Pollution Prevention Opportunities in Agriculture: A Comparison of Surge and Conventional Irrigation Practices for Onion Production

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Pollution Prevention Opportunities in Agriculture: A Comparison of Surge and Conventional Irrigation Practices for Onion Production

Study performed by the Malheur Experiment Station of Oregon State University

SUMMARY

The Pacific Northwest Pollution Prevention Research Center (PPRC) awarded a grant to the Malheur Experiment Station of Oregon State University in 1992 to conduct a study on the use of surge irrigation in row crops. The PPRC recognizes the importance of the agricultural sector both economically and environmentally in the Pacific Northwest. While most pollution prevention work has been focused on chemical and manufacturing sectors, the potential for reducing pollution impact from agriculture practices is significant.

The current practice of “conventional irrigation” is a method in which water is continuously applied during irrigation. An alternative, called “surge irrigation," is a method in which the flow of water to crops is oscillated. Surge irrigation has potential to reduce water usage and runoff, and decrease nitrate leaching into groundwater.

The Malheur Experiment Station completed a one-year study of onion crops comparing surge irrigation to conventional, continuous irrigation. The results of the study showed that at this site, surge irrigation of onions used 45 percent less water and resulted in 186 pounds per acre less total nitrogen being leached through the soil profile than conventional irrigation. These results were obtained while maintaining acceptable onion yield and quality.

INTRODUCTION

Issue

Water quality is becoming an increasingly 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 and pesticide residues in freshwater supplies. Nitrates can become a serious non-point source pollutant in intensive horticultural areas with heavy rainfall or as a result of inefficient irrigation. Efficient irrigation alternatives to conventional irrigation are needed for groundwater protection.

Northeastern Malheur County has been designated as a Groundwater Management Area by the Oregon Department of Environmental Quality (DEQ) because elevated groundwater nitrate concentrations in several areas 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 DEQ to be a primary source of nitrate found in the groundwater.

Furrow irrigation is commonly used for onion production in Malheur County. With this method each furrow has water distributed to it using a gated irrigation pipe, typically constructed of polyvinyl chloride (PVC). Both the conventional and surge methods are considered furrow irrigation. Sprinklers or drip systems may be alternatives to conventional irrigation, but their applicability to onion production or economic feasibility have not been researched. However, sprinkler and drip irrigation require greater energy costs, disposal costs, and material costs than conventional irrigation. However, surge irrigation has been identified as a technically feasible, economically viable alternative.

Backmound

Irrigation management is the most effective way to control drainage from irrigated crop land. This can be accomplished be controlling the amount of water applied and by increasing the uniformity of application (Hanson, 1989).

Surge irrigation is a relatively new process designed to improve irrigation efficiency. When using surge irrigation, water is applied to an irrigation furrow intermittently during an irrigation set, whereas in conventional irrigation, water is applied to the furrow continuously during the irrigation set (Yonts et al., 1991). With surge irrigation, the field is divided into two sections and water is applied to each section periodically by switching back and forth from one section to the other during the irrigation set, using a switch valve, commonly referred to as a surge valve.

For example, given a 20-acre field of onions and the duration of the irrigation set is 24 hours, using conventional irrigation the entire 20 acres would be irrigated a full 24 hours. Using surge irrigation, the field would be split into two 10-acre sections. Each side of the field would be irrigated alternately for approximately 45 minutes to one hour for the entire 24-hour irrigation set. Note that in a real-world setting, the number of days between irrigation sets would vary significantly depending on the crop and weather conditions. During the experiment described in this report, irrigation sets were about one to three weeks apart.

Surge irrigation is designed to apply water more uniformly down the length of irrigation furrows than conventional furrow irrigation. The increase in irrigation uniformity reduces water use and can minimize both deep percolation and runoff, thereby reducing nitrate contamination in the groundwater.

Surge irrigation has been studied in Colorado and Utah as a method to reduce salt loading of the Colorado River. A 1991 study conducted by Bartholomay and Champion demonstrated that surge irrigation reduced deep percolation of salts by 50 percent. The reduction in salt loading of groundwater was calculated to be 419 tons of salt (Bartholomay and Champion, 1991).

Surge irrigation does not always produce improved water distribution compared to conventional methods. The underlying principle of surge irrigation is that the hydraulic properties of the soil are modified during the on/off furrow stream cycles (Goldhamer et al, 1987). Another study indicated that surge exerts a greater impact on the hydraulic properties of coarser textured soil than on fine textured soils (Saleh and Hanks, 1989).

Proposal

Surge irrigation of onions was proposed as a potential method for reducing the nitrate loading on the groundwater in Northeast Malheur County. At the time (1991) the feasibility of using surge irrigation for onions grown on silt loam, which is common in the region, had not been studied. This experiment was undertaken to test both the feasibility of surge irrigation of onions and this method of irrigation on silt loam.

Research was conducted in 1992 by the Malheur Experiment Station of Oregon State University to compare surge irrigation of onions with conventional furrow irrigation. The study investigated and compared onion yield, water application, water runoff and nitrate leaching using surge irrigation and conventional irrigation.

METHODS

Site Location and Preparation

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

Prior to the experiments, the soil was fumigated Telone C- 17 at 18 gallons per acre in the fall of 1991, Seed beds were prepared in the fall of 1991 with furrow spacings of 42 inches. Fertilizer (comprised of 100 pounds of nitrogen, 160 pounds of phosphorus, 80 pounds of potassium, five pounds of zinc, one pound of boron and 80 pounds of sulfur per acre) was broadcast and incorporated during fall seed bed preparation.

Site Layout

Figure 1 (on page 10) shows the study site that was subdivided into three 4.4 acre sections to compare surge and conventional irrigation. Surge irrigation was applied to two sections and the third section was irrigated using the conventional technique. Within the three sections, 16 crop observation sites (each 350 square feet) were identified prior to planting. Eight observation sites were in the surge area and eight were in the conventional irrigation area. The sites were arranged in paralleled sets of four. The closest sites to the slotted irrigation pipes (sites designated as A) were located 25 feet down field, and the other sites were consecutively spaced at 175-foot increments down field (sites B at 200 feet, sites C at 375 feet, and sites D at 550 feet from the irrigation pipes).

Initial Sampling and Planting

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 155^{o} F for 48 hours, and analyzed for nitrate and ammonium nitrogen to determine the amount of nitrogen available in the profile before planting.

Aztec onion seeds were planted on 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 pounds of nitrogen per acre plus 25 pounds of potassium per acre, and on May 18 at 50 pounds of nitrogen per acre, providing total sidedressed fertilizer of 130 pounds of nitrogen per acre and 25 pounds of potassium per acre.

Equipment

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 LCV-5 Surge Master. Eight-inch gated PVC pipe provided water to both irrigation systems.

Irrigation and Flow Measurement

The first irrigation occurred on April 8, 1992, (see Table 1 on page 11). 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 and Soil Sampling

Onion tissue samples were collected from each observation site on August 22, 1992. The samples were 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 taken out of storage and graded on January 4, 1993.

The soil profile in each observation site was sampled to a depth of five feet between August 27 and September 3, 1992, in one-foot increments. The samples were oven dried at 155^{o} F for 48 hours, and analyzed for nitrate and ammonium 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

Txe 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.

Irrigation Efficency

Table 2 (on page 12) shows that irrigation efficiency was greater under surge irrigation with an estimated 23.95 acre-inches of water applied and 6.95 acre-inches as runoff (29 percent) compared to the continuous system with 43.65 acre-inches of water applied and 21.75 acre-inches as runoff (49.8 percent). .

Evapotranspiration of early planted onions was 25.10 acre-inches in 1992 based on the AgriMet weather station at the Malheur Experiment Station. Evapotranspiration is a summation of water consumption by the plants and water loss due to evaporation, and can be thought of as the “water demand.” Water infiltration (i.e. water that actually enters into the soil structure) under both systems was less than the onion crop evapotranspirational demand, with the surge system considerably less than demand (8.1 acre-inches less than the evapotranspirational demand). Ideally, the surge irrigation system should have been used once or twice more frequently during the season to satisfy crop evapotranspirational demand.

Onion Yield

Onion yield data from the observation sites is shown in Table 3 (on page 12). The average total onion yield from the continuously irrigated observation sites was 65,000 pounds per acre and the marketable yield was 59,900 pounds per acre. The average total yield for the surge irrigated observation sites was 56,000 pounds per acre and marketable yield was 50,000 pounds per acre.

These results were contradicted by the yield records of the cooperating farmer who farmed the area. The cooperator’s records showed a marketable yield of 57,500 pounds per acre for the entire area with no variation between the conventional and surge irrigated areas. The exact reason for this difference is not known, but the cooperator’s measurement averages yield over a much larger area for each type of irrigation and, therefore, minimizes fluctuations which the 350 square foot observation sites may magnify. The observation sites were subjected to much higher levels of disturbance (such as walking on them) due to all the measurements that were made in them throughout the growing season, which may be a reason for the discrepancy.

The data also indicates that distance from the irrigation pipes had a significant effect on yield for onions that were surge irrigated. Observation site A at 25 feet from the irrigation pipes showed a yield more than 10,000 pounds per acre higher than sites B, C or D. This large drop in the first 200 feet is higher than would be desirable.

Onion Tissue Analysis

Crop tissue analysis shows that differences due to irrigation were not significant, as seen in Table 4 (on page 13). The bulb and top dry weight yield, and the total top nitrogen content decreased as the distance from the irrigation pipes increased. The interaction effect of irrigation method and plot position was not significant for the tissue composition categories.

Soil Analysis

The spring soil analyses indicate that total nitrate and total available nitrogen content in the continuous plots was significantly higher prior to planting than in the surge area (see Table 5 on page 13). After harvest, total nitrate and total available nitrogen in the surge irrigated plots was higher than in the continuous irrigation. More nitrogen (186 pounds per acre) was lost from the soil during the season in the continuously irrigated plots than in the surge plots. Nitrogen loss with both methods 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 method were not significantly different for spring and fall soil nitrogen analyses or for total available nitrogen accounting. Total available nitrogen accounting was 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. Crop nitrogen uptake removed a large amount of nitrogen from the top of the soil profile in both irrigation systems. The average available nitrogen content from two to five feet below the surface 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 conditions. Nitrogen leaching losses could have been less for both systems with lower nitrogen inputs over the last two years.

CONCLUSIONS

The most general conclusion of the study was that surge irrigation is feasible for furrow irrigated onion grown on silt loam soils. While surge irrigation has been employed in other parts of the United States (particularly Colorado and Nebraska), it is an important result for regional farmers to see that surge irrigation can be successfully used in the Northwest.

These additional conclusions were made based on the results of the study:

1. Surge irrigation produced the same onion yield and comparable onion quality as continuous irrigation, while using much less water.

Yield data from the grower show that the surge and continuous irrigation areas had equal yield (57,500 pounds per acre). The observation sites used in the experiment generated results which showed surge irrigation to have a lower yield, but this data is deemed less reliable since it is from a smaller area and the observation sites were disturbed repeatedly during the growth season by sampling and observation foot traffic activities.

Surge irrigation used 23.95 acre-inches of water, while continuous irrigation used 43.65 acre-inches, resulting in a net water savings of about 45 percent.

2. Yields using surge irrigation decreased significantly as a function of distance from the irrigation pipes.

   The three observation sites that were 200 to 550 feet from the irrigation pipes all had yields more than 10,000 pounds per acre less than the observation site, which was 25 feet from the irrigation pipe. Continuous irrigation resulted in a more gradual decrease with distance. The surge systems should have been used once more during the season.

3. Surge irrigation resulted in much less runoff water (6.95 acre-inches, or 29 percent of the total water applied) than continuous irrigation (21.75 acre-inches, or 49.8 percent of the total water applied).

4. More nitrogen was “unaccounted” (186 pounds per acre 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.

Therefore, the study showed that surge irrigation of onions in the site’s soil used less water, produced less runoff, and resulted in less nitrogen leaching into the soil profile, while maintaining acceptable crop yield and quality.

POTENTIAL IMPLICATIONS-OF THE STUDY

1. Surge irrigation will become more appealing if water prices increase or quantities of available water decreases.

   Water is currently very inexpensive in the part of Oregon where the study took place. Farmers in Malheur County pay approximately $20 per acre ($5 per acre-foot) for water for the entire growing season. This cost is significantly less than the true cost of irrigation water. The irrigation needs in the region exceeded the supply during at least half of the recent years, another reason to switch to a more efficient irrigation method.

2. Methods such as surge irrigation are needed to help protect the groundwater.

   As previously discussed, northeastern Malheur County is classified as a groundwater management area by the Oregon DEQ because of unacceptable nitrate-nitrogen levels. Many other agricultural areas throughout the country either currently have or face this same nitrate problem. Methods such as surge irrigation can greatly reduce the nitrate leaching as shown in this study.

3. The benefits of surge irrigation will make it a more economically viable alternative as water prices increase and regulations that protect the groundwater become more strict. However, independent-minded growers are more likely to respond positively to savings in water, fertilizer, and labor than to a "control" philosophy brought about by regulations. Surge irrigation has these savings, which will interest growers, regardless of regulations.

COST OF SURGE IRRIGATION EQUIPMENT

Costs for surge irrigation equipment will vary depending on the size of the farm. The cost of one eight-inch surge valve with its controller runs between $1,500 and $1,800. Each valve can supply water to 10 to 40 acres depending on soil, lay of the land and crop type. On some models the controller (the "brains" and "brawn" of the valves) can be interchanged between several valves thereby reducing the cost for a multiple-valve system. Eight-inch diameter PVC piping to deliver water to the surge valve run from $1.50 to $2 per foot depending on the specific type of application.

FINANCIAL ASSISTANCE

The cost of installing water conservation equipment such as surge valves may be too large for the budget of some growers. There are cost sharing and financial assistance programs available to growers. Some grants require that the grower submit a water management plan and agree to follow it for a designated period of time.

Information on financial assistance for installing water conservation structures such as surge irrigation equipment can be obtained from the following Northwest Agricultural Stabilization and Conservation Service (ASCS) offices:

Alaska State ASCS Office:	(907) 745-7982
Idaho State ASCS Office:	(208) 334-1486
Oregon State ASCS Office:	(503) 692-6830
Washington State ASCS Office:	(509) 353-2307
Northwest Area ASCS Office:	(202) 720-6942

Each county has its own ASCS office, with different levels of funding for each county depending on the county's designation in terms of water quality. The state offices can supply information on a specific county's water quality status and telephone number. In addition, the Soil Conservation Service (SCS) has an office in all counties. SCS provides technical assistance to growers who are going to buy water conservation equipment or develop water management plans. ASCS offices can provide telephone numbers for SCS offices. Both ASCS and SCS are branches of the United States Department of Agriculture.

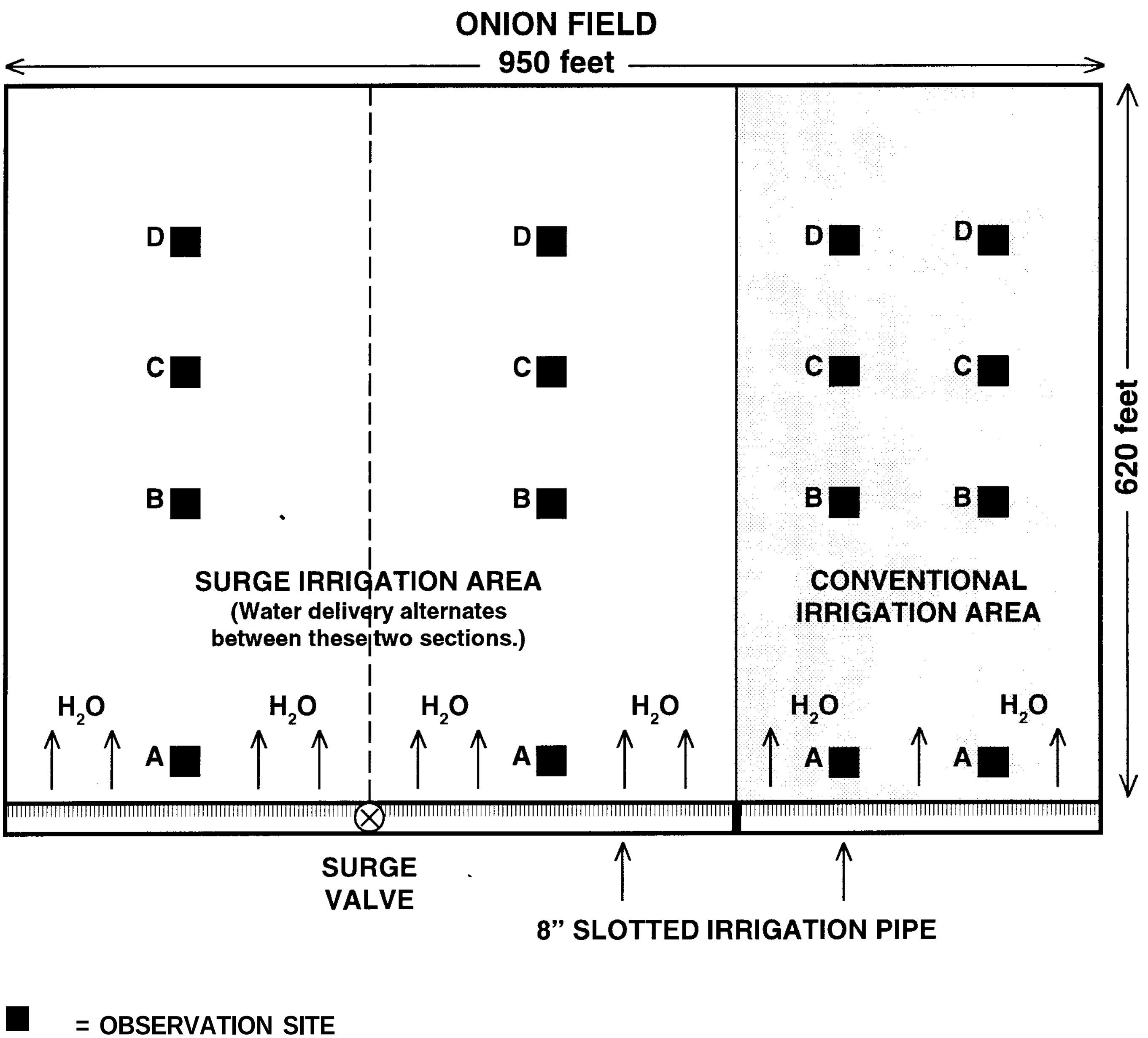
RECOMMENDATIONS

Additional experiments are needed to detail the variety of crop and soil types for which surge irrigation is effective. The Malheur Experiment Station of Oregon State University has done further work on surge irrigation in the region on wheat, which showed promising results (Shock et al, 1993).

More information on these studies can be obtained by contacting the station at:

Oregon State University
Malheur Experiment Station
595 Onion Avenue
Ontario, OR 97914
(503) 889-2174

Figure 1. Surge Irrigation Study Site Layout



Note: Not to scale

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

Date (1992)	Surge Irrigation Duration (Hours)	Conventional Irrigation Duration (Hours)
4/8 to 4/9	24	27.5
5/5 to 5/6	24.7	25.5
5/18 to 5/20	45.8	24.4
5/28 to 5/29	25.1	25.3
6/4 to 6/5	30	24.3
6/11 to 6/12	30.3	24
6/24 to 6/25	27.7	25.3
7/1 to 7/2	26.1	23.1
7/7 to 7/9	30	22
7/15 to 7/16	29	29
7/21 to 7/22	36	35.3
7/28 to 7/29	35.9	24.5
8/4 to 8/6	24	26.2
8/12 to 8/13	24	24
Total Hours:	**412.6**	**360.4**

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

Irrigation System	Date	Irrigation Duration (hours)	Inflow Acre-Inches	Outflow Acre-inches	Outflow %	Infiltration Acre-inches	Infiltration %
Conventional	5/6	25.5	3.342	1.825	54.6	1.517	45.4
	5/20	24.4	2.604	1.612	61.9	0.922	38.1
	5/29	25.3	3.165	1.041	32.9	2.124	67.1
	Average				**49.8**		**50.2**
Surge	5/5	24.7	1.499	0.339	22.6	1.16	77.4
	5/18	45.8	2.544	0.929	36.5	1.615	63.5
	5/28	25.1	1.507	0.419	27.8	1.088	72.2
	Average				**29**		**71**

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

Treatment		Yield by Market Grade, x100 lbs/acre							
Irrigation	Position	Rot	Cull	Small	Medium	Jumbo	Colossal	Marketable Yield	Total Yield
Conventional	25 ft. (A)	16	9	2	11	163	493	657	695
	200 ft (B)	23	15	2	13	230	408	638	691
	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**
Surge	25 ft (A)	20	25	1	9	171	462	633	687
	200 ft (B)	23	15	3	23	240	253	493	557
	375 ft (C)	23	10	3	22	265	167	432	490
	550 ft (D)	18	7	6	34	365	176	441	506
	Average	**21**	**14**	**3**	**22**	**235**	**265**	**500**	**560**
Overall Average		**23**	**11**	**2**	**18**	**232**	**317**	**549**	**605**

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/acre	%	lbs/acre	%	lbs/acre	lbs/acre	lbs/acre
Conventional	25 ft (A)	9.2	6386	1.3	2366	1.7	82	39	121
	200 ft (B)	9.1	6311	1.4	1099	1.6	91	18	109
	375 ft (C)	9.7	6038	1.4	1299	1.6	82	21	103
	550 ft (D)	9.3	5526	1.5	1309	1.8	81	24	105
	Average	**9.3**	**6065**	**1.4**	**1518**	**1.7**	**84**	**25**	**109**
Surge	25 ft (A)	9.8	6769	1.3	1838	1.8	86	33	118
	200 ft (B)	9.8	5480	1.5	1059	1.9	80	22	101
	375 ft (C)	9.8	4803	1.4	934	1.9	68	18	86
	550 ft (D)	9.3	4736	1.4	1155	1.8	68	21	89
	Average	**9.7**	**5447**	**1.4**	**1247**	**1.9**	**75**	**23**	**99**
Total Average		**9.5**	**5756**	**1.4**	**1383**	**1.8**	**79**	**24**	**101**

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

Treatment		Spring Soil Analysis			Fall Soil Analysis			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/acre							
Conventional	25 ft (A)	325	216	540	59	84	143	265	-406
	200 ft (B)	274	213	487	111	82	193	302	-315
	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
Surge	25 ft (A)	220	181	401	235	89	324	442	-88
	200 ft (B)	216	185	401	168	83	251	352	-179
	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**
Total Average		**301**	**203**	**505**	**168**	**82**	**250**	**354**	**-280**

Appendix A:
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