Small Lysimeters for Measurement of Water Use and Herbage Yield

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Highlight: *Small weighing lysimeters provide a useful tool for investigating simultaneously soil water use and plant productivity in annual grasslands. Details of construction, sensitivity and accuracy of weighing, and field and harvest techniques are given. PVC irrigation pipe is used for both the lysimeter and its sleeve–5 inch and 6 inch nominal diameter, respectively. Weight changes equivalent to .002 inch (.05 mm) can be detected, allowing diurnal water use to be determined if desired. Comparisons using shoot harvest and soil water use for Spring, 1971, show good agreement between the lysimeters and the field.*

Weighing lysimeters can provide useful information concerning water relations because they physically confine soil water. However, most lysimeter installations employ relatively large lysimeters to simulate surrounding community conditions, thereby precluding sufficient replication to estimate variability within communities. In Russia, the State Hydrological Institute has carried out extensive experimentation with lysimeters of various sizes, concluding that small lysimeters need not substantially distort either the water or thermal regimes within the lysimeter with respect to the field (Konstantinov, 1966). The lysimeters specified by the Russian Hydrological Institute were 0.05 m^2 in surface area, 0.5 m deep, and were constructed with steel walls. Smaller diameters were discouraged because the conductivity of the walls disturbed the temperature conditions with the lysimeter, while shallower lysimeters were precluded by the expected depth of rooting of the experimental grasses (barley, wheat, and rye). This paper describes a modification of the USSR small lysimeter and discusses some simple field techniques for meaningful replication in the field.

Construction of the Lysimeters

The major disadvantage of small lysimeters for field use is their small surface-to-edge ratio, allowing a greater potential for thermal distortions in the enclosed volume of soil. In the Russian lysimeters,

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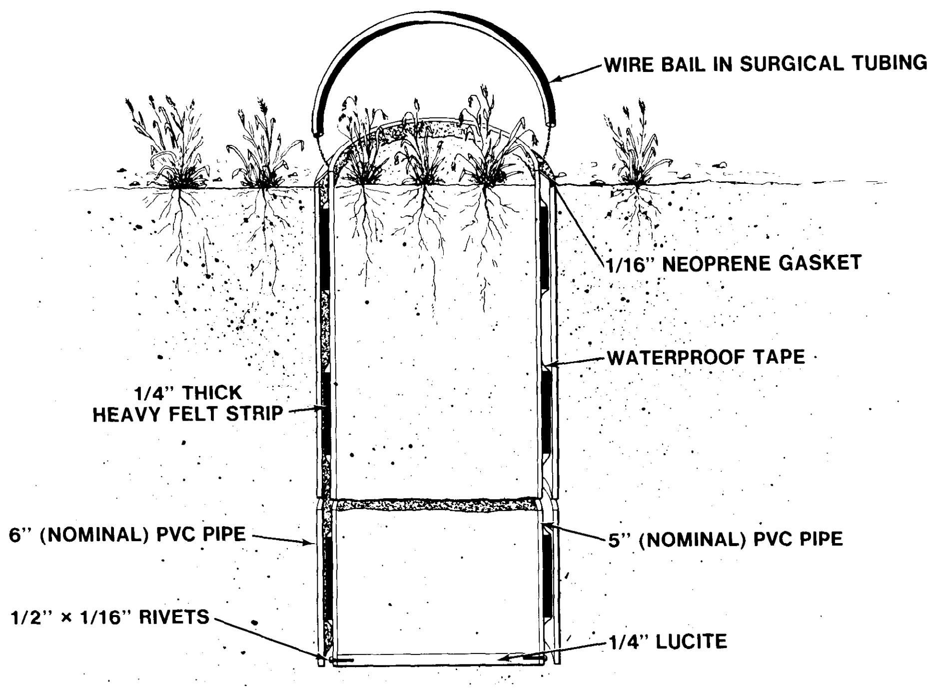

Fig. 1. *Details of construction of small lysimeter. The lysimeters discussed in the text were 60 cm deep, but shallow-rooted plants may not require that depth.*

thermal disturbance was induced by two factors: the high conductivity of the metal walls of the lysimeter and its sleeve; and the air gap between the lysimeter and sleeve. The disadvantages of metal can be avoided by using plastic irrigation pipe (polyvinyl chloride) for both the lysimeter and the sleeve. Nominal 5-inch diameter pipe has an outside diameter (OD) of 5.65 inches (14.4 cm) and an inside diameter (ID) of 5.2 inches (13.2 cm), providing an internal cross section of 138 cm^2. Three or four strips of 0.25-inch-thick felt, about a quarter to a half inch wide, taped around the outer walls of the lysimeter, form "O" rings for a snug fit with the inner walls of the sleeve, which is nominal 6-inch diameter irrigation pipe with an ID of 6.2 inches (15.7 cm). The felt should be covered with waterproof tape, to prevent absorption of water in any form and the tape lubricated with oil or hard grease if necessary. Finally, a neoprene annulus just smaller in ID than the OD of the lysimeter, with an OD just greater than the OD of the sleeve, serves as a shield over the gap between lysimeter and sleeve, preventing wind, rain, and radiation from entering the gap. This series of baffles prevents convection currents between the lysimeter and its sleeve, encouraging horizontal isotherms within the lysimeter, just as in the field. The entire array of baffles and gasket is removed with the lysimeter for weighing. Figure 1 is a detailed cross section of the modified lysimeter.

Field Techniques

Installation of lysimeters in stone-free soil is a simple operation using a screw-type power auger to dig a hole the required depth. The diameter of a 7-inch hole is generally somewhat less than the OD of the 6-inch piping (6.7 inches or 17.0 cm) used for the sleeve, so the sleeve slices off a small amount of soil which must be cleared out of the hole (an ice cream scoop is handy for this). The lysimeter can then be inserted in the sleeve and the annular gasket smoothed as necessary. The entire procedure is more readily accomplished in moist soil rather than dry.

Placing soil in the lysimeters presents much the same problems faced in placing soil in garden pots. In relatively homogeneous soils without well developed horizons, dry soil can be poured into the lysimeter while bumping the lysimeter vigorously to remove excess air. The final bulk density can be controlled by varying the screening of the dry soil before use. Table 1 shows bulk density with different screen size on a sandy loam. Finely screened soil should be added slowly and bumped around in the lysimeter until it feels firm to the touch, lest excess air in the soil be displaced during wetting, causing extensive shrinking.

Table 1. Bulk densities (g/cm³) attainable as a function of screening size (mesh/inch) of the dry soil.

Screen size	Bulk density
2	1.25[1]
8	1.35
20	1.45

[1] Field conditions.

These lysimeters weigh approximately 35 pounds at field capacity. A portable scale with 25 kg capacity and 5 gram resolution[1] provides sufficient accuracy for determining water losses of 0.002 inch (0.05 mm) from the surface area of the lysimeter. If stationary and covered, this scale will weigh a calibration weight of 8.000 kg to within ±5 grams for periods approaching a year. Weighings of this sensitivity, however, *must* be shielded from wind; otherwise, the variability of the weighings may be increased by factors of five or ten.

To duplicate field conditions of grassland surfaces, soil cores can be taken, using a sharpened section of the 5-inch PVC pipe. The soil core slides readily into the lysimeter when pressed with a heavy weight placed on a plywood circle on top of the core. The maximum practical depth of the core probably depends on soil texture and moisture; for sandy loam, 30 cm was very difficult, but 10 cm was easy. The wet soil in the lysimeter must be "fluffed up" at its surface prior to core insertions to assist hydraulic contact between the core and the underlying lysimeter soil.

Total water loss is readily measured as evaporation from unvegetated soil surfaces and evapotranspiration from vegetated lysimeters. Unvegetated lysimeters are prepared by removing living plants, leaving any mulch intact, before installing them in the field. Comparing water losses from vegetated and unvegetated lysimeters gives the transpirational loss.

Soil temperatures and water potential can be monitored in as great detail as desired, merely by placing thermistors, thermocouples, or psychrometers at the desired depth as the lysimeters are filled.

Herbage yields within the lysimeters are measured by harvesting, but the precision of estimation is generally not the same for roots and shoots. Root estimates are obtained from samples of the soil and cores to be placed in the lysimeters. The samples are washed through, say, a 20-mesh/inch screen and floating root material collected for weighing and ashing necessary to account for soil particles held by the roots. After the period of study, the soil is washed out of the lysimeters with a high pressure water nozzle, with the soil again passing through a 20-mesh/inch screen—this collects all particles of 20-mesh size and larger. This material is then floated in water to separate root material for drying and ashing, just as was the "background" sample. The difference is root growth in the lysimeter, but with a larger standard error than for shoot growth, which is

[1] Maco model 25, is available from Mantes Scale Co., San Francisco, California. Brand names are for reader's convenience and do not constitute endorsement of the product.

Table 2. Average *Bromus tectorum* shoot production (g/m^2) and total water loss (cm) estimated from lysimeters and in the field. Spring 1971, in a field at 1.700 ft elevation.

Location	Shoot production[1]	Water loss[1]
Lysimeter	156 ± 18	16.9 ± 0.6
Field	170 ± 24	16.5 ± 0.8

[1] Numbers following ± are standard errors.

estimated merely by clipping the plants from some cores when preparing the lysimeters and just before washing the soil out of the lysimeters.

Table 2 compares data from the lysimeters and from the field. The field water loss (determined gravimetrically) and herbage yields are very close to those from the lysimeter measurements in both average and variability. Not shown is the precision attainable from periodic weighings—13 lysimeters yielded an average standard error of 0.017 cm/day (9% of the mean) from 10 weighings in 60 days.

Conclusions

The small lysimeters used in groups provide a precise picture of water use during the season and an accurate total for the season. Likewise, the productivity in the lysimeters reflected both the average herbage yield and the natural variability encountered in the field. The lysimeters are not expensive—PVC pipe costs about $1/ft, and construction of each lysimeter takes about 2 hours of shop time. The data attainable through using several to many of these small lysimeters are unparalleled by other lysimeter techniques and consequently offer a potential for new insights into water relations and productivity in annual grasslands with only a modest capital investment.

Literature Cited

Konstantinov, A. R. 1966. Evaporation in Nature. Available from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151, $8.36; translated from the Russian.