IRRIGATION CRITERIA AND DRIP TAPE PLACEMENT FOR 'UMATILLA RUSSET' POTATO PRODUCTION

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Water quality and water scarcity issues may lead growers to adopt drip irrigation for potato (*Solanum tuberosum* L.). The ideal soil water potential irrigation criterion for drip-irrigated potato is unknown. A drip system will cost less if one drip tape irrigates two potato rows instead of a tape for every row. The tuber yield and quality response of 'Umatilla Russet' potato was examined with variable drip tape placement and irrigation criteria. The first factor was either one drip tape between two potato rows, or two tapes (one tape over each row). The second factor was automated irrigation at -15, -30, -45 or -60 kPa soil water potential. The factorial trial was replicated five times in 2000 and again in 2001. Tubers were evaluated for yield, grade, physical defects, specific gravity, and fry color. The tape placement factor (one tape per row or one tape for two rows) had a significant effect on every variable except total marketable yield and tuber bud-end fry color for which interaction effects with soil water potential were significant. Irrigation with one tape at -15 or -30 kPa produced more total yield and as much or more marketable yield as any other treatment. Maximum marketable yield was estimated to have occurred at irrigation plus precipitation slightly above Et_c both years.

Introduction

Water quality and water scarcity issues may lead some growers to adopt drip irrigation for potato production. The objectives of this study were to investigate and document the performance of 'Umatilla Russet' under drip irrigation, and to explore the interaction of drip tape placement and irrigation criteria for potato crop production. It would be desirable to reduce the amount of drip tape used and to conserve water. This was the second year of testing 'Umatilla Russet' potatoes grown with variable irrigation criteria and drip tape placement.

Materials and Methods

The 2001 trial was conducted on Owyhee silt loam where winter wheat was the previous crop. The wheat stubble was flailed, the field was furrow irrigated and disked, then 50 lb N/acre and 44 lb P/acre were broadcast. In the fall, the field was ripped with Telone II injected at 22 gal/acre. The field was fall-bedded on 36-inch row spacing. A soil test taken on April 17, 2001 showed available nitrate plus ammonia totaled 68 lb N/acre in the top 2 ft of soil, 20 ppm extractable P, 272 ppm K, 1 percent organic matter, and pH 7.8.

Certified seed was hand cut into 2-oz seed pieces and treated with Tops-MZ-Gaucho dust. Potato seed was planted on April 19, 2001 using a Parma two-row cup planter (Parma Corp., Parma, ID) with the center furrowing shovel removed. Seed piece spacing was 9 inches in the row, with rows 36 inches apart.

Prowl at 1 lb ai/acre plus Dual at 2 lb ai/acre, in 30 gal/acre spray mix, was applied on May 1 for weed control. The herbicides were incorporated with a spike-tooth bed harrow that formed a broad, flat-topped bed over the two potato rows. The toolbar at the back of the bed harrow had two wide shovels to lift soil out of the furrows, a spool of drip tape, and shanks to inject a single drip tape on the first pass, 2-3 inches deep in the center of the bed. A 16-ft length of 5/8-inch chain dragged in a “vee” from the shovel shanks pulled soil into the center of the bed. On the second pass with the bed harrow, in the opposite direction from the first pass, two drip tubes were injected 2-3 inches deep, directly over the two potato rows. The drip tape was 1000 Path (Nelson Irrigation, Walla Walla, WA), 8 mil thick, with 12-inch emitter spacing, and 0.22 gal/min/100 ft flow rate. In plots where one tape was to remain between the two potato rows, the outside two tapes were removed manually during the drip system installation. In the plots where a tape was over each row of potato plants, the center tape was removed manually during the drip system installation. Water was supplied to the drip tapes through 1/2-inch PVC pipe, with the five plots of each treatment fed by one valve. Matrix herbicide was applied preemergence at 1.2 oz/acre on May 7.

A complete factorial set of treatments was arranged in a randomized complete block design. Plots were two rows (6 ft) wide by 50 ft long. The first factor was either one drip tape between two potato rows, or two tapes (one tape over each row). The second factor was automated irrigation at -15, -30, -45 or -60 kPa soil water potential in the root zone measured with granular matrix sensors (GMS, Watermark Soil Moisture Sensors, Model 200SS, Irrometer Corp, Riverside, CA).

The four soil water potential levels and two tape placements were tested in all eight combinations in a randomized complete block design with five replicates. The GMS were installed between plants in the potato row, with three GMS per plot. Two GMS with the center of the sensor at 8-inch depth measured soil water potential for the irrigation criteria, and a third GMS, installed at 16-inch depth, monitored infiltration below the root zone.

The automated irrigation system (Shock et al. 2002) read the soil moisture sensors in each plot every 6 hours, using multiplexers connected to a data logger (model CR10, Campbell Scientific, Logan, UT). If the average of the sensor readings from all five replicates of a treatment was less (drier) than that treatment's irrigation criterion, the irrigation valve to that treatment was opened. Plots with two tapes received a 1.5-hour irrigation, and plots with one tape received 3 hours of irrigation, so that each irrigation applied 0.1 inch regardless of the number of tapes. If the 0.1-inch irrigation did not sufficiently wet the soil to bring the sensor readings back above the criterion for a treatment, at the next 6-hour interval another irrigation would be applied. Water meters measured the volume of water applied to each treatment, and the meter readings were recorded daily.

All of the nitrogen fertilizer was injected through the drip tape. A 120-gal tank was used to hold a solution of 150 lb calcium nitrate dissolved in 111 gal of water by stirring with a paddle on an electric drill. The solution was metered into the irrigation water using a model A30-2.5 Dosmatic metering pump (Dosmatic USA International, Inc., Carrolltown, TX) at a rate of 1 gal of fertilizer solution to 500 gal of irrigation water. Fertilizer was injected to supply 50 ppm NO_3 in the drip irrigation water, beginning with the first irrigation on May 26.

Leaf petioles were monitored regularly to assure that plant nitrogen status remained in the ideal range for all treatments. On June 17 and 18, 11 lb N/acre, 8 lb S/acre, 0.17 lb Cu/A, and 0.21 lb Mn/acre were injected to correct deficiencies shown in the first petiole test, which was taken on June 11. From June 18 to July 16, dissolved calcium nitrate fertilizer was injected to maintain 50 ppm NO_3 in the drip system. On July 17 to 18, 10 lb S/acre, 5 lb Mg/acre, 0.25 lb Zn/acre, and 0.25 lb Mn/acre were injected to correct deficiencies shown in the third petiole test, taken on July 12. From July 18 to July 31, calcium nitrate solution was again injected at 50 ppm NO_3. Fertilizer was injected to supply 50 ppm NO_3 in the drip system from June 2 to July 10. On July 10 additional calcium nitrate was injected to bring the total applied N on all treatments to 140 lb N/acre. From July 11 to August 2 fertilizer solution was injected to maintain 50 ppm NO_3 in the drip system. From August 3 through the final irrigation on September 19, no fertilizer was injected.

Fungicide applications to prevent late blight infection consisted of an aerial application of Ridomil Gold and Bravo at 2 lb/acre on June 14, and then Dithane at 4 pint/acre on June 22. Powdered sulfur was applied at 30 lb/acre by aerial application on July 14 and again on July 28 to control powdery mildew.

The vines were flailed on September 19. Potatoes were lifted on October 1 with a two-row digger (John Deere, Moline, IL) that laid the tubers back onto the soil in each row. The drip tape was dug along with the potatoes. It fed over the two-row primary chain digger and was gathered by hand and tied in bundles for disposal. At harvest, the potatoes in each plot were visually evaluated for defects such as growth cracks, knobs, curved or irregularly shaped tubers, pointed ends, or stem end decay. A 5-ft alley was measured at the ends of each plot. All tubers from the interior 45 ft of each plot were placed into burlap sacks and stored in a barn under tarps until grading.

Tubers were graded October 24 and a 20-tuber sample from each plot was placed into storage. The storage was kept near 90 percent relative humidity and the temperature was gradually reduced to 45°F. Samples were removed from storage December 5-6, specific gravity was measured using the weight-in-air, weight-in-water method for 20 tubers. To determine stem end fry color, 20 tubers/plot were cut lengthwise and center slices were fried for 3.5 min in 375°F soybean oil. Percent light reflectance was measured on the stem and bud ends of each fried slice using a model 577 Photovolt Reflectance Meter (Seradyn, Inc., Indianapolis, IN), with a green tristimulus filter, calibrated to read 0 percent light reflectance on the black standard cup and 73.6 percent light reflectance on the white porcelain standard plate (Shock et al. 1994).

Results and Discussion

Potatoes planted on April 19 did not fully emerge until May 20 due to cool-to-hot temperature fluctuations in April and May. Dry weather prevented late blight from developing in 2001. Precipitation for April through September was 2.13 inches.

2000 Drip Irrigation Management Factors Trial

Data for the 2000 trial have been presented previously (Shock et al. 2001. Yields in 2001 were generally higher than in 2000. In 2000 tuber specific gravity was influenced by the irrigation criteria and tape placement. There were more sugar ends in 2000, and lower percent of U.S. No. 1 tubers in

2000. The automated drip system applied more water than the AgriMet estimate of evapotranspiration (Et_c) to the treatments irrigated at -15 kPa with either one tape per row or one tape per two rows (data not shown).

2001 Tape Placement

The average total yield of all eight treatments was 582 cwt/acre, with a significantly higher total yield, 634 cwt/acre, with one tape for two rows (Table 1). Total US No. 1 grade tubers were significantly higher with one tape per row. The yield of under 4-oz-tubers was significantly higher with a drip tape on every row. Treatments with a drip tape for every row of potato plants produced more tubers in the 6- to 12-oz grade, averaging 271 cwt/acre, compared to 168 cwt/acre with one tape for two rows. Conversely, the treatments with one tape for two rows produced 217 cwt/acre over 12 oz, compared to 129 cwt/acre for one tape for each row. A tape for each row also produced significantly fewer US No.2 grade tubers, with a significant interaction between the irrigation criterion and the drip tape.

2001 Soil Water Potential

Treatments with irrigation automated at -45 and -60 kPa yielded less than the -15 and -30 kPa treatments (Table 2). Yield of U.S. No. 1 grade tubers was significantly higher with the two wetter irrigation criteria. The -15 kPa treatments with 458 cwt/acre U.S. No. 1, and the -30 kPa treatments with 468 cwt/acre, produced more U.S. No. 1 than the -45 and -60 kPa treatments, 398 and 339 cwt/acre, respectively. Marketable yield for processing, which included the U.S. No. 1 and U.S. No. 2 grades, averaged 548 cwt/acre overall, with the -45 and -60 kPa treatments producing progressively less marketable yield.

2001 Tuber Quality

Stem end fry color was the only tuber quality variable affected by irrigation levels and tape placement (Table 2). A high percentage (7 percent) of sugar ends resulted from the use of one tape for two rows and irrigation at -45 kPa. Average tuber fry color was not affected by tape placement or soil water potential irrigation level. Tuber specific gravity was not affected by irrigation level and tape placement.

2001 Water Use

The automated irrigation system applied substantially more water than Et_c of 25.7 inches to the -15 kPa treatment with one tape per two rows, which received 32.9 inches of water. The –30 kPa treatment with one tape per two rows received 27.7 inches, slightly more than Et_c. One tape per row at -15 kPa resulted in 18.0 inches of water applied. The -30 kPa treatment with one tape per row applied 18.0 inches, the -45 kPa treatment with one tape per two rows applied 22.9 inches, and the -45 kPa with one tape per row applied 15.5 inches. The -60 kPa treatment with one tape per two rows applied 21.3 inches, and the -60 kPa with one tape per row applied 11.0 inches.

The automated, sensor-driven irrigation was a feedback control system, and soil water potential oscillated around the average treatment criteria (data not shown). This oscillation was more pronounced in the drier treatments, which had a pattern of irrigating four times a day for 3 or 4 days then not irrigating for 3 days. The two -15 kPa treatments irrigated every day, but not always all four times every day. The treatments with one tape per row received less water for a given soil water potential criterion because the sensors were closer to the tape, which increased the efficiency in wetting the GMS and reduced lag time in the feedback oscillation of irrigation frequency.

During the 2001 season, average potato yields were 402 cwt/acre in Malheur County. Yields in the current trial were higher, possibly in part because the field had not grown a potato crop in 10 years. Many growers have a shorter rotation between potato crops, which usually leads to increased pathogens in the soil. Typically, 43.2 inches of water are applied using furrow irrigation, and 36 inches are applied using sprinkler irrigation. From the county yield and water use figures, sprinkler and furrow irrigation result in 1,116 and 931 lb of potatoes for each acre-inch/acre of water applied. Using drip irrigation with a tape for every row and irrigating at -30 kPa, yield was 3,217 lb/acre for each acre-inch/acre of applied water, with adequate tuber grade and quality. The -45 and -60 kPa treatments with one tape per row had water use efficiency of 2,707 and 2,854 lb/acre for each acre-inch/acre of applied water, but tuber quality was adversely affected at these drier irrigation criteria.

Combined 2000 and 2001

When the data for both years were analyzed together, the tape placement factor (one tape per row or one tape for two rows) had a significant effect on every variable except total marketable yield and tuber bud-end fry color for which interaction effects with tape number were significant (Table 2). Irrigation with one tape for two rows at -15 or -30 kPa produced more total yield than drier treatments. Marketable yield, which includes tubers with defects that cause them to be graded U.S. No. 2, was highest with one drip tape for two rows of potatoes, and the -15 and -30 kPa irrigation levels. One tape for two rows produced more tubers over 12 oz, which can be undesirable for processing if the tubers are too large to fit through the French fry cutting machinery. One tape per row produced more tubers in the 6- to 12-oz category, but also produced more tubers under 4 oz, which could cause volunteer potato problems as they may remain in the soil after harvest. With one tape per row, specific gravity was higher, stem-end fry color was lighter, and there were fewer sugar ends. With one tape per two rows, the highest incidence of sugar ends, 8 percent, was at the -15 kPa irrigation level. If the contract allowed a tolerance for sugar ends, one drip tape for two rows could be more economical. There were more cull potatoes with the -15 kPa irrigation with either one tape per row or one tape for two rows.

The irrigation criterion considered alone only influenced the total U.S. No. 1 and over-12-oz size categories, producing more U.S. No. 1 tubers and fewer oversized tubers over 12 oz, with a tape on each row. Tuber defects that graded U.S. No. 2 were highest with the -15 and -30 kPa irrigation levels.

Tape placement and irrigation criterion interacted to influence total yield, total marketable potatoes, and U.S. No. 2 yield, due to higher yield with one tape per two rows but more U.S. No. 2 tubers. The year variable showed a difference in stem-end fry color and sugar ends, with more in 2000. The tape-by-year interaction was significant for percent U.S. No. 1, total yield, with more U.S. No. 1 tubers at the wetter irrigation criteria in 2001, and also significant effects on 6- to 12-oz, under 4 oz, percent U.S. No. 2, culls, and bud-end fry color. The irrigation criteria by year interaction was significant only for culls. The three-way interaction of tape, kPa, and year was significant for percent U.S. No. 1, marketable, total U.S. No. 1, U.S. No. 2, stem-end fry color, and sugar ends.

Future Opportunities with Drip Irrigation

The drier treatments in this study were based on soil water potential that would be in the acceptable range of dryness for furrow or sprinkler irrigated potatoes. With this soil moisture sensor-driven automated drip irrigation system the drier treatments often had several days between irrigations, as shown by the flat regions of the lines in the graphs of applied water (Fig. 1 and 2). If the objective had been to grow a potato crop with a limited water supply, the tuber grade and quality might be harmed less with a daily irrigation with a fraction of Et_c.

Other research has shown that application of irrigation that closely matches the water needs of the crop results in better nitrogen use efficiency and reduced leaching potential. Less N fertilizer was required in the current trials than is routinely used by growers.

Drip irrigation might be used to deliver systemic fungicides or insecticides in small doses directly to the root system of the crop, possibly reducing production costs and chemical use. Hypothetically, these smaller doses might be able to substitute for high rates of soil fumigants used to prepare the soil for a potato crop. A systemic fungicide might replace aerial spraying on a scheduled basis to protect the foliage from late blight. Systemic fungicide could also potentially improve yields by preventing early vine death, thus prolonging the growing season.

Acknowledgments

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References

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Table 1. 'Umatilla Russet' 2001 yield, grade, and processing quality when grown with automated drip irrigation using either one tape for two rows or a tape for every row, at four levels of soil water potential. Malheur Experiment Station, Oregon State University, Ontario, OR, 2002.

			Yield by grade										Fry color			
Number of drip tapes		U.S. No. 1	Total yield	Total marketable	Total U.S. No. 1	Over 12 oz	6 to 12 oz	4 to 6 oz	Under 4 oz	U.S. No. 2	Cull	Specific gravity	Stem end	Bud end	Average	Sugar ends
	kPa	%	----------	----------	----------	----------	cwt/acre	----------	----------	----------	----------	g cm^{-3}	--------	% Reflectance	--------	%
one per two rows	-15	69	651	619	451	285	158	8	11	167	17	1.0884	39	48	43	4.0
	-30	70	658	623	460	274	175	11	11	163	19	1.0906	40	46	43	2.0
	-45	60	620	580	370	178	182	11	14	210	20	1.0892	39	46	43	7.4
	-60	49	608	566	297	131	158	8	14	269	28	1.0886	41	47	44	3.0
	Mean	62	634	597	394	217	168	9	12	202	21	1.0892	40	47	43	4.1
one per row	kPa															
	-15	82	563	535	464	165	265	34	18	71	10	1.0915	41	47	44	3.0
	-30	82	579	547	477	140	304	34	18	70	10	1.0920	41	47	44	3.0
	-45	83	515	481	425	141	241	42	20	56	12	1.0922	43	46	45	0.0
	-60	82	467	431	381	71	274	37	25	50	7	1.0900	41	46	44	0.0
	Mean	82	531	499	437	129	271	37	20	62	10	1.0914	42	46	44	1.5
Average	kPa															
	-15	76	607	577	458	225	212	21	15	119	13	1.0900	40	47	44	3.5
	-30	76	618	585	468	207	239	22	14	117	14	1.0913	41	46	44	2.5
	-45	71	567	531	398	160	212	27	17	133	16	1.0907	41	46	44	3.7
	-60	65	537	498	339	101	216	22	19	159	18	1.0893	41	46	44	1.5
Overall	Mean	72	582	548	416	173	220	23	16	132	15	1.0903	41	47	44	2.8
LSD(0.05)	Tapes	4	12	13	35	53	61	8	4	24	7	NS	2	NS	NS	NS
	kPa	NS	NS	18	49	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Tapes x kPa	8	NS	NS	NS	NS	NS	NS	NS	48	NS	NS	NS	NS	NS	5.4

Table 2. 'Umatilla Russet' average of 2000 and 2001 yield, grade, and processing quality when grown with automated drip irrigation using either one tape for two rows or a tape for every row, at four levels of soil water potential. Malheur Experiment Station, Oregon State University, Ontario, OR, 2002.

				Yield by grade									Fry color			
Number of drip tapes		U.S. No. 1	Total yield	Total marketable	Total U.S. No. 1	Over 12 oz	6 to 12 oz	4 to 6 oz	Under 4 oz	U.S. No. 2	Cull	Specific gravity	Stem end	Bud end	Average	Sugar ends
	kPa	%	-------------	-------------	-------------	-------------	cwt/acre	-------------	-------------	-------------	-------------	$g\ cm^{-3}$	--------% Reflectance--------			%
one per two rows	-15	68	578	532	355	226	154	14	26	138	21	1.0883	37	45	41	7.5
	-30	70	557	510	350	209	160	20	31	121	8	1.0917	36	44	40	7.0
	-45	64	542	496	307	157	167	19	28	154	10	1.0882	37	45	41	6.0
	-60	57	524	474	279	116	156	21	32	181	7	1.0878	37	45	41	5.3
	Mean	65	550	503	354	177	159	18	29	149	18	1.0890	37	45	41	6.4
one per row	-15	78	535	474	458	133	245	41	45	56	15	1.0924	40	46	43	3.0
	-30	78	547	488	469	109	274	47	48	59	8	1.0939	39	45	42	3.0
	-45	75	481	414	398	93	215	55	56	51	10	1.0912	38	44	41	5.8
	-60	73	440	375	339	59	216	50	56	49	7	1.0909	39	45	42	4.3
	Mean	76	501	438	384	98	237	48	51	53	12	1.0921	39	45	42	4.0
Average	-15	73	557	503	407	180	199	28	36	97	18	1.0904	38	46	42	5.3
	-30	74	552	499	409	159	217	33	40	90	14	1.0928	38	45	41	5.0
	-45	69	512	455	353	125	191	37	42	103	15	1.0897	38	44	41	5.9
	-60	65	482	424	309	87	186	36	44	115	13	1.0894	38	45	41	4.8
Overall	Mean	70	526	470	369	138	198	33	40	101	15	1.0906	38	45	41	5.2
LSD(0.05)	Tapes	2	12	NS	16	19	20	4	4	10	4	0.0019	1	NS	1	2.1
	kPa	NS	NS	NS	23	27	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Tapes x kPa	NS	24	28	NS	NS	NS	NS	NS	20	NS	NS	NS	NS	NS	NS
	Year	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2	NS	NS	2.9
	Tape x Year	3	17	NS	NS	NS	28	NS	6	14	7	NS	NS	1	NS	NS
	kPa x Year	NS	NS	NS	NS	NS	NS	NS	NS	NS	7	NS	NS	NS	NS	NS
Tape x kPa x Year		6	NS	20	32	NS	NS	NS	NS	28	NS	NS	3	NS	NS	5.9