MANAGEMENT FACTORS ENHANCING THE FEASIBILITY OF SUBSURFACE DRIP IRRIGATION FOR POTATO

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Introduction

The objective of this trial was to measure the effect on potato (CV. Umatilla Russet) yield and grade of three drip irrigation management factors, and their possible interactions. Where potatoes have been grown with drip irrigation, usually one tape is used for every bed. As an alternative to reduce the cost of using drip irrigation for potatoes, one tape was used in a wide raised bed to irrigate two rows of plants. In Malheur County silt loam soils, the irrigation criteria for the onset of furrow or sprinkler irrigation is -50 to -60 kPa. For drip irrigation, since the amount of water added each time is much less than the other systems, a wetter irrigation criteria may be required. Some researchers have found that calcium nitrate is a better N source than urea for Solanaceous crops (nightshade family crops such as tomato and potato), so these nitrogen sources were compared. Polyacrylamide (PAM) can help flocculate soil particles, so PAM was added to the irrigation water with the calcium nitrate to attempt to reduce soil cloddiness and tare dirt stuck on harvested tubers.

Treatments consisted of two levels of soil water potential, -30 and -60 kPa, that would start the irrigation; either one drip tape or two per two-row bed; and injection of a solution of either calcium nitrate with polyacrylamide or a urea solution. Each of the three factors (soil moisture at two levels, one or two drip tapes, and two means of N addition) were combined in every way. The resulting eight factorial treatments were arranged in a randomized complete block design with five replications. The effects of each factor on potato yield and grade were compared, and total water applied was compared to an estimate of evapotranspiration.

Materials and Methods

The 1999 study was conducted on Owyhee silt loam in a field that was in winter wheat the previous year. The stubble was flailed then disked twice and 100 lb P_2O_5/acre and 20 lb N/acre were broadcast. The field was deep ripped, moldboard plowed, fumigated with Telone II at 25 gallon/acre in October, and bedded into 72-inch beds in November, 1998.

Soil samples were taken in March from the top and second foot, and complete analysis was performed. The top foot of soil had pH 7.5, 0.5 percent free lime, 1.5 percent organic matter, 7 ppm nitrate-N, 5 ppm ammonium-N, 35 ppm P, 375 ppm K, 3160 ppm Ca, 284 ppm Mg, 151 ppm Na, 1.7 ppm Zn, 5.4 ppm Fe, 7.9 ppm Mn, 0.5 ppm Cu, 10 ppm sulfate-S, and 0.5 ppm B.

On April 7, the field was sprayed with Roundup to control volunteer wheat and winter annual weeds. Certified Umatilla Russet potato seed was cut by hand into 2-oz seed pieces and treated with Tops MZ. Potatoes were planted on April 22 with seed pieces planted 10-in deep, spaced 9 in apart in 36-in rows. A two-row-per-bed configuration was maintained at planting by leaving off the center furrowing shovel of the Parma two-row cup-type planter. On April 29, the beds were formed with a spike-tooth bed harrow and winged shovels, dragging a 12-ft vee of 5/8-in chain to pull soil into the bed center. A tank mix of Prowl at 1 lb ai/acre plus Dual at 2 lb ai/acre in 30 gal/acre water was applied for weed control on May 17.

On May 18, tape was shanked in to a depth 3 to 4 in. The drip tape was 8 mil Nelson Pathfinder (Nelson Irrigation, Walla Walla, WA) with emitters every 12 in and 0.22 gal/min/100 ft output at 10 psi. Potatoes had not emerged by that date, because of cool, dry, windy weather. The first pass injected a single drip tape in the center of the bed. A second pass in the opposite direction injected two drip tapes above the potato rows. In plots where one tape was to remain between the potato rows, the outside 2 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-in PVC pipe, with the five plots of each treatment fed by one valve. Plots were two rows (6 ft) wide by 33 ft long, with a 2-ft alley between replicates.

Soil water was kept nearly constant in each treatment by high-frequency, automated drip irrigations based on soil water potential measurements. Irrigation was automated by granular matrix sensors (GMS, Watermark soil moisture sensors, model 200 SS, by Irrometer Corp., Riverside, CA). The GMS were installed 9 in from the plant row June 8 through 10, with two sensors 6 in deep and one sensor 24 in deep in each plot. A control program read the sensors every 6 hours. The GMS were connected through multiplexers to a data logger that controlled the irrigation solenoid valves. The relationship between sensor electrical resistance and soil moisture had already been determined (Shock, Barnum, and Seddigh, 1998). The volume of water applied to each treatment was recorded by a water meter.

When the average sensor reading of the shallow sensors in a treatment reached the assigned moisture criterion (either -30 kPa or -60 kPa), the program sent a signal to the solenoid valve to irrigate that treatment. The same signal also opened a solenoid on a pressurized fertilizer injector, to provide a metered flow of either polyacrylamide plus calcium nitrate solution or a urea solution into the irrigation water. Irrigation duration with one tape per double row of plants was 3 hrs and the duration with 2 tapes was 1.5 hrs. Each irrigation added 0.106 acre-in/acre regardless of irrigation criteria or tape configuration.

Petioles were sampled June 14 and June 30 and analyzed for nitrate. Petioles sampled on July 14 had complete nutrient analysis. Separate samples were taken from all replicates of plots receiving nitrogen in the form of urea or calcium nitrate. Aerial application of fungicide on July 19 included 0.2 lb/acre Zn, 0.25 lb/acre Mn, and 0.1 lb/acre Cu, as indicated by the July 14 petiole test.

On September 20, the potatoes in the 2-ft alleys were dug by hand, and the vines were flailed. On September 28-29, the tubers were lifted with a two-row digger. Observations of clods and dirt clinging to the tubers were recorded. The tubers were picked up by hand. On October 15, each sack of potatoes was weighed, then the potatoes were graded. At grading, a 20-tuber sample of US Number One tubers from each plot was placed into storage. Storage temperature was slowly lowered to 45 °F. On January 25-26, 2000, the specific gravity and fry color of 10 tubers from each sample were measured.

Results and Discussion

The petiole nitrate levels on June 14, averaged over irrigation treatments and tape placements, were 24,800 ppm with urea and 24,200 ppm with calcium nitrate with a sufficiency level of 24,400 ppm. On June 30, nitrate levels were 20,300 ppm with urea and 22,300 ppm with calcium nitrate with a sufficiency level of 18,300 ppm. On July 14, petiole nitrate levels were 15,700 ppm with urea and 26,500 ppm with calcium nitrate with a sufficiency level of 15,900 ppm. Although the design was to add the same amount of N of either form, total fertilizer added to the potatoes in the growing season was 120 lb N/acre with urea, and 145 lb N/acre with calcium nitrate. The preplant soil test showed 68 lb N/acre in the top two feet of soil. Statistical analysis showed a significant effect from the fertilizer factor only for 4 to 6 oz tubers, with 95 cwt/acre of 4 to 6 oz tubers with the calcium nitrate, compared to 109 cwt/acre with urea. The fertilizer factor was omitted from the model for subsequent analysis. The petiole response and lack of tuber yield and quality differences by N source demonstrates the feasibility of using the drip irrigation system to supply all N fertilizer for potato production.

The yield, grade categories, and tuber processing quality responded to the irrigation levels and number of drip tapes (Table 1). Percent US Number One tubers averaged 73.7 percent overall, and was significantly higher in treatments with two drip tapes or with -30 kPa irrigation set point. Two drip tapes and -30 kPa set point also significantly increased total yield, and the yield of Number One tubers and Number One tubers over 12 oz. The drip tape x irrigation criteria interaction was not significant for Number One tubers over 12 oz. Two tapes per bed or a -30 kPa set point produced significantly more 6- to 12-oz Number One tubers, but the treatment interactions were not significantly different. Two tapes produced slightly more 4- to 6-oz Number One tubers,

-60 kPa produced slightly more tubers under 4 oz, and one tape per two rows of potato plants produced more US Number Two tubers. Yield of cull tubers was higher at the -30 kPa set point, and none of the treatments differed significantly in the amount of rotten tubers.

Potato processing quality, as measured by fry color and specific gravity, were not influenced, with the exception of slightly lighter bud end fry color for tubers grown with two drip tapes.

Sacks of tubers were weighed for gross weight before they were dumped onto the grading table and tare dirt (the soil clinging to the tubers that was knocked off during grading) was significantly more in treatments with two drip tapes. Tubers with soil clinging to them were counted during grading, and no significant differences were found. At harvest, the tubers and soil were evaluated visually on a scale from 0 to 5 for soil on the tubers, and from 0 to 10 for cloddiness of the soil in the beds. More soil was observed on tubers with two drip tapes or a -30 kPa set point, and more clods were seen in plots with one drip tape.

Automated, high-frequency drip irrigation resulted in less water applied than the US Bureau of Reclamation AgriMet estimate of potato crop evapotranspiration (Et_c) for potatoes emerging May 25 at Ontario (Figure 1). The applied water plus rainfall in most treatments followed along with the AgriMet estimate of Et_c, getting further behind as the season progressed. Where only 1 drip tape serving two rows of potatoes and -60 kPa irrigation set point was used, the applied water fell sharply behind Et_c; on average only 10.6 acre-in/acre had been applied by August 30, while Et_c accumulated 23.7 acre-in/acre. Total rainfall during the potato growing season added only 1.16 in of applied water. The two N treatments with a -30 kPa set point and two drip tapes per bed applied on average 18.1 acre-in/acre of water, which may be closer to the actual Et_c for drip irrigated potato. Buried drip irrigation does not wet the soil surface as much as sprinkler or furrow irrigation, so the evaporation component of Et_c should be less for subsurface drip irrigation.

Comments

Drip irrigation is not recommended to growers at the present time, given the relatively high cost of drip irrigation systems, the relatively low value of potatoes for processing, and the lack of knowledge of how to make the best use of a drip irrigation system in potato production.

Irrigating at -30 kPa was more productive than at -60 kPa, so it appears that the potato irrigation criteria for drip systems may be wetter than for furrow or sprinkler systems on silt loam in Malheur County. The ideal irrigation point could be determined through further testing. The use of only one tape for every two rows of potato plants was less productive than placing a tape down every row. It remains to be seen if one tape could effectively irrigate two rows of potato plants if the irrigation criteria was wetter than -30 kPa. One tape for two rows of potatoes would save money in terms of expenditures for tape. The silt loam used in this trial had 0.5 percent free calcium, so the free calcium may have limited any benefit that calcium nitrate could have had over urea. The addition of PAM failed to reduce cloddiness or soil stuck to the tubers.

References

Shock, C.C., J. M. Barnum, and M. Seddigh. 1998. Calibration of Watermark soil moisture sensors for irrigation management. Proc. Irrigation Assoc., 139:146.

Table 1. The effect of drip tape number and irrigation criteria, and their interaction, on Umatilla Russet yield and quality. Malheur Experiment Station, 1999, Oregon State University, Ontario, Oregon.

				Yield by Grade						
Drip tape	US Number One	Total yield	Marketable	Total US Number One	Over 12 oz	6 to 12 oz	4 to 6 oz	Under 4 oz	US Number Twos	Culls
	percent	----------	----------	----------	----------	cwt/acre	----------	----------	----------	----------
1 tape	70.9	455.9	362.1	324.9	42.4	190.5	92.1	86.7	37.2	6.7
2 tapes	76.5	535.0	433.4	410.0	56.0	243.1	110.8	91.6	23.5	9.4
LSD (0.05)	2.0	22.9	21.2	19.2	12.5	15.9	9.8	NS	6.4	NS
Irrigation set point										
-30 kPa	75.8	523.7	427.8	397.3	60.3	235.7	101.3	84.6	30.5	10.5
-60 kPa	71.6	467.3	367.7	337.5	38.0	197.9	101.6	93.7	30.2	5.6
LSD (0.05)	2.0	22.9	21.2	19.2	12.5	15.9	NS	8.9	NS	3.7
Tape x irrigation interaction										
1 x-30 kPa	74.2	498.3	409.4	369.6	61.4	216.8	91.4	78.8	39.8	9.6
1 x-60 kPa	67.6	413.5	314.8	280.2	23.3	164.2	92.8	94.6	34.6	3.8
2 x-30 kPa	77.4	549.1	446.2	425.1	59.3	254.7	111.2	90.4	21.1	11.4
2 x-60 kPa	75.7	521.0	420.6	394.8	52.7	231.6	110.5	92.7	25.8	7.4
LSD (0.05)	2.9	32.4	29.9	27.1	17.7	NS	NS	NS	NS	NS
Mean	73.7	495.5	397.8	367.4	49.2	216.8	101.5	89.1	30.3	8.0

Table 2. The effect of drip tape number and irrigation criteria, and their interaction, on Umatilla Russet characteristics. Malheur Experiment Station, 1999, Oregon State University, Ontario, Oregon.

	Rot	Gross	Tare dirt	[1]Dirty tubers	[2]Tuber dirt	[3]Clods	Spec. gravity	Stem	Bud	Avg fry
Drip tape	---------cwt/acre---------			avg./ plot	visual score		g cm^{-3}	-----% reflectance------		
1 tape	0.4	458.9	3.0	0.6	1.6	7.9	1.0880	44.1	47.7	45.9
2 tapes	0.7	545.3	10.3	2.3	3.2	6.7	1.0865	44.6	48.6	46.6
LSD (0.05)	NS	22.2	4.1	NS	0.49	0.72	NS	NS	0.9	NS
Irrigation set point										
-30 kPa	0.8	531.1	7.4	1.1	2.85	6.95	1.0871	44.2	48.3	46.2
-60 kPa	0.3	473.1	5.8	1.8	1.95	7.65	1.0873	44.5	48.0	46.3
LSD (0.05)	NS	22.2	NS	NS	0.49	NS	NS	NS	NS	NS
Tape x irrigation interaction										
1 x-30 kPa	0.6	502.8	4.4	0.7	2.2	7.5	1.0878	44.0	48.2	46.1
1 x-60 kPa	0.3	415.0	1.5	0.4	1	8.3	1.0882	44.2	47.2	45.7
2 x-30 kPa	1.1	559.5	10.5	1.4	3.5	6.4	1.0865	44.4	48.4	46.4
2 x-60 kPa	0.2	531.1	10.1	3.2	2.9	7	1.0865	44.9	48.8	46.8
LSD (0.05)	NS	31.3	NS	NS	NS	NS	NS	NS	NS	NS
Mean	0.5	502.1	6.6	1.425	2.4	7.3	1.0872	44.4	48.1	46.2

[1]Dirty tubers were counted at grading.

[2]Tuber dirt was scored on a 0 to 5 scale at harvest.

[3]Clods were scored on a 0 to 10 scale at harvest.

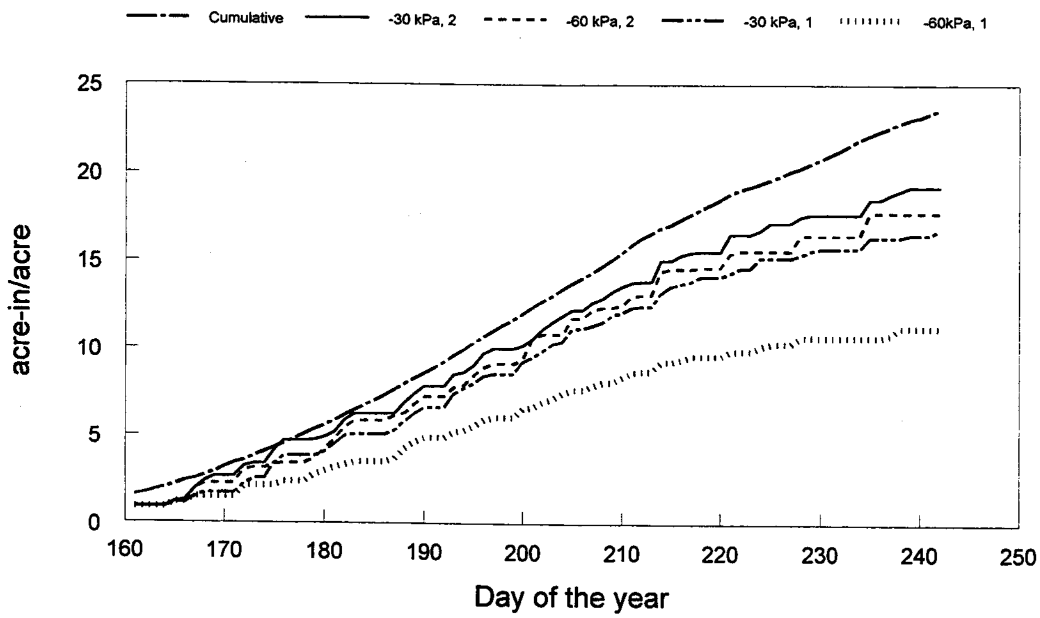

Figure 1. Comparison of cumulative potato evapotranspiration to the cumulative rainfall plus water applied by four different drip irrigation treatments. Irrigation criteria were soil water potentials of -30 or -60 kPa using either a drip tape in every bed (2 tapes per 2 beds) or a single tape to irrigate two beds. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1999.