Leaf Moisture Variation Within Corn Leaf Sections[1]

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Abstract

This study was designed to determine the variation of leaf moisture along the length of individual leaves at specific positions on corn plants under two different soil moisture conditions. The effect of darkness was also studied under a high moisture condition.

Eight-weeks-old corn plants were watered to above field capacity and divided into three treatments, varying according to specified time intervals to sampling and period of darkness. At the end of the specified time interval, the individual leaves of each plant were removed and cut into five-inch sections. Moisture determinations were made on each section and recorded.

The 0-5 inch section (measured from the tip of the leaf) was the driest part of each leaf regardless of the treatment. The 20-25 inch section (nearest the plant stem) contained the highest moisture percentage regardless of treatment. Wilted plants were found to show a greater variation in the moisture content within a single leaf than well-watered plants.

Light affected leaf moisture through its effects on transpiration, a factor which becomes important when sampling leaves at different times of the day.

When measurements are taken on a plant leaf where the entire leaf surface or area is incorporated in the measurements, the use of the entire leaf for a related moisture determination does not present serious analysis problems. Errors may arise, however, if a small portion of a leaf is used to represent the moisture for the entire leaf or if a small portion of the leaf is employed for spectral measurements and leaf moisture is determined for the entire leaf. In many instances it is necessary to know the variability of leaf moisture within a specific leaf, especially when the plant is subjected to different environmental conditions. The variations of leaf moisture within a leaf are also important when measuring reflection. Sinclair (6) showed the reflective responses of leaves reacted inversely to small changes in leaf moisture.

This experiment was designed to determine the variation of leaf moisture along the length of individual leaves at specific positions on corn plants under two different soil moisture conditions.

Experimental Method

Twelve corn plants were grown in separate pots in the greenhouse for 8 weeks. There were three treatments each utilizing four plants.

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All plants were watered to above field capacity and additional watering was terminated throughout the length of the experiments. After a 24-hour period, 8 plants were placed in a dark room with a temperature of 21.1°C. Of these 8 plants, 4 plants were designated for Treatment 1 and four for Treatment 2. The 4 plants remaining in the greenhouse were under normal greenhouse conditions for a period of 72 hours without additional water and designated as Treatment 3.

The plants for Treatment 1 were removed after 8 hours of darkness and placed under greenhouse lights (4000 ft-c) for a period of 10 hours. At the end of this time, the individual leaves of each plant were removed and cut into 5-inch sections.

Leaf moisture was determined by weighing each leaf section on a micro-balance accurate to 0.0001 g. The leaves were dried for 48 hours in a 70°C oven and then re-weighed. The moisture percentage was determined on a fresh weight basis [(Fresh Leaf Weight—Dry Leaf Weight)/Fresh Leaf Weight x 100 = % Moisture Content].

In Treatment 2, the corn plants were taken individually from the dark room after 16 hours of darkness. The individual leaves were removed and cut into 5-inch sections as quickly as possible before the plants could lose significant water by transpiration. Moisture determinations were made on each section and recorded.

The 4 corn plants used for Treatment 3 were severely wilted after growing for 72 hours without additional water. The leaves were cut into 5-inch sections for moisture determination. The moisture content of each leaf section was determined and recorded.

Results and Discussion

All leaves are not of the same length on a corn plant. Since the leaves were numbered beginning with 1 as the lowest leaf on the plant, the leaf length was found to vary between 24 and 30 inches for leaf positions 4 through 10. Since the leaves were cut into 5-inch sections, some of the leaves were cut into 5 sections and others into 6 sections.

For statistical analysis, a more favorable analysis model could be applied if the section numbers were equal; therefore, a weighted procedure was used to reduce the values of the 6 sections to 5 sections. Lettering the sections alphabetically so that A is the 0-5-inch section beginning at the tip of the leaf, B is the 5-10-inch section, etc.; then the following 5 sections were obtained in the weighting procedure wherever 6 sections existed, as follows:

1) $$\frac{5A + 1B}{6} = A'$$

2) $$\frac{4B + 2C}{6} = B'$$

3) $$\frac{3C + 3D}{6} = C'$$

4) $$\frac{2D + 4E}{6} = D'$$

5) $$\frac{1E + 5F}{6} = E'$$

The moisture determinations of the 5-inch leaf sections revealed some interesting correlations and interactions. The mean moisture values for Leaves 4 through 10 for all treatments are given in Figure 1. The 0-5-inch section (taken near the tip of the leaf) was the driest part of each leaf regardless of the treatment. The 20-25-inch section (taken near the plant stem) contained the highest moisture regardless of treatment.

An analysis of variance was performed on the well-watered plants using the dark and light treatments by employing the following linear model:

$$X_{ijkl} = u + K_i + P_{j(i)} + L_k + KL_{ik} + PL_{jk(i)} + S_l + KS_{il} + PS_{jl(i)} + LS_{kl} + PLS_{jkl(i)}$$

where X_{ijkl} is the leaf moisture percentage as influenced by leaf section l from leaf k of plant j growing under treatment i.

u = population mean

K = light factor where i = 1, 2

P = plant factor where j = 1, 2, 3, 4

L = leaf factor where k = 1, 2, 3, 4, 5, 6, 7

S = section factor where l = 1, 2, 3, 4, 5

The results of this analysis indicate that light is a significant factor on leaf moisture but that the effect of leaves and sections is highly significant (Table 1). The interactions of light x leaves, light x sections, leaves x sections, as well as light x leaves x sections were highly significant.

An indication that leaf position has a significant effect on leaf moisture was shown by Johannsen (2). The effect of the leaf sections on leaf moisture is shown in Figure 1. The sections closest to the plant stem had the highest moisture percentage and the sections taken at the tip of the leaves had a lower moisture percentage in all treatments.

The interaction of light x leaves can be explained by noting that light will help to control stomata openings. Milthorpe and Spencer (5) concluded that the stomata openings strongly controlled plant transpiration. Kramer (3) indicated that moisture varies in different plant leaves because of transpiration differences in different leaves. Leaves near the top of the plant begin to transpire earlier in the day than the lower leaves.

The effects of mutual shading of one or more leaves over other leaves have an effect on transpiration (1). Shaded leaves do not transpire as much as the other leaves when plants have adequate water. This might explain the reason for the highly significant interaction between light x leaf sections. Fischer and Hagan (1) reviewed the works of other authors which show a variation in the number of stomata along an individual leaf. The possibility of a difference in leaf structure along an individual leaf would also cause

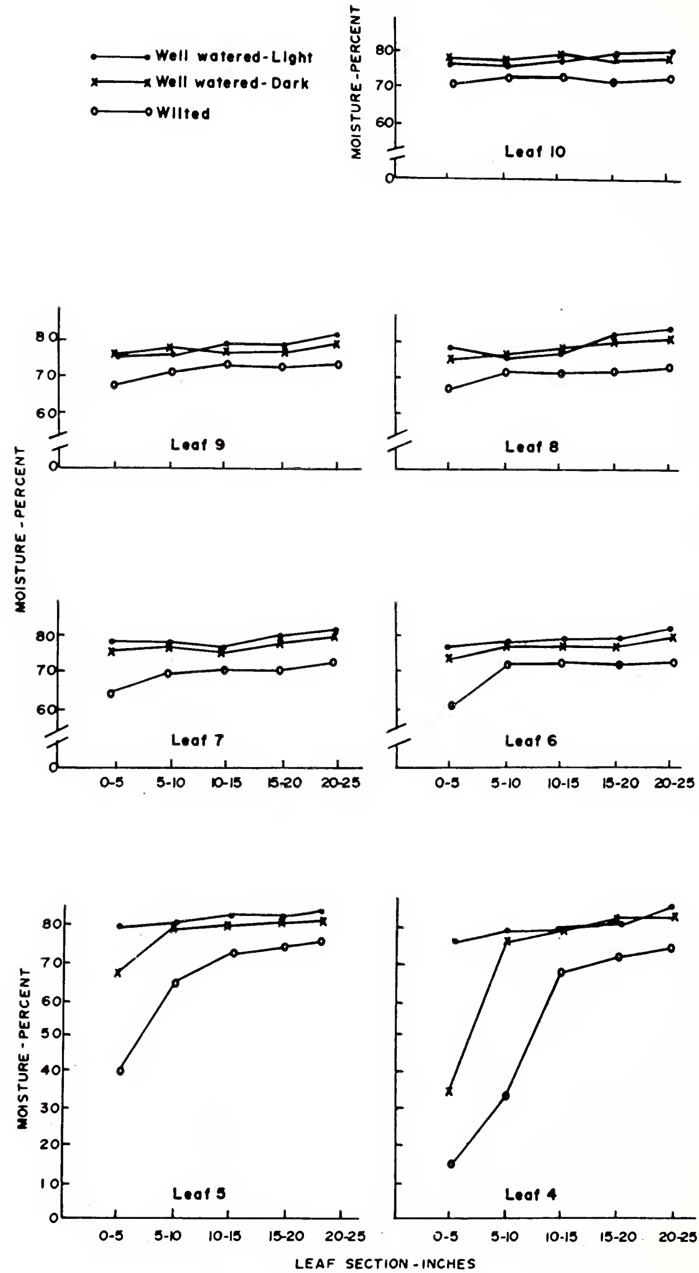

FIGURE 1. *Mean leaf moisture content of corn leaf sections from three different treatments.*

TABLE 1. *Analysis of variance of leaf moisture sections of light and dark treatments using well-watered corn plants.*

Source	df	SS	MS	F
Light	1	0.04489	0.04489	7.51*
Error (a)	6	0.03587	0.00598	—
Leaves	6	0.04271	0.00712	5.98**
Light x leaves	6	0.09635	0.1606	13.50**
Error (b)	36	0.04295	0.00119	—
Sections	4	0.28236	0.07059	21.20**
Light x sections	4	0.08108	0.02027	6.09**
Error (c)	24	0.07992	0.00333	—
Leaves x sections	24	0.31301	0.01304	8.20**
Light x leaves x sections	24	0.23862	0.00944	5.94**
Error (d)	144	0.22859	0.00159	—
Total	279			

* Significant; ** Highly Significant.

leaf moisture to vary. These factors would explain the highly significant difference found among the leaf sections.

The significant effect of light and darkness on plant moisture differences may result from temperature interacting with light. The plants in the dark treatment were kept at room temperature prior to the moisture determinations. The plants in the light treatment were under high intensity lights which gave higher temperatures as well as a differential in temperature along the vertical axis of the plant. Millar (4) reported data which indicate that leaf turgidity varies with change in leaf temperature. He did not test the significance of this factor, but he did show a significant difference in the turgidity measurements due to the temperature of the laboratory. Since the temperature of leaf samples changes with the temperature of the laboratory, its importance should not be minimized.

The strong interaction of light x leaves x sections could not be explained without further testing. To seek an explanation for this interaction, an analysis was run separately on both the dark and light treatments of the well-watered plants. The results are shown in Table 2. Highly significant values were found for the effect of leaves, sections and leaves x sections on leaf moisture for both treatments. The F value for the effect of sections on leaf moisture for the light treatment was considerably higher than that obtained for the dark treatment.

The leaves x sections interaction for the dark treatment shows a higher F value compared to that of the same interaction in the light treatment. This may be due to the dryness of the leaf tips of the lower leaves shown in Figure 1.

The above factors are likely to be causing some of the highly significant interaction of light x leaves x sections. A plot of the marginal means of Leaves 4 through 10 of the three treatments is given in Figure 2. A crossover of these means occurs between the 9th and 10th leaves of the light and dark treatments. The difference in the slope of the marginal means between the two treatments and the crossover indicates that the light has an influence in this interaction.

TABLE 2. *Analysis of variance of corn leaf moisture determined in sections on individual leaves under two different lighting treatments.*

Source	df	SS	MS	F
Well-Watered—Light				
Replications	3	0.01171	0.00390	9.26**
Leaves	6	0.02192	0.00365	8.69**
Error (a)	18	0.00757	0.00042	—
Sections	4	0.06487	0.01622	54.07**
Error (b)	12	0.00358	0.00030	—
Leaves x sections	24	0.00606	0.00025	2.27**
Error (c)	72	0.00775	0.00011	—
Total	139			
Well-Watered—Dark				
Replications	3	0.02416	0.00805	4.09*
Leaves	6	0.11714	0.01952	9.91**
Error (a)	18	0.03538	0.00197	—
Sections	4	0.29857	0.07464	11.74**
Error (b)	12	0.07635	0.00636	—
Leaves x sections	24	0.54557	0.02273	7.40**
Error (c)	72	0.22084	0.00307	—
Total	139			

* Significant; ** Highly Significant.

The wilted treatment of four plants was analyzed separately and the results are shown in Table 3. There were highly significant differences indicated by the F tests for leaves, sections and leaves x sections interaction in their effects on leaf moisture. The tips of the wilted leaves were noticeably lower in moisture content for all leaves which explains in part the high value obtained for the test of the effect of leaf sections on the leaf moisture content.

TABLE 3. *Analysis of variance of corn leaf moisture of plants that were in a wilted condition under high intensity greenhouse lights.*

Source	df	SS	MS	F
Replications	3	0.01251	0.00417	0.51
Leaves	6	0.68705	0.11451	14.12**
Error (a)	18	0.14602	0.00811	—
Sections	4	0.72946	0.18236	50.80**
Error (b)	12	0.04312	0.00359	—
Leaves x sections	24	1.12431	0.04685	13.09**
Error (c)	72	0.25785	0.00358	—
Total	139			

** Highly Significant.

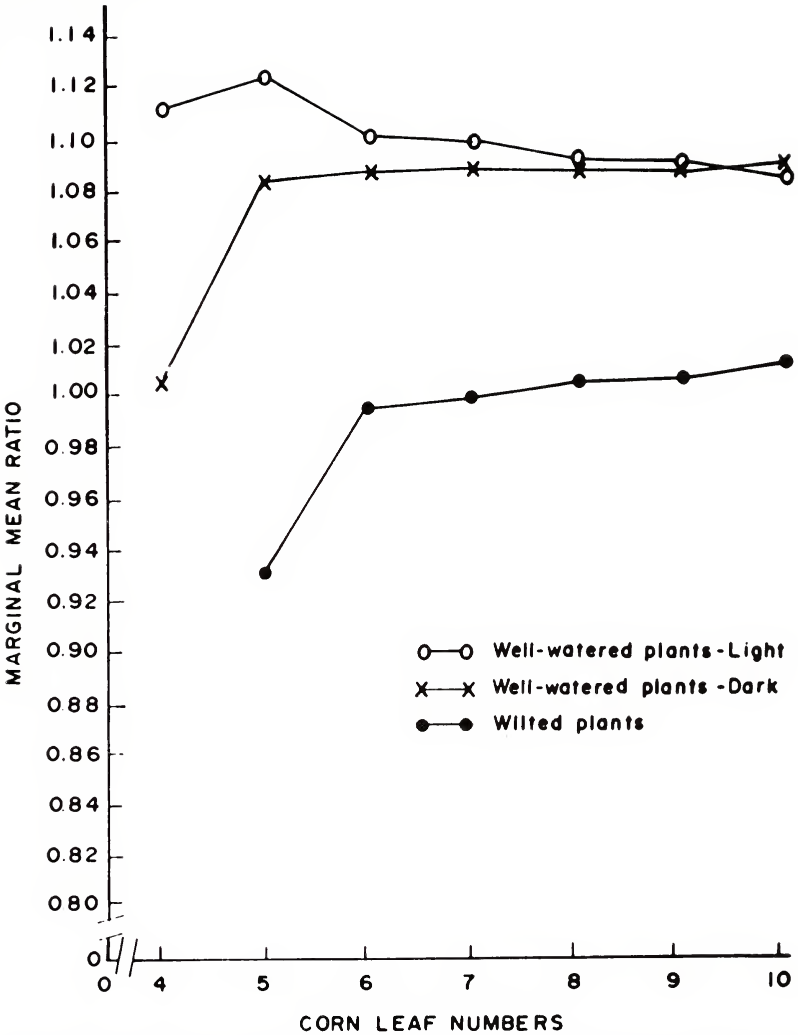

FIGURE 2. *Marginal mean values of corn leaf moisture for three different environmental conditions.*

Conclusions

1) The leaf moisture varies significantly within the same leaf. If only part of a leaf is sampled for moisture determination or if measurements are being made which can be influenced by leaf moisture, this should be considered. Therefore, it is recommended that the same portion of the leaf be used consistently throughout an experiment for more uniform and interpretable moisture conditions.

2) Light and its effect on transpiration cause variation in the leaf moisture of a corn plant. This factor becomes important when

a researcher is sampling leaves at different times of the day. Sampling of leaves should therefore always be conducted under similar lighting conditions for more comparable results. When taking leaf samples from field plots, cloudy *versus* sunny conditions should be observed as well as the time of day regardless of soil moisture conditions.

3) The moisture content of leaves varies with leaf position as shown by previous research.

4) Wilted plants show a greater variation in the moisture content within a single leaf than with well-watered plants. The variation between leaves is similar to that shown by the well-watered plants. The variation of light *versus* dark treatments on wilted plants was not performed due to a shortage of plants. The effect of light is expected to be greater on wilted plants since reduced transpiration caused by the dark period would cause a larger moisture increase within the leaves in this condition. Further work should be performed on the light and dark period effect on wilted plants before specific recommendations can be made on sampling procedures.

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