Temperature and Relative Humidity Inside Corn Canopies and in Standard Shelters during July and August, 1970 and 1971[1]

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Abstract

Temperature and relative humidity within the microclimate of corn canopies were compared to macroclimate temperature and relative humidity recorded in a standard National Weather Service shelter for the period July 17 to August 15, 1970 and 1971. Unaspirated wet bulb and dry bulb thermocouples exposed at one meter were used to measure corn canopy temperature and relative humidity. A hygrothermograph was exposed in a shelter for macroclimate measurements. Corn canopy maximum temperatures were higher than shelter maximum temperatures and, conversely, corn canopy minimum temperatures were lower than shelter minimums during both years. Relative humidity within the corn canopy during this period was similar in both years although differences occurred in macroclimate relative humidity patterns.

This study suggests that temperatures obtained from standard National Weather Service shelters can be used to approximate temperatures within a corn canopy. Relative humidity, however, can be quite different within a corn canopy than within a standard shelter.

Introduction

Following any unfavorable agricultural situation such as delayed corn maturity in 1967 or the unprecedented development of Southern Corn Leaf Blight (SCLB) in 1970 and 1971 (3), agriculturists often look first to anomalous weather conditions for an explanation. Weather data are collected and published by the National Weather Service from a network of instruments exposed under standard conditions. These data furnish excellent macroclimatic comparisons, but unless relationships between these data and microclimatic conditions are known, a correct assessment of the effect of macroclimatic anomalies upon biological response within a micro-environment can only be hypothesized.

This paper describes temperature and relative humidity patterns observed within a corn canopy and compares them with those from standard instrumental exposures for a period from mid-July to mid-August in 1970 and 1971. These microenvironmental measurements were taken as part of a corn growth and development study conducted at the Purdue University Agronomy Farm, West Lafayette, Indiana.

Description of Experiment

A summary of published temperature data (4) for the 1970 and 1971 growing seasons and the 18-year (1953 to 1970) average for the Purdue University Agronomy Farm is shown in Table 1. In this study, a 30-day period from July 17 to August 15—a period important in the SCLB development—was examined during both years.

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[1]Journal Paper No. 4632. Agricultural Experiment Station, Purdue University. Partially supported by National Oceanic and Atmospheric Administration, Cooperative Agreement E-205-69.

TABLE 1. *West Lafayette 6NW, Purdue University, Agronomy Farm temperature summary °C.*

	April		May		June		July		August		September	
	Max[1]	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
Normal[2]	16.1	4.6	21.8	9.7	27.0	14.7	29.2	16.7	28.2	15.4	25.2	11.2
1970	16.4	4.7	23.8	11.4	26.5	14.8	29.1	16.8	28.1	15.3	25.8	12.3
1971	16.7	2.4	20.6	7.8	29.8	17.3	27.3	15.6	27.2	14.2	26.1	14.2

[1]Average daily maximum temperature and average daily minimum temperature, 8 AM observation day.

[2]1953-1970 average.

Environmental temperature and relative humidity data were from a hygrothermograph exposed in a medium National Weather Service shelter at the Purdue Agronomy Farm Agricultural Weather Station. The corn experimental area was located about 200 m north-northeast of the weather station. Corn population was about 62,000 plants per ha planted in 76 cm-wide rows oriented north to south. The corn canopies were approximately 2.7 m tall in both years with an average leaf area index during the study period of 3.5 in 1970 and 4.0 in 1971. Seventy-five per cent silk dates were August 3, 1970 and July 27, 1971.

Copper-constantan thermocouples (24-gauge wire) were utilized to measure dry and wet bulb temperatures at 1 m within the corn canopy. Dry bulb fluctuations were reduced by shielding the thermocouple junction with white tape. A wet bulb was formed by tying a muslin wick securely around a bare thermocouple junction and extending the muslin downward into a water reservoir. Output from the thermocouples was recorded on a multi-point recorder.

Relative humidities measured by wet and dry bulb thermocouples were compared with those from a hygrothermograph exposed at the same location within the corn canopy during September 1971. The hygrothermograph used in the corn canopy was calibrated with the shelter hygrothermograph before and after the September study. The least squares regression equation for the calibration period was $Y = 1.718\ X - 70.266$, where Y is relative humidity taken from the hygrothermograph and X is that from the thermocouples. R^2 was 0.83. Since relative humidity in the shelter was recorded with a hygrothermograph, corn canopy relative humidities calculated from wet and dry bulb thermocouples data were corrected by this equation for this study.

Results and Discussion

Temperature

Temperatures in the shelter for the period from July 17 to August 15, 1970 and 1971 are shown in Figure 1. Daily maximum and minimum temperatures during 1970 were close to normal with periods both above and below normal. In 1971, daily maximum and minimum temperatures were well below normal with only a short period in August having above normal temperatures.

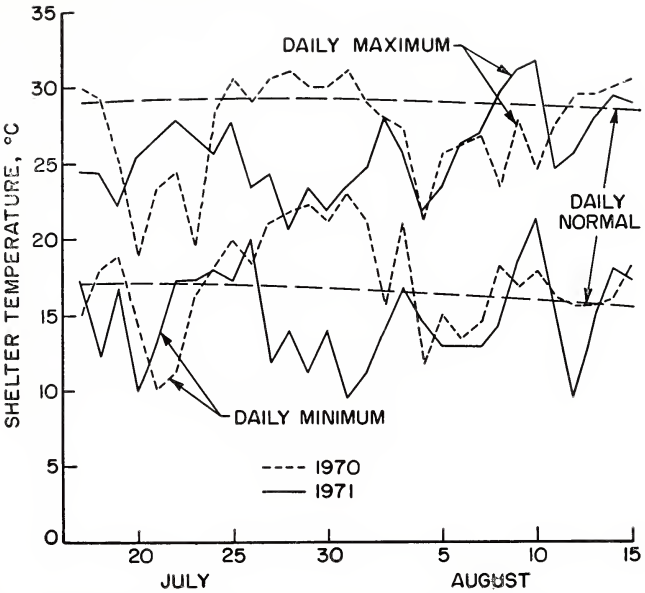

FIGURE 1. *Daily maximum and minimum shelter temperatures at West Lafayette 6NW, Purdue University Agronomy Farm, July 17 to August 15, 1970, 1971, and 30-year (1931-1960) normal.*

Hourly shelter temperatures averaged for the 30-day period from 17 July to 15 August show that 1971 temperatures were 2 to 3°C lower than 1970 temperatures (Fig. 2). An average hourly standard deviation of 1.3°C was found in 1970 and 0.9°C in 1971.

Differences between temperatures in the canopy and in the shelter for each hour are also shown in Figure 2. Nighttime temperatures within the canopy averaged 1.5°C lower than those in the shelter during 1970 and 0.5°C lower in 1971. Midday temperature differences reached a maximum of 1.2°C greater in the canopy than in the shelter during 1970 and 0.6°C during 1971. This difference between the two years can partially be explained by a denser canopy leaf area in 1971 than in 1970. The 1971 canopy did not permit as great a radiational exchange between the 1 m level in the canopy and the macroenvironment as did the 1970 canopy. Radiational heating and cooling of the canopy interior was therefore less during 1971 than during 1970. The early evening hours were a time of greatest temperature differentials between the macroenvironment (shelter) and the corn canopy. Rahn and Brown (2) have also found the corn canopy microenvironment to be warmer in daytime and cooler at night than the macroenvironment as measured in an instrument shelter.

Temperature differences in Figure 2 could reflect differences between exposures and also differences between types of instruments, *i.e.*, thermocouples within the canopy and a hygrothermograph in the shelter. The temperature data shown in Table 1 are from a third type

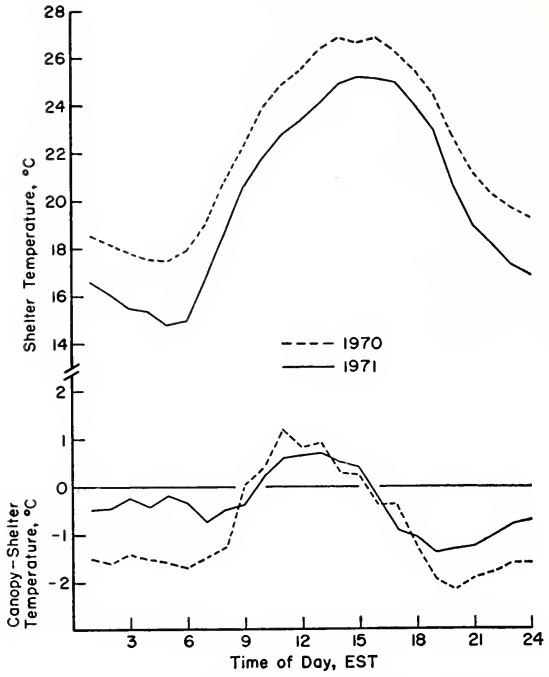

FIGURE 2. *Average hourly shelter temperatures and average hourly difference, corn canopy minus shelter temperature, for the period 17 July to 15 August, 1970 and 1971.*

of instrumentation, liquid-in-glass maximum and minimum thermometers. Accuracy in reading both time and temperature from hygrothermograms and thermocouple charts defeat quantification of any estimate of bias due to instrumental differences[2].

If temperature differences shown in Figure 2 are used to estimate maximum, minimum, or mean temperatures within a corn canopy from published climatological data, bias arising from the time of observation must be considered. Mitchell (1) has shown that estimates of mean temperature were near the true daily mean if the observational day ended at 8:00 AM, but the maximum and mean temperatures were biased upward if the observational time was 5:00 PM. An 8:00 AM observational day was used in this study for summarizing all temperature data.

[2]Published (4) maximum temperatures from liquid-in-glass thermometers averaged 0.6°C higher and minimum temperatures 0.7°C lower than those from a hygrothermograph exposed in the same standard shelter. A hygrothermograph and thermocouples exposed at 1 m within a corn canopy during September 1971, recorded the same nighttime minimum temperatures. Daytime maximum temperatures, however, were recorded about 1°C higher on the hygrothermograph. The higher daytime temperatures were due to sunfleck heating of the hygrothermograph while thermocouples remained in shaded locations during both the July-August and September periods.

Relative Humidity

Three basic instruments are used by the National Weather Service to measure relative humidity. Hygrothermographs, of the type exposed in a shelter for the data in this paper, depend upon absorption of water vapor by human hair. Hygrothermometers of the type currently exposed at airport weather stations consist of a ventilated dew cell to obtain dew point data. Relative humidity measurements with this instrument are usually lower than those recorded by a hygrothermograph. A third type instrument is the wet and dry bulb psychrometer. Although the psychrometer is usually force ventilated, an unaspirated thermocouple version of this instrument was used for canopy measurement of relative humidity in this study.

Relative humidity data in the corn canopy were not recorded prior to July 26, 1970. Thus hourly relative humidities in the shelter and canopy were averaged for the 21-day period from July 26 to August 15 (Fig. 3). The 1970 hourly relative humidities in the shelter were generally higher than those in 1971. The largest differences, 5% to 10%, occurred during the morning hours. The 1970 and 1971 corn canopy relative humidities, however, were similar throughout the day.

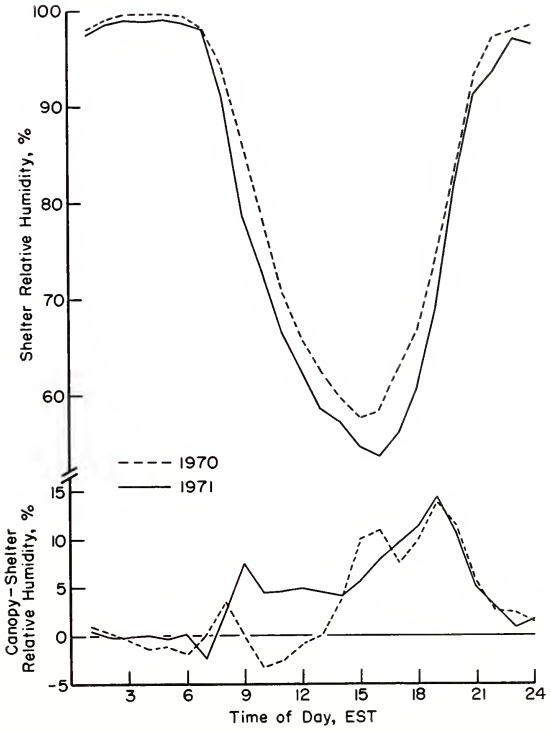

FIGURE 3. *Average hourly shelter relative humidity and average hourly difference, corn canopy minus shelter relative humidity for the period July 26 to August 15 1970 and 1971.*

Relative humidities in both the shelter and corn canopy were close to 100% during the nights in both years.

Hourly relative humidity differences, canopy minus shelter, were similar during the night, afternoon, and early evening hours in both years (Fig. 3). Morning relative humidities, however, did not show similar characteristics in 1970 and 1971. During 1970, relative humidity in the corn canopy and shelter changed at about the same rate until 2:00 PM, but in 1971 the shelter relative humidity decreased more rapidly in the morning than did the corn canopy relative humidity. Hourly standard deviations of the relative humidity differences were about 3% at night and 10% in the afternoon. The large afternoon deviations were caused by a few periods of rain and high humidity.

Conclusions

During the 30-day period, July 17 to August 15, 1970 and 1971, temperatures at 1 m within a corn canopy were lower at night and higher during the day than temperatures recorded in a standard National Weather Service shelter. The shelter relative humidity was greater in 1970 than in 1971 with the largest differences occurring during the morning hours. Relative humidities within the corn canopy, however, showed similar average hourly trends during the morning hours in 1970 and 1971. Relative humidity in both the corn canopy and shelter averaged close to 100% at night in both years.

These data suggest that temperatures obtained from standard National Weather Service shelters can be used to approximate temperatures within a corn canopy. Relative humidity, however, can be quite different within a corn canopy than within a standard shelter.

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