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Management of Trickle-Irrigated Orchards for Increased Water use Efficiency

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Texas A&M University

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MANAGEMENT OF TRICKLE IRRIGATED ORCHARDS FOR INCREASED WATER-USE EFFICIENCY

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ABSTRACT

Trickle irrigation is the most efficient method of irrigating peach orchards in Texas. With a trickle irrigation system, a producer may make full use of a limited or low-volume water supply to apply precise amounts of water to the root zones of individual trees. Improved irrigation scheduling methods offer the potential for further savings in water and energy to pressurize the water since peach trees require less than a fully-watered state for production. This report describes research to determine the crop coefficients for peach trees that would result in an optimum irrigation schedule. One major effort evaluated the physiological response of the peach tree to varying irrigation regimes. This thrust indicated that a crop coefficient as low as 0.53 produced similar physiological responses (leaf water potential, leaf resistance, and transpiration rate) as a crop coefficient of 0.7. The critical period for initiation of stress was during the period before harvest. A large twin weighing lysimeter facility was designed and installed. Preliminary results for mature peach trees showed water use rates at the maximum evapotranspiration rate approached a crop coefficient of 1.0. The research indicates that the peach tree is a luxury consumer of water; improved irrigation scheduling is achievable.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the special efforts of several people who contributed much to this project. Dr. Terry Howell was the architect of the concept for the project and was instrumental in obtaining financial support from the Office of Water Research and Technology, U.S. Department of Interior, through the Texas Water Resources Institute. Mr. Dale Allred contributed significantly to the design and installation of the lysimeter facility. Mr. J. S. Newman and his staff at the Stephenville Agricultural Research and Extension Center provided sterling support to the project. Special thanks are in order for Dr. J. R. Runkles, Evelyn Teaff and Pat Feagan of the Texas Water Resources Institute for their outstanding assistance with the management, administration, and financial aspects of the research efforts.

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INTRODUCTION

Trickle irrigation in its various forms is used for 10,000 hectares (25,000 acres) of tree crops in Texas, according to the 1981 survey by the Irrigation Journal. Gravity and sprinkler irrigation account for an additional 7,000 hectares (16,000 acres). The trend is toward increasing conversion to trickle irrigation from gravity and sprinkler and from dryland production. Several advantages of trickle irrigation are responsible for this conversion, especially in peaches and in new plantings of citrus and peaches.

In young trees, applications of water can be made to the individual trees without wasting water between the trees. In mature trees, trickle irrigation can be used efficiently in areas with a low-volume water supply and in shallow soils or undulating terrain not suited to other irrigation methods. The application efficiency and distribution efficiency of trickle irrigation are quite high, so limited water can be used more effectively. Several other benefits of trickle irrigation are known. These include decreased labor requirements, the potential for automated operation, the ability to conduct cultural activities while irrigation is occurring, the ability to apply fertilizer through the irrigation system, and an overall improved control of the water. Several advantages of yield and quality are also claimed as a result of a more uniform moisture management.

Irrigation scheduling remains a problem, however. Peach trees (*Prunus persica*) are apparently luxury consumers of water. The tree will consume water in addition to that required for optimal fruit production and tree growth. Excessive water application will promote fungal diseases of the trunk, increase the costs of pumping, and decrease the acreage that could be irrigated. The excess growth is lost through pruning. Evidence exists that fruit quality may suffer. Goldberg et al (1976) state that it is considered good practice to slightly stress deciduous fruits four to six weeks before picking in order to promote fruit quality and storage quality of the fruit.

The seasonal weather progression and the inability to take rainfall into account rule out fixed amount scheduling (e.g., 100 liters per day for a mature tree) as an efficient method of scheduling irrigation. The methods based on application of the water consumed the previous day will inevitably provide the maximum water the tree will use. These methods include maintenance of a constant surface wetted area of the emitter and scheduling to maintain a tensiometer reading below a specified suction.

A more efficient irrigation scheduling method is to calculate the potential evapotranspiration rate for the previous day, convert that to volume of water use by a representative tree, and apply a fraction of that amount of water through the trickle irrigation system. Several factors must be known. The potential evapotranspiration (PET) rate can be estimated from evaporation pan measurement or from calculation with a PET model based on measurements of atmospheric parameters. A crop coefficient is then used to convert this PET estimate into crop water use. The crop coefficient for peaches recommended for Texas is 0.7 (Keese and New, 1981). Doorenbos and Pruitt (1977) cite crop coefficients by months for peaches and other deciduous fruits as a function of general climatic condition.

Selection of crop coefficients for the optimum irrigation schedule should be a function also of the peach variety. Harvest in Texas will be from late May through August, with the harvest of the major commercial varieties occurring in July. Water requirements should be a function of the period of the development of the fruit, which achieves two-thirds of its weight during the latter one-third of its growing period. A common practice in Texas is to reduce the irrigation to just enough to prevent leaf fall between harvest and the end of the growing season in late fall.

Selection of crop coefficients for peaches is complicated by the inherent variability in individual trees as well as varietal differences. The trees are typically pruned into an open crown configuration with three or four scaffold branches. Annual pruning restricts the height to about 2.5 meters. These pruning practices and the thinning of the fruit early in the season introduce a variability that confounds statistical evaluation of results of experiments and trials. Consequently, a large number of trees in each replication are required to obtain statistical significance of yield differences that may be of commercial significance.

The basic objective of this research was to determine the crop coefficients for peaches that would result in the optimum irrigation schedule. Specific objectives were:

1. To determine the daily evapotranspiration of peach trees as a function of potential evapotranspiration and soil water status.
2. To determine the physiological responses of the tree, including yield and plant water status to environmental factors.
3. To develop management guidelines to efficiently utilize trickle irrigation systems to increase water use efficiency in peach production.

METHODOLOGY

The research was conducted along two major lines of approach. The major effort was directed toward quantification of the physiological response of the peach tree to environmental factors. The physiological response measurements included leaf water potential, leaf resistance and conductance, and transpiration rate through diurnal cycles from mid-season to post-harvest. These measurements were related to measurements of soil moisture status and irrigation water applied in order to determine the response of the tree to moisture availability. Yield and fruit size measurements were also obtained. Volume I of this Technical Report contains a description of this aspect of the research.

A second phase of the research was directed toward the accurate measurement of the daily evapotranspiration of the peach tree. Soil moisture budget methods using neutron probe measurements lacked the necessary daily precision, so a weighing lysimeter facility was designed and installed. The facility consisted of two cylinders 2.44 m diameter and 1.52 m deep. A mature peach tree was transplanted into each lysimeter. The weights of the containers were measured with three strain-gage load cells.

The description of the lysimeter facility is contained in Appendix A. The lysimeters became fully operational in June 1982, so a detailed description of the daily evapotranspiration is not availab.e. This research is continuing.

RESULTS

Preliminary results of the research to determine the daily evapotranspiration of a mature peach tree indicates a water use rate of the order of 125 to 150 liters (33 to 40 gallons) for peach trees with a canopy diameter of 4.6 meters (15 feet). This fully-watered state is the equivalent of up to about one cm equivalent depth water per unit area of canopy (0.40 inches water). This rate is approximately full evaporation pan. Wind loading on the trees apparently translates as a weight gain during windy periods, which lessens the ability to detect hourly water use. This does not interfere with the daily measurement of evapotranspiration, however.

Results of the physiological response to environmental factors included:

1. Maximum (lowest negative) values of leaf water potential occurred near dawn when an equilibrium state between leaf water and soil water potentials occurred. The minimum (highest negative) values of leaf water potential occurred around local solar noon, which indicated a dominant influence of radiation. Sunset values of leaf water potential were lower than the sunrise values, which indicated a lag in the recovery of the leaf water status.
2. Leaf water potentials and leaf resistances were higher in the shaded leaves for all irrigation treatments. This has the obvious interpretation of reduced transpiration in a shaded leaf.
3. Peach trees with a heavy fruit load were more sensitive to moisture stress and developed stress symptoms more rapidly. When the fruit load was removed (harvest) the stress levels decreased for comparable environmental conditions.

4. Comparisons of trees on four irrigation regimes indicated that the plant water status of the 4-emitter (crop coefficient of 0.7) and 3-emitter (crop coefficient of 0.53) trees were not significantly different. This reinforced the concept that the peach tree is a luxury user of water, since no physiological response to the extra water could be detected.
5. The tree on a 1-emitter regime (0.18 crop coefficient) developed stress earlier in the day and reached lower leaf water potentials. Stomatal closure, as evidenced by the leaf resistance measurements, occurred earlier in the day. Yields from 1-emitter trees in the replications were significantly lower.
6. Ground covers covered with several centimeters of soil were installed to eliminate evaporation from the wetted areas of the trickle emitters and to reduce the soil moisture additions from rainfall were beneficial to the tree growth. Pruning weights for comparable irrigation regimes were twice as great for the trees with ground covers. The trees were visibly larger after mid-season. One possible beneficial effect of the ground cover was the net increase in soil water availability to the trees.

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APPENDIX A

Installation of a Large Twin Weighing Lysimeter Facility

INSTALLATION OF A LARGE TWIN WEIGHING LYSIMETER FACILITY[1]

Marshall J. McFarland, Dale H. Allred, James S. Newman,
and Josiah W. Worthington[2]

Introduction

A lysimeter is essentially a container enclosing a volume of soil for hydrological measurements of the soil-water reservoir. The lysimeter isolates the sides and base of the soil volume hydrologically from the surroundings (Tanner, 1967). The top may either be similar to the surroundings or be modified, such as with a cover or rainout shelter, to modify or control the influences of evaporation and precipitation. A wide range of measurement devices and sensors is in use to sample, directly measure, or indirectly infer the physical and chemical nature of the water, either under soil tension or in the gravitational state.

Weighing lysimeters provide a means of converting changes in weight over periods as short as an hour or less to equivalent transpiration of the crop in the lysimeter. Weighing lysimeters represent the only accurate and reliable method for directly measuring crop evapotranspiration over short periods of time (Black et al, 1968; Van Bavel and Myers, 1962) or in field conditions (Van Bavel, 1961; Ritchie and Burnett, 1968).

Non-weighing lysimeters are also in widespread use, but for different measurements of the physical and chemical forms of the water in the

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soil-water reservoir. Lysimeters with water table controls have been used to develop criteria for subsurface drainage system design. Reichman et al (1979) studied the yield of corn with various depths to the water table in large non-weighing field lysimeters. The rims were buried 20 cm below the land surface to allow unhindered cultural practices and similar surface hyrological and encironmental conditions at the surrounding field. The water tables were maintained with float activated switches to add or remove water. Cannell et al (1980a and 1980b) developed a non-weighing lysimeter system to study the effects of transient waterlogging on crops, especially wheat.

Non-weighing lysimeters are also in use to determine the movement and chemical changes of water in a soil column. The residence time, distance of travel, and chemical changes have been determined for herbicides (Glass and Edwards, 1979), fertilizer materials (Goh et al, 1979; Dowdell and Webster, 1980; and Jurgens-Gschwind and June, 1979), and leachate from sanitary landfill. Detergents, radioactive isotopes, and other potential groundwater pollutants can also be examined in lysimeters (Parizek and Lane, 1971). Salt movement can be evaluated in non-weighing lysimeters, although Robbins and Willardson (1980) used a weighing system for their study.

Lysimeters documented in the literature range in size from the 100 square meter surface area of the undisturbed monolith natural lysimeter (Kitching and Bridge, 1974) to a 0.12 square meter area of a pan lysimeter for interception and collection of effluent leachate at varying depths (Parizek and Lane, 1971). Large weighing lysimeters for ET investigations exist at several sites (see Sammis, 1981 for size comparisons of some large weighing lysimeters).

The design criteria for lysimeters accordingly are as varied as the uses and types of lysimeters.

Lysimeter Design Criteria

A major restriction that must apply to all lysimeters regardless of design is that great care must be exercised in interpreting the results for practical conditions. This is especially valid for lysimeter experiments to determine natural processes involving the soil-water reservoir.

Evaluation of actual ET in field crops with a lysimeter requires that the lysimeter area be indistinguishable from the surrounding area. The measured ET will not be representative of the rest of the field if the lysimeter crop is shorter, denser, thinner, if a non-cropped border exists, or if the moisture availability in the lysimeter is different (King et al, 1956). The crop in the lysimeter should have a normal rooting profile, which is relatively difficult to achieve for any plant grown in a container. Van Bavel and Myers (1962) recommend a normally drained soil column of approximately 150 cm depth. Attention must be paid to the conditions at the base of the lysimeter (Tanner, 1967). The moisture tension will be different, ordinarily lower, than for a comparable depth in the field. Thus, lysimeters will have more moisture available in stress periods. Solutions are to either construct a deep lysimeter or to maintain a suction on the base to be representive of the soil moisture tension in the field (Van Bavel, 1961).

The surface area for crop ET measurement should be representative of the crop, both in terms of geometry (Ritchie and Burnett, 1968) and effective area (Tanner, 1967). The ET per unit area for the lysimeter should be the same as the ET per unit area for the surrounding area. The guard or border area, or the surrounding field, must have as small a discontinuity due to the lysimeter rims as possible. Mustonen and McGuinness (1967) reported a 10 to 20 percent increase in radiation for the crop in the lysimeter as a result of the gap between the field and the lysimeter. A large gap also contributed to a differing thermal environment in the lysimeter than in the field. Thus, design requirements point toward a large lysimeter for ET investigations.

For lysimeter systems for non-ET purposes, the depth, surface area, and geometry are not significant as design criteria. The requirements for natural conditions dictate that the soil profile either be carefully reconstructed or that the soil volume be an undisturbed monolith. Disturbed soil has differing physical properties due to a changed structure and profile. A change in the physical properties, which include hydraulic characteristics, will result in changes in the moisture and aeration regimes, which may change the chemical properties. These would involve mineralization and denitrification of nitrogen and different capacities of the soil to buffer or degrade potential pollutants (Belford, 1979).

Brown et al (1974) and Fritschen et al (1973) describe procedures for placing large undisturbed monoliths in lysimeters. These procedures basically involved excavating a trench around the monolith, then either fitting the lysimeter walls to the monolith or carefully sliding the lysimeter downward over the monolith. Base plates are inserted beneath the lysimeter with hydraulic jacks. The lysimeter is then lifted, welded, instrumented, and lowered into a prepared facility. Fritschen et al (1973) and Sammis (1981) reported difficulties with insertion of the base plates due to large rocks or consolidated materials. Bhardwaj and Sastry (1979) reported successful use of the technique.

Smaller monolith lysimeters, such as those used for drainage investigations, can be constructed of sheet metal or pipe (e.g., large PVC) forced into the ground with dead weights or jacks. The cores can then be lifted for instrumentation or transporation to a lysimeter facility (Brown et al, 1974; Dowdell and Webster, 1980; and Robbins and Willardson, 1980).

A natural undisturbed monolith can be created by installing sidewalls of metal or rubber membrane to either the water table or an impervious rock formation. Kitching and Bridge (1974) constructed two lysimeters with surface areas of 100 square meters each to measure infiltration in Nottinghamshire. Their sidewalls were 5.4 meter deep; infiltration was measured with water level recorders in observation wells. Calder (1976) used sidewalls of corrugated iron to a base of impermeable clay to determine the water budget of a forested plot of 84 square meters.

A different approach to measuring the amount and chemical composition of drainage from effluent disposal through an irrigation system was used by Parizek and Lane (1971). A five meter trench was dug to allow small pan lysimeters to be inserted into the trench wall to intercept and collect gravitational water.

An alternative to an undisturbed monolith is to remove the soil layer-by-layer from the site, insert the instrumented lysimeter container, and repack the soil to original profile and bulk density. Reichman et al (1979) used this method to construct large lysimeters for their investigation of drainage system design. Their containers were constructed of plywood to support and shape a 30 mil nylon reinforced butyl rubber membrane. Ritchie and Burnett (1968), Heatherly et al (1980), Tan and Fulton (1980), and Black et al (1968) reconstructed the soil profile, which seems necessary for large rectangular lysimeters that are representative of the field crop geometry. The large rectangular lysimeters described in the literature are reinforced with interior gusset plates and/or external ribs to prevent deformation.

An additional design criteria for weighing lysimeters is sensitivity. For hourly values of evapotranspiration, a sensitivity of the weighing mechanism expressed in mm of water per unit surface area can be expressed. Mechanical balance weighing lysimeters can attain 0.02 mm by counterbalancing the majority of the lysimeter weight, then measuring with strain gage load cell or hydraulic means the weight changes due to water gains and losses. For large lysimeter installations such as at Davis, California, the mechanical balance mechanism is constructed beneath the lysimeter (Pruitt and Angus, 1960). For smaller lysimeters, Voisey and Hobbs (1972) report accuracies of 0.017 mm water for several lysimeters transported via an electric hoist on a travelling gantry to the weighing mechanism. Comparable accuracies cannot be obtained easily without a mechanical balance, but sensitivities of hundredths of a millimeter are not required for daily or longer period evaluations of transpiration. Millimeter accuracies are reported with hydraulic weighing systems or with non-counterbalanced load cell mechanisms.

Design of Lysimeter for Peach Tree ET

Irrigation research at the Stephenville Agricultural Research and Extension Center into the optimal water requirements of peach trees (*Prunus persica*) indicates that the peach is a luxury user of water. The trees will consume water in addition to that required for optimal fruit production and tree growth. The excess water may not be desirable from a management standpoint. Increased pruning requirements, fungal diseases of the trunk, costs of pumping, and possible decreased fruit quality and irrigation acreage capability are unwanted aspects of fully watered trees.

The long-term primary objective of this research is to determine the optimal water requirements of peach trees. Lysimeters were deemed essential to the research in order to confine the root volume so that a precise measurement and control of water could be obtained. The extreme variability of mature peach trees ruled out a representative plant population in the lysimeters, while the cost of the lysimeter facilities precluded replications. A decision was made to install a twin weighing lysimeter facility for mature peach trees. The tree in one side would receive the maximum water it could use (i.e., irrigation to replace ET the previous day) while the companion tree would receive a fraction of this water. Physiological measurements including yield, shoot growth, and leaf water status would provide the basis for evaluation on these two trees. The results will be difficult to interpret without calibration to a field environment. A single tree in a weighing lysimeter will not be representative of a tree in a natural orchard situation, so soil and leaf water status will also be measured in different irrigation treatments.

The primary design criteria were:

1. Sensitivity. Daily ET measurements to an accuracy of several liters water were required, based on an expected maximum ET rate of about 230 liters per day in the fully watered treatment. The equivalent water over the surface area would be on the order of a few millimeters.

2. Disturbed vs. monolith soil. A normal or field environment rooting density and profile was not a criterion, so a disturbed soil consisting entirely of the A-horizon loamy sand was used for the lysimeters. A monolith would have been extremely difficult to obtain, since the soils at the Stephenville Agricultural Research and Extension Center are layered with extremely hard B horizons. A description of the soil is contained in Appendix I. Rooting patterns are assumed to be a function of water source in design of trickle irrigation systems, so a standard rooting pattern in trickle irrigated peach trees has little significance.

3. Size and shape. A cylindrical container large enough for a mature peach tree was desired. Peach trees are shallow rooted, so a 1.52 meter depth was selected. The surface projection of the rooting pattern is often assumed to be a drip line, so a 2.44 meter diameter cylinder was selected as a compromise between total weight and necessary size for the trees with a canopy diameter of approximately 4.6 meters. The dry weight of the soil volume was calculated at about 10,700 kg with a net weight of about 13,700 kg.

4. Instrumentation. An automatic, continuous weighing mechanism was desired, along with automatic, continuous recordings of on-site meteorological variables. Temperature, wind run, relative humidity, and radiation measurements were required for calculation of potential evapotranspiration. Precipitation measurements were also needed. Soil moisture measurements, when required, would be made from neutron access tubes placed in the container.

5. Site. Ideally, the lysimeter facility would be constructed at a representative site within an orchard. This would provide the required representativeness, without border or edge effects. We elected to place the lysimeter facility in the headquarters area for ease of accessibility, observation, available water supply, and future ease of conversion to peach trees of different variety or age, or even conversion to pecan or apple trees. The selection of site as a compromise of several considerations implies that site effects will be present and will have to be accounted for in the analysis of the results.

6. Water control. A metered water irrigation system will supply the required irrigation water to each lysimeter. Each lysimeter would be equipped with drainage systems to collect and measure drainage water from excessive rainfall or over-irrigation.

Lysimeter Construction

Design details for the twin weighing lysimeter facility are shown in Figure 1. Cost was an important consideration, since the budget was limited. This design of one covered access passage to serve both lysimeters represented a minimum of excavation and construction. Access to the passage and the lysimeter weighing mechanisms is gained through a top door and ladder.

The inner container is 10 gauge rolled steel, while the outer container and access passage are constructed of reinforced concrete. The inner containers are 2.44 m diameter cylinders that are 1.52 m deep. In view of the structural strength of cylinders, no gusset plates or other reinforcements were added. In the 18 months since filling with soil, no deformations of the walls have occurred that would require correction.

A gap of approximately five cm exists between the inner container and the outer wall. This gap amounts to eight percent of the surface area of the inner container, which is 4.68 square meters.

An outer wall of reinforced concrete was selected instead of steel or other material in view of cost, strength, and life expectancy. The total distance between the lysimeter soil and the surrounding soil was not a design consideration for this tree lysimeter design.

The lysimeter pit was excavated by a skilled backhoe operator and dressed with shovels. This shape provided the outer form for pouring the wall and floor concrete after the rebar was placed. The inner form for the passageway was constructed of plywood with 2x4 cross-bracing. The inner forms for the lysimeters consisted of the lysimeter tanks. When the lysimeter steel was ordered, the order for the lysimeter steel specified that the bases not be welded to the tanks and that the final side seam not be welded. This gap was opened to 0.3 meters and made rigid by welding iron pipe to the inside of the container. Eleven iron pipes about three m long were welded in a vertical position to the inner wall. The base was welded to the top to form frames that could be transported and lowered into the lysimeter pits with a forklift.

After the walls cured, the lysimeters were lifted from the pits. The side seam was welded. To form a rigid base, a five cm layer of fiberglass grating was sandwiched between two 10 gauge steel plates and securely bolted. The lysimeter was welded to the top plate. The supports for the weighing mechanisms were constructed, as shown in Figure 2, to prevent deformation about the load-bearing points.

The completed lysimeters were placed on wooden blocks in the pits for filling. A network of perforated PVC pipe was laid on the lysimeter floor and covered with about eight cm of pea gravel to facilitate free water drainage. The lysimeters were filled with topsoil.

In the early spring of 1981, two mature peach trees were transplanted into the lysimeters. The trees were Redglobe on Nemaguard rootstalk with a 14.7 cm trunk diameter and a 4.6 meter diameter canopy. The trees were six year old trees and had been pruned into the typical open crown configuration with three scaffold branches. The height was limited by pruning to 2.5 meters. Transplanting was accomplished by hand-digging a one-meter ball of root zone, wrapping the ball with burlap, and lifting the tree with a forklift for transportation to the lysimeter. Tree growth was noted to be slower than normal the first year in the lysimeters, but has been more-or-less normal this year when compared with trees in the orchard. Early season climatic conditions resulted in a light and unevenly distributed bloom, however. The completed facility is shown in Figure 3.

A Campbell CR-21 Micrologger[1] was selected as the data logger for the environmental measurements and the strain gage load cell measurements. Output from the nine channels is printed on paper tape and loaded on a cassette tape recorder for direct entry into the on-line computer disk files. Measurements are recorded at least hourly for temperature, relative humidity, wind run, precipitation, solar radiation, and net radiation over the canopy. Two channels record the weights of the lysimeters.

Three compression strain gage load cells connected in parallel provide the weights of each lysimeter. The load cells are Model LG-104-20M from Gentran, Inc. of Sunnyvale, California.[1] Each has a 9080 kg (20,000 lb) capacity. Characteristics for the load cells are in Table 1.

TABLE 1. Load Cell Characteristics

Model LG-104-20M; pressure and temperature compensating.

Linearity:	0.2 percent full scale, or 18.16 kg.
Hysteresis:	0.05 percent full scale, or 4.54 kg.
Repeatability:	0.03 percent full scale, or 2.72 kg.
Total Accuracy:	0.25 percent full scale, or 22.70 kg.
Sensitivity:	2 millivolt/volt excitation voltage.

An external power supply (15 volt, 200 milliampere) was used for each lysimeter, so the sensitivity was 30 millivolts (mv) over 9080 kg. The output voltage is additive, so the system sensitivity is 908 kg/mv. The sensitivity of the micrologger is 0.005 mv, which corresponds to 4.45 kg.

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[1] Trade names are mentioned for the convenience of the reader and do not constitute an endorsement by the authors or the Texas Agricultural Experiment Station.

If the response is linear over the limited range of weight changes for the lysimeter, the sensitivity of the load cells and the micrologger system is five kg. A calibration run was conducted in June, 1982, over a limited weight range of 300 kg using tractor weights. The mv output was displayed on the micrologger as the weights were loaded and unloaded in two trials for each lysimeter. The results of one trial in the west lysimeters are shown in Figure 4. The linearity assumption appears good; no problems with hysteresis or repeatability were noted. Slight differences existed between the lysimeters, however. The calibrated sensitivity was 892 kg/mv for the east lysimeter and 902 kg/mv for the west lysimeter. Possible explanations for the differences include load cell performance, inaccuracies in reading output (the micrologger display was to the nearest hundredth of a millivolt) or small variations in excitation voltage. Calibrations over a 34 kg range with weights ranging from one kg to five kg supported the assumed sensitivity of about five kg in each lysimeter.

Five kg water is the equivalent of five liters or 5,000 cubic centimeters volume. This volume over the surface area of the lysimeter is 1.07 mm, while the equivalent depth of the effective area (assumed to be the canopy area) is 0.03 mm. These sensitivities are sufficient for ET measurements for periods of one hour or more.

One problem was encountered in the use of the micrologger to record output from the load cells. The micrologger instructions specify that none of the sensors be grounded, which would include the load cells. A ground in an environmental sensor occurred that did not apparently affect that sensor's measurements. The impact on the load cell data was a series of apparently good readings followed by erratic behavior.

Costs

Costs for materials and construction were 10,719, including the load cells, data logger, and steel. Itemized costs are shown in Table 2.

TABLE 2. Itemized costs for the twin lysimeter facility (1981).

Micrologger weather station with printer and sensors	$ 3,760
Load cells (6), wire, and junction boxes	4,071
Power supply for load cells (2)	256
Steel tanks (2)	951
Base plates (4)	304
Fiberglass grating for base (2)	200
I-beams, channel iron, plate iron	183
Rebar	84
Concrete, pea gravel and sand	508
Supplies for construction of forms and cover	282
Backhoe excavation	120
TOTAL	$10,719

Summary

A twin weighing lysimeter was installed at the Stephenville Agricultural Research and Extension Center. Design of the lysimeter to measure relative evapotranspiration rates of well-watered and less than well-watered mature peach trees allowed cost-saving features such as a concrete outer wall and strain gage compression load cells. The lysimeters were installed with local expertise and labor; no significant problems were encountered. Preliminary examination of the data indicates that the facility will adequately serve the research purposes.

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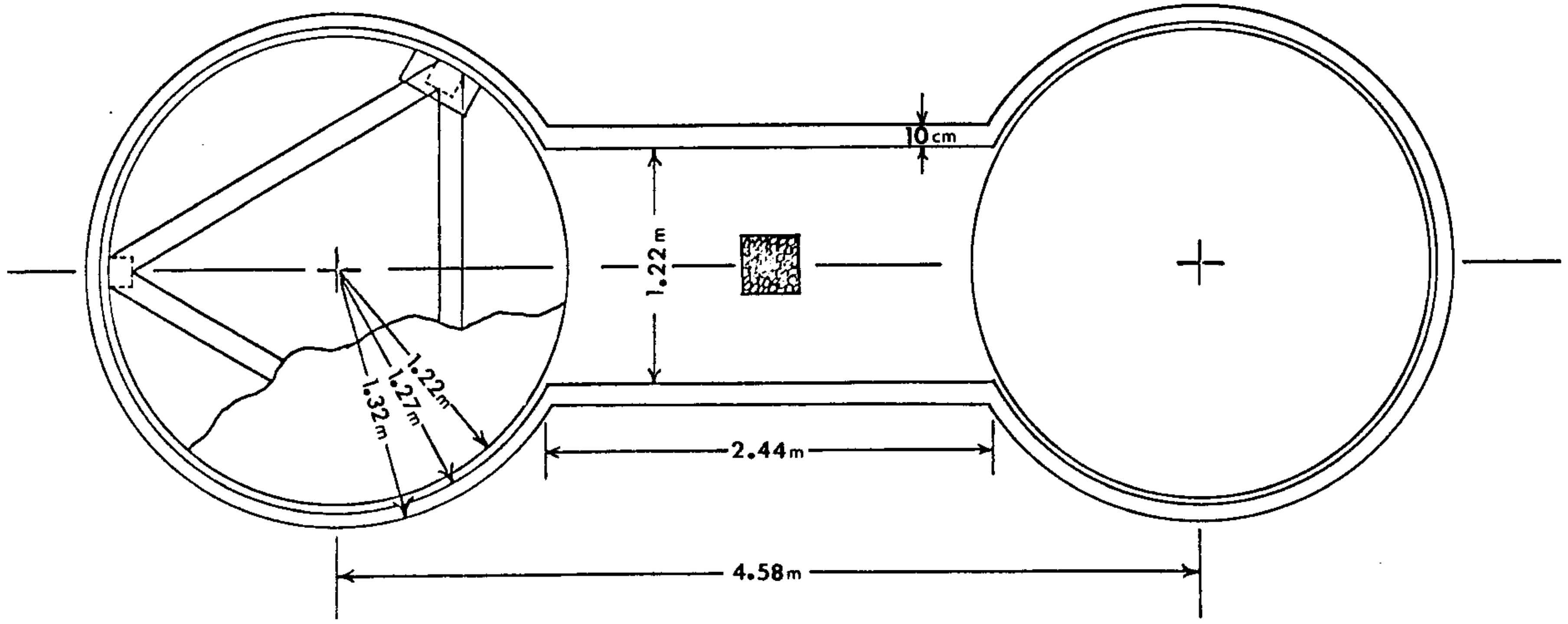

Figure 1. Design detail of twin weighing lysimeter, plan view.

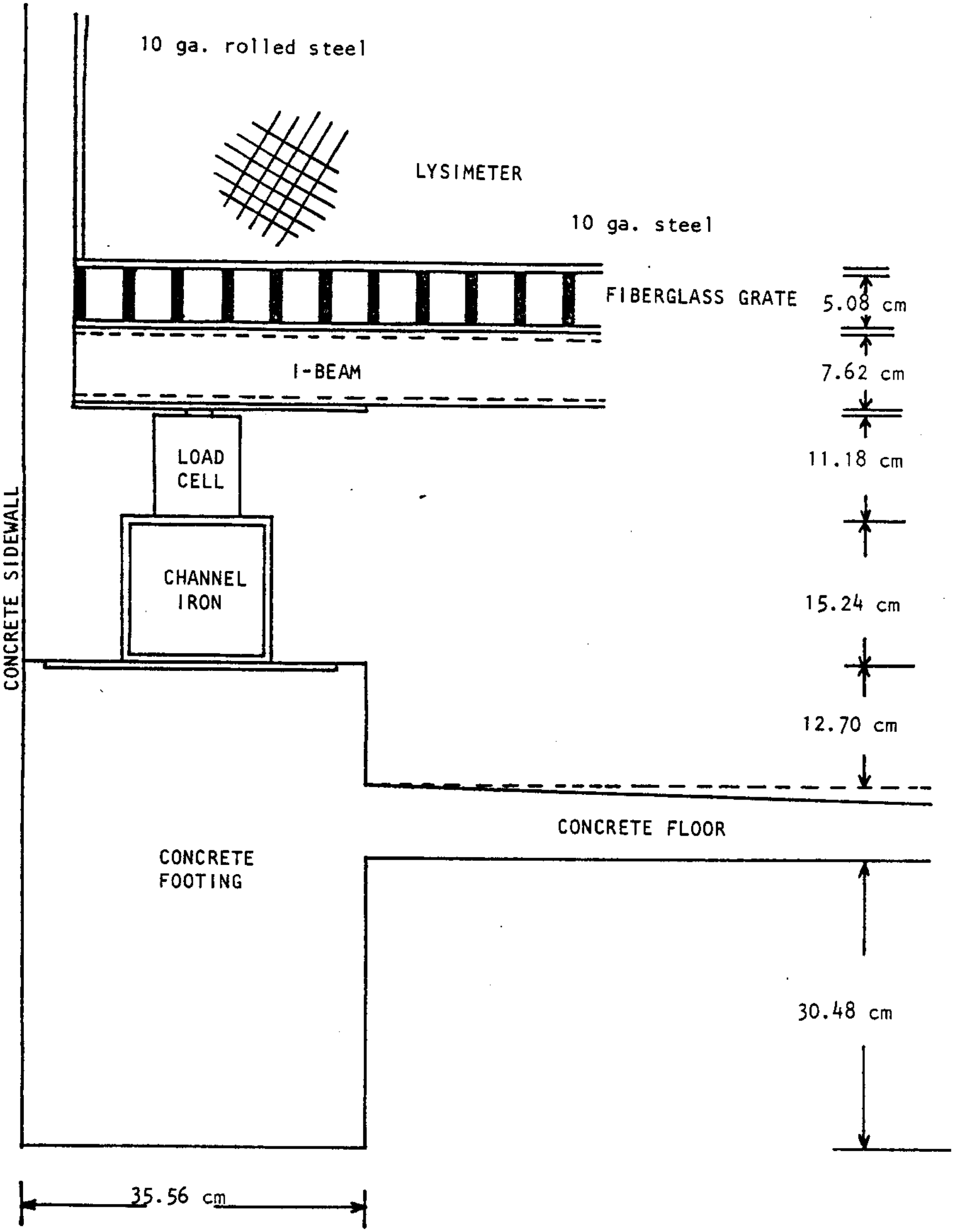

Figure 2. Design detail for load cell installation.

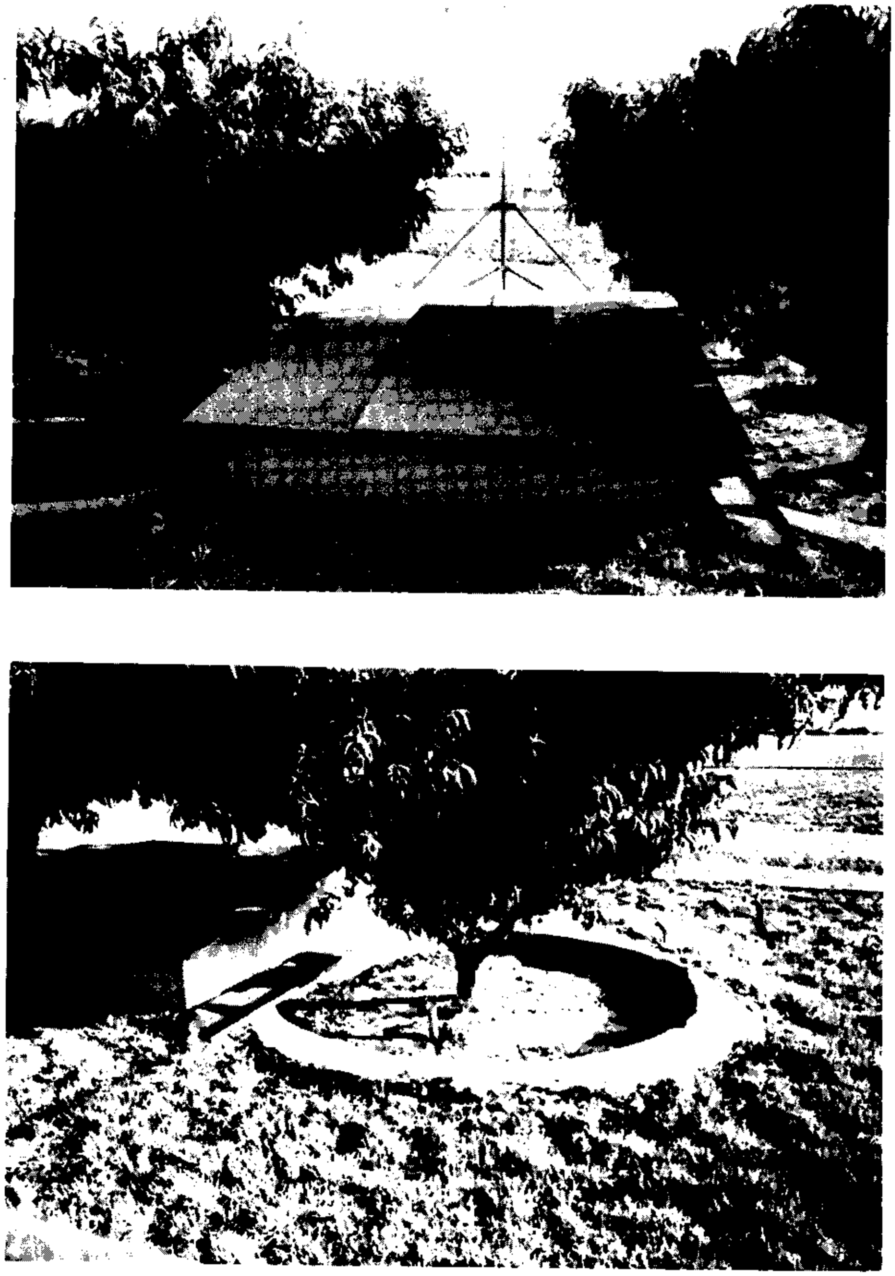

Figure 3. Completed twin weighing lysimeter facility. The environmental sensors are mounted in the mast in the center background. Access to the load cells is gained through the trap door in the cover.

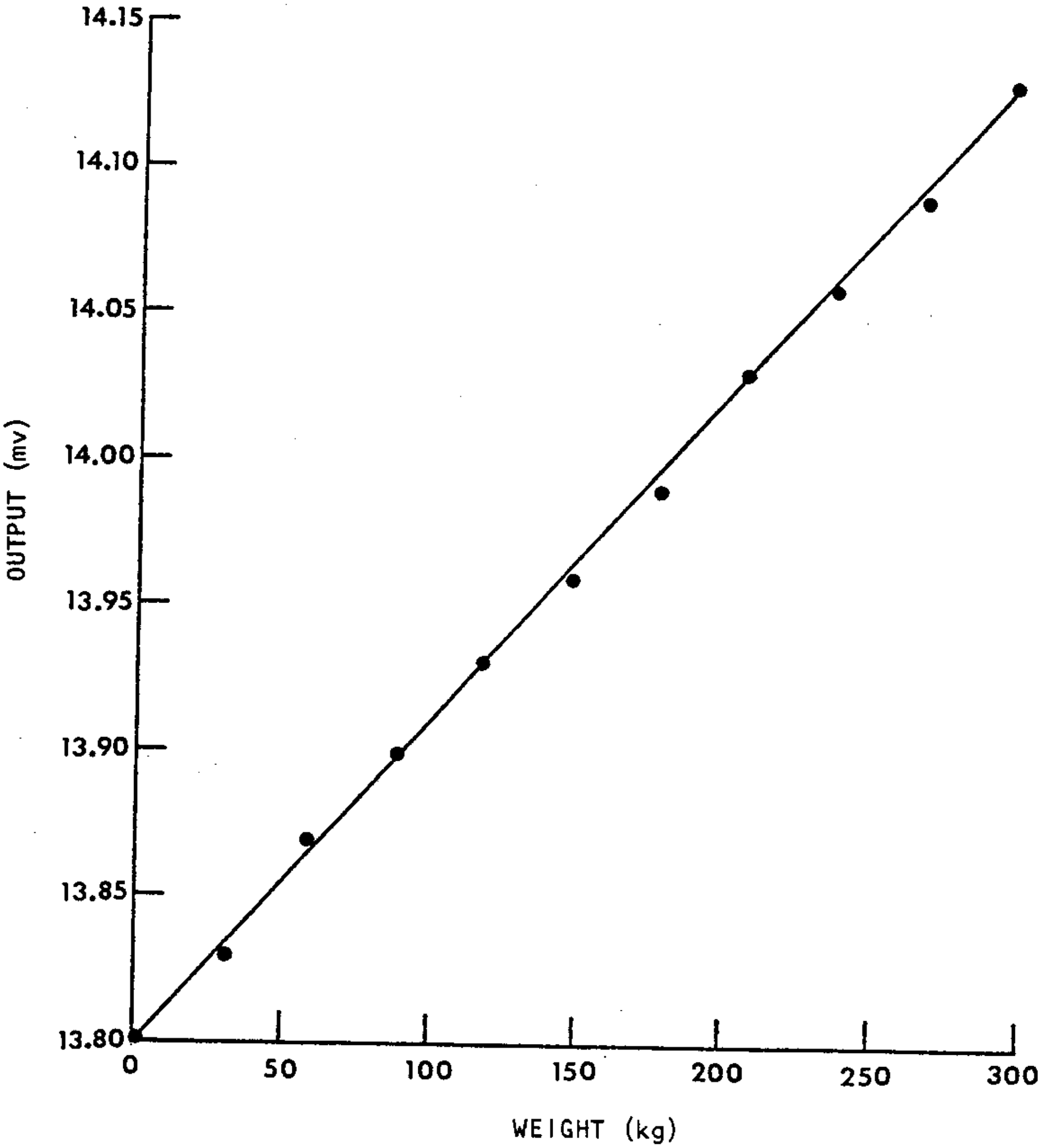

Figure 4. Calibration curve for west lysimeter. The linear correlation coefficient is 0.9997, the equation of the line of best fit is mv - 13.800 + 0.00111 (weight in kg).

APPENDIX A. Soils Description.

Windthorst Fine Sandy Loam (Typic Udic Paleustalfs)

Horizon

A1----------0- 4'' -- Grayish-brown (10YR 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak, fine, subangular blocky and weak, fine, granular structure; soft, very friable; slightly acid; clear, smooth boundary.

A2----------4-10'' -- Light yellowish-brown (10YR 6/4) fine sandy loam, yellowish brown (10YR 5/4) moist; massive; soft, very friable; slightly acid, abrupt, smooth boundary.

B21t-------10-18'' -- Red (2.5YR 4/6) sandy clay, red (2/5YR 4/6) moist; strong, fine and medium, blocky structure; extremely hard, very firm; nearly continuous clay films on faces of most peds; medium acid; gradual, smooth boundary.

B22t-------18-38'' -- Yellowish-red (5YR 5/6) sandy clay, yellowish red (5YR 4/6) moist; many, medium, faint, strong-brown mottles; many, distinct, brownish-yellow mottles; moderate, coarse, blocky structure; extremely hard, very firm; common discontinuous clay films on faces of peds; medium acid; gradual, wavy boundary.

B3t--------38-50'' -- Coarsely and prominently mottled-red (2.5YR 4/8), yellowish-brown (10YR 5/8), and pale-brown (10YR 6/3) sandy clay loam; thin lenses and pockets of sandy loam; weak, coarse, blocky structure; extremely hard, very firm; slightly acid; gradual, wavy boundary.

C----------50-60'' -- Light-gray clay with prominent coarse mottles of red and yellow; massive; slightly acid.

(from Stahnke et al, 1980)