Water Distribution Uniformity under Pulsing Irrigation

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Introduction

Self-propelled sprinkler irrigation systems are well known for their capability of uniformly applying water and chemicals, enabling efficient management of irrigated agriculture. With the recent development of new technologies such as Global Positioning Systems (GPS) and Geographical Information Systems (GIS), it has been possible to measure soil and crop spatial variability in the field, allowing a better management of crop inputs. In irrigated agriculture, these developments sparked an interest in implementing the capability of selective application of water and chemicals through self-propelled sprinkler systems. The main objective of this study was to evaluate the performance of a linear move sprinkler system installed at the Irrigated Agriculture Research and Extension Center (IAREC), Washington State University, modified to apply variable rates across the main lateral using the concept of pulse irrigation.

Variable Rate Application with Sprinklers

Several methods have been proposed for variable application along the sprinkler mainline (Buchleiter et al., 2000): 1) Multiple manifolds with different sprinkler packages, 2) Pulsing groups of sprinklers, and 3) Variable orifice sprinklers.

An example of multiple manifolds is described by Roth and Gardner (1989), in which three spray lines are used to deliver different flow rates in various combinations to achieve incremental flow rates. This approach was also used by the USDA-ARS Coastal Plains Soil, Water, and Plant Research Unit in Florence, SC, on two small center pivot units (Camp et al., 1999). The mainline was divided into 13 segments, each with 3 independently controlled, parallel manifolds with spray nozzles spaced 5ft apart. The manifolds and nozzles were sized to provide 1/7, 2/7, and 4/7 of a base application depth. Thus all combinations can deliver from 0 to 100% in 1/7 increments.

A second approach for applying variable rate is pulse irrigation (Fraisse et al., 1995a). It consists of a series of irrigation cycles, where each cycle includes an operating phase (time on) and a resting phase (time off). A diagram of pulse irrigation sequences is shown in Figure 1. The total time of a single pulse (t_c) is equal to the irrigation operating time (t_i) plus the resting time (t_b). The slope of the solid line during the operating and resting phases indicate the actual sprinkler application rate. The slope of the dashed line reflects the average application rate, which is lower than the actual rate. D_T is the total depth applied and D_t is the depth of water applied during a pulse or cycle. The advantage of this approach is the ability to deliver incremental depths in a continuous form rather than in incremental steps of the previous method. The system installed at IAREC is an example of this approach.

A third approach uses the same principle of pulse irrigation but does not completely turn flow off. A concentric pin is inserted and removed in the sprinkler orifice using a linear actuator (King et al., 1997). A time averaged application rate ranging from 40 to 100% of the maximum flow can be achieved without major effects on the sprinkler application pattern.

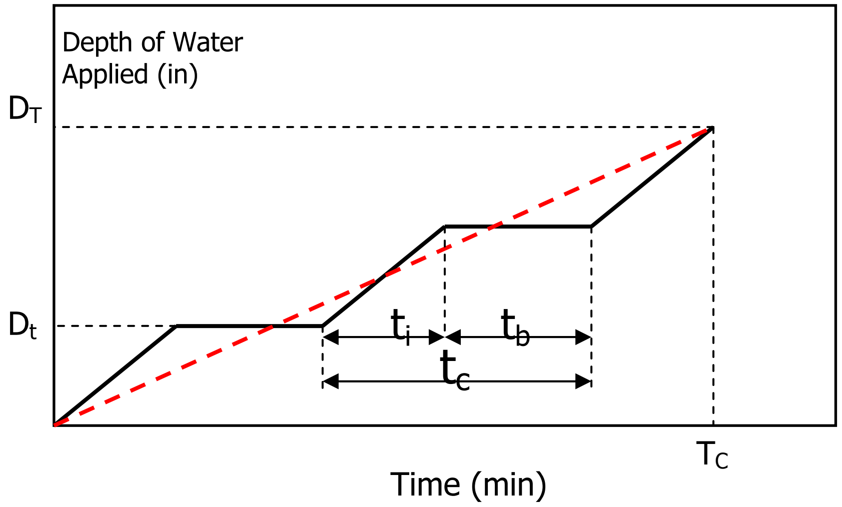

Figure 1. Pulse irrigation pattern.

Modified Linear Move system at IAREC

The self-propelled linear irrigation system installed at IAREC was modified to allow variable rate water application, allowing better control of water and chemicals applied to an experimental field. The system is composed of four spans, each 120 ft long with sprinklers installed 5 ft apart. Variable application rate capability was implemented using the concept of pulse irrigation for self-propelled sprinkler systems developed by Fraisse et al. (1995b). The system was modified to allow the application of different depths of water in each half span.

In order to control/cycle each half span of the linear move system, all existing risers were plugged. In the middle of each span, two 2-inch outlets were threaded and a PVC manifold ($1^{1/2}$ in) serving each half-span installed. The manifolds were plumbed with a manual valve and a 24v solenoid valve. Drop tubes and sprinklers were installed downstream from the valves. A low-pressure cut-off valve is installed upstream from each sprinkler to reduce system drainage when the valve is turned off. Each 24v solenoid valve is connected to a relay-driver on the cart. The relay-driver is controlled by a CR10 measurement and control module. The relay-driver can be operated manually or automatically by the CR10. Software in the CR10 allows the user to specify a wide range of on/off cycle ratios, and cycle times. The system has proven to be very versatile, allowing the application of different water depths under each half span during the same irrigation event.

Application Uniformity Evaluation

The application uniformity (CU) for the system was evaluated under normal and pulsing operating conditions using a line of catch can collectors spaced 5 ft apart in the direction of the main lateral (110 ft) and a grid of 45 catch can collectors spaced 2.5 ft in the direction of movement.

The test procedure followed the general guidelines of the ASAE S436 (ASAE, 1992), for uniformity testing of center pivot and linear move irrigation systems. The catch cans used had diameter of 3.5 inches and height of 6.8 inches (the minimum recommended is 3.2 by 3.9 in). Catch can spacing was 5 feet (at least 30% of sprinkler wetted diameter) and testing occurred at more than three different speeds or time settings.

Two types of sprinkler heads were used in this study: 360° rotator (ROT) spray nozzles (R3000, D6-12°) and 360° fixed plate grooved (FPG) spray nozzles (LDN, 1 level - 24 grooves). Nozzle sizes were the same (1/8”) in the two sets of sprinklers and pressure regulators (15 psi) were installed upstream of each sprinkler head. Sprinkler height was set at 36 inches for all tests. Wind conditions during the tests ranged from less than 1 to 7.6 miles per hour. The majority of the tests were conducted with wind speeds between 2 and 4 miles per hour. Application uniformity was evaluated under normal and pulsing conditions, using 1 minute pulsing cycles. Previous research by Fraisse et al. (1995b) indicated that one minute to a maximum of two minutes cycles should be used in linear move systems.

Results and Conclusions

A total of 37 uniformity tests were conducted, of which 20 using the FPG heads and 17 using the ROT heads. Table 1 shows the timer settings, pulsing cycles used for the tests, and the results obtained for the line of catch cans and for the grid. As expected, the uniformity of application was lower for the FPG sprinkler due to the fixed grooved deflector plate that forms distinct streamlines. The distinct streamlines may miss or not a collector can and, depending on the start-stop sequence, either deposit a large quantity of water or completely miss a collector. Figure 2 shows a graphical representation of the Christiansen uniformity coefficients measured with the system operating under normal (not pulsing, 60/0) conditions and pulsing conditions (30/30 and 15/45 cycles). Trend lines indicated that uniformity tends to decrease with speed when the system is pulsing. The majority of the tests were conducted during calm or low wind conditions (2 to 4 miles per hour). Results with both the ROT and FPG sprinklers do not show any significant decrease of uniformity with increasing wind speeds up to 7.6 miles per hour.

The results obtained indicated that pulse irrigation can be successfully used to vary the water application in each half span of a linear move irrigation system, allowing the application of distinct depth of water across the system. The flexibility obtained is important for implementing water management studies at IAREC and will greatly benefit our research program in potato cropping systems. We are currently investigating the implementation of further automation and flexibility that will allow the system to automatically change the water application pattern in the direction of movement. This modification will allow the system to automatically apply different treatments in each research plot, saving time and labor. Uniformity of application of both sprinklers was evaluated and coefficients of uniformity observed for the ROT were, on average, higher than for the FPG sprinkler under low wind conditions. More tests are needed to fully characterize the uniformity of application on a wide range of speeds and wind conditions. Tests under higher wind conditions are planned for this coming year and results will be available by the end of 2003.

References

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Test No.	Sprinkler Type	Direction Movement	Timer Setting	Pulsing Cycle	Wind (MPH)	CU (%) Line	CU (%) Grid
1	ROT	S	5	30/30	4.3	92.7	91.6
2	ROT	S	10	30/30	7.6	90.3	90.5
3	ROT	S	15	30/30	3.4	91.5	86.1
4	ROT	N	15	30/30	2.4	89.1	93.2
5	ROT	N	20	30/30	1.7	89.3	91.2
6	ROT	N	20	30/30	0.6	79.1	86.0
7	ROT	S	20	30/30	5.7	83.9	90.8
8	ROT	S	20	30/30	3.6	88.4	81.4
9	ROT	N	20	30/30	5.6	90.8	93.5
10	ROT	S	10	60/00	1.6	92.3	92.7
11	ROT	N	15	60/00	2.9	86.0	94.3
12	ROT	S	15	60/00	3.9	92.5	92.9
13	ROT	S	20	60/00	3.3	87.2	94.1
14	ROT	N	20	60/00	3.4	92.6	94.7
15	ROT	S	20	60/00	3.4	91.0	91.0
16	ROT	N	25	60/00	3.3	94.3	94.8
17	ROT	S	25	60/00	1.4	92.4	91.4
18	FPG	S	5	15/45	2.3	75.1	70.4
19	FPG	S	5	15/45	1.7	70.0	64.4
20	FPG	N	10	30/30	3.9	75.4	82.0
21	FPG	S	10	30/30	4.8	71.7	78.8
22	FPG	N	10	30/30	4.6	81.5	81.4
23	FPG	S	15	30/30	3.6	72.4	71.9
24	FPG	S	15	30/30	2.3	75.4	77.4
25	FPG	S	15	30/30	3.4	69.3	67.5
26	FPG	S	15	30/30	2.5	67.8	74.2
27	FPG	N	20	30/30	2.6	71.6	65.5
28	FPG	N	20	30/30	2.3	68.2	71.6
29	FPG	N	20	30/30	5.8	67.3	77.1
30	FPG	N	20	30/30	2.7	72.6	66.7
31	FPG	N	10	60/00	0.8	85.5	76.9
32	FPG	N	10	60/00	1.4	58.1	62.3
33	FPG	N	15	60/00	2.8	73.7	72.2
34	FPG	N	15	60/00	1.8	77.1	80.1
35	FPG	N	15	60/00	1.5	66.4	70.3
36	FPG	S	20	60/00	3.6	71.0	69.9
37	FPG	N	25	60/00	2.7	72.6	66.0

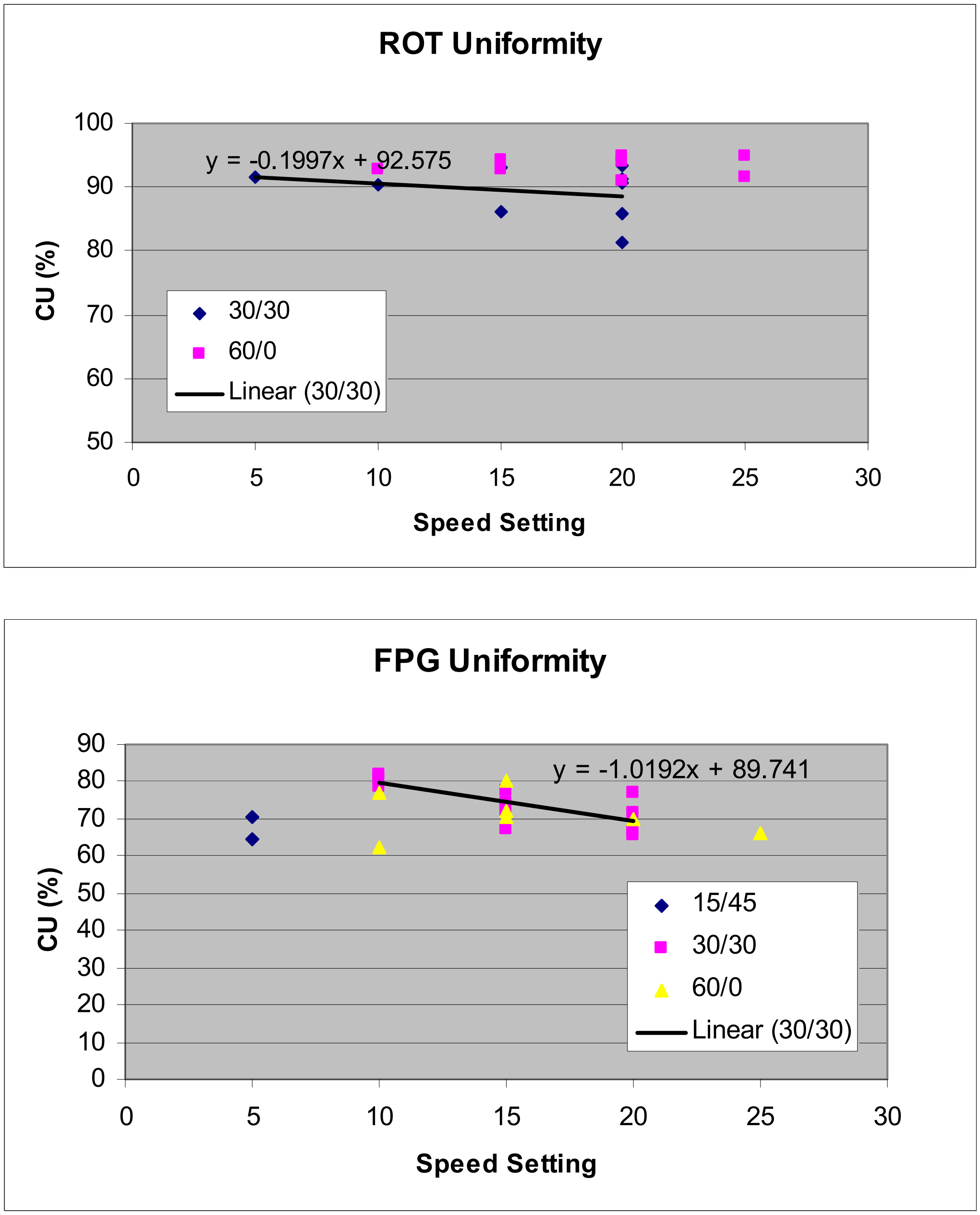

Figure 2. Measured coefficients of uniformity, CU (%).