THE EFFECT OF SURGE IRRIGATION ON ONION YIELD AND QUALITY, IRRIGATION EFFICIENCY, AND SOIL NITROGEN LOSSES

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Ontario, Oregon, 1992

Objectives

The objectives of this trial were to:

1. Compare onion yield under surge irrigation with continuous flow irrigation.
2. Estimate irrigation efficiency under surge irrigation and continuous flow irrigation.
3. Compare estimates of nitrogen leaching under surge irrigation with continuous flow irrigation.

Introduction

Water quality is increasingly becoming an important issue in regions of irrigated agriculture. Losses of applied chemicals from agricultural lands through irrigation water runoff and deep percolation can result in elevated levels of nitrate nitrogen and pesticide residues in fresh water supplies. Groundwater nitrate contamination can become acute in intensive horticultural areas with heavy rainfall or with inefficient irrigation methods. Efficient irrigation alternatives are needed for groundwater protection.

Northeastern Malheur County has been designated as a Groundwater Management Area by the Oregon Department of Environmental Quality because groundwater nitrate nitrogen concentrations have been found in several areas that exceed the U.S. Environmental Protection Agency's maximum contaminant level of 10 mg/l. Onion production practices in the area are believed by the Oregon Department of Environmental Quality to be a primary source of nitrate found in the groundwater. Furrow irrigation is commonly used for onion production in Malheur County. It is not known whether changing to sprinkler irrigation or to drip systems is economically feasible or applicable for onion production.

Surge irrigation is a process where water is applied to an irrigation furrow intermittently, whereas in continuous-flow (or conventional) irrigation, water is applied to the furrow during the entire irrigation set (Yonts et al., 1991). With surge irrigation, water is cycled from one half of the field to the other half during an irrigation set, using a switch valve, commonly referred to as a surge valve.

Research was conducted in 1992 to compare surge irrigation of onions with conventional, continuous-flow furrow irrigation. Surge irrigation is a method of furrow irrigation designed to apply water more uniformly down the length of irrigation furrows than conventional furrow irrigation. Less water is applied due to greater irrigation uniformity. Nitrate nitrogen leaching through the soil profile may be reduced if less water is applied and less deep percolation occurs. Surge irrigation has been studied in Colorado and Utah as a method to reduce salt loading of the Colorado River. Surge irrigation has also been studied in California as a means to eliminate irrigation runoff from agricultural lands. The Malheur Experiment Station study investigated onion yield, water application, water runoff, and estimated nitrate leaching under surge irrigation in comparison with conventional furrow irrigation.

Methods

The trial was conducted on 13.2 acres (950 feet long by 620 feet wide) of Owyhee silt loam on a grower's field about one mile north of Nyssa, Oregon just west of Oregon Highway 201. A Nyssa, Oregon onion grower (cooperator) provided the study site and performed all agricultural operations during the trial, excluding irrigation. Soil sampling, soil moisture monitoring and analyses, evaluation of crop yield and quality, and nutrient content determinations were part of this investigation.

The soil was fumigated with Telone C-17 at 18 gal/ac in the fall of 1991. Seed beds were prepared in the fall with furrow spacings of forty-two inches. Fertilizer (100 lbs N/ac, 160 lbs P/ac, 80 lbs K/ac, 5 lbs Zn/ac, 1 lb B/ac, and 80 lbs S/ac) was broadcast and incorporated during fall seed bed preparation.

The study site was subdivided into three 4.4 acre sections to compare surge with conventional furrow irrigation. The surge system irrigated two of the sections and the conventional system irrigated the third section. Within the three sections, sixteen crop observation sites (each 350 ft^2) were identified prior to planting. The sites were arranged with eight observation sites in each irrigation system. The sites were arranged in parallel sets of four with each set located along the same three irrigation furrows. The closest sites to the irrigation pipes (sites designated as A) were located 25 feet downfield, and the other sites were consecutively spaced at 175 foot increments downfield (sites B at 200 feet, sites C at 375 feet, and sites D at 550 feet from the irrigation pipes).

The soil profile in each observation site was sampled to a depth of five feet on March 19-20, 1992 in one-foot increments. The samples were oven dried at 155â F for 48 hours, and analyzed for nitrate-N and ammonium-N to determine the amount of nitrogen available in the profile before planting.

Aztec onion seeds were planted March 31, 1992 with two double rows to a bed, and with one seed every three inches in each of the double rows. Fertilizer was sidedressed twice, with nitrogen applied as URAN on May 11 at 80 lbs N/ac plus 25 lbs K/ac, and on May 18 at 50 lbs N/ac, providing total sidedressed fertilizer of 130 lbs N/ac and 25 lbs K/ac.

Water was pumped through a four foot bubble-type weed screen to provide constant hydraulic head to both irrigation systems, and to filter out litter from the water. The surge valve and controller used for this study was an eight inch Waterman LVC-5 Surge Master. Eight inch gated PVC pipe provided water to both irrigation systems. The first irrigation occurred on April 8, 1992 (Table 1). Water applied to each system was proportional to the irrigation duration, but the surge system irrigated twice as much ground. During each irrigation, water inflow, advance times, and outflow measurements were made to estimate the amount of water applied by each system, and the amount of runoff water from each observation site. Soil moisture content was determined before and after irrigation using either a CPN 503 DR or a Troxler neutron probe.

Irrigation inflow was determined by timing the collection of water flowing into the furrows with a 3.1 liter can. Outflow readings were taken periodically during each irrigation with a flume located at the bottom of the field. Water applied, runoff, and infiltration were estimated from the inflow and outflow measurements.

Onion tissue samples were collected from each observation site August 22, 1992, and oven dried, ground, and analyzed for total dry matter and nitrogen content. The onions from each observation site were harvested on August 24-26, 1992 and stored. The harvested onions were graded on January 4, 1993.

The soil profile in each observation site was sampled to a depth of five feet between August 27, 1992 and September 3, 1992 in one-foot increments. The samples were oven dried at 155â F for 48 hours, and analyzed for nitrate-N and ammonium-N to determine the amount of available nitrogen remaining in the soil profile after harvest.

Total nitrogen supply to the crop was calculated by adding the amount of available soil nitrogen in the spring to the amount of nitrogen fertilizer applied to the crop. Plant nitrogen uptake was determined from the harvested tissue samples. Plant nitrogen uptake plus available nitrogen remaining in the soil after harvest was designated as "accounted" nitrogen. The difference between the total available nitrogen in the spring and "accounted" nitrogen was considered lost and designated as "unaccounted" nitrogen.

Results and Discussion

Irrigation efficiency was greater under surge irrigation with an estimated 23.95 ac-in of water applied and 6.95 acre-in as runoff (29 percent) compared to the continuous system with 43.65 acre-in of water applied and 21.75 acre-in as runoff (49.8 percent) (Table 2). Evapotranspiration of early planted onions was 25.10 acre-in based on the Agrimet weather station at the Malheur Experiment Station. Water infiltration under both systems was less than the onion crop evapotranspirational demand, with the surge system considerably short. The surge irrigation system should have been used once or twice more frequently during the season to satisfy crop evapotranspiration.

The average total onion yield from the continuously irrigated observation sites was 650 cwt/ac and marketable yield was 599 cwt/ac (Table 3). The average total yield for the surge irrigated observation sites was 560 cwt/ac and marketable yield was 500 cwt/ac. The cooperator's yield records show 575 cwt/ac for the entire area with no difference between irrigation systems. The effect of irrigation system on onion grade was significant in the observation sites for the cull, medium, colossal, marketable, and total yield categories. The effect of site position on yield was significant for all grade categories except for the onions showing signs of rot. Yields in the surge observation sites were much smaller in the observation sites located more than fifty feet downfield from the irrigation pipes. The effect of interaction between irrigation treatment and site position was significant only for medium grade onions and total yield. Closer inspection of Table 3 shows that yields were higher in the surge irrigation observation sites for medium and jumbo onions. Colossal, marketable, and total yields were higher in the continuous irrigation observation sites.

Crop tissue analysis shows that differences due to irrigation were not significant (Table 4). The effect of site position down the length of the water run decreased bulb and top dry weight yield, and total top nitrogen content. The interaction effect of irrigation and plot position was not significant for the tissue composition categories.

The spring soil analyses indicate that total nitrate-nitrogen and total nitrogen content in the continuous plots was significantly higher prior to planting than in the surge area (Table 5). After harvest, total nitrate and total nitrogen in the surge plots was higher than in the continuous. More nitrogen (186 lb per/ac) was lost from the soil during the season in the continuous plots than in the surge plots. Nitrogen loss under both irrigation systems was probably due to leaching during and following irrigation. Losses due to volatilization of ammonia were assumed to be negligible. Site position and the interaction between site position and irrigation system were not significantly different for spring and fall soil nitrogen analyses, or for total available nitrogen accounting averaged over the top five feet.

The differences in soil nitrogen content before and after the season demonstrate that more nitrogen was leached through the profile under continuous irrigation (Figure 1). Crop nitrogen uptake removed a large amount of soil nitrogen from the top of the soil profile under both irrigation systems. The average available nitrogen content of the lower three feet remained relatively unchanged between planting and harvest in both systems. The largest losses in soil nitrogen occurred in the second foot of the soil profile under continuous irrigation.

The experimental design did not involve true treatment replications, but only replications of observations, so the reader is cautioned not to exaggerate the limited predictive value of the data from this demonstration trial.

Conclusions

Yields from the two systems show that continuous irrigation produced higher yields than surge irrigation in the observation sites. Grower observations from the entire field showed equal yields under both irrigation systems. Supplying adequate water to the crop throughout the field had an important effect on yields. Yield differences in the surge irrigation observation sites were depressed with distance from the irrigation pipe. This suggests that surge didn't apply water effectively to the crop on the downfield observation sites. Further work with surge irrigation is necessary to verify yield differences between surge and conventional irrigation. It may be possible under surge irrigation to improve water distribution to the end of the furrow by using straw mulch or by changing the surge irrigation management.

More nitrogen was "unaccounted" (186 lb/ac more) from the soil profile in the continuous irrigation observation sites than from the surge irrigation sites. The unaccounted nitrogen was probably lost to leaching from the soil profile in the observation sites. If equivalent yields can be produced under surge irrigation, profits may be maintained while scarce water resources are conserved and less nitrate leached toward groundwater.

Figure 1. Influence of surge and continuous furrow irrigation on the available nitrogen as ammonium and nitrate under onions, Nyssa, Oregon, 1992.

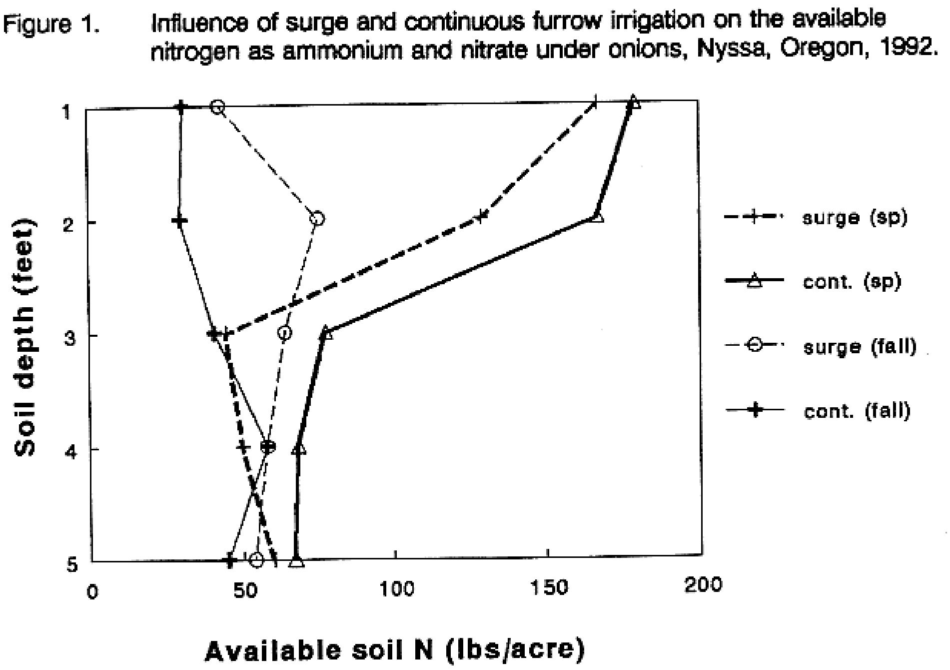

Table 1. Irrigation date and duration comparing surge and conventional furrow irrigation for onion production. The surge irrigation system irrigated twice as many acres during each set as the continuous irrigation, Nyssa, Oregon, 1992.

Irrigation date	Irrigation type	Irrigation duration
		- - - hr - - -
04-08-92	surge	24
04-09-92	continuous	27.5
05-05-92	surge	24.7
05-06-92	continuous	25.5
05-18-92	surge	45.8
05-20-92	continuous	24.4

05-28-92	surge	25.1
05-29-92	continuous	25.3
06-04-92	surge	30
06-05-92	continuous	24.3
06-11-92	surge	30.3
06-12-92	continuous	24
06-24-92	surge	27.7
06-25-92	continuous	25.3
07-01-92	surge	26.1
07-02-92	continuous	23.1
07-07-92	surge	30
07-09-92	continuous	22
07-15-92	surge	29
07-16-92	continuous	29
07-21-92	surge	36
07-22-92	continuous	35.3
07-28-92	surge	35.9
07-29-92	continuous	24.5
08-04-92	surge	24
08-06-92	continuous	26.2
08-12-92	surge	24
08-13-92	continuous	24
TOTAL	surge	412.6
	continuous	360.4

Table 2. Water inflow, outflow, and infiltration of surge and continuous irrigation systems based on May observations during three irrigations, Nyssa, Oregon, 1992.

Irrigation system	Date	Irrigation duration	Inflow	Outflow		Infiltration	
		hour	ac-in	ac-in	(%)	ac-in	(%)
Continuous	5-06	25.5	3.34	1.83	-54.6	1.52	-45.4
	5-20	24.4	2.6	1.61	-61.9	0.92	-38.1
	5-29	25.3	3.17	1.04	-32.9	2.12	-67.1
	Average				-49.8		-50.2
	Total	360.4	43.665§	21.745§		21.920§	
Surge	5-05	24.7	1.5	0.34	-22.6	1.16	-77.4
	5-18	45.8	2.54	0.93	-36.5	1.62	-63.5
	5-28	25.1	1.51	0.42	-27.8	1.09	-72.2
	Average				-29		-71
	Total	412.6	23.950§	6.946§		17.000§	

§ based on the estimates from three measured irrigations.

Table 3. Onion yield results from the 1992 surge irrigation trial, Nyssa, Oregon, 1992.

Treatment		Yield by Market Grade							
		Rot	Cull	Small	Medium	Jumbo	Colossal	Marketable yield	Total yield
Irrigation	Position	- - - - - - - - - - - - - - - - - - - cwt/ac -							
	25 ft. (A)	16	9	2	11	163	493	657	695
	200 ft (B)	23	15	2	13	230	408	638	691
Continuous	375 ft. (C)	43	9	2	11	246	313	559	624
	550 ft. (D)	25	4	3	20	278	261	540	591
	Average	26	9	2	14	230	369	599	650

	25 ft. (A)	20	25	1	9	171	462	633	687
	200 ft. (B)	23	15	3	23	240	253	493	557
Surge	375 ft. (C)	23	10	3	22	265	167	432	490
	550 ft (D)	18	7	6	34	265	176	441	506
	Average	21	14	3	22	235	265	500	560
Average		23	11	2	18	232	317	549	605
	irrigation	ns	ns	0.9	4	ns	44	32	34
LSD (0.05)	position	ns	7.6	1.3	5	38	63	46	48
	irrigation X position	ns	ns	ns	7	ns	ns	ns	68

Table 4. Onion bulb and top composition and dry weight yield for the 1992 surge irrigation trial, Nyssa, Oregon, 1992.

Treatment		Onion bulb composition			Onion top composition		Crop N recovery		
		Percent dry weight	Dry weight yield	Dry weight total N	Dry weight yield	Dry weight total N	Bulbs	Tops	Total
Irrigation	Position	%	lbs/ac	%	lbs/ac	%	--------- lbs/ac --------		
	25 ft. (A)	9.2	6,386	1.3	2,366	1.7	82	39	121
	200 ft. (B)	9.1	6,311	1.4	1,099	1.6	91	18	109
Continuous	375 ft. (C)	9.7	6,038	1.4	1,299	1.6	82	21	103
	550 ft. (D)	9.3	5,526	1.5	1,309	1.8	81	24	105
	Average	9.3	6,065	1.4	1,518	1.7	84	25	109
	25 ft. (A)	9.8	6,769	1.3	1,838	1.8	86	33	118
	200 ft. (B)	9.8	5,480	1.5	1,059	1.9	80	22	101
Surge	375 ft. (C)	9.8	4,803	1.4	934	1.9	68	18	86
	550 ft. (D)	9.3	4,736	1.4	1,155	1.8	68	21	89
	Average	9.7	5,447	1.4	1,247	1.9	75	23	99
Average		9.5	5,756	1.4	1,383	1.8	79	24	101
	irrigation	ns	ns	ns	ns	ns	ns	ns	ns
LSD (0.05)	position	ns	969	0.3	621	ns	ns	10	ns
	irrigation X position	ns	ns	ns	ns	ns	ns	ns	ns

Table 5. Soil nitrogen analyses from the 1992 surge irrigation trial, Nyssa, Oregon, 1992.

Treatment		Spring soil analyses			Fall soil analyses			Nitrogen accounting	
		Total nitrate-N 0-5 ft.	Total ammonium-N 0-5 ft.	Total available N 0-5 ft.	Total nitrate-N 0-5 ft.	Total ammonium-N 0-5 ft.	Total available N 0-5 ft.	Accounted N 0-5 ft.	Unaccounted N 0-5 ft.
Irrigation	Position	------------------------------ lbs/ac --							
	25 ft. (A)	325	216	540	59	84	143	265	-406
	200 ft. (B)	274	213	487	111	82	193	302	-315
Continuous	375 ft. (C)	383	221	604	157	82	240	343	-391
	550 ft. (D)	412	188	601	171	74	246	351	-380
	Average	349	209	558	125	81	205	314	-373
	25 ft. (A)	220	181	401	235	89	324	442	-88
	200 ft. (B)	216	185	401	168	83	251	352	-179
Surge	375 ft. (C)	278	215	494	216	86	301	388	-236

	550 ft. (D)	295	212	507	227	76	303	391	-246
	Average	252	198	451	211	83	295	394	-187
Average		301	203	505	168	82	250	354	-280
LSD (0.05)	irrigation	64	ns	84	41	ns	41	45	131
	position	ns	ns	ns	ns	ns	ns	ns	ns
	irrigation X position	ns	ns	ns	ns	ns	ns	ns	ns