IMPROVED NITROGEN AND IRRIGATION EFFICIENCY FOR POTATO PRODUCTION

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Summary

Management alternatives for reducing N fertilizer and irrigation water application rates were tested for furrow irrigated potatoes in replicated half acre plots. Potato yield, grade, and quality were maintained with a reduction of N fertilizer application below commercial and university recommendations, with a reduction in applied water using surge irrigation, and with the combination of both practices. Nitrogen fertilizer costs were reduced and the risks of nitrate leaching were reduced without sacrificing gross income.

Introduction

Previous small plot research at the Malheur Experiment Station has demonstrated the effectiveness of using greatly reduced nitrogen fertilizer inputs for optimum potato production. The N rates achieving maximum potato yield in these experiments were substantially lower than the Oregon or Idaho fertilizer guide recommendations, irrespective of whether the potatoes were irrigated by sprinklers or furrow.

Irrigation scheduling according to soil water potential measurements and water applications according to evapotranspiration calculations have also thoroughly tested here.

Surge irrigation is a tool that can be used to improve the water application efficiency of furrow irrigation. In surge irrigation, water is applied to an irrigation furrow intermittently during an irrigation set, whereas in continuous-flow (or conventional) irrigation, water is applied to the furrow during the entire irrigation set. With surge irrigation, a switch valve, commonly referred to as a surge valve, is used to repeatedly cycle water from one half of the field to the other half. Total water application can be reduced substantially with the use of surge irrigation. Previous research at the Malheur Experiment Station with wheat and onions has demonstrated the effectiveness of surge irrigation in reducing water applications while maintaining crop yield and quality equivalent to conventional furrow irrigation.

The reduced water applications with surge irrigation could result in a reduction of nitrate leaching and the need for applied nitrogen. This trial compared potato production with conventional and reduced N inputs under either conventional furrow irrigation or surge irrigation in field scale plots. Plots were 0.5 acres each with 600-foot long irrigation runs. The intent was to investigate the interaction between reduced nitrogen fertilizer and reduced water inputs on crop yield and quality. Further studies not reported here examined the fate of nitrogen and water moving across the field.

Procedures

The 1995 trial was conducted on a Greenleaf silt loam previously planted to wheat at the Malheur Experiment Station. The field was fumigated with 19 gals/ac of Telone II and bedded into 36-inch hills in the fall of 1994. A soil sample taken from the top foot on May 1, 1995 showed a pH of 7.6, 1.4 percent organic matter, 19 meq per 100 g of soil cation exchange capacity, 4 ppm nitrate-N, 7 ppm ammonium-N, 14 ppm phosphorus, 178 ppm potassium, 1748 ppm calcium, 256 ppm magnesium, 340 ppm sodium, 0.7 ppm zinc, 4.4 ppm iron, 4.1 ppm manganese, 0.7 ppm copper, 13 ppm sulfate-S and 0.7 ppm boron.

The experimental design had the irrigation and nitrogen fertilizer treatments as main plots with a half acre per plot replicated three times (Table 1), These main plots were 12 rows wide and 600 feet long. The top, middle, and bottom down the 600 feet of irrigation run in each main plot were handled as separate parts of the field for sampling purposes, and seven potato varieties as split-plots within the sampling areas (Table 2). The seven varieties were planted in 50 foot long rows in the top , middle, and bottom of each plot within the sampling area.

The Oregon fertilizer guide recommended 270 lb N/ac (210 lb N/ac based on the preplant soil analyses plus 60 lb N/ac for 3 tons of wheat residue) and the Idaho fertilizer guide recommended 255 lb N/ac (210 lb N/ac based on the preplant soil analyses plus 45 lb N/ac for 3 tons of wheat residue) for this site. A potato processing company and a soil fertility lab each recommended 300 lb N/ac based on the residual soil nitrate and ammonium and the cropping history. Consequently 300 lb N/ac was used as the recommended nitrogen fertilizer rate.

Table 1. Irrigation and N management treatments used to demonstrate the possibility of reduced inputs. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1995.

Treatment	Irrigation type	Pre-emergence N (May 19) lb N/ac	Post-emergence "water run" N lb N/ac	Total N applied lb N/ac
1	Alternating furrow	200	100**	300
2	Alternating furrow	120	30***	150
3	Alternating surge	200	100**	300
4	Alternating surge	120	30***	150

**July 13 ***July 31

Two-ounce seed pieces of Shepody potatoes were planted May 3 at 9-inch spacing except for small areas planted to six other varieties in three parts of each main plot. On May 19, Thimet 20G at 3 lbs ai/ac was shanked-in along with urea for the pre-emergence nitrogen (Table 1). The urea was applied to both sides of the hill (Figure 1). The shanks were adjusted to place the urea in bands located at the same depth as the seed piece and offset 9 inches from the hill center. The hills were remade with a Lilliston cultivator. The herbicides Prowl at 1 lb ai/ac and Dual at 2 lbs ai/ac were broadcast on the entire soil surface on May 23 and incorporated with the Lilliston. A late blight and insect control program consisting of weekly aerial applications of fungicide and insecticide mixes was initiated on July 14 and continued through August 26.

Gated pipe was arranged to permit all 12 plots to be irrigated simultaneously. A Waterman Model LVC-5 surge valve automatically oscillated water from three of the surge irrigation plots to the other three surge irrigation plots. The valves on the gated pipe were adjusted to deliver the same flow rate to all furrows in the surge and conventional irrigation systems.

Six granular matrix sensors (GMS, Watermark Soil Moisture Sensors Model 200, Irrometer Co., Riverside, CA) were installed in the top foot of soil and three GMS were placed in the second foot of soil in each plot. The GMS in the top foot of soil were offset 6 inches from the hill top and centered 8 inches below the hill surface and the second foot GMS were placed in the hill center and centered 20 inches below the hill surface. Half of the first foot sensors were located on the wheel traffic side of the potato hill and the other half were located on the non-wheel traffic side of the hill. Sensors were read five times per week from June 10 to September 4 at close to 8 AM. Irrigations were started when the average soil water potential in the first foot of soil dried to -50 kPa. All the surge plots or all the conventional furrow irrigation plots were irrigated separately as needed to maintain the soil water potential wetter than -60 kPa.

At each irrigation, every other furrow was irrigated, with the irrigated furrows alternating from irrigation to irrigation. Seventeen irrigations were used from June 12 to September 1. Irrigation durations were 24 hours from June 12 through July 17 and 12 hours from July 17 through September 1.

Petiole samples were collected from Shepody plants in top, middle and bottom of each plot every two weeks from June 21 to August 16, and analyzed for nitrate. Tubers from 40 feet in the top, middle and bottom of each plot were harvested on September 26 and evaluated for yield and grade. A subsample was stored and analyzed for tuber specific gravity and stem-end fry color in early November.

The soil was sampled in one-foot increments down to six feet in each plot before planting and after harvest and analyzed for nitrate and ammonium. The N balances were calculated by subtracting the post harvest accounted nitrogen (crop N uptake plus available soil N after harvest) from the nitrogen supply (available soil N in spring plus fertilizer N plus N from irrigation water plus N from organic matter mineralization). Nitrogen contribution from the irrigation water was estimated to be 1.4 lb N/ac-inch/ac of water infiltration. Nitrogen contribution from organic matter mineralization was estimated by anaerobic incubation at 104 °F for 7 days.

Results and Discussion

Conventional furrow irrigated plots required 15 irrigations totaling 304 hours and surge irrigated plots required 21 irrigations totaling 388 hours. The actual duration of water applications with surge irrigation would be half of that for conventional irrigation. Actual water applications were 304 hours for conventional irrigation and 194 hours for surge irrigation (a 36 percent reduction in applied water). Soil water potential at 8-inch depth remained drier during the season in the surge irrigated plots than in the furrow irrigated plots (Figure 2). Since the depth of the water in the furrows during surge irrigation oscillates, the amount of time during which the irrigation can effectively wet the hill is reduced in surge irrigation compared to conventional furrow irrigation.

There was no significant difference in tuber yield or grade between treatments over all varieties (Tables 2 and 3, Figure 4). There was no significant difference in tuber specific gravity or fry color between treatments over all varieties (Table 4). The varieties responded similarly to the treatments. COO83008-1 had the lightest frying tubers averaged over all treatments. Ranger Russet, AO82611-7, and COO83008-1 had the highest tuber specific gravity.

Petiole nitrate levels over time did not differ between the furrow and surge irrigated plots (Figure 3). Petiole nitrate remained in the excessive range (Jones and Painter, 1974) after July 20 in the high N plots. Petiole nitrate became inadequate on July 27 and deficient on August 3 in the low N plots.

Tuber yield was just as high with 150 lb N/ac as with 300 lb N/ac. Perhaps the banding of the N fertilizer after planting improves the fertilizer use efficiency compared to broadcast applications. When broadcast applications are used, substantial amounts of N can be lost to leaching, lost to volatilization, or be located in tops of the potato hill that are inaccessible to the roots. Alternating furrow irrigation also reduces the amount of water applied and could reduce nitrate leaching, leaving more N available to the plants and greater residuals for the following year.

Rainfall events during the 1995 season provided substantially more water at several times in June and July than the crop required, and estimated nitrogen balances for the season were understandably negative (Tables 5 and 6). Reduced N application was associated with lower calculated nitrate leaching losses.

Conclusions

Nitrogen fertilizer savings were achieved with either conventional or surge irrigation of potatoes without compromising tuber yield or grade. Banding of the nitrogen fertilizer after planting may result in better uptake efficiency and reduced losses compared to broadcast applications. Potatoes were grown with surge irrigation with tuber yield and quality comparable to conventional furrow irrigation and with substantially less water applied during the season. Further research to determine the appropriate furrow or hill shape to be used with surge irrigation could result in more effective wetting of the hills and in a reduction of the number of irrigations necessary.

Literature cited

Jones, J.P. and Painter, C.G., 1974. Tissue analysis: A guide to nitrogen fertilization of Idaho Russet Burbank Potatoes. University of Idaho, College of Agriculture, Cooperative Extension Service, Agricultural Experiment Station, Current information series # 240, June 1974.

Table 2. Influence of reduced N application and surge irrigation on the tuber yield and grade of seven potato varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.

Variety	Irrigation type	N rate	Potato yield by market grade										
			US Number One				US Number Two				Marketable	Undersize	Total yield
			4-6 oz	6-10 oz	>10 oz	total	4-6 oz	6-10 oz	>10 oz	total			
		lb N/ac	cwt/ac										
R. Burbank	Furrow	300	103.6	142.5	137.8	383.9	3.3	2.9	10.4	16.6	400.5	61.5	462.0
	Furrow	150	101.9	154.4	112.4	368.7	1.8	5.1	17.0	23.9	392.6	53.8	446.4
	Surge	300	79.5	146.5	102.9	329.0	3.0	5.6	13.0	21.6	350.5	59.2	409.7
	Surge	150	106.4	157.9	104.8	369.2	3.0	3.3	8.3	14.7	383.9	57.8	441.7
	Average		97.9	150.3	114.5	362.7	2.8	4.2	12.2	19.2	381.9	58.1	440.0
Shepody	Furrow	300	20.6	57.6	285.0	363.2	0.5	3.0	31.8	35.3	398.6	14.7	413.3
	Furrow	150	24.0	65.4	290.9	380.3	0.2	1.2	6.0	7.4	387.7	14.2	401.9
	Surge	300	20.9	59.9	300.1	380.9	0.9	2.6	18.8	22.3	403.2	14.7	417.9
	Surge	150	26.9	68.6	284.9	380.5	0.3	2.1	9.9	12.3	392.8	10.7	403.5
	Average		23.2	63.0	290.0	376.1	0.5	2.2	16.6	19.2	395.3	13.5	408.9
F. Russet	Furrow	300	79.8	108.1	139.2	327.1	0.3	3.5	9.0	12.8	339.9	59.4	399.3
	Furrow	150	55.3	117.5	132.9	305.8	0.1	0.9	5.3	6.4	312.1	44.5	356.7
	Surge	300	67.2	96.8	141.3	305.3	0.3	0.5	8.5	9.3	314.6	62.6	377.3
	Surge	150	92.6	129.0	106.7	328.4	0.6	2.5	7.1	10.2	338.6	59.9	398.5
	Average		73.7	112.9	130.1	316.6	0.3	1.8	7.5	9.7	326.3	56.6	382.9
R. Russet	Furrow	300	40.0	89.7	147.4	277.1	3.0	4.2	10.0	17.2	294.3	28.3	322.6
	Furrow	150	41.3	97.7	161.3	300.3	0.5	7.5	9.3	17.3	317.6	27.0	344.6
	Surge	300	51.9	95.6	167.9	315.4	1.3	2.4	15.1	18.8	334.2	29.3	363.5
	Surge	150	50.4	108.3	128.5	287.3	1.7	2.6	8.7	13.0	300.3	28.7	329.0
	Average		45.9	97.8	151.3	295.0	1.6	4.2	10.8	16.6	311.6	28.3	339.9
AO 82611-7	Furrow	300	62.6	116.1	187.6	366.3	1.6	2.6	9.8	14.0	380.2	38.4	418.6
	Furrow	150	56.5	119.1	186.5	362.0	0.6	3.0	6.8	10.4	372.4	32.5	404.9
	Surge	300	56.7	104.9	199.3	360.8	2.8	5.9	12.7	21.3	382.2	32.5	414.7
	Surge	150	57.3	103.1	149.7	310.1	0.4	2.6	9.4	12.5	322.5	31.3	353.8
	Average		58.3	111.3	182.8	352.4	1.4	3.6	9.7	14.7	367.1	33.8	401.0
COO 83008-1	Furrow	300	38.6	98.2	219.2	356.1	0.8	1.6	2.8	5.2	361.2	19.7	381.0
	Furrow	150	33.0	98.5	224.5	356.0	0.7	2.3	8.5	11.5	367.5	16.6	384.1
	Surge	300	24.4	77.9	276.0	378.2	0.4	1.5	10.6	12.5	390.7	14.0	404.7
	Surge	150	38.7	111.3	206.3	356.3	0.2	1.5	5.8	7.6	363.9	15.5	379.4
	Average		33.2	96.3	232.6	362.1	0.5	1.8	7.3	9.6	371.7	16.1	387.8
NDTX 8-731-1R	Furrow	300	56.5	114.1	228.5	399.1	0.0	0.0	0.0	0.0	399.1	29.9	429.0
	Furrow	150	54.2	146.1	238.7	439.0	0.0	0.0	0.0	0.0	439.0	28.3	467.3
	Surge	300	44.8	114.6	245.8	405.2	0.0	0.0	0.0	0.0	405.2	35.3	440.5
	Surge	150	59.1	121.0	227.2	407.2	0.0	0.0	0.0	0.0	407.2	31.7	438.9
	Average		54.2	123.6	234.2	412.0	0.0	0.0	0.0	0.0	412.0	31.3	443.4
All varieties	Furrow	300	58.6	104.1	188.7	351.5	1.5	2.7	11.4	15.6	367.1	37.2	404.3
	Furrow	150	52.4	112.8	190.0	355.2	0.6	3.0	7.9	11.5	366.7	31.2	397.9
	Surge	300	50.4	99.6	201.0	351.0	1.4	2.9	11.7	16.0	367.0	35.6	402.6
	Surge	150	61.6	114.2	172.6	348.4	0.9	2.1	7.0	10.0	358.5	33.7	392.1
LSD (0.05) Trt			7.8	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
LSD (0.05) Variety			8.9	14.2	27.4	29.2	1.2	1.6	5.1	6.1	30.0	6.3	27.2

Table 3. Influence of reduced N application and surge irrigation on the tuber market grade distribution of seven potato varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995 Ontario, OR, 1995.

	Treatment		Potato market grade distribution								
			US Number One			US Number Two					
Variety	Irrigation	N rate	6-10 oz	>10 oz	total	4-6 oz	6-10 oz	>10 oz	total	Marketable	Undersize
			%								
R. Burbank	Furrow	300	30.5	30.3	83.0	0.7	0.6	2.2	3.5	86.6	13.4
	Furrow	150	34.5	25.1	82.5	0.4	1.1	3.8	5.2	87.8	12.2
	Surge	300	35.3	24.6	79.6	0.6	1.4	3.2	5.3	84.9	15.1
	Surge	150	35.8	23.6	83.3	0.7	0.8	1.9	3.4	86.7	13.3
	Average		34.0	25.9	82.1	0.6	1.0	2.8	4.4	86.5	13.5
Shepody	Furrow	300	13.8	69.4	88.3	0.1	0.6	7.1	7.8	96.1	3.9
	Furrow	150	16.4	71.8	94.3	0.0	0.3	1.3	1.7	96.0	4.0
	Surge	300	14.4	71.6	91.1	0.2	0.7	4.4	5.3	96.4	3.6
	Surge	150	17.1	70.5	94.2	0.1	0.5	2.5	3.1	97.3	2.7
	Average		15.4	70.8	92.0	0.1	0.5	3.8	4.4	96.4	3.6
F. Russet	Furrow	150	33.4	36.1	85.2	0.0	0.2	1.2	1.4	86.6	13.4
	Surge	300	25.1	38.0	80.7	0.1	0.1	2.3	2.5	83.2	16.8
	Surge	150	32.3	27.0	82.6	0.1	0.6	1.8	2.5	85.1	14.9
	Average		29.6	33.8	82.5	0.1	0.5	1.9	2.4	84.9	15.1
R. Russet	Furrow	300	28.3	44.4	84.8	1.2	1.5	3.1	5.8	90.6	9.4
	Furrow	150	27.6	45.5	85.3	0.1	2.8	2.9	5.9	91.2	8.8
	Surge	300	27.1	45.5	87.0	0.3	0.7	4.0	5.0	92.1	7.9
	Average		28.9	43.7	86.0	0.6	1.5	3.2	5.2	91.2	8.8
AO 82611-7	Furrow	300	27.9	44.4	87.4	0.3	0.6	2.4	3.3	90.7	9.3
	Furrow	150	29.8	45.2	89.5	0.1	0.5	1.5	2.2	91.7	8.3
	Surge	300	25.6	47.6	86.9	0.7	1.5	3.1	5.2	92.1	7.9
	Surge	150	28.7	41.9	87.3	0.1	0.9	2.9	3.9	91.1	8.9
	Average		28.0	45.0	87.8	0.3	0.9	2.4	3.6	91.4	8.6
COO 83008-1	Furrow	300	26.0	56.6	93.2	0.2	0.4	0.8	1.4	94.6	5.4
	Furrow	150	26.0	57.6	92.6	0.2	0.6	2.2	2.9	95.5	4.5
	Surge	300	19.4	67.8	93.3	0.1	0.4	2.7	3.2	96.5	3.5
	Surge	150	30.2	53.0	93.9	0.1	0.4	1.4	1.9	95.8	4.2
	Average		25.3	59.0	93.2	0.1	0.5	1.9	2.5	95.7	4.3
NDTX 8-731-1R	Furrow	300	25.7	54.1	93.0	0.0	0.0	0.0	0.0	93.0	7.0
	Furrow	150	32.3	49.9	94.0	0.0	0.0	0.0	0.0	94.0	6.0
	Surge	300	26.3	55.3	91.9	0.0	0.0	0.0	0.0	91.9	8.1
	Surge	150	27.8	51.7	92.8	0.0	0.0	0.0	0.0	92.8	7.2
	Average		28.0	52.6	92.9	0.0	0.0	0.0	0.0	92.9	7.1
All varieties	Furrow	300	25.8	46.7	86.7	0.4	0.7	2.8	3.9	90.6	9.4
	Furrow	150	28.5	47.1	88.8	0.1	0.8	1.9	2.9	91.7	8.3
	Surge	300	24.9	49.4	86.9	0.3	0.8	2.9	4.0	90.9	9.1
	Surge	150	29.2	43.8	88.7	0.3	0.6	1.9	2.7	91.4	8.6
LSD (0.05) Trt			ns	ns	ns	ns	ns	ns	ns	ns	ns
LSD (0.05) Variety			3.5	4.8	2.1	0.3	0.4	1.2	1.1	1.5	1.5

Table 4. Influence of reduced N application and surge irrigation on tuber specific gravity and stem-end fry color of six potato varieties. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.

Variety	Irrigation type	N rate	Stem-end fry color	Specific gravity	Variety	Treatment	N rate	Stem-end fry color	Specific gravity
		lb N/ac	% reflectance				lb N/ac	% reflectance	
R. Burbank	Furrow	300	34	1.089	R. Russet	Furrow	300	42.4	1.099
	Furrow	150	28.6	1.090		Furrow	150	42.6	1.102
	Surge	300	29.7	1.084		Surge	300	43.2	1.096
	Surge	150	28.0	1.090		Surge	150	43.4	1.101
	Average		30.1	1.088		Average		42.9	1.100
Shepody	Furrow	300	42.7	1.093	AO 82611-7	Furrow	300	39.9	1.093
	Furrow	150	45.1	1.092		Furrow	150	41.7	1.095
	Surge	300	43.7	1.087		Surge	300	43.2	1.092
	Surge	150	46.8	1.087		Surge	150	43.7	1.097
	Average		44.6	1.090		Average		42.0	1.094
F. Russet	Furrow	300	29.8	1.084	COO 83008-1	Furrow	300	44.7	1.091
	Furrow	150	32.4	1.091		Furrow	150	46.9	1.095
	Surge	300	30.0	1.081		Surge	300	47.5	1.092
	Surge	150	33.1	1.092		Surge	150	49.3	1.096
	Average		31.3	1.087		Average		47.3	1.094
All varieties	Furrow	300	38.6	1.092					
	Furrow	150	39.7	1.094					
	Surge	300	39.7	1.089					
	Surge	150	40.7	1.094					
LSD (0.05) Trt			ns	ns					
LSD (0.05) Variety			2.1	0.003					

Table 5. Influence of reduced N application and surge irrigation on the seasonal available nitrogen accounting in potatoes and in the soil profile. Malheur Experiment Station, Ontario, OR , 1995.

Irrigation type	N rate	N supply				Fall nitrogen accounting			Balance*
		Pre-plant soil available N (0-6')	Fertilizer N	N in irrigation water	Estimated N mineralization	Fall soil available N (0-6')	Plant N recovery	Accounted N	
	lb N/ac	——— lb/ac ———							
Furrow	300	186.5	300	18.6	206.2	165.3	228.2	393.5	-317.8
Furrow	150	182.2	150	18.6	215.9	122.1	162.2	284.3	-282.3
Surge	300	180.5	300	18.6	253.4	173.4	202.2	375.6	-377
Surge	150	188.8	150	18.6	233.9	133.7	177.2	310.9	-280.4
LSD (0.05) N		ns				39.3	ns	81.9	ns
LSD (0.05) Irr		ns				ns	ns	ns	ns
LSD (0.05) N X Irr		ns				ns	ns	ns	ns

* based on the difference between all N supplies and fall N accounting.

Table 6. Influence of reduced N application and surge irrigation on the seasonal available nitrogen accounting in potatoes and in the top two feet. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.

Irrigation type	N rate	N supply				Fall nitrogen accounting			Balance*
		Pre-plant soil available N (0-2')	Fertilizer N	N in irrigation water	Estimated N mineralization	Fall soil available N (0-2')	Plant N recovery	Accounted N	
	lb N/ac	——— lb/ac ———							
Furrow	300	63.2	300	18.6	206.2	80.5	228.2	308.8	-279.3
Furrow	150	63	150	18.6	215.9	54.7	162.2	216.9	-230.6
Surge	300	64.8	300	18.6	253.4	78.2	202.2	280.3	-356.5
Surge	150	65.3	150	18.6	233.9	54.8	177.2	232.1	-235.7
LSD (0.05) N		ns				17.3	ns	69.5	-72.5
LSD (0.05) Irr		ns				ns	ns	ns	ns
LSD (0.05) N X Irr		ns				ns	ns	ns	ns

* based on the difference between all N supplies and fall N accounting.

Figure 1. Nitrogen fertilizer was shanked into the bed between the furrow and seed piece. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.

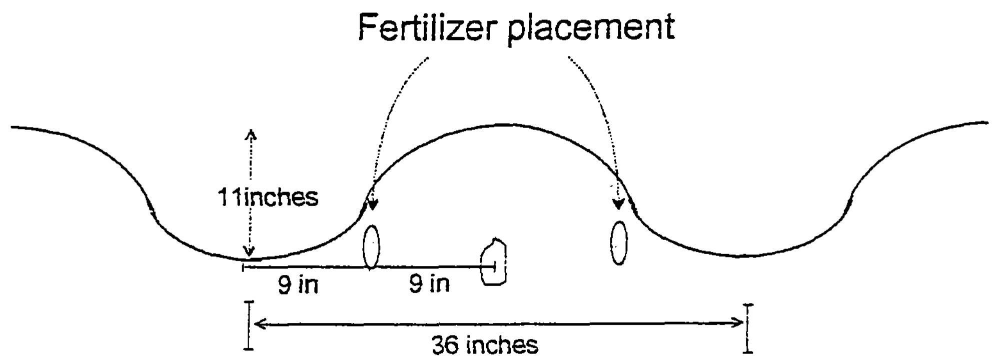

Figure 2. Soil water potential at 8-inch depth over time for conventional furrow irrigated and surge irrigated potatoes. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.

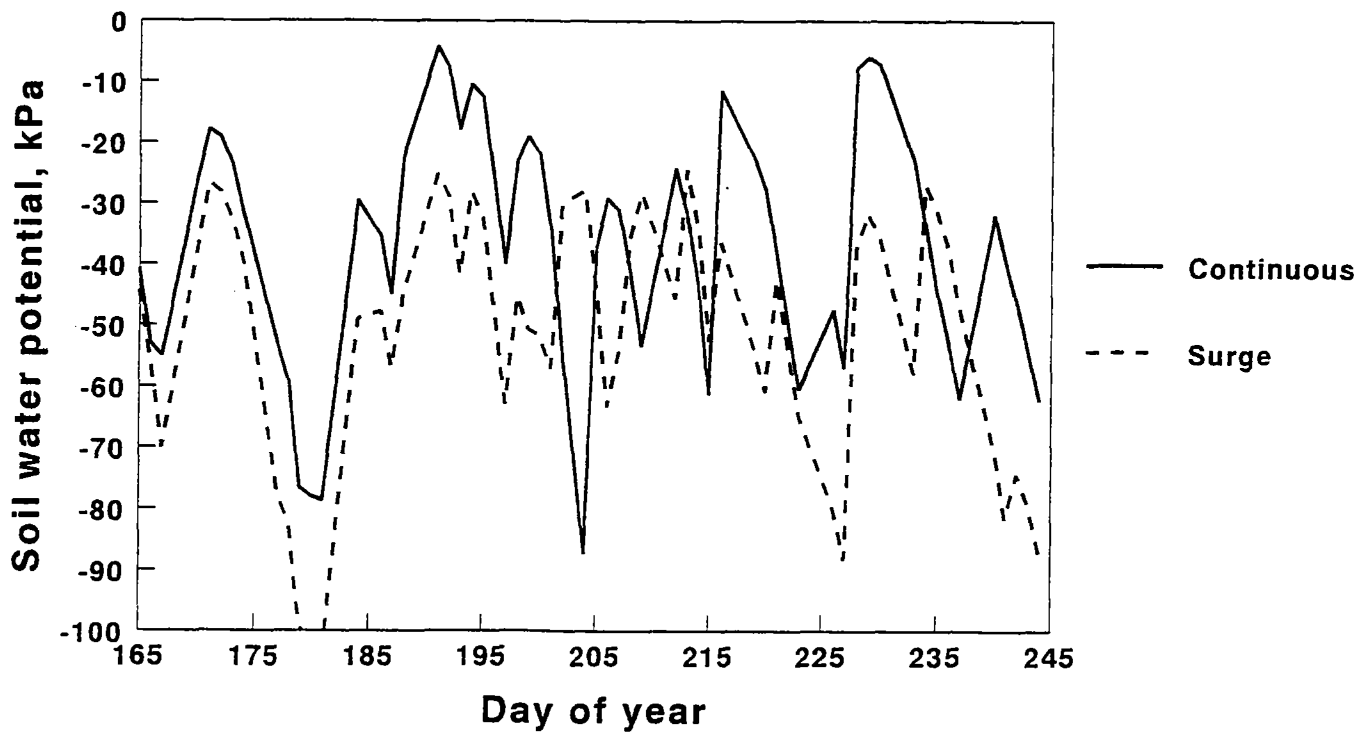

Figure 3. Petiole nitrate over time with reduced N fertilizer inputs and conventional furrow vs surge irrigated potatoes. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.

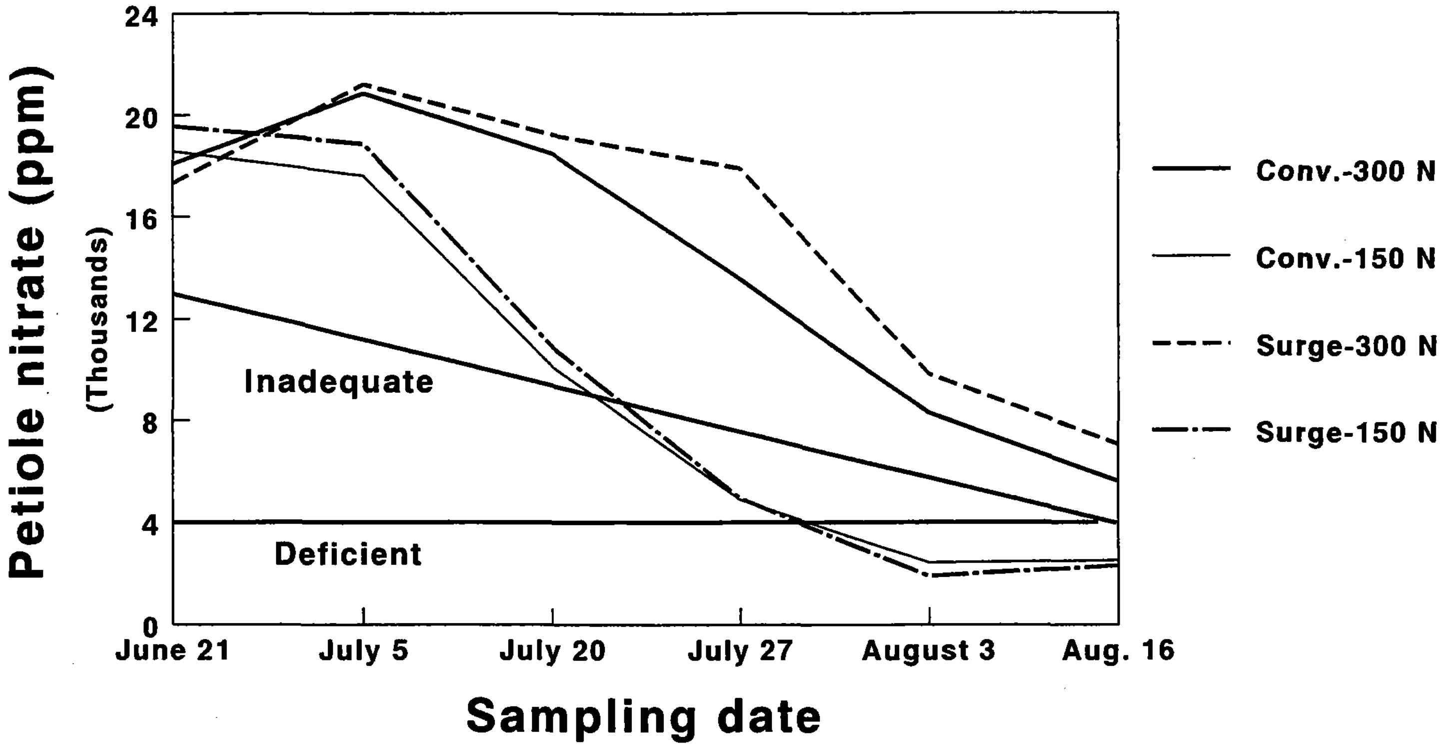

Figure 4. Tuber yield with reduced N applications and conventional furrow vs surge irrigation. Malheur Experiment Station, Oregon State University, Ontario, OR, 1995.