Application of LESA Technology in Saskatchewan

J. Gillies, K.B. Stonehouse, L.C. Tollefson, T. H. Hogg

Abstract

A large percentage of intensive irrigation in Saskatchewan is developed using high pressure centre pivot irrigation technology. The high evapotranspiration conditions which usually occur during a typical Saskatchewan growing season can result in water losses in excess of 30%. New irrigation technology, low energy precision application (LEPA), has been developed in the United States to conserve both water and energy. As part of the Irrigation Sustainability Component of the Canada-Saskatchewan Agricultural Green Plan Agreement a study was initiated to evaluate the potential of implementing LEPA technology under Saskatchewan conditions. An existing two tower centre pivot irrigation system at the Canada-Saskatchewan Irrigation Development Centre (CSIDC) was modified to include LEPA technology along with the existing conventional high pressure technology. Comparison of these two technologies was conducted during the 1994 growing season using two crops, faba bean (Vicia faba L.) and barley (Hordeum vulgare L.). Preliminary results indicate greater application efficiency and a reduction in energy consumption with low pressure compared to high pressure systems. Uniformity of water distribution, crop water use and crop yield trend comparisons require further work before definite conclusions can be made.

INTRODUCTION

A large percentage of intensive irrigation in Saskatchewan is developed using high pressure centre pivot technology. Such systems reduce labour inputs and provide for more flexible crop production options. However, water losses as high as 30% or more can occur using such technology under high evapotranspiration conditions - high wind, high temperature and low relative humidity (Clark and Finley 1975; Lyle and Bordovsky 1983).

New irrigation technology, low energy precision application (LEPA), has been developed in the United States to conserve both water and energy (Lyle and Bordovsky 1981). The LEPA approach uses drop tubes to discharge irrigation water at low pressure near the soil surface. This technology has been used primarily for row crop irrigation with application efficiencies typically exceeding 95% (New and Fipps 1990). The possible application of this new technology under Saskatchewan conditions has created much interest among irrigators and irrigation equipment dealers.

As part of the Irrigation Sustainability Component of the Canada-Saskatchewan Agricultural Green Plan Agreement, a study was initiated to evaluate the potential for implementation of LEPA technology under Saskatchewan conditions. An existing two tower pivot that irrigates 2.8 ha at the Canada-Saskatchewan Irrigation Development Centre (CSIDC) was modified to include LEPA technology along with the existing conventional high pressure technology. This system was used for a "side-by-side" comparison of these two technologies.

SYSTEM CONVERSION

Modifications to the system for inclusion of LEPA technology included:

1. installation of flexible drop tubes fitted with Seninger LDN nozzles (low drift) and 69 kPa pressure regulators.
2. installation of diaphragm valves for on/off control of each individual sprinkler (low and high pressure).

3. installation of a second Singer control valve in the valve chamber to facilitate the lower flow rate (7 l/s) and pressure (69 kPa) required for the LEPA nozzles. The original Singer valve maintained the flow rate (10 l/s) and pressure (310 kPa) for the conventional high pressure impact sprinklers.

4. installation of a C.A.M.S. (computer automated management system) control panel to manage both types of irrigation (on/off control, direction of travel, percentage timer, end gun on/off control, low pressure shut down, low voltage shut down).

MONITORING AND DATA COLLECTION

In 1994, two crops faba bean (Vicia faba L.) and barley (Hordeum vulgare L.), solid seeded with conventional field equipment, were grown in the area under the modified centre pivot irrigation system. During the growing season LEPA technology was evaluated and compared with conventional technology using the following parameters:

1. uniformity of water distribution;
2. water application efficiency;
3. energy consumption;
4. crop water use; and
5. crop yield.

To determine the uniformity of distribution catch cans were placed in the field following ASAE Standard S436 (1994). This standard states that the collectors must be placed in a radial line with a spacing not exceeding 30% of the average wetted diameter of the sprinkler nozzles, must be located so that no interference from the crop growth occurs and must be placed between 1.25 and 3.0 m above the ground. Placement of the collectors for the conventional impact sprinklers met the standard. However, the LEPA sprinklers were only 0.56 m above the ground surface and were designed to travel through the crop canopy. For this reason the standard could not be followed. To achieve a catch for the LEPA sprinklers the collectors were placed as close to the ground surface as possible in an area where the crop had been removed.

Soil moisture was monitored in 0.15 m depth increments to a 1.2 m depth with a field calibrated CPN Model 503 neutron moisture meter at four locations for each crop-system combination throughout the growing season.

During the summer of 1994, as the system was operated under varying wind conditions, the catch in each of the collectors was measured and recorded. The coefficient of uniformity was calculated using the Heermann and Hein modified equation (ASAE 1994). The application efficiency was calculated as the average amount of water applied expressed as a percentage of the theoretical application. Energy consumption was calculated from the pressure and flow rates of the system during its operation (James and Blair 1984). Crop water use was calculated by adding rainfall, irrigation and the difference between initial soil moisture water content (0-1.2 m) at seeding and final soil moisture water content (0-1.2 m) at harvest. An estimate of soil moisture storage and water infiltration were obtained from differences in soil moisture content from one measuring period to the next. Crop yields were estimated from specific area samples collected at ten locations for each crop-system combination.

RESULTS

Coefficient of Uniformity
The coefficients of uniformity calculated for the conventional high pressure and low pressure LEPA systems on the modified centre pivot displayed a decreasing trend at higher wind speeds (Figures 1 and 2). However, over the wind conditions tested in 1994 there was little change in the coefficient of uniformity for both systems. The average coefficients of uniformity for the high and low pressure sides of the modified system were 85 and 84% respectively. These values are within the range observed by other workers who found satisfactory uniformity when using low pressure (Arshad Ali and Barefoot 1978; James et al 1982; Nir et al 1980).

Application Efficiency

Application efficiency for the modified centre pivot system decreased for both high and low pressure as the wind speed increased (Figures 3 and 4). The high pressure application efficiency ranged from 89% at a wind speed of 3 km/h to 70% at a wind speed of 32 km/h. The low pressure application efficiency ranged from 95% at a wind speed of 11 km/h to 74% at 37 km/h. Preliminary results from the present work indicate higher application efficiency was obtained at lower pressure similar to results observed by other workers (Lyle and Bordovsky 1983; Vlotman and Fangmeier 1983).

Energy Consumption

Energy consumption for the modified centre pivot system was calculated in terms of kWh/m3 of water applied reaching the soil surface (James and Blair 1984). The high pressure operation mode showed an increase from 0.098 kWh/m3 at a wind speed of 3 km/h to 0.128 kWh/m3 at a wind speed of 32 km/h (Figure 5). The trend for the low pressure mode ranged from 0.047 kWh/m3 at a wind speed of 3 km/h to 0.067 kWh/m3 at a wind speed of 37 km/h (Figure 6). The low pressure mode had a less pronounced increase in energy consumption compared to the high pressure in addition to a consistently lower value. Average energy consumption of the high pressure mode (0.108 kWh/m3) was 1.9 times that of the low pressure mode (0.057 kWh/m3). Energy savings of 10-16% (Vlotman and Fangmeier 1983) and 20-40% (Gilley an Mielke 1980) have been reported where pressure requirements were lowered. Gilley and Watts (1977) suggested energy savings of 40-50% are attainable by lowering the pressure requirements.

Crop Water Use

The two systems were compared for crop water use and soil moisture change over the growing season using analysis of variance procedure. Total crop water use over the growing season was higher for the high pressure component of the modified centre pivot system than for the low pressure component for both faba bean and barley (Table 1). Soil profile moisture change also displayed a greater amount of water stored in the soil (as indicated by the larger negative value for growing season profile moisture change) for the low pressure application than for the high pressure application. This would indicate that more water reached the soil. These differences, however, were not significant indicating that both systems supplied equivalent quantities of water to the growing crops. New and Fipps (1990) suggest at least 20% more water will reach the soil surface with LEPA systems than with conventionally equipped centre pivot systems.
Figure 1. Effect of wind speed on the coefficient of uniformity for the conventional high pressure system.

Figure 2. Effect of wind speed on the coefficient of uniformity for the low pressure system.
Figure 3. Effect of wind speed on the application efficiency for the conventional high pressure system.

Figure 4. Effect of wind speed on the application efficiency for the low pressure system.
Table 1: Growing season profile moisture change and total water use

<table>
<thead>
<tr>
<th>Crop</th>
<th>Irrigation System</th>
<th>Rainfall</th>
<th>Irrigation</th>
<th>Profile Moisture Change</th>
<th>Total Water Use</th>
</tr>
</thead>
</table>
Crop yield was compared under the two systems using analysis of variance. Faba bean yield was significantly higher using LEPA irrigation than conventional high pressure irrigation (Table 2). The opposite occurred for barley. Faba bean is a long season crop that has an indeterminate growth habit which continues to grow and use water as long as growing conditions are favourable. Barley is a shorter season crop with a determinate growth habit. Lodging of the barley using the LEPA mode of the modified system was evident at harvest, which likely contributed to the lower yield.

New and Fipps (1990) indicate consistently greater crop yields from LEPA systems than from conventional high pressure systems and suggest the difference is due to more irrigation water reaching the soil and crop. Schneider and Howell (1994) found the yield increase from LEPA irrigation of winter wheat in comparison with spray irrigation to be small. Much more work needs to be done under Saskatchewan conditions before definite conclusions can be drawn on the effect of LEPA irrigation on crop yield.

### Table 2: Crop yields

<table>
<thead>
<tr>
<th>Irrigation System</th>
<th>Faba bean (16% moisture)</th>
<th>Barley (14.8% moisture)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEPA</td>
<td>3591</td>
<td>5330</td>
</tr>
<tr>
<td>CONVENTIONAL</td>
<td>3057</td>
<td>6143</td>
</tr>
<tr>
<td>Significance</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>CV</td>
<td>15.7%</td>
<td>17.9%</td>
</tr>
</tbody>
</table>

### Conclusion

Preliminary results indicate some differences between the conventional high pressure and low pressure centre pivot technology. The major difference occurred in application efficiency and energy consumption. Under the meteorological conditions present in 1994 greater application efficiency and a reduction in energy consumption was obtained for the low pressure application compared to the high pressure application. Uniformity of water distribution and crop water use displayed similar trends for the high and low pressure application. Crop yield for a high water use crop (ie. faba bean) displayed increased yield using low pressure system application. Further work is required before definite conclusions can be made.
References


Christiansen, J.E. 1942. "Irrigation by Sprinkling." Bulletin 670. Agricultural Experimental Station, University of California, Berkeley, CA.


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