AN INEXPENSIVE RECORDING TRANSPIROMETER

RAYMOND E. GIRTON, Purdue University[1]

In the quantitative study or demonstration of transpiration, it is frequently desirable to have an apparatus available which will automatically and continuously record the amounts of water lost by transpiring plants. The instrument herein described has been designed to fill this need at a very small cost, or at no cost at all if access is had to a few simple materials. As constructed by the author, the apparatus was made entirely of articles found in and about the botanical laboratories at Purdue, including such objects as old curtain rollers, aluminum lids, several large needles, and a piece of photographic film. The result was an instrument which could be used conveniently for following the loss of water by evaporation from a potted plant or free water surface, or from both sources at the same time.

The apparatus under consideration is given the name "*transpirometer*," although this term does not seem to be used in text books of plant physiology or in the better known writings on transpiration. Instruments for measuring temperatures, however, we designate as thermometers, instruments for measuring barometric pressures as barometers, and apparatus for measuring respiration as respirometers. Therefore it appears logical to use the term "*transpirometer*" for an instrument which is constructed for measuring transpiration. The term "*transpirometer*" will accordingly be applied to the apparatus under consideration.

Description of the Apparatus. Figure 1 shows the transpirometer to consist of an arrangement of the following parts. A long extension spring (f) is attached to a bolt (e) bent in the form of a hook. This bolt passes through a wooden spool (b) which is firmly supported by the clamp (c) and ring stand (d). A thumb nut (a) permits a fine adjustment in height of the spring and consequently of the pot with plants (n). The lower end of the spring is fastened to a double aluminum strip (i) which is turned up at its lower end to form a hook through which the loop of wire (m) supporting the plants passes. The strip (i) is also provided with two small holes, thus serving as a pivot bearing for the needle pivot of the aluminum lever arm (g). The fulcrum seat (h) for the lever is also of aluminum and is screwed to a wooden block supported by the clamp (k) and ring stand (l). Both the fulcrum seat (h) and the double aluminum strip (i) are slotted so that the lever arm may be easily slipped into or out of position without disturbing the remainder of the apparatus.

The essential part of the transpirometer is the spring (f) which supports the experimental plants. Loss of water by transpiration ma-

[1] The author is indebted to Professors G. E. Read and J. H. McKee for their careful reading and criticism of the manuscript.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

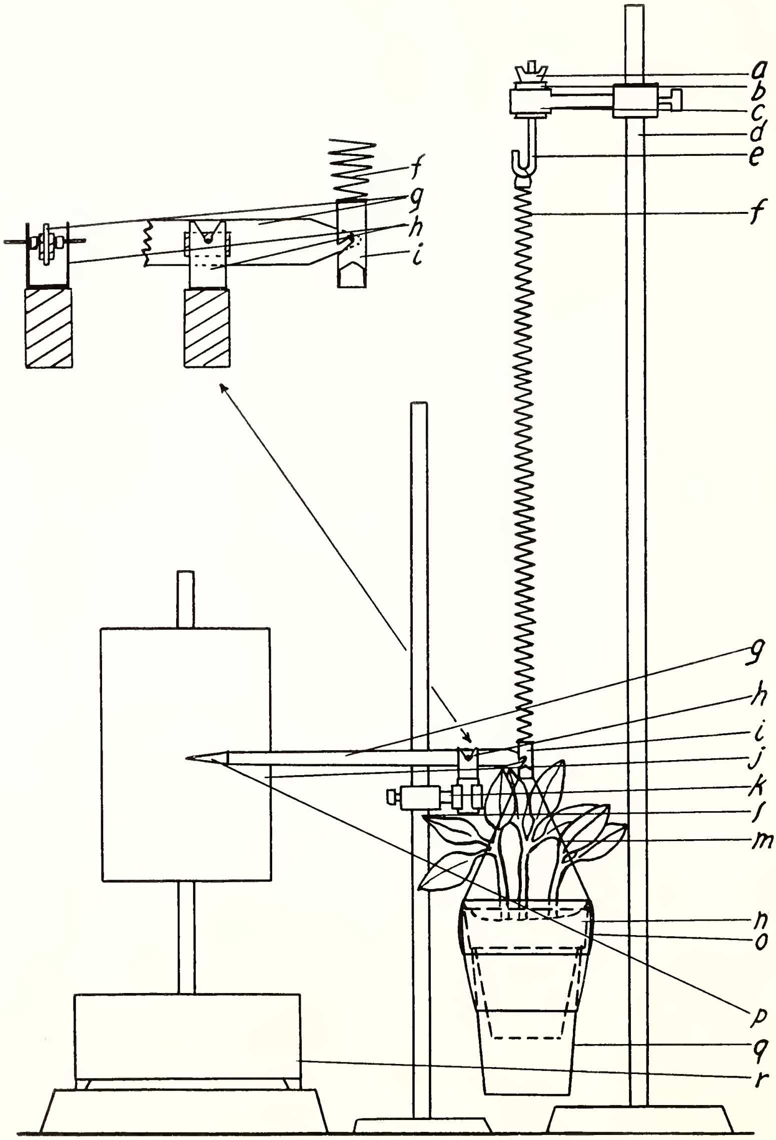

Fig. 1—Recording transpirometer. (a) thumb nut, (b) spool guide, (c) clamp, (d) ring stand, (e) hook bolt, (f) spring, (g) lever arm, (h) fulcrum seat, (i) pivot-bearing strip, (j) drum, (k) clamp, (l) ring stand, (m) supporting wire, (n) pot with plants, (o) rubber-strip seal, (p) stylus, (q) aluminum beaker, and (r) clinostat.

terially lessens the weight of the potted plant, thereby causing the spring to contract. The amount of contraction is magnified by the lever arm (g) and recorded graphically upon smoked paper attached to the slowly revolving drum (j). A very satisfactory spring for this purpose may be obtained from an old curtain roller. This spring easily supports a weight in excess of one kilogram and is sensitive to relatively small changes in weight.

In setting up the apparatus a four and one-half-inch pot of soil containing some rapidly transpiring plants is used. After a thorough irrigation, the soil is allowed to drain for a short time before the pot is placed in the aluminum beaker (q). A three-inch section of rubber inner tubing from an automobile tire is then fitted over the pot and beaker to prevent lateral water loss. This rubber strip extends slightly above the edge of the pot, so that the coating of warm wax mixture, which is next applied, effectively seals the soil and exposed inner pot surfaces from evaporation. The sealed plant is then attached to the hook at the lower end of the spring as indicated in the diagram. After the fulcrum seat (h) has been aligned with the pivot bearing (i), the lever arm may be slipped into place. The position of the lever is then easily adjusted up or down by means of the thumb nut (a). It is desirable to adjust the lever arm initially so that the part in contact with the revolving drum has an agle of 10-20 degrees above the horizontal. As weight is lost by the evaporation of water, the lever arm gradually falls past the horizontal axis to some position below, depending upon the total amount of water lost. Where the angle of the lever arm movement is not too great, vertical distances measured from a horizontal reference line may be taken as a direct measure of the water loss. If the weight of the potted plant is determined initially and at the completion of an experiment, the total water loss thus obtained divided by the total vertical distance through which the celluloid stylus (p) has moved, gives the number of grams transpired equivalent to one centimeter vertical distance on the drum. With the aid of this factor the amount of water lost can be determined for any time desired if the rate of drum rotation is known. The drum used by the author was revolved once in 12 hours by the clinostat (r).

When operating the transpirometer, certain precautions must be observed to insure satisfactory results. The celluloid stylus attached to the end of the lever arm should be kept pressed against the drum with a force sufficient to leave a clear mark, but not great enough to interfere with the movement of the lever. The spring (f) changes appreciably in length with changing temperature. Where a considerable range of air temperatures is encountered, a correction for this factor may be desirable. Exposure to strong sunlight also results in a considerable increase in the length of the spring due to heat absorption. For this reason it is advisable to shade the spring from direct sunlight when conducting experiments with changing light intensities. Finally it should be stated that while the apparatus can be operated in a light breeze from an electric fan, strong air currents are highly unsatisfactory.

Certain supplementary pieces of apparatus have proved useful in performing experiments with the transpirometer. They include a good laboratory balance for taking initial and final weights of the transpiring plant, a reliable thermometer for determining air temperatures, and a wet and dry bulb apparatus for making humidity determinations. Should it be desired to compute transpirational water loss per unit leaf surface area, blueprint paper and a planimeter will be necessary for measuring leaf areas. A recording thermometer may also be useful for providing correction data where large temperature fluctuations are encountered.

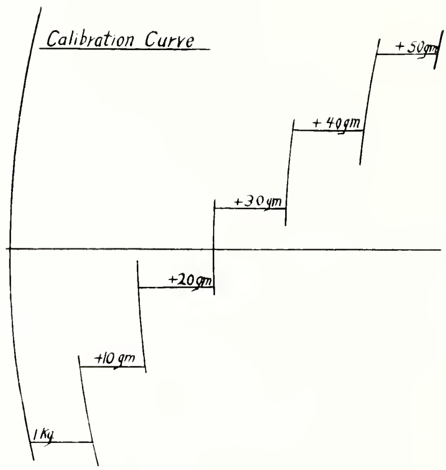

Fig. 2—Calibration-curve record obtained for a one kilogram load plus additional 10 gram increments.

Preliminary Tests. Several trial experiments were carried out in order to test the elasticity of the spring. In one case, a kilogram weight was suspended for a period of 20 hours. No appreciable increase in length was recorded in the revolving drum. This was true, however, only after a preliminary stretching had been effected by the same weight. For this reason it is considered desirable to expand the spring for several hours before setting up an experiment with an unstretched spring.

A test of a second type was made to determine the relation between

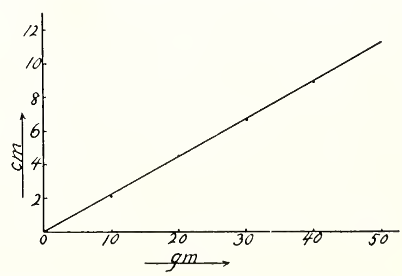

Fig. 3—Calibration curve based upon data obtained from the drum record shown in figure 2.

the length of the extended spring and the weight supported. The spring was first stretched with a one-kilogram weight. Further increases in length due to the addition of other weights were recorded over a range of 50 grams. The record obtained from this test is shown in Figure 2. These results when plotted demonstrate a linear relationship between weight and distance as indicated in Figure 3.

Transpiration Records. Several experiments were performed with transpiring plants under fairly uniform temperature conditions in order to observe the apparatus in actual use. These tests were conducted over different lengths of time and with varied environmental conditions.

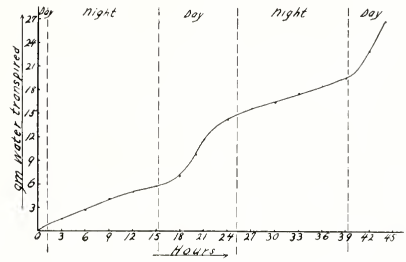

Fig. 4—Transpiration curve for potted bean plants under laboratory conditions. Transpiration values are expressed as actual amounts of water lost in grams.

The first of these experiments extended over a period of 44 hours and traced the course of transpiration of potted bean plants exposed to alternate darkness and to daylight of low intensity in the laboratory. The resulting curve plotted from values determined at three-hour intervals is shown in Figure 4. The increased rate of transpiration during daylight, in spite of dull and cloudy weather, is easily seen by the greater steepness of the parts of the curve corresponding to the daylight hours. A second transpirometer (results not shown) carrying a sealed control pot was operated for the same period and indicated only slight fluctuations from the horizontal reference line due to temperature changes and possibly a slight stretching of the spring.

A repetition of the preceding experiment was carried out for a shorter period (21 hours) in the greenhouse with similar results. In

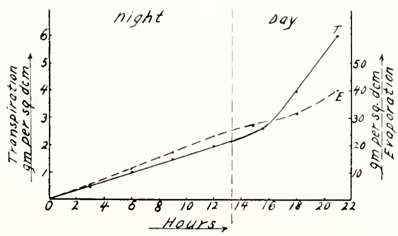

Fig. 5—Transpiration from potted bean plants under greenhouse conditions compared with evaporation from a free water surface. The water loss is expressed in each case as grams per square decimeter of exposed surface. T=transpiration curve. E=evaporation curve.

this experiment an aluminum beaker filled with distilled water was attached to the duplicate apparatus so that the transpirational loss of water from the plants might be compared directly and simultaneously with the loss by evaporation from a free water surface of nearly constant level. The results of this experiment are indicated in Figure 5. It may be seen from this figure that transpiration was greatly accelerated by the light of day, while evaporation was not thus affected.

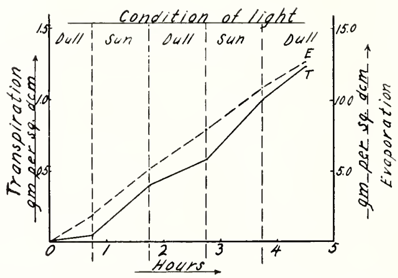

Fig. 6—Effect of varied light intensities upon transpiration and evaporation. T=transpiration from potted bean plants. E=evaporation curve for a free water surface.

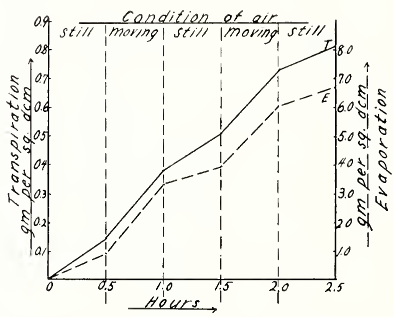

Fig. 7—Effect of still and moving air upon transpiration and evaporation. T=transpiration curve. E=evaporation curve.

Tests concerned with the effects upon transpiration and evaporation of changing light intensities and of still and moving air were also performed in the laboratory. In spite of relatively short experimental periods, appreciable differences were recorded between the rates of transpiration in bright and dull light, and in moving and still air. Figures 6 and 7 indicate the relationships found in these experiments.

Summary. A simple and inexpensive transpirometer is herein described which has proved useful for tracing the course of transpiration over extended periods of time, for demonstrating relative rates of transpiration during day and night, for indicating the effects of still and moving air and of bright and dull light on transpiration, and for securing comparisons between the water losses by transpiration and by direct evaporation from a free water surface.