SURGE FLOW AND ALTERNATING FURROW IRRIGATION OF PEPPERMINT TO CONSERVE WATER[1]

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Abstract

Surge flow and alternating furrow irrigation methods were compared against continuous flow for water saving and crop yield on a field of second-year peppermint *(Mentha piperita, L.) in* a Madras loam soil. Surge flow irrigation creates a series of on and off cycles of water flow. Alternating furrow consists of irrigating every-other furrow during every-other irrigation so that all furrows are irrigated over the course of two irrigations. Continuous flow will irrigate all rows each time. Measurements were taken of furrow advance, runoff, finishing time, and soil water tension. Oil and dry matter yields were not significantly different among methods. The results indicate surge flow and alternating furrow irrigation methods are beneficial for saving water without significant yield loss.

Introduction

The surge flow concept in surface irrigation was first introduced at Utah State University by Stringham and Keller (1979). By definition, surge flow is the intermittent application of water to irrigation pathways, creating a series of on and off periods of constant or variable duration. In other words, irrigation water is turned on and off in cycles that allow the soil to drain the standing water. The desired effect is to reduce the infiltration of water into the soil at the top end of the field. Research has been done in Utah, Colorado, and Washington with water savings on sandy and silt loams. Miller and Shock (1993) compared surge irrigation with conventional continuous flow on an onion field in Ontario, Oregon. They reported a decrease in runoff on surge flow from 50 percent on continuous to 29 percent on the surge flow, resulting in a slight yield loss of 90 cwt/ac, only 15 cwt/ac below the area's average. Available nitrogen was also monitored. Surge flow irrigation resulted in a loss of 186 lb N/ac less than continuous flow.

The reduction in infiltration rate is the phenomenon that makes surge flow irrigation desirable, and it is caused by at least four physical processes (Stringham et al., 1988). First, *consolidation due to soil particle migration and reorientation* during the off cycle results in a less permeable soil near the surface (Samani et al., 1985). During draining, the sand will settle out of the water first, then the silt and clay particles will settle on top. The small particles that settle out later will clog the pores that conduct water, thus reducing the infiltration rate. Also, the density of these smaller particles is greater, reducing the pores' size.

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Second, *air entrapment* reduces the infiltration during water reapplication (Linden and Dixon, 1975). During the off cycle, air enters the top of the soil after the water recedes. The bulk of the soil water is below the surface with air above it. As water is re-applied, the air becomes trapped between the water applied and the water below in the soil. The trapped air increases in pressure, and it is this pressure working against the entering water that reduces the infiltration rate.

Third, the *redistribution of water* slows the hydraulic gradient, the force that drives water flow. Infiltration is caused by both gravity (the weight of water pushing it downward) and soil suction (the ability of dry soil to wick water). During the off cycle, the water in the soil continues to be redistributed by these forces even though there is no water at the surface. When another irrigation cycle occurs, the soil gradient forces of gravity and suction are distributed over greater lengths, decreasing the infiltration rate.

Fourth, *channel smoothing* results from the off cycles, as the furrow channels become more streamlined throughout the irrigation season. The smoothing is caused by the particle migration mentioned above. The flatter, wider channels lower the water level in the furrow which reduces infiltration into the sides of the bed and moves the water faster down the furrow.

Surge flow irrigation has not yet been tested for soils and field conditions in central Oregon. The objective of this study was to increase irrigation efficiency without yield loss. The study compared surge flow, continuous flow, and alternating furrow irrigation practices. Alternating-furrow irrigation was included as a treatment because it previously showed water savings and an increased dry matter yield compared to continuous (Mitchell et al., 1993a).

Materials and Methods

The experiment was conducted in a field of 3.21 acres, with 2.0 acres of peppermint surrounded by a border crop of spring wheat. The soil was Madras loam (fine-loamy, mixed, mesic, Xerolic Durargid). The field had a slope of 2.0 percent with a 560-ft irrigation run.

On April 12, 1993, the second-year peppermint was fertilized with 250 lb/ac of fertilizer (40-0-0-6) which was a mixture of urea and ammonium sulfate. On July 23, 1993 a second application of 150 lb/ac of fertilizer (40-0-0-6) was applied. The furrows were dug using a rotary corrugator, which covered the bed with a mulch and buried the fertilizer. The furrows were 4.5 inches deep and 30 inches apart.

The peppermint was harvested on August 17, 1993 with a forage harvester. Five fresh weight samples were taken from a 12.5 ft X 3.33 ft area at five distances along the irrigation runs, 100, 200, 300, 400, and 500 ft. The samples were distilled at COARC.

The experiment was a random block design with four replications (Figure 1). Each treatment was 12.5 ft wide consisting of five furrows. The field was irrigated using a gated pipe system with water flowing through a flow meter and a pressure reduction tank. Two lengths of gated pipe were set up to accommodate the surge flow method. One pipe was set to deliver water to two of the four surge flow replications and the other pipe was set for the other two replications. Both pipe were set for the continuous flow and alternating furrow replications. The gates were calibrated and monitored to deliver 5 gallons of water per minute using a stop watch and a 5-liter pitcher. A flow meter determined the total flow in the entire system.

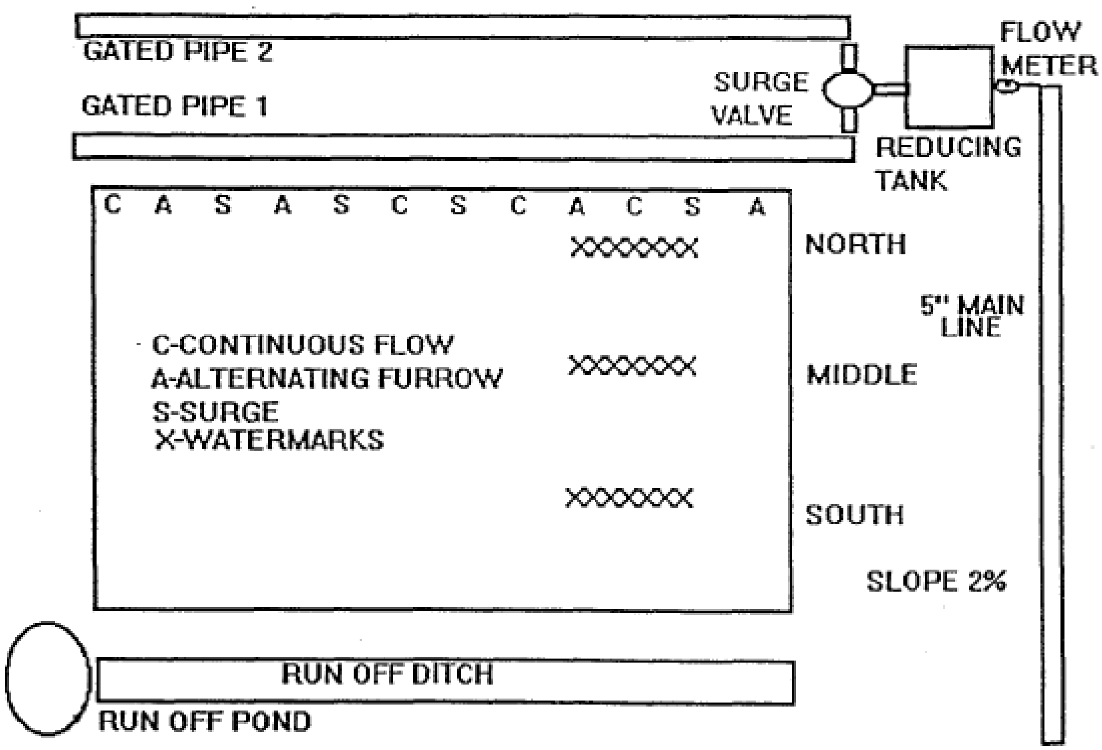

Figure 1. Design of furrow irrigation experiment, Madras, OR, 1993.

The Waterman LVC-5 6-inch Surge Flow Valve was used to control the surge flow irrigation (Waterman Industries, Inc. P.O. Box 458, Exeter, CA 93221). The control panel may be programmed with seven programs. Three are preset for specific furrow run lengths and four are designed with a specific number of surge cycles. In this experiment, program 5 was set according to the time required to advance 1/5 of the furrow run or at 100 ft. The rest of the surge flows were automatically calculated by the program using initial surge flow cycles. Each surge flow cycle's duration increased as follows: for a 30-minute first surge flow the cycles lasted 30, 46, 58, 66, and 74 minutes. After the first five cycles were completed the program automatically ran several "finishing" cycles with reduced cycle times. The finishing cycles were to minimize runoff. The water was shut off when all treatments were soaked across the bed.

The first furrow irrigation occurred on July 1. At this time the stand was approximately 9 inches tall and not at full canopy. Subsequent furrow irrigations occurred on July 7,13, 27, August 3, 6, and 11. During the last two irrigations, all gates were open on the alternating furrows because of the long irrigation time that this treatment required.

Furrow Advance and Runoff

Furrow advance readings were taken every hour from each row during the irrigation periods to determine how much water was needed to advance to a designated point. When the row finished, runoff measurements were taken. Runoff measurements were taken each hour for continuous flow and alternating furrow irrigation methods. For the surge treatment, runoff measurements were taken every half hour due to the variation in the surge flow runoff during the on/off cycles. All five rows from plot were channeled with a plastic pipe into a runoff ditch. The readings were taken with a stop watch and a bucket, using a 1,000-ml graduated cylinder for accurate volume measurement. The flow rate data was integrated over time to calculate the amount of runoff in acre in/acre.

Granular Matrix Sensors

Granular matrix sensors (GMS) were placed in each of the three treatments at the south, middle and north sections of the field (Irrometer Co., P.O. Box 2423, Riverside, Ca, 92516.) The north and south locations had four GMS per treatment, one each at 16, 8, and 4 inches deep and an extra surface GMS laying horizontal just below the soil surface. The middle location had six GMS per treatment, one each at 16 and 8 inches and at the surface, and three GMS at the 4-inch level. The additional GMS at the 4-inch depth were needed to schedule irrigations, as this is the depth most sensitive to peppermint crop water need. (Mitchell, et al. 1993b). Readings were taken daily at 7:30 a.m.

Results

Furrow Advance

The furrow advance rates are compared in Figure 2 for the July 7 irrigation. The continuous flow treatment took 11,000 gallons of water reach the end of the field while the surge flow took 4,300 gallons. The furrow-advance volume was less for the surge flow compared to the continuous flow, but was similar for the last 140 ft of the field. The alternating furrow had a fast advance comparable to the surge irrigation, but then slowed down. This may have been be caused by additional infiltration into adjacent rows which reduced the water volume in the furrow. The continuous flow advanced to the end of the field in the least amount of time, but used the greatest amount of water.

Irrigation

Irrigation components are given in Table 1 for all seven irrigations. The surge flow and alternating- furrow treatment required only 50 and 42 percent of the water applied to continuous flow treatment, respectively. Surge flow and alternating furrow runoff was about 36 and 30 percent of the continuous flow (Figure 3.) Surge and alternating-furrow also received less net irrigation: 6.33 in and 7.9 in compared to 11.28 in for the continuous treatment. Alternating furrow had the least runoff, but took the longest time to finish (Figure 4.) This was because, during stream advance, all five rows absorbed water from the two or three rows being irrigated.

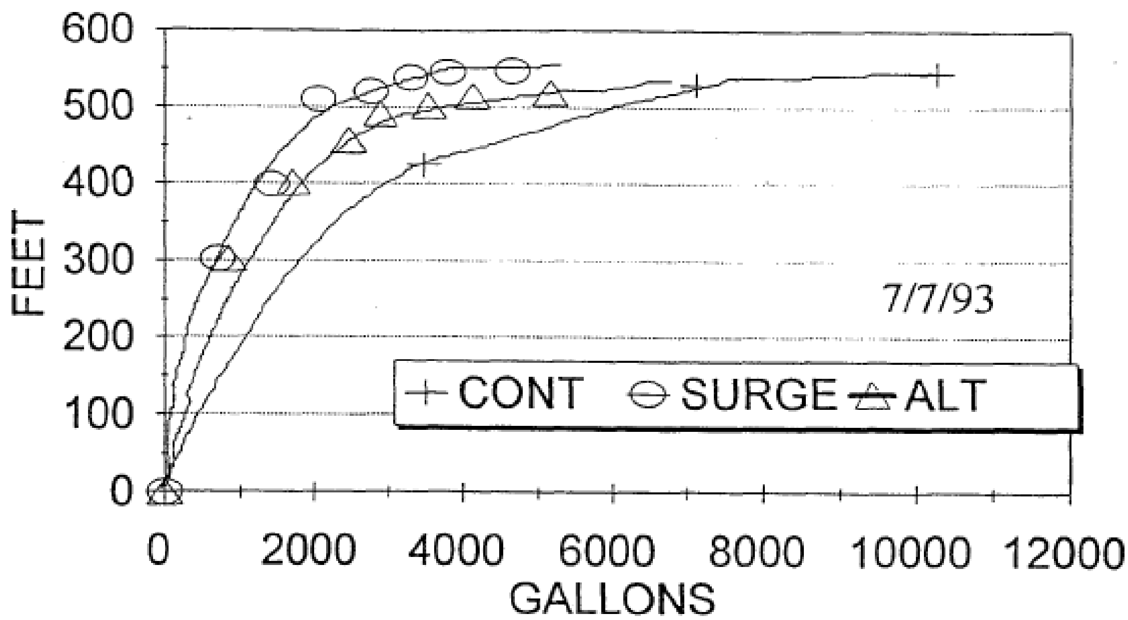

Figure 2. Furrow advance by volume, July 7 irrigation data, Madras, OR, 1993.

Table 1. Irrigation components of surge, alternating furrow study, Madras, OR, 1993.

DATE	SURGE			CONTROL			ALTERNATING FURROW		
	APPLIED	RUNOFF	NET	APPLIED	RUNOFF	NET	APPLIED	RUNOFF	NET
	acre in/acre			acre in/acre			acre in/acre		
07/01/93	1.59	0.15	1.43	3.17	0.44	2.73	1.27	0.05	1.22
07/07/93	1.09	0.27	0.82	2.17	0.62	1.55	1.20	0.09	1.12
07/13/93	0.83	0.23	0.60	1.65	0.74	0.91	0.60	0.13	0.46
07/27/93	1.51	0.20	1.31	3.02	0.89	2.13	1.81	0.12	1.70
08/03/93	1.33	0.24	1.09	2.66	0.81	1.85	1.06	0.09	0.97
08/06/93	0.73	0.27	0.46	1.47	0.28	1.19	1.47	0.38	1.08
08/11/93	0.98	0.37	0.61	1.97	1.05	0.92	1.97	0.61	1.36
TOTAL	8.06	1.73	6.33	16.12	4.83	11.28	9.38	1.48	7.90
% RUNOFF		21.50%			30.00%			15.75%	
% OF CONTROL	50.00%	35.83%	56.07%	100.00%	100.00%	100.00%	58.21%	30.56%	70.06%

Yield

There were no significant differences in dry matter yield between irrigation treatments, with an overall average and standard deviation of 3494 ± 619 lb/ac. There was also no effect from position in the field, differing from last year's results where peppermint yielded best near the top end of the field.

The oil yield was not significantly different at the a =0.05 level, but differed at the a =0.10 level, with the alternating-furrow treatment yielding 58.6 lb/ac compared to 52.9 lb/ac for both the surge and the continuous. The higher yield may have been helped by the final two irrigations being continuous-flow every furrow.

Also, maturity may have effected the oil yield. The entire field was harvested on the same day, and it is possible that the higher oil concentration (oil/dry matter) may have been due to a more mature plant.

Granular Matrix Sensors

The 4-inch depth GMS readings in the surge flow replication showed more stress than continuous flow and alternating furrow (Fig. 5), but the yields showed no evidence of stress. The effects of soil particle migration and reorientation may have slowed down the infiltration process. The irrigation duration could have been too short for an adequate amount of water to be absorbed. Since the yields showed no significant difference, this implies that peppermint can survive stress under these conditions to 100 kPa at 4 in and still produce an acceptable oil yield.

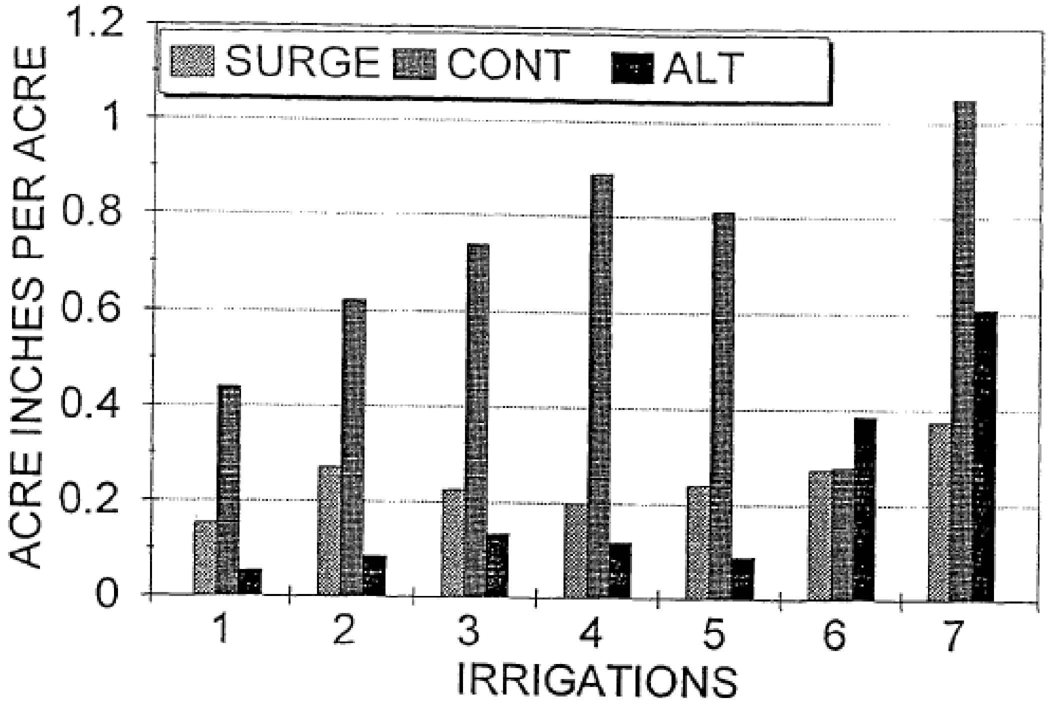

Figure 3. Runoff for all seven irrigations, Madras, OR, 1993.

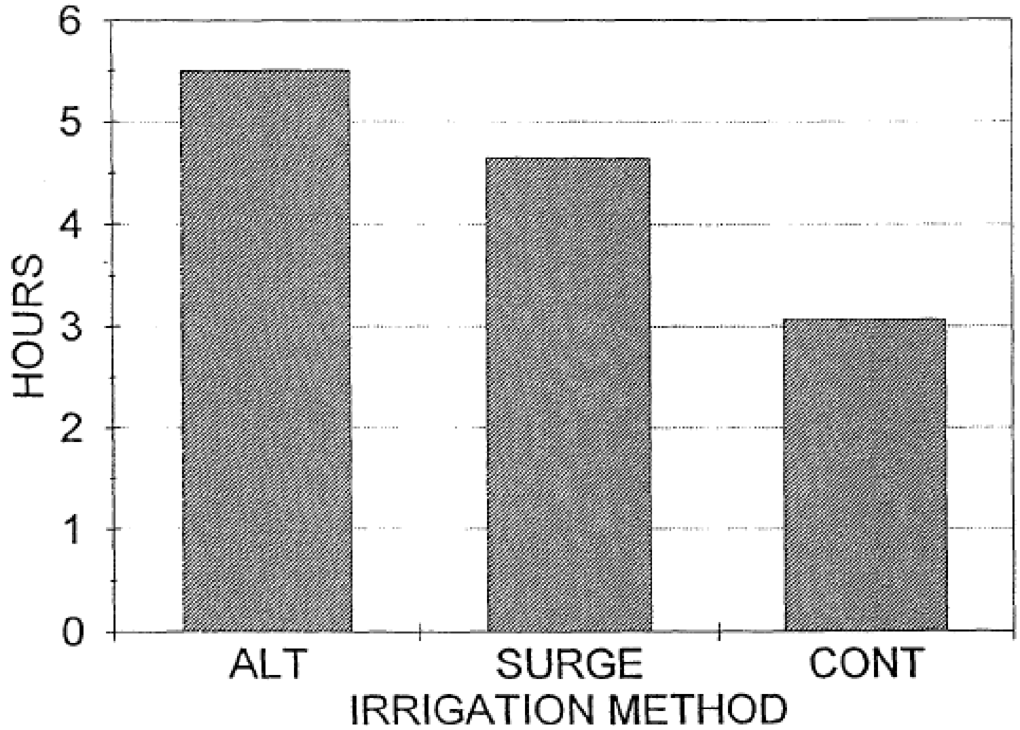

Figure 4. Average time to advance 560 ft of furrow, August 3 irrigation data, Madras, OR, 1993.

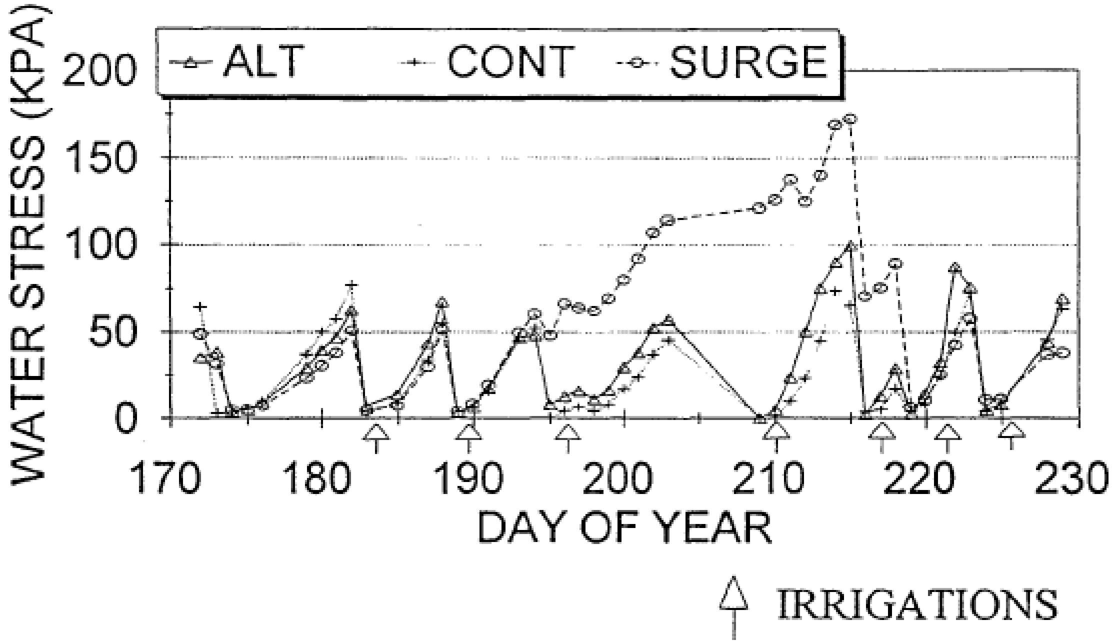

Figure 5. Soil tension at the four inch depth throughout the season, Madras, OR, 1993.

Conclusions

Surge flow irrigation proved to be a beneficial method of irrigation for peppermint. Surge flow saved water and reduced runoff with maintaining yields comparable with continuous flow. The alternating furrow also saved water without yield loss, but it takes longer to complete the irrigation and requires more labor for changing the gates each irrigation. Surge flow irrigation requires a minimal amount of labor since the valve controls the surge flows. However the initial cost of the valve and controller must be considered. The controller is movable and can work on several valves if they are operating at different times. When water is scarce, surge flow irrigation is an opportunity to conserve water.

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