IRRIGATION SYSTEMS AND BED CONFIGURATION INFLUENCE POTATO PERFORMANCE

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Introduction

Methods of irrigation used in potato production must ensure adequate and uniform application of water with minimum losses, such as deep percolation and runoff. Maintenance of a proper balance between soil water and soil air in the root zone for ideal root and tuber growth can be achieved by careful management of irrigation scheduling with properly designed furrow-, sprinkler-, and drip-irrigation systems.

Surveys of growers in the Treasure Valley of southeastern Oregon and southeastern Idaho indicated that 'Russet Burbank' tends to produce better quality tubers under sprinkler irrigation than with furrow irrigation (Shock et al. 1989, Trout et al. 1994). Shock conducted two replicated plot trials and two field demonstrations in growers' fields and Trout et al. (1994) carried out irrigation plot studies over 3 years on two sites to determine if the differences observed between sprinkler and furrow irrigation were an inherent result of the irrigation method. With precise irrigation scheduling, irrigation method did not affect yields, but sprinkler irrigation produced tubers with slightly better grade and much lower incidence of sugar ends.

Although potato is still most often irrigated using sprinkler irrigation, drip systems are used in potato production in a few areas where water is in short supply. Sammis (1980) compared sprinkler, surface drip, subsurface drip, and furrow irrigation for the production of potato and lettuce in New Mexico. The subsurface drip system with an irrigation criterion, meaning the point at which the next irrigation must be applied, corresponding to a soil water tension (SWT) of 20 kPa was the most productive among the irrigation systems assessed.

Shock et al. (2002) investigated the performance of 'Umatilla Russet' under drip irrigation in silt loam. The factors considered in the study were tape placement (one tape per row or one tape per two rows) and four SWT levels for automatically starting irrigation (15, 30, 45, and 60 kPa). Tape placement and irrigation criterion interacted to influence total yield, total marketable potatoes, and U.S. No. 2 yield. Results from this study indicated that potato should be irrigated at 30 kPa SWT, given the silt loam soil and 2.5 mm water applied at each irrigation. Eldredge et al. (1996) and Shock et al. (2002) determined that the ideal potato SWT irrigation criterion for furrow and sprinkler irrigation was 50-60 kPa on silt loam in the Treasure Valley.
Over the last 4-5 years, drip-irrigated potato trials carried out at the Malheur Experiment Station (MES) have shown reasonable tuber yields and grade (Shock et al. 2002, 2004,

2005; Akin et al. 2003). Although potato production normally uses hilled planting, our drip-irrigated trials have used flat beds. The flat beds have been used by preference, since we have studied the relative lateral placement of potato rows and drip tapes (Shock et al. 2002, 2004, 2005) along with other variables. If growers were to adopt drip irrigation, it would be more convenient if they could use drip irrigation in normal hilled beds.

Consequently, in 2004 hilled beds for sprinkler- and drip-irrigated potatoes were compared with flat beds with drip-irrigated potatoes (Shock et al. 2005). Potatoes planted in flat beds with one drip tape above the rows were more productive and of better quality than drip-irrigated potatoes grown in conventional beds. These results led us to propose that part of the benefits in potato quality observed with drip irrigation at Ontario over the past years might be associated with flat bed configuration and not with drip irrigation alone, per se.

Midmore et al. (1986) showed that mulch increased tuber yield by 20 percent during the summer in Peru. In the same country, Manrique and Meyer (1984) studied the impact of mulch on potato production during winter and summer seasons and found no effect on yields during the winter, but observed yield increases of 58 percent and improvements in soil moisture retention in the summer with surface mulch. Mahmood et al. (2002) reported that the use of mulch in Pakistan decreased daily maximum soil temperature at 6-inch depth, resulting in faster emergence, earlier canopy development, and higher tuber yields.

Since tuber yield and grade are affected by soil water status and heat stress, the main goal of this research was to investigate whether irrigation systems, irrigation criteria, bed configuration, and use of straw mulch can generate differences in soil temperature regime around the developing tubers, and quantify the influence of such management practice factors on the performance of six potato cultivars grown during the crop season of 2005 at Ontario, Oregon.

Materials and Methods

Six irrigation and bed configuration treatments were chosen to try to use irrigation system, bed design, irrigation criteria, and straw mulch to reduce soil temperature, as described below:

T_1 – Sprinkler irrigation, potato seeds planted in ordinary beds (rows bedded into 36-inch hills), with irrigation starting whenever the SWT was equal to 60 kPa;
T_2 – Drip irrigation, potato seeds planted in flat beds, with irrigation criterion based on a SWT of 30 kPa, with the expectation that the total irrigation amounts would correspond to about 70 percent of crop evapotranspiration (ET_c);
T_3 – Drip irrigation, potato seeds planted in flat beds, with daily irrigation matching ET_c;
T_4 – Furrow irrigation, seeds planted in ordinary beds, with irrigation starting when SWT reached a threshold of 60 kPa;
T_5 – Sprinkler irrigation, seeds planted flat in 36-inch rows, irrigation criterion of 60 kPa, and with irrigation amounts to match ET_c;

T_6 – Sprinkler irrigation, seeds planted flat in 36-inch rows, with irrigation starting at a SWT of 60 kPa, soil receiving 2,000 lb/acre of straw mulch at tuber initiation (on June 6), and irrigation amounts to match ET_c.

Procedures in 2005

All 6 treatments were replicated 7 times and the experimental design was split plot in a randomized complete block design, with a total of 42 plots and 252 subplots for 6 varieties.

The soil preparation for this trial differed from our usual practices. The soil was too wet to work or fumigate in the fall of 2004. Vapam® was applied at 75 gal/acre via sprinklers on March 3, 2005 and the field was spring bedded in April prior to planting. The summer weather pattern in 2005 was similar to 2004 and also similar to the 10- and 60-year averages.

Six potato cultivars ('Russet Burbank', 'Ranger Russet', 'Umatilla Russet', 'GemStar Russet', 'A92294-6', and 'A93157-6LS') were planted on April 19, 2005 in 42 12-ft-wide strips, each 90 ft long at MES, Oregon State University, in Ontario, Oregon. The planted harvest area of each cultivar was 30 seed pieces long.

Potato seed pieces (45 g) were treated with Tops-MZ® plus Gaucho® dust 1-2 weeks before planting, and then planted using a 2-row cup planter with 9-inch seed spacing in 36-inch rows. Planting depth was adjusted to plant the seed in each flat bed plot deeper than the seed was planted in each hilled treatment plot. After planting, hills were formed over the rows with a Lilliston rolling cultivator for the hilled treatment and a bed harrow for the flat bed treatments. Prowl® at 1 lb/acre plus Dual® at 2 lb/acre herbicide was applied as a tank mix for weed control on May 2 and was incorporated by 1.7 inch of rain over the following 10 days.

The soil temperature was measured continuously throughout the growing season in every plot at 4-inch depth below the surface in the plant row among the developing tubers using Hobo soil thermometers and dataloggers. Twelve of the plots had two additional temperature sensors at 4- and 8-inch depth on NASA SensorWeb Pods (NASA Jet Propulsion Lab, Pasadena, CA). Four pods were located in each of the sprinkler-, drip-, and furrow-irrigated potato plots.

The SWT was measured by granular matrix sensors (GMS, Watermark soil moisture sensors model 200SS, Irrometer, Co., Riverside, CA) at six locations in every plot at 8-inch depth below the surface in the plant row. Sensor data were read automatically using CR10 and 21X dataloggers and multiplexers (Campbell Scientific, Logan, UT). The GMS had been previously calibrated to SWT using tensiometers fitted with pressure transducers (Shock et al. 1998).

Irrigation episodes were scheduled to avoid SWT in the root zone exceeding the threshold of 30 kPa under the drip system for treatments 2 and 3, and of 60 kPa under furrow- and sprinkler-irrigation systems for treatments 1, 4, 5, and 6. Crop evapotranspiration (ET_c) was estimated by an automated AgriMet (U.S. Bureau of Reclamation, Boise, ID) station located about 0.25 miles from the trial on the Malheur Experiment Station.

Fungicide applications to control early blight and prevent late blight infection started with an aerial application of Ridomil Gold® and Bravo® at 1.5 pt/acre on June 13. On June 18, Endura® plus Dithane® was applied; on June 28, Dithane fungicide plus liquid sulfur with 6 lb phosphate (P_2O_5)/acre was applied on June 28. Bravo was applied again on July 20 and September 6. Dithane plus Tanos® was applied July 28. To prevent two-spotted spider mite and powdery mildew infestation, 6 lb sulfur (S)/acre was applied on August 20.

Petiole tests were taken from Russet Burbank plants every 2 weeks starting on June 13 for the sprinkler-, furrow-, and drip-irrigated potatoes. Potatoes in each irrigation system received nutrients in accordance with the petiole analyses. A total of 100 lb nitrogen (N)/acre, 40 lb P_2O_5/acre, 20 lb potash (K_2O)/acre, 30 lb sulfate (SO_4)/acre, 3.5 lb magnesium (Mg)/acre, 0.55 lb zinc (Zn)/acre, 0.8 lb manganese (Mn)/acre, 0.05 lb copper (Cu)/acre, 0.1 lb iron (Fe), and 0.02 lb boron (B)/acre was applied via drip irrigation system. The furrow-irrigated potatoes received 100 lb N/acre, 30 lb P_2O_5/acre, 10 lb SO_4/acre, 10 lb Mg/acre, 0.25 lb Zn/acre, 0.5 lb Mn/acre, and the sprinkler-irrigated potatoes received 100 lb N/acre, 50 lb P_2O_5/acre, 20 lb K_2O/acre, 4.5 lb SO_4/acre, 5 lb Mg/acre, 0.3 lb Zn/acre, 0.55 lb Mn/acre, 0.05 lb Cu/acre, 0.1 lb Fe/acre, and 0.02 lb B/acre.

Procedures in 2006

All 6 treatments were replicated 5 times and the experimental design was split plot in a randomized complete block design, with a total of 30 plots and 180 subplots for 6 varieties. More temperature sensors were used in 2006.

Procedures both years

Four potato cultivars ('Russet Burbank', 'Ranger Russet', 'Umatilla Russet', and 'A93157-6LS') were planted both years.

Vines were flailed in late September and tubers were harvested on October from each replicate, and graded by the U.S. No. 1 and No. 2 for processing standards, sorted by weight, and weighed in each size category. Specific gravity and length-to-width ratio were measured using a sample of 10 tubers. Stem and bud ends fry color was measured from a sample of 20 tubers frying in 375°F soybean oil for 3.5 minutes from each cultivar of every irrigation plot. Fry colors were read using a Photovolt Reflectance Meter model 577 (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. Visual evaluations included observations of desirable traits, such as a high yield of large, smooth, uniformly shaped and sized, oblong to long, attractively russeted tubers, with shallow eyes evenly distributed over the tuber length.

Data were analyzed with the General Linear Models analysis of variance procedure in NCSS (Number Cruncher Statistical Systems, Kaysville, UT) using the Fisher's Protected LSD means separation t-test at the 95 percent confidence level.

Results and Discussion

Irrigation systems and hilled rows made clear differences in potato performance among the cultivars studied. The drip-irrigation systems were the most conducive to the production of U.S. No. 1 tubers and the furrow-irrigation system was the least conducive (Table 1). Furrow irrigation was the least productive system tested. There was a tendency for flat beds to be advantageous compared to hilled rows. Not all of the statistical comparisons have been made.

None of the varieties tested expressed hollow heart, brown center, internal brownspot, or vascular discoloration in any of the irrigation treatments. The absence of these internal defects is commonplace for potato grown at MES.

The experimental line A93157-6LS was highly productive in every management system and averaged 76 percent U.S. No. 1 tubers. A93157-6LS produced U.S. No. 1 tubers under drip irrigation, regardless of the irrigation criteria adopted (data not shown).

Under drip irrigation, total yields were higher with drip irrigation and full ET_c than with drip irrigation using SWT; however, irrigation by SWT resulted in a greater proportion of U.S. No. 1 tubers and a less production of U.S. No. 2 tubers. Therefore, the application of full ET_c for drip-irrigation systems may not be needed to maximize potato productivity or optimize crop water use. Firm conclusions will have to wait for the evaluations of how much water was actually applied to each treatment.

As to mulching, there was a tendency for the straw mulch treatment to be advantageous compared to non-strawed potatoes, but the differences were not statistically significant. Nevertheless, further statistical analyses, taking into consideration soil temperature and moisture, need to be made to allow for more consistent inferences on the beneficial effect of mulching for potato production at Ontario. One result is clear: tubers from Umatilla Russet and A93157-6LS sprinkler-irrigated mulched rows planted flat were smoother than tubers from conventional sprinkler-irrigated hilled rows without mulch.

Thinking outside of conventional wisdom at the beginning of this project, we asked a series of questions:

a. Would it be possible to use sprinkler irrigation in such a way to reduce the heat load to developing tubers compared with conventional furrow irrigation? The answer to this question is apparently yes. But sprinkler irrigation does not seem to be as important as the shape of the hills.

b. Could potato be planted flat rather than bedded in "hills", so that the average tuber would be deeper from the surface? A flat bed might heat slower than a corrugated bedded hill soil surface. Would the deeper planting and flatter surface lead to cooler peak soil temperature around the developing tubers? Flatter beds appeared to result in cooler tubers and better quality tubers. The conventionally hilled soil tended to get hotter regardless of the irrigation system, but the soil in the conventionally hilled furrow irrigation system was hottest.

c. Could mechanically applied straw mulch moderate peak soil temperatures at tuber depth? Probably yes, but the effect is small and less than cooling contribution of the shape of the bed alone. Straw was of only modest benefit in reducing soil temperature. A heavier straw application would probably have been required to significantly lower maximum temperatures and heat load.

d. Would sprinkler irrigation, flat planting, and straw mulch interact to cool the temperature environment around developing tubers? If so, would the cooler soil temperatures be beneficial to the tubers? Yes. The cooler beds were beneficial to tuber quality. But the main effect seems to have been the bed shape. Sprinkler-irrigated potatoes had cooler soil temperatures when planted in flat beds.

e. So what about potato quality? Potato yields and tuber quality from the flat beds (treatments with cooler soil temperatures) tended to be improved compared to the conventionally hilled beds, over all potato varieties tested. But soil temperature is not all that is going on, since potatoes irrigated modestly by drip using a soil water tension (SWT) criterion were excellent (Table 1).

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Table 1. Potato tuber yield and quality in response to six irrigation and bed configuration treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 2005 and 2006.

Treatments	Total yield	Total marketable	Yield by grade category U.S. No. 1	Total No. 1	>12 oz	6-12 oz	4-6 oz	U.S. No. 2	<4 oz	Cull	Rot	Specific gravity	Fry color Stem end	Bud end	Average
	--------cwt/acre------		%	----------------------------cwt/acre----------------------------								g cm^{-3}	---% light reflectance---		
Russet Burbank	621	34	50	109	53	212	239	450	71	74	25	1.0806	33	43	38
Ranger Russet	553	62	50	159	130	339	136	475	50	25	3	1.0969	44	45	45
Umatilla Russet	519	62	52	160	108	319	121	440	55	18	5	1.0930	47	47	47
A93157-6LS	603	76	60	220	175	455	89	545	45	10	3	1.0945	46	45	46
Means overall	574	58	53	162	116	331	146	478	56	32	9	1.0913	43	45	44
LSD (0.05)	25.1	3.0	6.2	14.9	16.7	24.1	16.1	26.7	5.7	7.7	6.7	0.0022	1.0	0.7	0.7
Sprinkler, hilled	580	56	49	160	109	318	163	481	58	27	14	1.0907	42	45	44
Drip, flat bed, SWT	562	66	69	180	124	373	96	468	59	27	7	1.0922	44	46	45
Drip, flat bed, ET	596	59	60	173	124	356	124	481	63	49	5	1.0917	44	45	44
Furrow, hilled	526	52	49	141	73	264	174	437	50	28	11	1.0913	40	44	42
Sprinkler, flat bed	581	57	45	156	127	328	163	490	54	31	6	1.0913	43	45	44
Sprinkler, flat, straw	597	60	46	161	143	351	157	508	48	29	12	1.0905	43	46	44
Means overall	574	58	53	162	116	331	146	478	56	32	9	1.0913	43	45	44
LSD (0.05)	32.9	3.6	7.0	15.0	19.3	27.3	24.3	34.3	8.4	12.6	NS	NS	1.4	1.2	1.2
2005 Sprinkler, Hilled	651	49	46	152	121	319	233	551	78	7	14	1.0866	44	45	45
2005 Drip, Flat bed, SWT	618	71	62	201	176	439	119	558	59	1	1	1.0880	43	43	43
2005 Drip, Flat bed, ET	662	67	57	209	178	444	147	591	62	9	1	1.0900	44	43	44
2005 Furrow, Hilled	567	47	44	129	94	267	228	495	57	5	9	1.0920	42	44	43
2005 Sprinkler, Flat bed	654	52	49	163	132	344	229	572	73	8	1	1.0887	44	44	44
2005 Sprinkler, Flat, Straw	670	55	46	158	159	363	233	596	65	8	1	1.0882	44	45	45
Means 2005	637	57	51	169	143	363	198	560	65	6	5	1.0889	44	44	44
2006 Sprinkler, hilled	510	64	51	169	97	317	94	411	39	46	14	1.0948	40	46	43
2006 Drip, flat bed, SWT	506	61	77	159	71	307	72	379	60	53	14	1.0963	45	49	47
2006 Drip, flat bed, ET	531	51	63	136	69	268	102	371	64	88	9	1.0934	43	47	45
2006 Furrow, hilled	486	56	54	154	52	260	120	379	43	52	12	1.0905	38	44	41
2006 Sprinkler, flat bed	509	62	42	149	122	312	97	409	36	55	10	1.0938	41	46	44
2006 Sprinkler, flat, straw	524	66	46	165	126	338	82	419	32	50	22	1.0927	41	47	44
Means 2006	511	60	56	155	89	300	94	395	46	57	14	1.0936	42	46	44
LSD (0.05) Year	30.8	2.9	5.2	NS	25.3	NS	18.8	40.0	6.1	4.6	NS	0.0037	NS	0.5	NS
LSD (0.05) Year x tmt	NS	5.0	NS	21.3	27.3	38.6	34.4	NS	11.9	17.8	11.1	0.0040	2.0	1.7	1.7
LSD (0.05) Year x cltvr	NS	4.2	NS	NS	23.5	34.0	22.8	NS	8.1	10.9	9.4	0.0031	1.4	NS	1.0
LSD (0.05) Tmt x cltvr	NS	7.3	15.2	36.4	NS	59.0	39.5	NS	NS	18.9	16.4	0.0054	NS	NS	NS