plots are created. If the system is large enough that the outer circumference can be divided into more plots while still avoiding sprinkler overlap among treatments, most of the area within the pivot becomes unusable for any study of irrigation rates and timing, or for uniform irrigation of other treatments.

The same challenge applies to long LM systems. A common concession to the research is then to use one whole block for the irrigation and to eliminate replicates. Sub-plot variables may be created that test other variables like fertilizer rates, cultivars, and tillage, but the comparison among irrigation is made without replication, no matter how many subplots are created. This is also a common concession with other treatment variables that are difficult to apply. For example tillage is placed in long blocks that are easy to plow and cultivate. Those are then split into shorter plots with chemical and fertilizer treatments. Unless the long blocks are replicated in an acceptable randomized fashion, no comparisons are valid among the main tillage variable. Any apparent yield or other effect of the main tillage or main irrigation variable would be as attributable to "luck of the draw", soil, prevailing winds or other conditions rather than to the treatment itself.

Expensive alternatives to provide more replication may include use of multiple CP systems or multiple LM systems, each of which has each level of irrigation treatment included within. If enough equipment can be purchased and committed to one study, this is an excellent means of replication. It includes vagaries of individual systems and soils under them as found on farms, as well as the normal field conditions created by the pivots themselves. Few research centers can afford this luxury. Not only must the system cost be incurred, but more crop production, water, fuel, and land costs will accrue.

An alternative to reduce costs for irrigation and plots while still allowing the twin goals Of representative irrigation application and statistically valid design is afforded by two techniques developed at The University of Georgia: switched-sprinkler LM systems and Variable Rate Irrigation (VRI) controls on a CP system. This paper will discuss development and implementation of both techniques to enable irrigation scheduling research on important Southeastern crops.

RESEARCH PARK

This research is being conducted at the C.M. Stripling Irrigation Research Park (SIRP), near Camilla, Georgia. This University of Georgia facility encompasses 130 ac and has four 2-tower center pivot (CP) systems (one each from T-L, Lindsey, Reinke, Valley), one Valley 4-tower CP, two Valley 3-tower linear-move systems (drag- hose fed) plus surface and subsurface drip installations (Fig 1). Water is supplied by three 8- inch wells joined together in a buried 6-inch PVC piping system arranged in a loop form the backbone of the water distribution network.

Constant pressure is maintained by using CycleStop valves at each well. Use of a pressurized system with wells automatically cycling on and off and switching back and forth along with the CycleStop valves provides maximum flexibility for water distribution at constant pressure.

SYSTEM MODIFICATIONS

Linear-move Systems

By their design, LM systems are inherently efficient in the use of plot land. The two SIRP LM systems were installed to create a long rectangular field with replicated, randomly assigned irrigation plots and blocks for use in studies of rates of application, timing of irrigation, and scheduling methods for row and selected vegetable crops. As originally purchased, the two 3-tower systems (471 ft and 496 ft) were equipped with Nelson iWOB sprinklers on 90 inch spacing fitted with 15 psi regulators and on drops to position sprinklers 6 ft above the soil. The systems operated at 300 gpm at a pressure of 50-60 psi. Because of the 30+ ft 'throw' of these sprinklers and their designed overlap, large transition/buffer areas were required between adjacent irrigation treatments/plots within research blocks (along the mainline) and between blocks along the travel path (Fig 2). This allowed for only five plots within each block and nine total blocks. To accommodate a larger number of plots within each block, much trial-and-error testing was conducted to determine an acceptable nozzle spacing, flow rate, and droplet size to cover the individual plot areas while not throwing water so far as to create large transition areas between plots. (No manufacturer design program can handle such an arrangement.) The original sprinklers were removed and drops/sprinklers were installed on a 10 ft spacing. This allowed twelve plots to be established along the mainline (rather than 5 as previously) (Fig 3). Four sprinklers were "assigned" to cover each plot. The two new sprinklers on the outer edges of each plot were Nelson Part-Circle Spinner bodies with #28 nozzles (water directed toward inside of a plot) while the new inner two sprinklers were Nelson Spinner bodies (full circle) with #38 nozzles.

Each sprinkler was again fitted on a drop with a 10 psi regulator. With all sprinklers on, the systems had a flow rate of about 300 gpm at 50-60 psi system pressure. Because the full circle sprinklers wet a small portion of adjacent plots, only the center 18 ft of each plot was designated for data collection/sampling (Fig 3). Within this 18 ft zone, irrigation water from only the 4 sprinklers "assigned" to that particular plot impacted the sampling zone.

To make the linear- move systems suitable for irrigation research, each group of four sprinklers "assigned" to a plot needed to be controlled ON/OFF independently. Thus, each sprinkler/drop was fitted with a Rainbird DV valve operated by a 24VAC solenoid. Each plot's four valves were wired together and manually controlled by a switch installed near the main control panel. A 480-24 VAC transformer provided the switching voltage. The ability to control individual zones is shown in Fig 4. Because the sprinkler groups are controlled manually, human error causes occasional plot watering "mistakes".

To better document actual water application, a monitoring system was developed. A Campbell Scientific SV8PLUS GPS Receiver along with a Campbell CR10 datalogger and Campbell AM416 Relay Multiplexer was used to record GPS coordinates, LM mainline pressure, and switch position once per minute at any time the system was pressurized. A low voltage was supplied from the Campbell datalogger with resistors used to step down the voltage to about 2000 mV for the "ON" position, and about 500 mV for the "OFF" position. This data was stored on a Campbell memory module for later analysis.

Center Pivot System
The 614 ft Valley 4-tower center pivot was sited during installation such that it could irrigate a 3/4 circle (Fig 1). Scheduling tests were conducted only in the SE and NE quadrants. It was fitted with Nelson R3000 Rotator sprinklers each on drops with 15 psi regulators. The first 59 sprinklers were spaced 18 ft apart and last 10 were spaced 9 ft apart. Sprinklers were positioned approximately 8 ft above soil surface. The system was configured to operate at 400 gpm at system pressure of 50-60 psi. A Nelson SR100 end gun was also installed. To vary application amounts along the CP mainline, a VRI system was installed on the pivot. VRI, developed by The University of Georgia Precision Ag Team, is an innovative technology that enables a CP system to match field variability with an appropriately variable irrigation application, differentially applying irrigation water to match the needs of individual management zones within a field (Perry and Pocknee, 2003, Perry et al., 2003). While the original intent of installing VRI controls at SIRP was for demonstration purposes, VRI was also well suited to use by researchers needing to vary amounts applied to "plots" under a CP system.

The VRI system, which retrofits on existing CP sys tems, integrates GPS positioning into a control system which cycles individual sprinklers or groups of sprinklers OFF and ON (seconds ON per minute) and varies travel speed to achieve desired rates within management zones. The VRI system requires the fitting of Bermad pneumatic flow control valves on each Sprinkler drop. These valves are controlled via Asco solenoid valves based on control signals from a main controller.

With the VRI system installed, the SIRP CP field could be subdivided into "plots" as shown in Fig 5. Sprinkler control zones along the mainline have 3 sprinklers each. Each plot can have a watering regime spanning from 0% to 200% of "normal". Both the NE and SE quadrants were limited to 12 "plots" due to sprinkler overlap. However, accuracy level of the GPS receiver used by the VRI system added another level of constraint to the "plot" sizes, requiring researchers to collect data in a sub-area within each of the 12 plots.

TESTING AND RESULTS

Linear-move Systems
A catch-bucket uniformity test was conducted on the one of the SIRP LM systems with the new nozzle arrangement. Catch buckets (plastic paint buckets, 6.3 in diam., 7.9 in tall) were placed in a line with buckets spaced 3 ft apart, beginning 60 ft from the "engine" end of the LM and extending to the opposite end of the system. The buckets effectively measured application amounts from 10 of the systems 12 zones, with 11 buckets in each zone. Clearly, the new sprinkler arrangement created a wetting pattern that concentrated more water in the centers of each zone. The overall coefficient of uniformity of the LM's application was only 80%. However, the goal was not overall uniformity, but rather application in sufficiently uniform manner within each zone.

Center Pivot System

Because the SIRP VRI center pivot system is a new installation with a new sprinkler package designed for the system, a uniformity test has not yet been performed. It has been assumed thus far that uniformity should be quite high. It is worth noting that overall uniformity is not a great concern when using VRI controls since the system, by design, is applying water in a non-uniform manner relative to the entire CP. Of more importance is the uniformity of application within control "zones" along the mainline. However, in practical terms, to have uniform application within zones, the overall CP sprinkler package should be applying water in a uniform manner. In other testing (Perry et al., 2004, Perry and Pocknee, 2003, Perry et al., 2003), we have found that the addition of VRI controls to a typical, fairly uniform CP causes no adverse effects on overall uniformity. We do plan to conduct both uniformity tests and site-specific application tests on the SIRP VRI system during Fall of 2004 after crops have been harvested.

CONCLUSIONS

The switched-sprinkler LM systems provide a reliable method for applying irrigation water to the defined "zones" along the mainline. This allows researchers to conduct scheduling research with adequate numbers of replications in a manageable sized field.

The GPS-based monitoring system is able to monitor and store the position and switch status, thus enabling researchers to verify water application. LM systems do have some drawbacks. Changing direction of travel requires moving the supply hose which is a labor-intensive activity. Also, sprinklers on LM systems are not easily automated at the present time.

Also, the current manual system can only accomplish ON/OFF control. Variable-rate controls are not yet available. While VRI center pivot application tests have yet to be completed, anecdotal evidence from scientists and graduate students involved in studies using the VRI system suggests the system is working quite well and properly managing water application for their particular irrigation scheduling research. Overall coefficient of uniformity was 80%.

LITERATURE CITED

Perry, C.D., M.D. Dukes, K.A. Harrison. 2004. Effects of variable-rate sprinkler cycling on irrigation uniformity. ASAE Paper No. 04-1117, ASAE, St. Joseph, MI.

Perry, C. and S. Pocknee. 2003. Precision Pivot Irrigation Controls To Optimize Water Application. In Understanding & Addressing Conservation and Recycled Water Irrigation, the Proceedings of the 2003 Irrigation Association Meeting, San Diego, CA. pp. 86-92.

Perry, C., S. Pocknee, and O. Hansen. 2003. A variable rate pivot irrigation control system. In J. Stafford and and A. Werner (eds), ECPA 2003, Proceedings of the Fourth European Conference on Precision Agriculture, pp. 539-544.