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Comparison of Leaf and Stem Hygrometers for Measuring Changes in Peanut Plant Water Potential[1]

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ABSTRACT

For an "in situ" thermocouple hygrometer to be of value it must give reasonable estimates of plant-water potential and must respond rapidly to plant-water potential changes. Leaf thermocouple hygrometers (Wescor) and specially fabricated stem thermocouple hygrometers were evaluated on peanut (*Arachis hypogaea* L.) plants under well-watered and drought conditions in a growth chamber. When soil-water stress was low and plant-water movement was near steady state, the two sensors gave similar water potential values. When soil-water stresses were imposed or when plant process varied cyclically (eg., photosynthesis, transpiration), stem hygrometers sensed dynamic changes in the plant's water potential more consistently than did leaf hygrometers placed on leaves with intact cuticles. It appears that both the stem and leaf hygrometers hold promise for sensing plant water potential changes of peanut in the field.

Key Words: *Arachis hypogaea* L., Correlation, Fruit Yield, leaf hygrometer.

"In situ" methods that adequately describe a plant's water potential or changes in water potential are of considerable importance to plant-water relation studies. There are several reports on the design and virtues of "in situ" leaf thermocouple hygrometers (1, 3, 5, 6, 11). In general, such hygrometers are believed to overcome or at least minimize some of the sources of error associated with the use of leaf pieces, e. g., heat of respiration, water vapor sorption by the chamber walls, equilibration error, and errors due to tissue changes resulting from excision. Because they are nondestructive they should be more capable of sensing dynamic changes in plant-water potential.

A stem thermocouple hygrometer that is mounted in direct contact with xylem and responds rapidly to changes in plant-water potential has also been developed (10).

In the studies reported here we have compared leaf hygrometers placed over intact cuticles of peanut (*Arachis hypogaea* L.) leaflets with stem hygrometers embedded in nearby stems to measure and follow changes in plant-water potential under controlled environmental conditions. This work was preliminary to measuring plant-water potential change under field conditions.

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[3]Trade names and company names are given for the benefit of the reader and do not imply preferential endorsement by the U. S. Dept. of Agriculture over similar products or firms.

Materials and Methods

Single plants of peanut (*Arachis hypogaea* L.) cv. 'Florigiant' or 'Tifton 8' were grown in 4-liter containers of a peat-vermiculite mix (1:1). Plants were grown in specially constructed chambers with water and glass barriers below the lamps (12). The chambers were programmed for 25°C, 60% relative humidity, and 320 μl/liter CO_2 for 14-hour photoperiods and 20°C, 90% relative humidity for 10-hour nyctoperiods. The light source for growth and experimentation consisted of banks of VHO cool-white fluorescents supplemented with incandescents. During the experimental periods a constant day-night temperature of 25°C was maintained. The leaf thermocouple hygrometers used were similar to the design of Campbell and Campbell (1974) and were obtained from Wescor, Inc., Logan, Utah.[3] Leaflets were washed with distilled water and blotted dry with lens paper before use. The pistons were sealed with lanolin to the upper or lower surface of unshaded fully expanded leaves. Sealing was not difficult since the peanut cultivar was glabrous. No treatment to reduce cuticular resistance was used. In preliminary experiments it was noted xylene treatment (11) or use of abrasives (1) caused necrosis of the treated area almost immediately. Each stem thermocouple hygrometer (10), specially fabricated by Wescor, was centered on the 6-mm-long x approximately 1-mm-deep x several millimeters wide flat surface of a channel cut into a stem. The stem hygrometer unit was sealed with Mortite caulking gum, covered with polyurethane foam and wrapped with aluminum foil. These installations did not appear to affect normal functions of the plants. All water potentials were estimated from readings using a Wescor HR-33T Dew Point Mixrovoltmeter used in the Dew Point Mode. Voltage measurements of less than 1μV from units with dry junctions indicated that thermal gradients were not a problem in this study. All hygrometers were calibrated using filter paper disks saturated with varying NaCl solutions whose water potentials were given by Lang (9).

Results and Discussion

Leaf and stem-water potentials of a 3-month-old Florigiant peanut plant grown in the peat-vermiculite mix were followed for several days. Figure 1 depicts the plant's water potential for the first day under what was considered soil water sufficiency. The plant had been irrigated the preceding evening and two stem hygrometers and four leaf hygrometers affixed. The next morning initial values before and immediately after lights on for all hygrometers were within ± 1 bar. Within 30 minutes after lights on, the stem hygrometers detected the beginning of an oscillation in stem-water potential. The oscillation (cycling) showed considerable amplitude, about 4 bars in early morning and 6 bars in late afternoon. By constrast, only one of the four leaf hygrometers detected any oscillation in leaf-water potential and that one did not sense the first cycle (Fig. 1). The amplitudes of cycles in stem-water potential detected by the stem hygrometer were several bars greater than those eventually detected by the leaf hygrometer. Cycling was damped out toward the end of the day. Similar cycling of leaf-water potential has been reported for pinto beans (6), potato (3), and pepper (4). A short lag in minimal values of leaf-water potential as compared to stem-water potential is evident in Fig. 1. The lag in both the maximum and minimum leaf-water potentials sensed could result from greater resistances encountered by the leaf hygrometer in equilibrating with internal leaf-

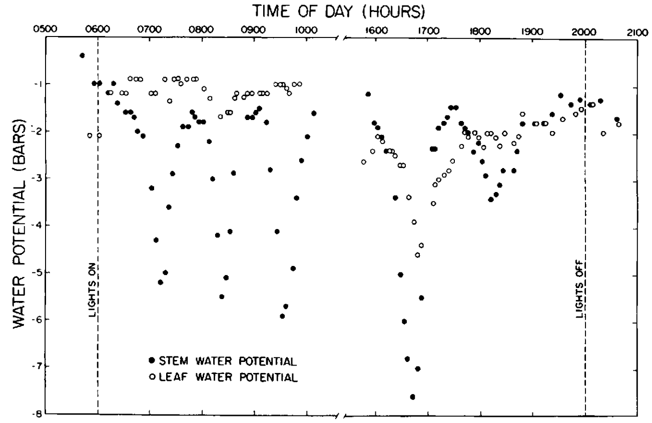

Fig. 1. Comparison of "in situ" peanut leaf-water potential measurements with "in situ" stem-water potential measurements under well-watered conditions.

water potential. Leaf diffusion resistances in these studies were usually much less than 100 seconds cm^{-1}; nevertheless, a limiting barrier resistance of 100 second cm^{-1} should permit attainment of hygrometer chamber vapor pressure within 99% of equilibrium in no more than 60 seconds. We had decided not to physically abrade or attempt to thin the leaf cuticle chemically to reduce cuticular resistances when it was noted that after any chemical or physical abuse of the leaflets the treated areas became necrotic. Leaf thermocouple hygrometers have been used "in situ" over the intact cuticle of sunflower and tomato (6), potato and wheat (3), pinto bean (7), and corn (13). Problems with excessive response times were not indicated. The resistance of the intact cuticle of corn was reported to prevent following rapid changes of leaf-water potential until surface wax was removed with xylene (11). Although the need for treatment was not indicated, the cuticles of potato, soybean, sunflower, pepper and oat have been thinned using surfactant and grit (1).

By the third day without watering, the peanut plant was water stressed (Fig. 2). The average leaf-water potential was lowered by at least 10 bars as compared to the first day and cycling had subsided. Plant-water potential decreased progressively during the morning hours. Lights were switched off for a short time to compare the responses of the two types of hygrometers. The leaf hygrometer sensed no perceptible change in leaf-water potential, whereas the stem hygrometer sensed an increase of a bar in water potential. Within minutes after water was added to the peat-vermiculite mix, both units sensed increasing water potential. The oscillation in plant-water potential resumed 2 hours after watering. Neither stem nor leaf-water potentials appeared to reach their pre-stress levels until the next day (Fig. 3). On this day all leaf hygrometers failed to sense cycling in plant-water potential and the measurements of leaf-water potential exhibited considerable scatter. In darkness, cycling was again eliminated. Both leaf and stem hygrometers gave similar readings until after the lights came on again.

Just what a leaf hygrometer measures, even theore-

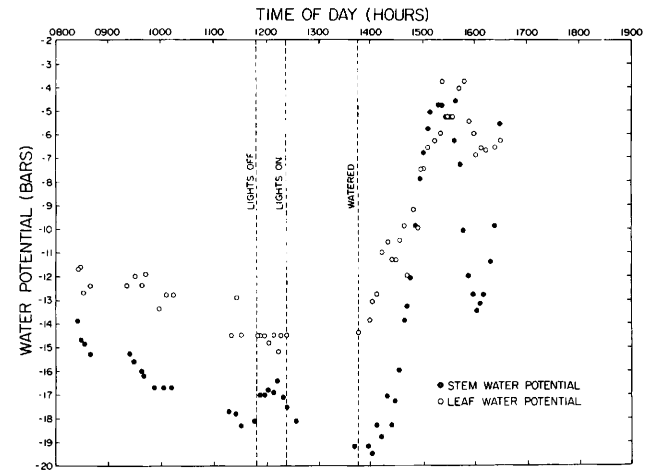

Fig. 2. Comparison 3 days later of "in situ" leaf-water potential measurements with "in situ" stem-water potential measurements before and after irrigation.

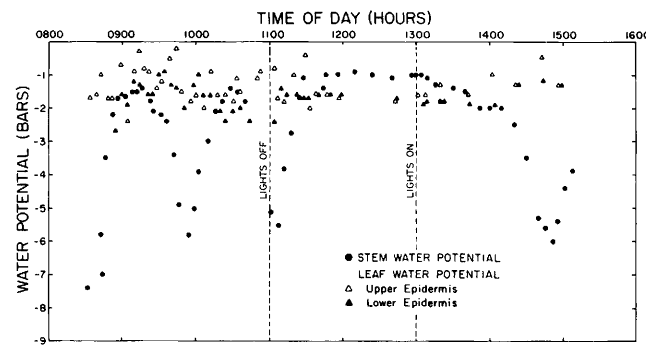

Fig. 3. Comparison of "in situ" leaf-water potential measurements with "in situ" stem-water potential measurements of the peanut plant the day following reirrigation.

tically, is uncertain. For water to move, gradients in water potential must exist (though flux may be considerable with small pressure gradients in the xylem). The magnitude of gradients in leaves from xylem to evaporating surfaces are unclear; however, placing a hygrometer on a leaf soon stops water movement toward the hygrometer so that a potential close to that of the xylem would be expected. The water potential of leaf xylem should differ little from that of nearby stem xylem because of the lack of an appreciable resistance to flow between the two locations.

Our experience has indicated that differences between leaves, hygrometer conditions, and sealing to the leaf can cause Wescor leaf hygrometers to read differently. Poor sealing usually is readily indicated by excessively low values in leaf-water potential. In one experiment we measured leaf-water potential of mature leaflets on a well-watered peanut plant with four different leaf hygrometers. The leaf hygrometers were all attached to lower surfaces of different leaves the preceding evening to permit attainment of equilibrium. Throughout the next day three of the four hygrometers were reading within a range of 3 bars, with a standard deviation of approximately 2 bars. The other leaf hygrometer was reading from 2 to 1 bar lower than the lowest of the others. A poor seal was suspected. Subsequently, it was replaced by two other leaf hygrometers. Two days later, under the same environmental conditions, all hygrometers were reading within a range of 2 bars, with standard deviations of generally less than a bar. In another experiment leaf-water potential measurements were made using the leaf hygrometer and compared with measurements using the Wescor C-52 chamber. Leaf disks were cut (7 mm) from adjoining leaflets on the same leaf that had a thermocouple hygrometer. Potentials as determined by the two methods agreed very closely (±.5 bar) from these paired leaflets. Both the stem and leaf hygrometers appeared capable of measuring water potential uninterrupted for periods as long as a week.

Throughout our experiments with peanut plants, the sensing ability of leaf hygrometers appeared to differ depending upon whether they were placed on the upper or lower surface of the leaflet. As Fig. 4 indicates, leaf hygrometer readings oscillated out of phase with those of the stem hygrometer; and, the leaf hygrometer placed on the upper surface showed a bar greater amplitude in the oscillation than the one on the lower surface of the same leaflet. Diffusion resistance measurements (8) indicated that not only oscillations in r_s occurred, but that the upper surface of the peanut leaflets had lower resistances than the lower surface, thus correlating the resistance with response.

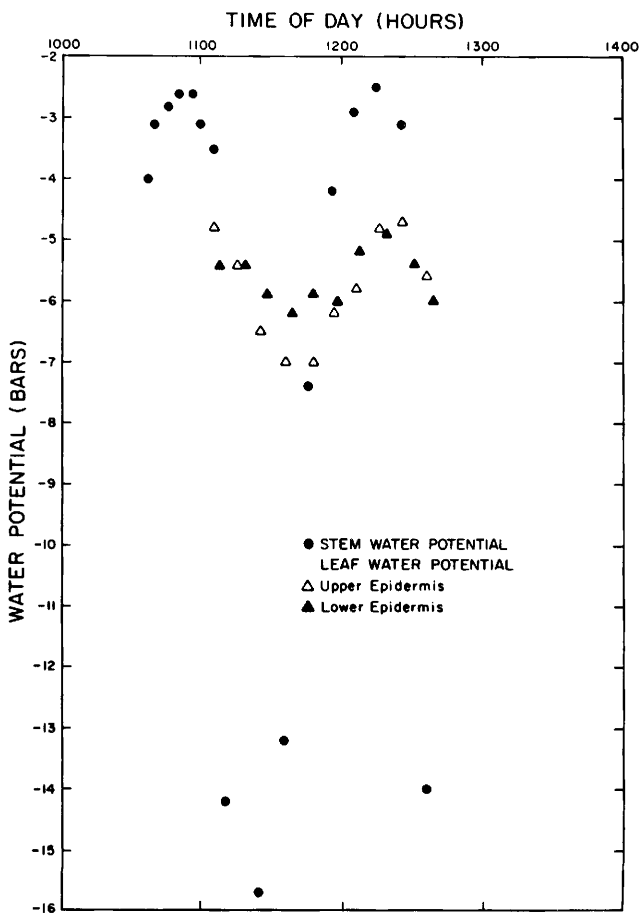

Fig. 4. Comparison of "in situ" leaf-water potential measurements of upper and lower leaf surfaces with "in situ" stem-water potential measurements of peanut under well-watered conditions.

Other experiments compared the two types of hygrometers on soybean plants. During two intensive experimental periods of 1 and 3 weeks' duration when very small oscillations in plant-water potential were sensed by stem hygrometers, they were not detected by leaf hygrometers; whereas at "steady state" leaf hygrometer measurements agreed quite closely with stem hygrometer measurements (± 1 bar).

This study seems to indicate that leaf hygrometers on peanut and soybean leaves with intact cuticles are less sensitive to dynamic changes in the plants water potential than embedded stem hygrometers. When the plant's water potential changes were not rapid, leaf hygrometer readings agreed closely with stem hygrometer readings.

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