Effect of Changing Soil Moisture on Corn Leaf Moisture[1]

C. J. JOHANNSEN and M. F. BAUMGARDNER
Agronomy Department and Laboratory for Applications of
Remote Sensing, Purdue University, Lafayette, Indiana 47907 and
D. WIERSMA
Agronomy Department and Water Resources Institute
Purdue University, Lafayette, Indiana 47907

Abstract

Greenhouse studies were conducted on corn plants with the two-fold purpose of: 1) determining the moisture content of corn leaves in different positions on the plant; and 2) determining if the time of day affects the leaf moisture at different leaf positions.

Corn plants were grown for a period of 8 weeks, at which stage each plant had a minimum of 12 horizontal leaves. All plants were watered to a soil moisture content of about 22%, and water was extracted by evapotranspiration. At 8 equal time intervals over a 64-hour period individual leaves were removed for moisture determination. All plants were subjected to a 16-hour daylength.

The maximum leaf moisture content at all time intervals was found near the middle of the plant. Uppermost leaves did not attain the moisture content of those in the middle, while advancing stages of senescence accounted for the lower moisture content of the lower leaves.

The effect of the time intervals on leaf moisture content was found to be highly significant, indicating that the leaf moisture content was affected significantly by soil moisture. Changes in corn leaf moisture followed the same trend as the soil moisture changes, regardless of the leaf position on the plant.

Moisture content of leaves sampled in the early morning was higher than that of samples obtained later in the day. The percent moisture in leaves exhibited pronounced diurnal changes, especially at low soil moisture levels (near the permanent wilting point).

In pursuit of making leaf reflectance measurements, researchers at the Laboratory for Applications of Remote Sensing (LARS) were finding variation in reflectance measurements at different leaf moisture contents. Earlier research showed that reflectance measurements from a DK-2 spectral reflectometer decreased from 0.5 to 2.6 μ with increasing plant moisture (11). These results were obtained from leaves of corn, soybeans, sorghum, sudan and wheat. Other research had shown that moisture content within plant leaves had a significant effect on reflectance response (6, 8, 10, 12). In all cases, leaf reflectance was inversely related to leaf moisture content.

The purposes of this research were: 1) to determine moisture content of corn leaves in different positions on the plant; and 2) to determine if the time of day affects the leaf moisture at different leaf positions. Such information would be valuable in the selection of leaves on which to make reflectance measurements in future studies.

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Experimental Procedures

The soil selected for the experiments was a Chelsea sand which contained sand, silt, and clay fractions of 91.7%, 3.8%, and 4.5%, respectively (1). Wiersma (13) showed that the soil has a field capacity of 0.10 to 0.14 inches of water per inch of soil. With this low water holding capacity, rapid changes in available soil moisture would occur under normal growing conditions.

Corn was selected as a study crop and the plants were grown in individual plastic containers. These containers or pots were 17 cm deep and 16 cm in diameter. Hendrickson and Veihmeyer (5) had shown that the size of the container would have no effect on the percentage moisture in the plant; therefore, it was assumed that the pots would be adequate for the experiments.

The soil was passed through a 2 mm sieve and 3,000 g (calculated on an oven dried basis) were placed in each pot. The pH of each pot of soil was adjusted to approximately 6.5 by mixing the proper amount of $Ca(OH)_2$ and MgO (5.5 parts $Ca(OH)_2$ and 1 part MgO) into the soil. Three seeds of corn were planted in each pot to insure that at least one plant per pot would be obtained. After about 1 week after emergence, the 2 least vigorous plants were removed from the pot.

Difficulties were experienced in adding water to a small volume of soil and obtaining a condition where the soil is saturated. Therefore, a method was used which completely saturated the soil and allowed drainage of the excess water. Figure 1 illustrates the watering procedure. Water was added to each pot through a tube connected between a water reservoir and the bottom of each pot. After the water had completely saturated the soil, the polyethylene pot was raised the height of 20 cm above the height of the water reservoir to drain off the excess water. This procedure resulted in a soil moisture condition of about 22% (7).

A high intensity lighting system of approximately 4,000 ft-c was used. The lights were turned on at 6 AM and turned off at 10 PM each day, providing day lengths of 16 hours. The plants were placed on a plywood board which was adjusted to a height that maintained at least 8 inches between the tops of the plants and the lights. An electric fan was used above the plants to prevent the development of "heat pockets" and injury to the corn plants.

Since the sandy soil had a low cation exchange capacity, plant nutrients had to be added at regular intervals. The correct amount of nutrients added (including micro-nutrients), depended upon the stage of growth of the plant. The temperature and humidity of the greenhouse varied depending upon the time of year. These factors also affect growth and thereby nutrient uptake.

Thirty-two corn plants were grown for a period of 8 weeks until each plant had a minimum of 12 horizontal leaves. All plants were

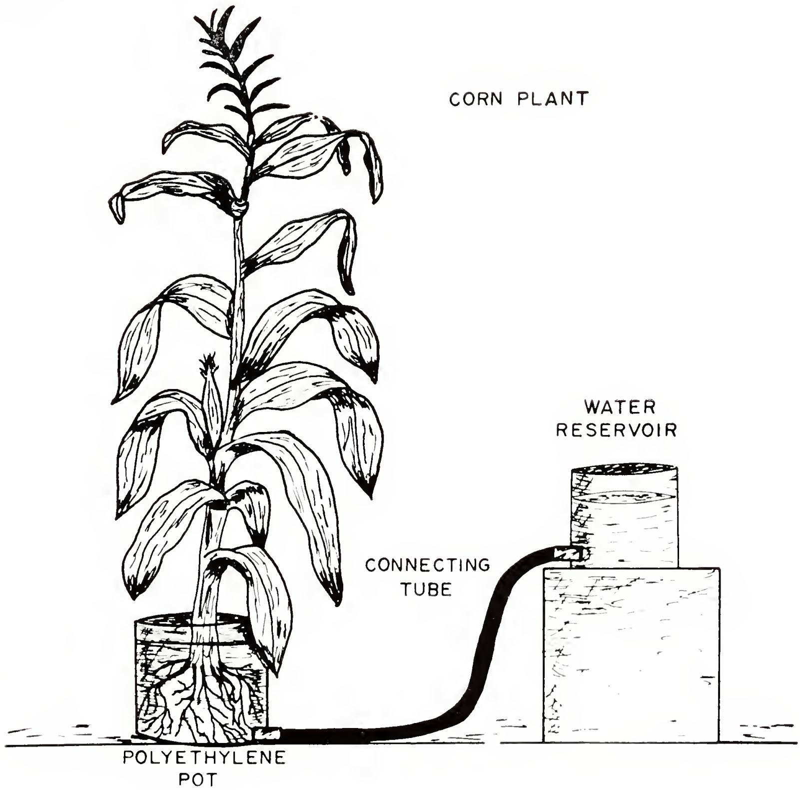

FIGURE 1. *Method used for watering corn plants in the greenhouse experiments.*

watered and placed on greenhouse benches and water was gradually diminished by evapotranspiration. At equal time intervals of 0, 8, 16, 24, 32, 40, 48, and 56 hours after watering, 4 plants were selected randomly and individual leaves were removed for moisture determination. Leaves were numbered sequentially from bottom to top to compare leaves from the same leaf position.

Leaf moisture was determined by weighing a leaf on a microbalance accurate to 0.0001 g. The leaves were dried for 48 hours in a 70°C oven and then reweighed. The moisture percentage was determined on a fresh-weight basis [(fresh leaf weight—dry leaf weight)/ fresh leaf weight X 100 = % moisture content].

The soil moisture content was determined at selected time intervals to relate soil moisture to plant leaf moisture. The method for determining soil moisture was to remove a soil core from each plot with a sampling tube and determine the moisture percentage on a dry weight basis (2).

Results and Discussion

The mean leaf moisture percentage was calculated for four plants for each leaf position at each time interval. The maximum leaf moisture contents at all time intervals were found between the 5th and the 7th leaf (near the middle of the plant). The moisture content decreased about 1 to 2% from Leaf Position 7 to Leaf Position 10 or 11, but then increased again at the top of the plant (Leaf Position 12). The moisture content of the uppermost leaves was generally lower than the leaves in the middle of plant. Leaves near the bottom of the corn plant were in advancing stages of senescence which accounted for lower moisture contents at Leaf Position 1 and 2.

Figure 2 shows the mean moisture contents of Leaf Positions 4, 7 and 10 with the corresponding mean soil moisture values for the 8 time intervals. The leaf moisture values show that the leaves near the middle of the plant have a slightly higher moisture content than leaf positions above or below this area. The mean values of Leaf Number 7 range from a high of about 82% at the early sampling intervals to a low of about 75% at the 56 hour interval. The soil moisture decreased from 22.8% to 3.23% during the first 40 hours. The lower moisture content was near the permanent wilting point (13).

Analysis of variance of these data shows that the effect of time intervals on leaf moisture content is significant at the 1% level (Table 1). Since the soil moisture content was decreasing during the time intervals and is responsible for the decreasing leaf moisture, this means that leaf moisture content is affected significantly by soil moisture. The researcher should interpret plant moisture values with a knowledge of the stage of plant growth, soil type, transpiration rates, and other variables.

TABLE 1. *Analysis of variance of corn leaf moisture change at different leaf positions during a 64-hour period.*

Source of variation	df	SS	MS	F
Time	7	.74832	.10690	9.10**
Plants	3	.06952	.02317	1.97
Positions	11	25.47922	2.31629	284.56**
Error (a) (time x plants)	21	.24683	.01175	
Positions x time	77	.83225	.01081	1.33
Error (b)	264	2.14921	.00814	

** Significant at the 1% level.

The effect of leaf position on leaf moisture content shows a high F value. This value was rechecked using data from Leaf Positions 4 through 12. The results of this analysis were very similar to those shown in Table 1 but the levels for the F test were lower for the effect of time and positions. These results indicate that leaf position

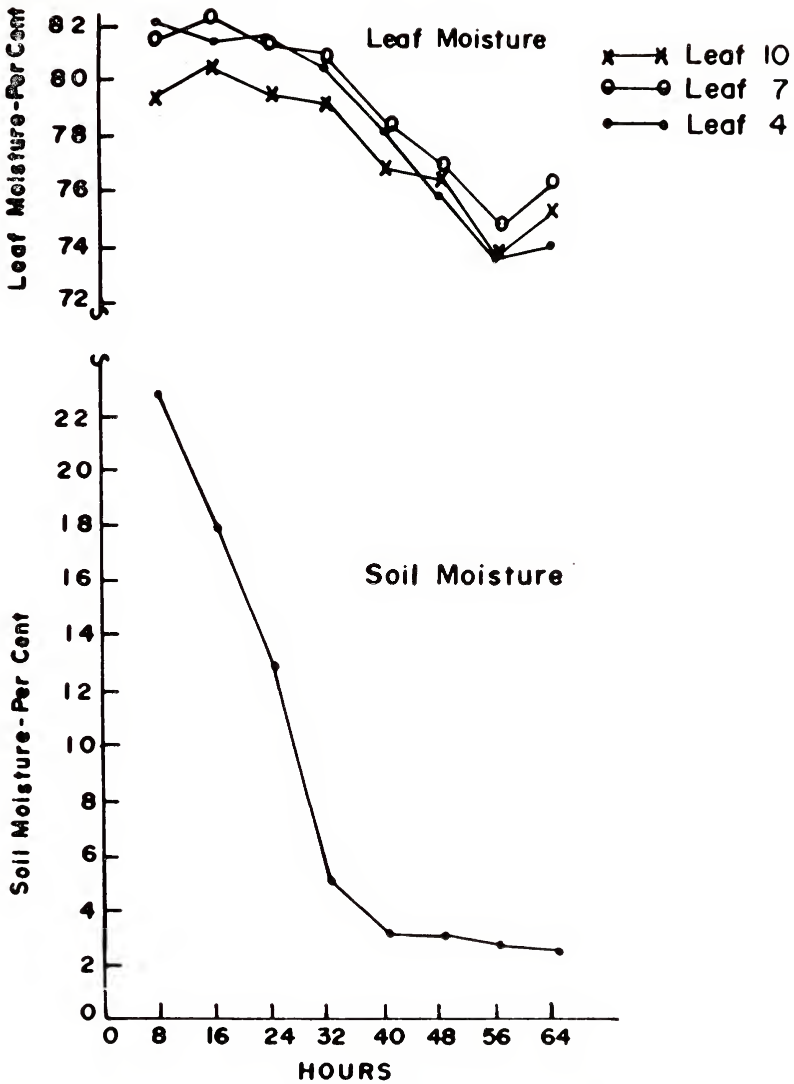

FIGURE 2. *Mean corn leaf moisture variation of three leaf positions compared to change in soil moisture.*

is an important consideration in determining leaf moisture content. The sampling of leaves from different plants growing at varying soil moisture levels is recommended for more interpretable and useful values of leaf moisture content.

The effect of different plants on leaf moisture was determined and did not show a significant difference. This result as well as nearly identical marginal means for the individual plants indicates that the plant differences did not affect leaf moisture content. The interaction of leaf position x time also was not significant. These results indicate that the effects of leaf position did not vary with the decreasing leaf moisture content.

The leaf moisture showed a slight increase at the 64-hour interval when compared to the previous time interval for all leaves. This reflected the early morning sampling time; as the greenhouse lights had been off the previous 8 hours. The same effect could be seen at the 16-hour sampling interval but not at the 40-hour interval. The reason for the difference at the 40-hour sampling interval was that the greenhouse lights were turned on 1 hour prior to sampling. Since the soil moisture was low at this time, the leaf moisture taken in during the night would be used quickly in transpiration causing the decrease in the leaf moisture content. The importance of diurnal effects on leaf moisture and the time of sampling is indicated by this example and others reported elsewhere (3, 4, 9).

Conclusions

1) The change of corn leaf moisture follows the same trend as the soil moisture changes regardless of the leaf position or height of the leaf on the plant. However, the effect of leaf position on leaf moisture was highly significant. If samples for leaf moisture are collected from the same leaf position throughout an experiment, the results should be more uniform and easier to interpret.

2) At a pre-tasseling stage of growth, the leaves near the mid-height of the plant have the highest moisture content at different soil moisture levels. This result may vary at other stages of growth but its effects should be considered when obtaining leaf samples.

3) The diurnal effect can greatly change leaf moisture content especially at low soil moisture levels (near the permanent wilting point). Leaf samples taken early in the morning were higher in moisture than those taken later in the day.

4) Leaf moisture appears to be a reasonable index of available soil moisture. It would seem, however, that one must have information on the stage of maturity, environmental conditions at the time of sampling, the type of plant and the type of soil to make meaningful interpretations.

Literature Cited

1. BAUER, H. J. 1967. The influence of soil texture, soil moisture, and relative humidity on corn plant transpiration and leaf moisture. Ph.D. Thesis, Purdue University. 88 p.

2. GARDNER, W. H. 1965. Water content. p. 82-127. *In* Methods of soil analysis, Part 1, Agronomy No. 9, American Society of Agronomy Inc., Madison, Wisconsin. 770 p.

3. ————————, and R. H. NIEMAN. 1964. Lower limit of water availability to plants. Science **143**:1460-1462.

4. EHRLER, W. L., and C. H. M. VAN BAVEL. 1967. Sorghum foliar responses to changes in soil water content. Agron. J. **59**:243-246.

5. HENDRICKSEN, A. H., and F. J. VEIHMEYER. 1945. Permanent wilting percentages of soils obtained from field and laboratory trials. Plant Physiol. **20**:517-539.

6. HOFFER, R. M., and C. J. JOHANNSEN. 1966. Ecological potentials in spectral signature analysis, p. 1-16. *In* P. L. JOHNSON [ed.], Remote Sensing in Ecology. University of Georgia Press, Athens. 244 p.

7. JOHANNSEN, C. J. 1969. The detection of available soil moisture by remote sensing techniques. Unpublished Ph.D. Thesis, Purdue University. 266 p.

8. MOSS, R. A., and W .E. LOOMIS. 1952. Absorption spectra of leaves. I. The visible spectrum. Plant Physiol. **27**:370-391.

9. NAMKEN, L. N. 1965. Relative turgidity technique for scheduling cotton (*Gossypium hirsutum*) irrigation. Agron. J. **57**:38-41.

10. RABINOWITCH, E. I. 1951. Photosynthesis and related processes, Vol. II, Parts I and II, Interscience Publishers, Inc., New York. 1489 p.

11. SINCLAIR, T. R. 1968. Pathway of solar radiation through leaves. Unpublished Master's Thesis, Purdue University. 179 p.

12. THOMAS, J. R., V. I. MEYERS, M. D. HEILMAN and C. L. WIEGAND. 1966. Factors affecting light reflectance of cotton, p. 305-312. Fourth Symposium of Remote Sensing of Environment, I.S.T., Univ. of Mich., Ann Arbor, Michigan.

13. WIERSMA, D. 1960. Moisture characteristics of some representative Indiana soil types. Proc. Indiana Acad. Sci. **69**:300-304.