LYSIMETER INVESTIGATIONS FOR
IRRIGATION IN MANITOBA

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INTRODUCTION

The importance of estimating evapotranspiration with acceptable accuracy is well recognized by agricultural engineers and others involved in resource use planning. The many problems connected with the question of transferability of evapotranspiration data, equations, and any other findings from one region to another one are also well known.

In Manitoba, Laliberte has been conducting studies on the transferability of the findings from southern Alberta to southern Manitoba. To this end, an experimental field irrigation station has been operated at Carberry, Manitoba, since 1967.

The author of this paper joined the research project in 1971, when nine small hydraulic weighing lysimeters were added to the equipment of the station for more accurate measurement of evapotranspiration, precipitation, and deep percolation.

This paper presents and discusses the results of the laboratory and field tests of the lysimeters, their performance and reliability, as well as the results of the first year of their use.

EXPERIMENTAL FIELD

The experimental field station was located on a farm, about 16 km (10 miles) north of Carberry in south-central Manitoba. Nine lysimeters and their reading scales were arranged in a single north-south-oriented row in the middle of a larger field (Figure 1).

In 1971, potatoes were planted in the field and in the lysimeters. Normal farm practices were used in all farm operations on both sides of the row of lysimeters. In the lysimeters themselves, and in the row between them, all work was done by hand.

Lysimeter 1 was 30 m (100 ft) from the northern boundary of the field. The distance between the lysimeters was 23 m (75 ft) with the exception of lysimeters 6 and 7, which were double-spaced to allow the irrigation main to be located between them.

The section of the field that included lysimeters 1, 2, and 3 was not irrigated. A sprinkler irrigation set was used to maintain the soil moisture between 60 and 100% of the available moisture (AM) in and around lysimeters 4, 5, and 6 and between 75 and 100% of the AM in and around lysimeters 7, 8, and 9.

Five tensiometers were set in each of the three areas to determine the timing of irrigation. A tensiometer was installed in one of each of the three sets of lysimeters and two were located in the field.

A weather station was located about 183 m (600 ft) from the northern end of the row of lysimeters. The weather station had recording and standard rain gauges, a class “A” evaporation pan, a pyrheliograph, two Bellani plate anemometers, two anemometers, one at the 2-m (6.6-ft) level and one at the 0.6-m (2-ft) level, a hygrothermograph, maximum and minimum thermometers, and a sling psychrometer.

LYSIMETERS

The lysimeters (Figure 2) were of the hydraulic weighing type that has been used in various modifications in many similar experiments. The main construction features and the operational principles, which are well known and have been described elsewhere (1), were slightly changed so that the accepted final design of the lysimeters enabled the measurement of not only evapotranspiration and precipitation, but also deep percolation, i.e., accumulation of free water at the base of the lysimeter.

A 0.102-m (4-inch) open-ended perforated plastic drain tube was fixed tightly...
This hole had a short stem on the outside to which a 0.051-m (2-inch) plastic pipe was clamped in a watertight connection. This pipe provided an underground gravity conduit, 3-m (10-ft) in length, to convey the drained water into a 0.203-m (8-inch) diam collecting and control well, which was deeper and provided a collecting space for the drained water. The water could be pumped from the well with a small portable pump and measured. The top end of the well was above the ground level and it was covered with a tight lid so that neither surface nor rain water could enter the system.

The plastic underground pipe and the 0.203-m (8-inch) well also provided a passage and protection for the tube from the hydraulic weighing system connecting the lysimeter to a vertical standpipe. The standpipe was fitted to a vertical standard equipped with a scale for measuring elevation.

For the water-filled (or water-antifreeze-filled) element supporting the lysimeter, rubber inner tubes with valves removed were used because they offered maximum strength and permitted practically unobstructed vertical movement of the lysimeter in the housing.

### TESTING AND RESULTS

The use of an inner tube as the fluid-filled supporting element caused concern about the accuracy and reliability of the hydraulic weighing system. The possibility was not dismissed that the tube, with its annular contact area, might expand and change its shape and volume as well as the contact area with the bottom of the lysimeter as the load varied, even though the pressures in the system were considerably below the pressures for which the tubes were fabricated.

The system was therefore carefully and extensively tested in the workshop before installation in the field. The testing at much wider load ranges than the expected field values has given very satisfactory results.

The fact that the contact area between the lysimeter bottom and the supporting hydraulic element (the tube) was smaller than the total area of the bottom of the lysimeter, proved to be an advantage, because the changes in the lysimeter loads, that is, in the soil moisture, were amplified on the reading scale of the balancing water column in the standpipe (Table I).

The ratio between changes in the standpipe scale readings and the changes in the moisture content in the lysimeter both expressed as equivalent depths of water depends upon the ratio of the supporting element contact area and the total lysimeter area. The fairly constant average ratio of 1.25 and the small standard deviation of 0.080 proved that there was little expansion or other changes of the supporting tube and that the system could be used and recommended with confidence. The standard deviation and potential small errors seemed to depend more upon human ability to read the scale correctly and precisely and upon the resolution of the scale than upon the hydraulic system.

In this study, scales with divisions of 1.59 mm (1/16 inch) were used, which, in consideration of the 1.25 ratio, enabled the detection of moisture changes in 1.27-mm increments. Using metric scales with 1-mm divisions would mean a slight further improvement in the resolution of the measuring system.

Field tests and calibrations were done first with the hydraulic system filled with water and later with a 1:1 water-antifreeze mixture. There were no significant changes in the basic 1.25 ratio, but there was some increase in the standard deviation, especially with the antifreeze mixture (Table I).

The water-filled systems showed the same sensitivity and quick reaction in the field tests as in the laboratory tests.

### TABLE I RESULTS OF LYSIMETER CALIBRATION AND TESTING

<table>
<thead>
<tr>
<th>Water-filled element</th>
<th>Antifreeze and water-filled element</th>
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<tr>
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<td>Lab. tests</td>
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<td>Mean change in the scale reading of the lysimeter (mm per mm)</td>
<td>1.250</td>
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<tr>
<td>Standard deviation (mm per mm)</td>
<td>±0.080</td>
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<tr>
<td>Standard deviation (\times 100) mean (%)</td>
<td>±6.4</td>
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</tbody>
</table>

Legend: 1, lysimeter filled with soil; 2, lysimeter housing; 3, flexible sealing, preventing surface rain water from entering the system; 4, rollers; 5, perforated open-ended plastic drain, diameter 102 mm (4 inches); 6, circular 51-mm (2-inch) diam opening in the lysimeter wall within one end of the drain pipe; 7, liquid-filled, ring-shaped supporting and weighing element; 8, plastic tube connecting the weighing element (#7) with the measuring acrylic pipe (#14); 9, copper tube protecting the plastic tube (#8) where it passes under the weighing element; 10, circular opening in the lysimeter housing wall with a short stem for clamping of the tube (#11); 11, hard PVC tube connecting the lysimeter housing with the control well and providing protected passage for tube (#8); 12, control well, diam 203 mm (8 inches); 12a, space for collecting deep percolation water drained from lysimeter; 13, watertight lid; 14, acrylic tube for measuring level of fluid; 15, scale; 16, standard (post).
Sensitivity to any small changes in the load caused difficulties in reading the scale during windy days when the level of the water column fluctuated in accordance with quickly changing force of the wind. The antifreeze mixture dampened the reaction of the hydraulic system a little but the excellent sensitivity was maintained.

All tests were done in multiple series of gradually increasing and decreasing lysimeter loads. In these tests the lysimeters were reliable for measuring evapotranspiration, precipitation, and seepage.

RESULTS

The lysimeters were installed between June 6 and 10, 1971, and readings on them were started on June 12, 1971. Readings were taken daily at 0830 at the same time as the weather station readings. Additional readings were taken immediately before and after any operation, such as weeding, that could have changed the weight of the lysimeters and caused errors in the water balance.

Recorded daily changes in scale readings were converted to equivalent depths of water in millimeters. The daily data were grouped into "decades" (three decades within a month, hence some having 11, and the first and last periods in the season in some instances less than 10 d). Mean daily evapotranspiration for each decade was calculated from the equation:

\[
ET = (D + P + I - R - S) / N \quad (1)
\]

where

\(ET\) = the mean daily evapotranspiration;

\(D\) = the summation of cumulative daily drops in the lysimeter moisture content, expressed in units of water depth;

\(P\) = the total precipitation depth;

\(I\) = the total irrigation applied;

\(R\) = the summation of cumulative daily increases in the lysimeter moisture content, expressed in units of water depth;

\(S\) = the depth of water drained from the lysimeter; and

\(N\) = the number of days on which readings were taken.

All terms of the equation were the values recorded or calculated within the particular period and they were all expressed as depths of water in millimeters. Surface runoff was not included in the water balance equation because the design of the lysimeter did not allow exchange of surface water between the lysimeters and their surroundings. This feature was insured by locating the lysimeters away from any runoff channel and by the approximate 40-mm (1.5-inch) extension of the lysimeters and their housings above the ground surface.

The average daily evapotranspiration rates for each irrigation treatment (Figure 3) showed basically the same trend. As expected, the curves representing the two irrigated treatments were nearly identical with slightly higher values for the higher moisture level treatment, whereas the nonirrigated treatment generally had substantially lower values of daily evapotranspiration.

The evapotranspiration rates of all three groups had two peaks and a period with lower daily evapotranspiration between them. This was different from the commonly presented and accepted evapotranspiration rates that increase steadily to a maximum and decrease again in a smoothly shaped curve.

One explanation of the two peaks is based on the growth pattern of the potato plant and assumes that the first period of higher and increasing daily evapotranspiration corresponds with the growth of the foliage, and the second period with the development of the tubers. The lower evapotranspiration between these two periods coincides with a relatively slower period of growth, during which only a small amount of new plant tissue is formed and mainly a "maintenance" transpiration takes place.

This explanation is supported by the findings (at the same location) of Birecki\(^\text{b}\), whose graphs of the changes of weight of potatoes (plants, foliage, and tubers) indicated clearly the two-stage development of potatoes. There were two periods of rapid weight increase separated by a period with small weight increase or even negative changes of the total weight of potato plants, depending upon the variety.

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\(b\) Unpublished internal report, Plant Science Department, Faculty of Agriculture, University of Manitoba, Winnipeg, Manitoba, 1970.
The seasonal evapotranspiration (Figure 4) of potatoes on the experimental plots in 1971 as determined by the lysimeters was approximately 372 mm (14.65 inches) in the irrigated plot and approximately 293 mm (11.53 inches) in the nonirrigated plot.

SUMMARY

A set of nine small-area hydraulic-weighing lysimeters was installed in 1971 in an irrigated field of potatoes near Carberry, Manitoba. Because of two substantial differences in their design as compared with similar lysimeters used elsewhere, the lysimeters were calibrated in the laboratory and in the field prior to data collection. The first modification was characterized by the replacement of the conventional full-area liquid-filled supporting element by a rubber tube with an annular contact area between the element and the base of the lysimeter. This increased the accuracy of the reading. The second change, the addition of a drain at the base of the lysimeter connected to a collecting well, made it possible to measure deep seepage losses.

The tests demonstrated that the modified lysimeters were reliable, sensitive, and reasonably accurate. The evapotranspiration of potatoes measured at the Carberry experimental site in 1971 was about 372 millimeters (14.65 inches) on the irrigated plots and 293 millimeters (11.53 inches) on the nonirrigated plots.

ACKNOWLEDGMENTS

This paper reports one phase of a project initiated by Dr. G.E. Laliberte on the consumptive use of water by some crops in southern Manitoba. The author sincerely thanks Dr. Laliberte for his support in preparing the paper and for his extensive editorial work on it.

REFERENCES