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Evaluating LESA Irrigation Systems in Potato Production in Southern and Eastern Idaho

Xi Liang
Assistant Professor of Cropping Systems Agronomy, University of Idaho

William (Howard) Neibling
Extension Water Management Engineer, University of Idaho Kimberly Research and Extension Center

Rui Yang
Postdoctoral Fellow, University of Idaho

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University of Idaho Extension

Introduction

IDAHO RANKED FIRST NATIONALLY in potato production in 2017 with a planted area of 310,000 acres. Potato is considered a high water-use crop and sensitive to drought stress. Improved irrigation practices that are able to increase irrigation efficiency, reduce water loss, and maintain crop yield are very critical, since reducing groundwater consumption in the Eastern Snake River Plain Aquifer is now required to help stabilize aquifer storage.

The typical sprinkler head configuration (mid-elevation spray application: MESA) has been widely used on pivot irrigation systems in Idaho. The nozzle height of MESA is usually 5–7 ft aboveground, which is higher than the plant height of small grains and potatoes. Low-elevation spray application (LESA) is a modification that places nozzles 1–2 ft aboveground. Table 1 summarizes the differences between MESA and LESA. In LESA, irrigation can be applied right above the canopy of potato plants (Figure 1). Compared with MESA, the lower nozzle height in LESA enables water droplets to spend less time in the air, which reduces water losses to wind drift and evaporation. Reduced water losses also increase the percentage of pumped water delivered to the soil. Furthermore, due to sprinkler head selection and reduced sprinkler spacing, the operating pressure can be reduced to 10 psi, which reduces pumping costs per growing season compared with MESA.

Table 1. Comparisons between MESA and LESA.

	MESA	LESA
Nozzle height aboveground (ft)	5–7	1–2
Application efficiency (%)	70–85	85–95
Pressure at the sprinkler (psi)	15–25	10
Outlet spacing (ft)	8–10	3–5

psi = pounds of pressure per square inch of water
Parameters are summarized from multiple publications.

Figure 1. Adjacent spans of LESA (right) and MESA (left) in a potato field in Rupert, Idaho (Photo by Xi Liang).

LESA has been successfully applied in row crops, such as beans and silage corn, and in close-growing crops of timothy hay, alfalfa, grass seed, mint, barley, and wheat, but has seldom been investigated in potato production. To address this need, three field experiments were conducted in southern and eastern Idaho to evaluate potato tuber yields under LESA and MESA.

Field Experiments

During the 2017 growing season, adjacent spans of LESA and MESA systems were tested in three potato fields in Rupert, Rexburg, and Rexburg Bench in southern and eastern Idaho. The potato fields in Rexburg and Rexburg Bench were irrigated through lateral pivot systems, while in Rupert the irrigation system was a center pivot. In Rexburg Bench and Rupert, the LESA span was the furthest from the pivot point, while it was on the next-to-outer-end span in Rexburg. The nozzle height of the LESA span was set at 2 ft above the furrow with nozzle spacing of 4.5 ft in all three fields. This height placed the sprinkler heads within the potato canopy for most of the growing season. For the adjacent MESA spans, the nozzle height was between 4 and 6 ft and the nozzle spacing ranged from 9 to 10 ft.

The potato variety was Russet Burbank in Rexburg and Rexburg Bench and Classic Russet in Rupert. Soil moisture was monitored using Watermark soil water tension sensors in Rexburg and soil volumetric water content sensors (10HS, Meter Environment, Pullman, Washington) in Rexburg Bench. Soil moisture sensors were installed directly below the nozzles. Soil moisture monitoring was initiated in mid-July when the plant canopy fully covered the ground. After vine kill, four 15-ft rows under LESA and MESA spans were randomly selected in the field and harvested for estimating tuber yields at each location. The four rows were considered replicates in statistical analysis. Tuber yields and US No. 1 yields were analyzed using the generalized linear mixed model of SAS (ver. 9.4, SAS Institute, Cary, North Carolina) by considering irrigation treatment (i.e., LESA and MESA) as a fixed effect and replicate as a random effect at each location.

Soil Moisture under LESA and MESA

Soil water tension is a measure of soil moisture as determined by measuring the force required for plant roots to extract water from the soil. Higher values of soil water tension represent lower soil water content. Soil water tension sensors have been used in irrigation scheduling in various crops for a number of years, and soil water tension limits for potatoes range from 20 to 60 kPa depending on soil types and irrigation systems. Soil water tension at the 6-in depth ranged from 0 to 60 kPa under both LESA and MESA although fluctuations were different between irrigation methods in Rexburg (Figure 2). At the 18-in depth, LESA and MESA exhibited similar soil water tension during the growing season (Figure 2).

Soil volumetric water content, the amount of water associated with a given volume of soil, had a narrow range from 0.15 to 0.25 in/in under LESA at the 6-, 12-, 18-, and 24-in soil depths (Figure 3). At the 12- and 18-in depths, soil volumetric water content under LESA was generally close to MESA, whereas MESA generally had higher soil water contents at the 6-in depth and lower water contents at the 24-in depth, compared with LESA (Figure 3).

The higher soil water content in the deeper part of the root zone (e.g., 24-in depth in LESA) (Figure 3) probably indicates higher net water application due to more water delivered to the soil surface under the LESA span. The higher net water application rates may necessitate adjustments in the irrigation schedule with LESA to minimize the risk nitrate-N leaching from the soil profile. However, there was little fluctuation in soil water content at the 18- and 24-in depths (Figures 2 and 3), suggesting that well-watered conditions resulted in relatively small deviations in water uptake by the potato plants. Since potato plants are shallow rooted, irrigation scheduling could be based on a soil profile depth of 12 in, although irrigation should be managed to maintain a full, but nonleaching profile to 24 in to provide a water buffer during hot dry periods.

Tuber Yields under LESA and MESA

In Rexburg and Rexburg Bench, LESA and MESA produced similar total tuber yields and US No. 1 yields (Table 2). In Rupert, the total tuber yield and US No. 1 yield under LESA were higher than MESA, even though the differences were barely significant (total tuber yield: $P = 0.08$; US No. 1 yield: $P = 0.09$) (Table 2). No significant differences in size distribution were found between LESA and MESA at any location (Figure 4).

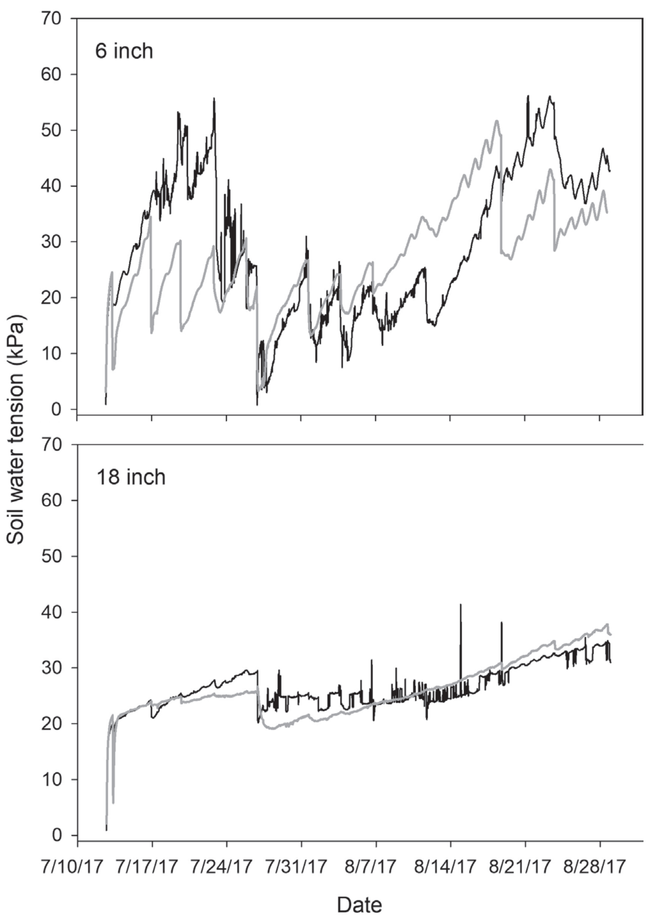

Figure 2. Soil water tension monitored at 6- and 18-in soil depths under LESA (grey) and MESA (black) in the summer of 2017 in Rexburg, Idaho.
kPa = newton per square meter = × 0.14 psi.

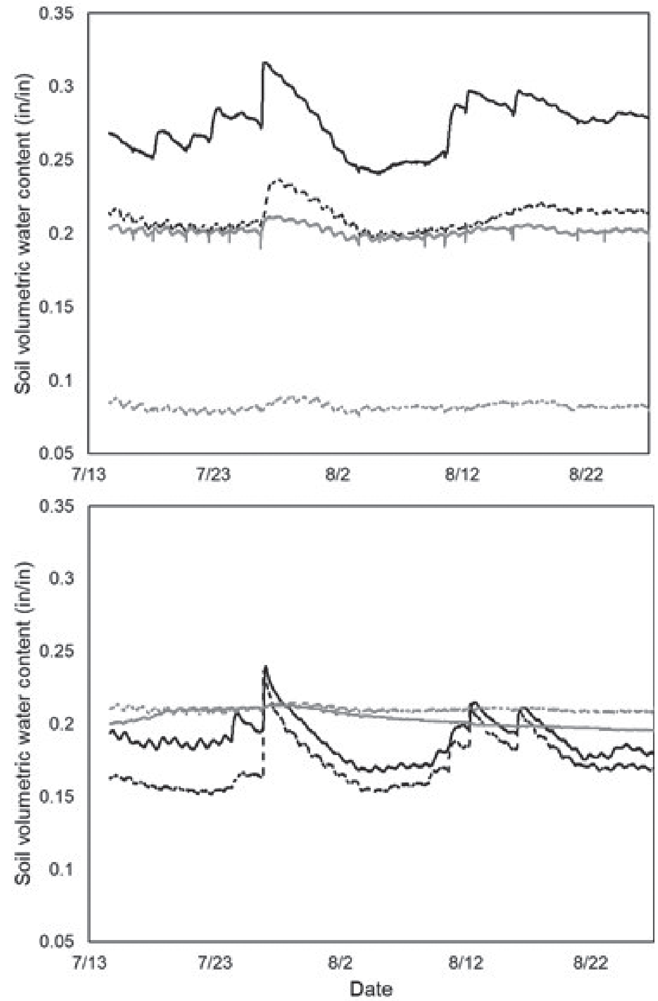

Figure 3. Soil volumetric water content monitored at 6- (black solid), 12- (black dash), 18- (grey solid), and 24-in (grey dash) soil depths under MESA (upper) and LESA (lower) in the summer of 2017 in Rexburg Bench, Idaho.

Table 2. Potato tuber yields and US No. 1 yields under MESA and LESA in three field experiments in Rexburg, Rupert, and Rexburg Bench, Idaho.

	Tuber yield cwt/acre	US No.1 yield cwt/acre
LESA: Rexburg	453	378
MESA: Rexburg	451	396
LESA: Rupert	554	535
MESA: Rupert	423	402
LESA: Rexburg Bench	430	362
MESA: Rexburg Bench	430	374

cwt = 100 lbs

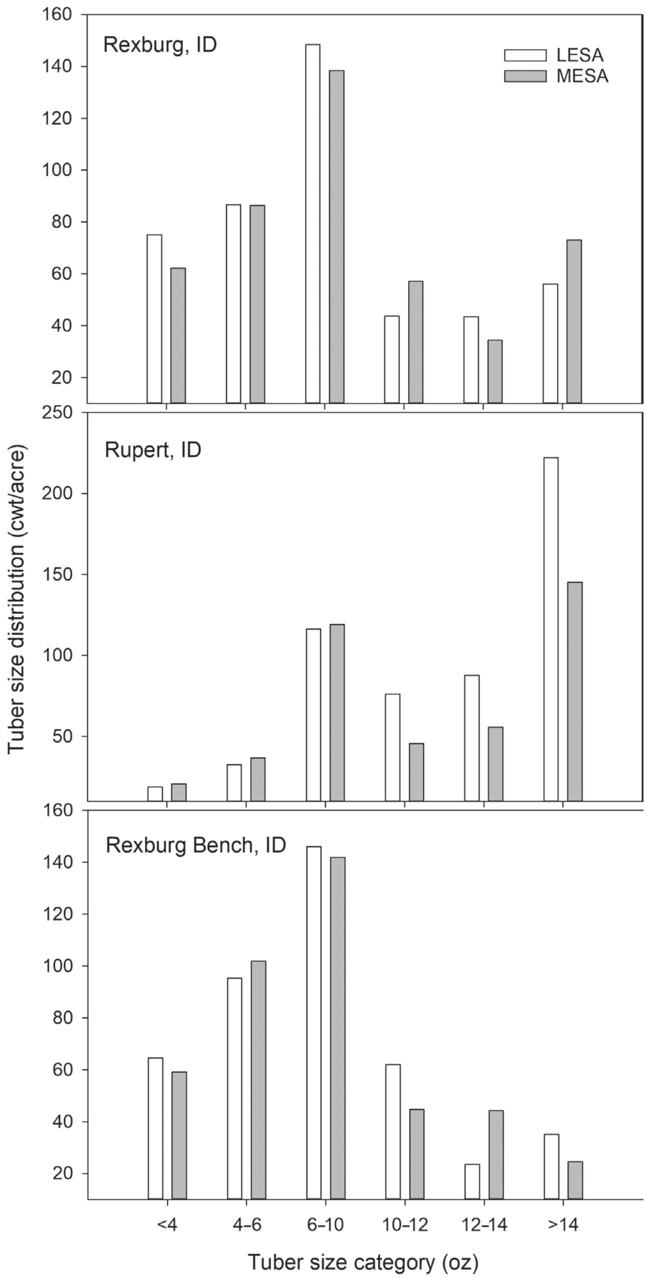

Figure 4. Potato tuber size distribution under LESA and MESA irrigation systems in Rexburg, Rupert, and Rexburg Bench, Idaho.

Cost Analysis of LESA and MESA

One of the great benefits of LESA is power savings, especially during hot summers when both water and power supplies are limited. The power savings could include pump configuration (reduced flow and pressure) and reduced run time.

Since only one span was modified to LESA in each field, it is impossible to measure the water quantity and energy use during the growth season, and thus an example is used to estimate seasonal costs of LESA. A typical ¼-mile-long center pivot system (irrigating 120 acres) with 150 ft of pumping lift is used to calculate the difference in power use between LESA and MESA. The irrigation rate is assumed to be 7.5 gpm/acre for a total pumping rate of 900 gpm. Operating pressure is assumed to be 40 and 25 psi for MESA and LESA, respectively, with power requirements of 55 and 47 kw (assuming 75% pumping efficiency). Since LESA applies a higher proportion of the water to the soil than MESA during the same run time, the total run time of LESA is shorter compared with the MESA. In our analysis, a 15% decrease in run time is assumed for LESA, comprising 1,700 hours of run time compared with 2,000 hours in MESA during one growing season. This results in an estimated 251 kW-hr savings per acre per growing season:

$$(55 \text{ kw} \times 2{,}000 \text{ h} - 47 \text{ kw} \times 1{,}700 \text{ h}) \div 120 \text{ acre} = 251 \text{ kw-hr/acre}$$

If the energy cost is assumed at $0.09/kw-hr, the energy saving in LESA will be $22.60/acre:

$$251 \text{ kw-hr/acre} \times \$0.09/\text{kw-hr} = \$22.60/\text{acre}$$

In the ¼-mile-long center pivot system, the costs to replace MESA drops (115 drops on spans 2–8) with a typical 9–10-ft spacing are $3,939 at $34.25 per drop, according to the pricing in 2015. The approximate costs for LESA replacement components for a ¼-mile irrigation system (230 drops on spans 2–8) equal $5,902 at $25.66 per LESA drop. Other miscellaneous costs associated with LESA replacements include LESA installation labor, pump rework, and a water-filtering system. If the labor costs for installation are assumed at $11/drop, the total installation costs will be $1,265 for MESA and $2,530 for LESA. The costs for pump rework and a water-filtering system in LESA are assumed at $4,300 for fifteen years, or $287/year, or $1,435 for the five-year life cycle for regulators and sprinklers.

According to pressure regulator manufacturers, regulator design life is 10,000 hours. For equipment usage of 2,000 hours per year, this means pressure regulators should be replaced every five years. Sprinkler manufacturers also suggest replacing sprinkler components on about a five-year interval. Therefore, the following MESA/LESA cost comparisons are made on a five-year life cycle.

Without considering the cost of interest, the difference in five-year total costs (e.g., equipment, labor, pump rework and water-filtering systems, and energy) between MESA and LESA is $8,882:

MESA: $3,939 + $1,265 + 55 kw × 2,000 h × 5 year × $0.09/kw-hr = $54,704;

LESA: $5,902 + $2,530 + $1,435 + 47 kw × 1,700 h × 5 year × $0.09/kw-hr = $45,822

Despite the extra costs of LESA equipment replacement, total life-cycle costs for LESA are still $8,882 less than for MESA. Additional financial benefits expected from conversion to LESA are reduced pivot track rutting (e.g., lower gearbox and drive motor replacement costs and lower labor costs). If the design flow rate is maintained after conversion (e.g., still at 7.5 gpm/acre), the LESA system will be able to meet peak evapotranspiration periods of up to 15%–20% higher than before conversion. However, if full flow is maintained, the system will need to be shut down for 15% of previous run time to meet a 15% pumping reduction.

Conclusions and Recommendations

- Potato tuber yield under LESA was similar to MESA at three locations: Rexburg, Rupert, and Rexburg Bench, Idaho.
- Irrigation scheduling should be adjusted by reducing the application rate or run time in LESA to reduce the potential for percolation and nutrient leaching below the root zone. Due to its high application efficiency and low wind drift and evaporation, LESA has the potential to increase crop production per unit of water applied.
- Due to reduced operating pressure and reduced hours of pump/pivot run time, pumping costs are lower for LESA compared with MESA. There are cost-related factors that must be considered when switching to LESA, including equipment costs, energy prices, and labor availability and costs. The savings from reduced pumping costs, however, can pay back the investment in equipment and expense in installation in a few years.

Further Reading

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