Potential for Irrigation Water Savings in a Potato Field by Varying the Hill-Furrow or Bed-Furrow Configuration

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EXECUTIVE SUMMARY

In southern Alberta, potatoes are always hilled after planting and covered with sufficient soil to prevent tuber greening, to ensure drainage in the area of tuber formation, and to facilitate mechanical harvest. The ideal shape for the potato hill, according the Manitoba Agriculture, Food and Rural Initiatives, is one with a peaked top and gradual slope to the furrow position.

However, with a profile described as ideal, much of the precipitation (either irrigation or rainfall) moves by gravity into the furrow position. Water ponds in the furrow position and if retained, gradually infiltrates with time. Infiltrated water in the furrow position is believed to move into the hill position via soil matric forces. In coarse-textured soils, it has been shown that rainfall or irrigation water infiltrated in the furrow position percolates through the soil, moves below the root zone, and is effectively lost to the plant.

A research project commenced in 2004 to identify the fate of precipitation (irrigation and rainfall) that infiltrated the soil in the "ideal profile" hill and the furrow position. The project continued in 2005 to determine the fate of infiltrated precipitation with altered hill shapes.

Based on the results of 2005, a new three-year project began in 2006 to quantify the potential irrigation water savings of the altered hill shapes. The three treatments (standard hill, flat-topped hill, and wide bed) were arranged in a randomized strip plot design replicated four times. Soil moisture in each treatment was generally kept between 65 to 90% of available.

The irrigation requirement to maintain the treatments was 487, 442, 449 mm for the standard hill, flat-topped hill, and double-seeded bed, respectively, in 2006 and 442, 408 and 411 mm for the same treatments in 2007. This translates into approximately 10% less irrigation water required for the flat-topped hill shape compared to the standard hill shape.

Total yield was greater in 2006 for both the flat-topped hill (72.3 Mg ha^{-1}) and wide bed (69.2 Mg ha^{-1}) compared to the standard hill (61.4 Mg ha^{-1}); however, the treatments were not significantly different. Significantly greater marketable yield was realized from the flat-topped hill treatment in 2006. This treatment also had a significantly greater number of marketable size tubers. In 2007, there were no significant differences in total yield, however, the standard and flat-topped treatments had significantly greater number and yield of tubers in the size category 113-170g.

Rainfall amounts recorded at the Brooks meteorological station for 2006 in July and August were only 5.4 and 22.1 mm, respectively, and 4.0 and 43.6 mm for 2007 for the same months. Thus, irrigation applications were the principal source of soil available moisture for plant transpiration. The study will continue in 2008 in similar textured soil, but most likely with different meteorological conditions, in order to assess the range of

potential irrigation application savings able to be realized by altering potato hill shapes.

INTRODUCTION

Relative to other crops grown in southern Alberta, potatoes require a very intensive irrigation management program to maximize economic returns. Potatoes have a relatively low tolerance to water stress, develop a shallow rooting system, and are typically grown on coarse-textured soils with inherently low water holding capabilities. Accordingly, growers must have an advanced knowledge of soil moisture status to maintain soil moisture at prescribed levels.

The infiltration of irrigation and rainfall into a potato hill is often assumed to be uniform. However, due to the implied topographic relief of hill-furrow tillage systems, it has been reported that the actual infiltration and subsequent redistribution of irrigation water is quite variable. Starr et al. (2005), Robinson (1999), and Saffigna et al. (1976) reported that more water enters the soil through the furrow than through the ridge or hill. It is believed that between precipitation events, increased soil matric forces due to declining soil moisture levels within the potato hill act to redistribute some of the water into the hill position where it can be used by the plant. However, Starr et al. (2005) reported that uptake of soil moisture from the furrow position or toe of the hill was undetectable and the lowest soil moisture storage was in the center position of the potato hill.

Improved irrigation efficiency may be realized by altering the standard, "ideal" hill shape so more of the applied irrigation water has time to infiltrate into the hill/bed before ponding in the furrow position. Mundy et al. (1999) planted three rows of potatoes in a 1.9 m wide bed to evaluate the effect on yield and quality. Although there were not always statistically significant differences, they reported the wider bed retained more moisture compared to the standard hill. Steele et al. (2006) compared yield and quality of potatoes planted within the furrow position of a modified ridge/furrow system to conventional standard-hill planted potatoes. They found significantly higher yields and a greater yield of larger size potatoes were harvested from the furrow-planted treatments compared to the hill-planted treatments. On two sampling dates for soil moisture, they found significantly higher soil moisture in the furrow position than in the hill. Starr et al. (2005) concluded that management practices targeted at wetting the hill center under the sprinkler would likely improve water use efficiency.

The objective of this study was to quantify the water savings in altered hill/bed forms compared with the standard hill and to identify the influence altered bed shapes have on tuber yield and quality.

METHODS

Three treatments consisting of a standard hill, flat-topped hill and wide bed were arranged in a randomized strip plot design, replicated four times at the Crop Diversification Center South in Brooks, Alberta. Plot sizes were 6.1 x 6.1 m with a 4 m buffer between plots for a total planted area of 828 m^2. Hill forms were prepared using a Netagco power hiller/bedder. Standard and flat-topped hill treatments consisted of six rows, 0.91 m apart. The wide bed treatment consisted of three, 1.8 m beds. Flat-topped hill preparation involved maintaining the same rotor configuration as for a standard power-hiller but setting the rear shaper blade to flatten or "drag off " the peak of the standard hill (Fig. 1). The double-seeded bed was prepared by setting a firm tension on the rear shaper blade (Fig. 2).

Fig. 1. Final hill shape of the flat-topped treatment.

Soils at the site are Orthic Brown Chernozem (Chin Soil Series) with soil texture ranging from loam to silt. Average available soil moisture (between field capacity and wilting point) was 164 mm.

Fig. 2. Power-hiller set to form 1.8 m wide bed.

In 2006, the plots were prepared and seeded with treated Russet Burbank potato pieces spaced 30 cm within the row at a depth of 15 cm on May 12. A hand-move irrigation system, equipped with Nelson directional impact sprinklers with 4.76 mm nozzles and individual shut-off valves, were used for applying irrigation water. The lateral line was positioned along the south edge of the plots so that each sprinkler, set at 180°, would wet a complete plot.

In 2007, treated Russet Burbank potato pieces were seeded on May 9 at a depth of 15 cm and an in-row spacing of 30 cm. A hand-move irrigation system was again used but the main lateral line was positioned within the center rows of the plots with risers positioned center to each 6.1 x 6.1 m plot. Senninger mini-wobblers with 2.38 mm nozzles were used for applying the irrigation water.

Aluminum access tubes were installed in the hill position near the center of each plot for soil moisture determinations with a CPN 503 soil moisture meter. Soil moisture was measured twice each week from planting until harvest. Each treatment was irrigated once average soil moisture in the top 60 cm of soil profile for the four replicates reached 65% of available. Standard rain gauges were placed adjacent to the access tube for determining irrigation applications and rainfall amounts.

Individual soil temperature probes were installed in each plot. They were positioned near the seed piece within the hill or bed and were buried 0.14 m below the soil surface.

In 2007, Hobo® H8 Pro Series combined relative humidity and temperature sensors, secured in a weatherproof shield, were placed in-row, approximately 10 cm above the soil surface, within each plot. Sensors were programmed to take hourly readings of temperature, relative humidity, absolute humidity, and calculated dew point temperature. Hourly within canopy relative humidity values were compared to the Environment Canada meteorological station, Brooks, located approximately 0.5 km from the plot area.

Agronomic operations.

2006
Fertilizer was broadcast on April 26 at a rate of 168 kg ha^{-1} of N and 84 kg ha^{-1} of P. Insecticides (Admire and Decis) were sprayed twice (July 5 and August 22, respectively) to control Colorado potato beetle. Dithane, Pencozeb and Ridomil Gold/Bravo were sprayed on July 16, August 3, and August 22, respectively, for early and late blight control. Plots were sprayed with the dessicant, Reglone, on September 5 and were harvested on September 13 using a single row harvester.

2007
Fertilizer was broadcast on May 5 at a rate of 140 kg ha^{-1} of N and 50 kg ha^{-1} of P. Admire was applied on July 5 to control Colorado Potato Beetle. Dithane, Bravo 500 and Ridomil Gold were applied on July 13, July 26 and August 20, respectively, for blight control. Reglone was applied on September 5 and the plots were harvested September 17.

All tubers from the four center rows of each treatment were harvested and evaluated for yield, size, quality, and specific gravity.

The Holm-Sidak method was used for all multiple mean comparisons with $p < 0.05$.

RESULTS

Meteorology

Rainfall amounts recorded at the Brooks meteorological station for 2006 in July and August were only 5.4 and 22.1 mm, respectively. In 2007, rainfall amounts of 4 and 43.6 mm were recorded for July and August, respectively. Thus, irrigation applications were the principal source of soil available moisture for plant transpiration.

Water use and evapotranspiration

The standard hill treatments required 7.8 and 9.2% greater irrigation amounts in 2006 and 9.9 and 10.3% in 2007 than the double-seeded bed and flat-topped treatments, respectively (Table 1). Water use efficiency was greater for both the flat-topped and double-seeded bed compared to the standard.

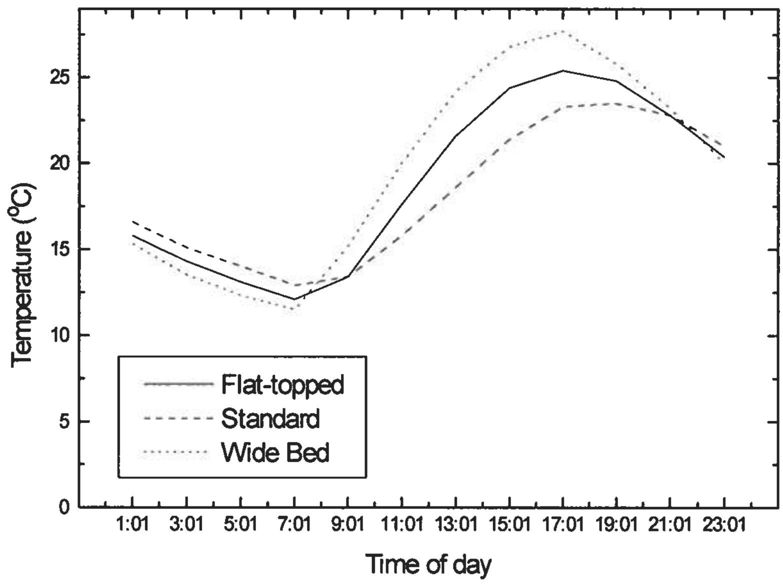
Table 1. Irrigation demand and evaporatranspiration for the three hill-shape treatments.

Treatment	Irrigation (mm)		Evapotranspiration (mm)		Water-Use Efficiency (kg/ha.mm)	
	2006	2007	2006	2007	2006	2007
Standard	487	442	500	462	126.0	157.0
Flat Topped	442	408	499	461	163.5	165.8
Wide Bed	449	411	489	441	154.2	165.3

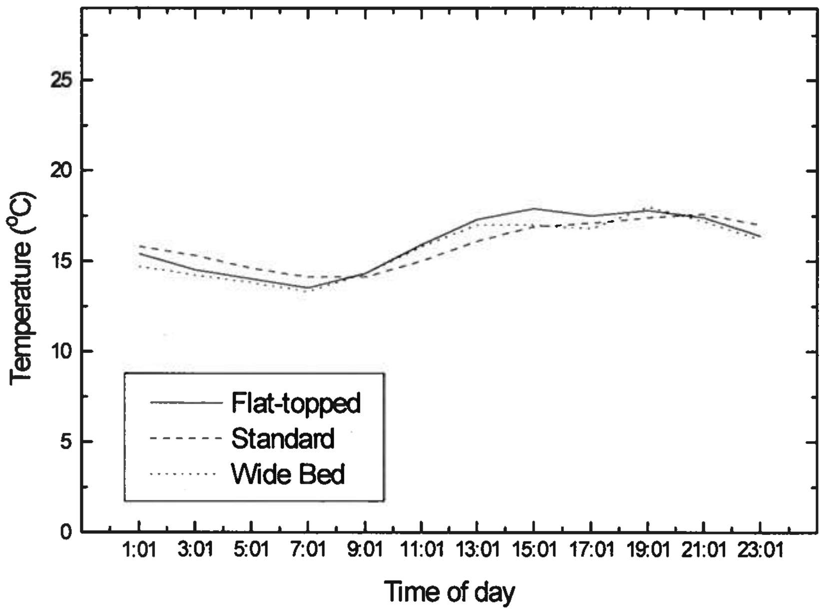
Evapotranspiration was similar for all three treatments, indicating that transpiration was not restricted in any treatment.

Soil Temperature

Daily maximum soil temperatures were higher in the flat-topped or wide-bed treatments early in the season in 2007, but as soil shading due to plant growth occurred, there were no marked differences in soil temperature (Fig. 4). Daily minimum soil temperatures were similar throughout the growing season.



(a)



(b)

Fig. 4. Average soil temperatures for the three hill-shape treatments on (a) May 17 and (b) June 16, 2007.

Relative humidity comparisons.

The difference between seasonal maximum within potato canopy relative humidity compared with the Brooks regional meteorological station averaged just under 10% (Fig. 5). Daily maximum relative humidity occurred during the evening hours in all but the days during an irrigation application. The greatest relative humidity differences (greater than 20%) between the regional meteorological station and the within potato canopy occurred during and within 24 h following an irrigation application (Fig. 6).

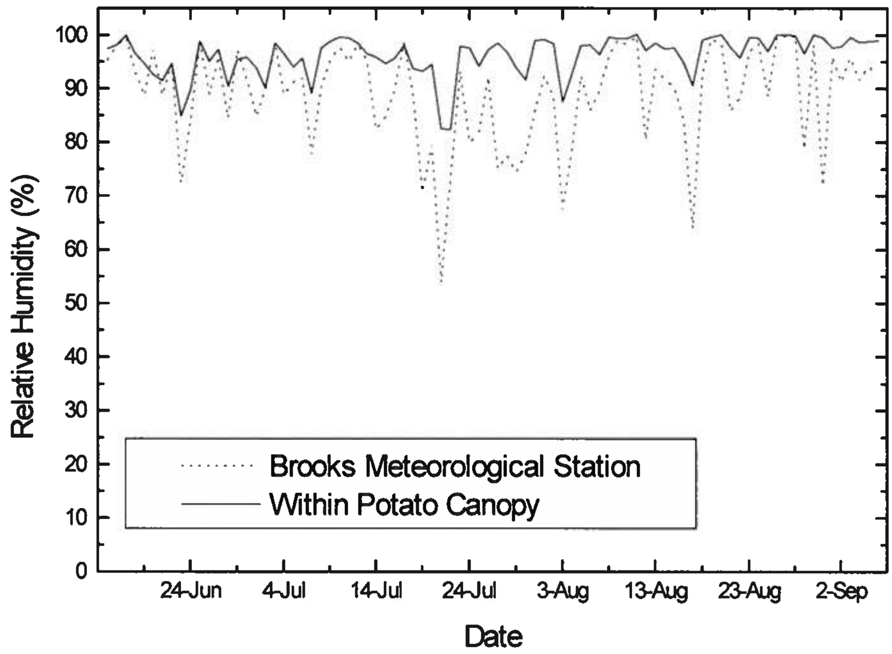


Fig. 5. Daily maximum relative humidity differences between Brooks meteorological station and within potato canopy in 2007.

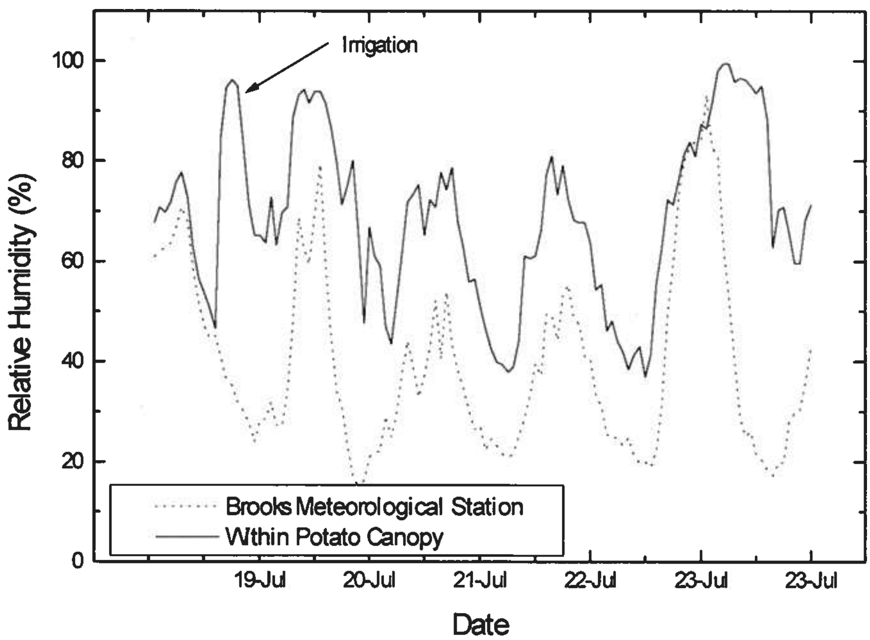


Fig. 6. Within potato canopy relative humidity dynamics after an irrigation event in 2007.

The largest difference for relative humidity, averaging 25% for the season, between the Brooks meteorological station and within potato canopy was observed for minimum daily RH (Fig. 7). Relative humidity is elevated during peak evaporative demand periods in an actively transpiring potato crop, not short of water. The elevated canopy relative humidity helps the plants to remain cooler than they would be if transpiration were restricted due to reduced soil water.

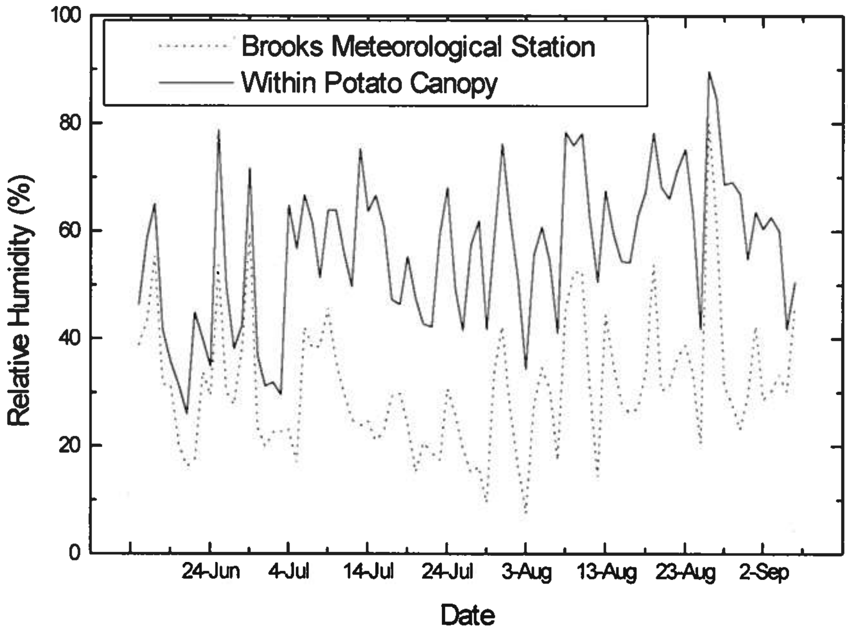


Fig. 7. Daily minimum relative humidity comparing within canopy to the Brooks regional meteorological station in 2007.

Tuber yield and quality

Marketable yield (171-284 g) and total number of tubers were significantly greater in the flat-topped hill compared with the double-seeded bed and standard hill treatments in 2006 (Table 2). In 2007, there were no significant differences in total yield, however, the standard and flat-topped treatments had a significantly greater number and yield of tubers in the size category 113-170 g.

Table 2. Yield comparisons for the three hill-shape treatments.

2006										
	Yield (Mg ha^{-1})					Number of Tubers (count)				
	Size Categories (g)					Size Categories (g)				
Treatment	Total	< 113	113-170	171-284	>284	Total	<113	113-170	171-284	>284
Flat-top	72.3	15.8	19.3	22.8a	11.9	267a	118	75a	57	17
Wide-Bed	69.2	16.6	18.2	20.2ab	12.2	255b	115	71ab	52	17
Standard	61.4	13.1	15.5	17.3b	13.0	216b	94	57b	45	20
							Percentage of total yield			
							44.2	27.9	21.5	6.5
							45.2	27.7	20.3	6.8
							43.4	26.4	20.9	9.4
2007										
	Yield (Mg ha^{-1})					Number of Tubers (count)				
	Size Categories (g)					Size Categories (g)				
Treatment	Total	< 113	113-170	171-284	>284	Total	<113	113-170	171-284	>284
Flat-top	61.6	15.0	15.1b	18.1	8.9	246	119	59ab	46	13
Wide-Bed	61.7	15.6	11.6a	18.5	11.1	259	142	46a	48	16
Standard	63.1	15.4	15.1b	19.9	9.1	249	118	60b	50	13
							Percentage of total yield			
							48.4	24.0	18.7	5.3
							54.8	17.8	18.5	6.2
							47.4	24.1	20.1	5.2

Where significant hill shape effects on the potato yield were detected by analysis of variance, column means followed by the same letter are not significantly different at $p<0.05$.

DISCUSSION

Altering the standard hill to a flat top or wide bed allowed more applied precipitation to infiltrate the hill or bed. Starr et al. (2005) reported that infiltration of applied water did not reach the center of the hill under sprinkler irrigation. Irrigations to ensure sufficient soil moisture in the center of a standard hill shape translate into excessive runoff and ponding of the applied water in the furrow position. Deep percolation of applied water and minimal or no uptake of soil moisture by the potato plant from the furrow position results in a loss of irrigation water applied.

It is hypothesized that the change in sprinkler from the impact sprinkler used in 2006 to a mini-wobbler in 2007 was the reason for a better water use efficiency (WUE) for the standard hill shape in 2007 compared to 2006. The mini-wobbler was rated with an application rate of 6.2 mm h^{-1} , whereas the published application rate of the impact sprinkler was 10.3 mm h^{-1}. A higher application rate would mean more of the applied irrigation water would move into the furrow position for the standard hill shape and eventually infiltrate.

Greater marketable yield, increased number of marketable tubers, and reduced tuber deformities resulted when soil moisture in the potato hill was not allowed to fluctuate between moist and dry, but rather kept at higher soil moisture content for longer. These yield results are consistent with, and support the findings of Kang et al. (2004) who found that more frequent watering with drip irrigation, and not allowing the soil profile to dry, resulted in the highest yield of potatoes. Similarly, Steele et al. (2006) reported an increase in tuber quantity and size for furrow planted potatoes compared with potatoes planted in a hill.

Initial warmer soil temperature after planting with the wide-bed or flat-topped hill should help to lessen tuber diseases. Warton et al. (2007) identified a higher incidence of rhizoctonia the longer the seed tuber remained in wet, cold soil prior to emergence. The flatter hill surface with the wide-bed or flat-topped hill intercepts more incoming solar radiation, has less shading effect, and thus warms faster.

Within canopy relative humidity differences were not expected among treatments and none were observed. However, the differences between within canopy maximum and minimum relative humidity values compared to the nearby meteorological station can be used to calibrate disease models when the source of the meteorological data is outside the monitored field.

PRELIMINARY CONCLUSIONS

A 10% water savings for irrigated potato production is possible in southern Alberta by modifying the standard hill shape to either a flat-topped or wide-bed hill shape.

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