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Temperatures During Maize Growth: Differences Between Six U.S. Locations and Possible Implications for Growth and Grain Yield

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Summary

While temperature has been identified as a major environmental element affecting maize (*Zea mays* L.) grain yields in different regions, there has been little published information comparing thermal environments of maize in different regions. The objective of this paper was to compare daily temperature normals (1951-80) during three portions of the maize growing season at six U.S. locations to determine possible limitations to growth and yield. Planting and silking dates were obtained from various published and unpublished data for locations in central Texas, northern Florida, southern Michigan, the Corn Belt, and the Texas High Plains. Excluding the southern Michigan location, the range across locations of normal mean daily temperature from planting to silking was 3°C. At silking, this range was 4°C for all six locations. The greatest temperature differences occurred during the 40 days following silking. Means during this interval had a range of 7°C. Normal daily maximum and minimum values had similar trends. Thus, high ambient temperatures before silking do not account for yield differences between different U.S. regions. Likewise, hybrids developed for southern locations do not require increased heat tolerance before or at silking. However, higher temperatures during grain filling in the southern locations may be a yield limitation and a factor to be considered in hybrid adaptation.

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Introduction

High temperatures affect crop yields primarily by two mechanisms. Plant respiration increases with increasing temperature (McCree and Silsbury 1978), thereby decreasing available assimilate for grain production. In addition, increased temperature decreases the duration of development, which results in less total intercepted photosynthetically active radiation during a developmental stage and, even with adequate water, less total photosynthesis (Duncan et al. 1973). This also reduces available assimilate for grain production.

The effect of temperature on maize (*Zea mays* L.) yield is somewhat controversial. Peters et al. (1971) reported that increasing the night temperature during the period from flowering to maturity from 18 to 29°C reduced maize yield by 40 percent. Likewise, Bates (1955) found mean maximum June temperature to be negatively correlated with yields at Temple, Texas. In a study of yields for 38 years in five Corn Belt states, Thompson (1969) found that above normal monthly temperatures during June, July, and August significantly reduced yield. In contrast, Quin (1981) concluded, based upon field respiration measurements, that minimum night temperatures of 22 to 25°C were not a major cause of low maize yields in the tropics and Stacey et al. (1957) found that if rainfall was adequate, maize yields in Georgia were greater when daily maximums near the end of the growing season were 38°C instead of 27°C or lower.

There have been only a limited number of studies on temperature effects during the grain filling period. While kernel growth rate has been shown to increase with temperatures in the range of 15 to 30°C (Major and

Table 1. Locations used for temperature data and locations and sources of maize phenological data

Temperature data[1]	Phenological data	Source of phenological data
Lansing, MI	southern MI	Rossman et al. (1985) Erdmann et al. (1981)
Lubbock/Amarillo, TX[2]	Halfway, TX	Unpub. data of J. Wright
Tallahassee, FL	Quincy, FL	Wright and Rhoads (1981)
Des Moines, IA	Ames, IA	Hanway and Russell (1969)
Columbia, MO	Columbia, MO	Kiniry and Keener (1982)
Waco, TX	Temple, TX	Kiniry and Ritchie (1984)

[1]Taken from 1951-80 normals published by National Oceanic and Atmospheric Administration (1982).

[2]A mean of the two locations.

Table 2. Dates of planting, silking, and 40 days after silking for locally-adapted maize hybrid at six U.S. locations

Location	Planting date	Date of 50 percent planting[1]	Silking date	40 days after silking
southern MI	11 May	1 May-10 June	15 July (65)[2]	24 August (105)
Halfway, TX	26 April	15-30 April	13 July (78)	22 August (118)
Quincy, FL	16 March	1-31 March	25 May (70)	4 July (110)
Ames, IA	15 May	5-15 May	24 July (70)	2 September (110)
Columbia, MO	6 May	30 April-10 May	10 July (65)	19 August (105)
Temple, TX	16 March	10-25 March	4 June (80)	14 July (120)

[1]The range of dates reported (personal communication) by the individual state Statistical Reporting Service offices, based on their records for the appropriate crop reporting districts in each state.

[2]Days after planting.

Schaalje 1985), the interaction of rate and duration of grain filling in determining final kernel weight at different temperatures has not yet been described. Estimates of the normal temperatures during grain filling for different U.S. locations would be valuable for designing future experiments on this topic.

Knowledge of air temperatures during grain filling as well as during other maize development stages in different regions would help in the understanding of detrimental effects of high air temperature on yields. This would be useful for breeders interested in knowing the degree of high temperature tolerance needed for hybrids in different areas. It is the purpose of this report to compare daily normals of maximum, minimum, and mean temperature during different portions of the maize growing season at different U.S. locations.

Materials and Methods

Six locations, representing extremes of the U.S. corn growing regions, were chosen based on availability of data for maize planting, silking, and maturity dates and for normal daily maximum, minimum, and mean air temperature (National Oceanic and Atmospheric Administration 1982) from nearby stations (Table 1). Average temperatures of the means, maximums, and minimums for the planting to silking interval and for the 40 days following silking, calculated using the normal means for every fifth day, were compared across locations. Temperatures for the day of silking were also compared across locations. Temperature normals for Lubbock and Amarillo, Texas were averaged to approximate the temperatures of Halfway, Texas. Two of the locations, Tallahassee, Florida and Lansing, Michigan, were selected due to their proximity to

areas where high maize yields have been obtained. Grain yields greater than 22 Mg ha^{-1} in southern Michigan (Erdman et al. 1981) and 16.6 Mg ha^{-1} in Quincy, Florida (Wright and Rhoads 1981) have been reported.

Planting dates (Table 2), representative of typical dates for the areas, were within the range of dates of 50 percent planting for the appropriate crop reporting districts in each state (Statistical Reporting Service, personal communication).

In this study, the grain filling period was 40 days following silking. Dates of physiological maturity were not as readily available from the references as silking dates. When reported, they typically occurred 100 to 125 days after planting.

Results and Discussion

Planting occurred at all locations when the mean air temperature was between 13 and 17°C (Fig. 1). Between planting and silking (65 to 80 days after planting), Lubbock/Amarillo had the highest maximum temperatures and Columbia the lowest. The range of mean temperatures during this time was less than that for the maximums or minimums. Except for Lansing, Michigan, all temperatures increased at all locations through silking. Approximately 70 days after planting the temperature range across locations began to increase. Temperatures at Lansing, Michigan and Des Moines, Iowa (a representative Corn Belt location) decreased whereas temperatures at the southern locations continued increasing.

The range of mean temperatures from planting to silking at all locations except Lansing, Michigan was 2°C (Table 3). This location was noticeably cooler, with a mean of 18°C, primarily because of cooler temperatures immediately before silking (Fig. 1). At silking, mean temperatures across locations had a range of 4°C. The three southern locations differed by 1°C from Des Moines, Iowa. Finally, the greatest variation between locations in mean temperature (7°C) was in the 40 days following silking. The range of maximum and minimum temperatures during all these periods was higher and would have ordered slightly differently.

Normal mean, maximum, and minimum temperatures during the period from planting through silking and at silking had less variability across locations than temperatures during the grain filling period. Temperatures prior to silking and at silking at the southern locations were not consistently greater than the other locations.

Thus, breeders and physiologists in the southern United States should concentrate on the grain filling period for purposes of breeding for high temperature tolerance and identifying yield limitations due to high temperature. Work such as that by Major and Schaalje (1985), which quantifies temperature responses during the grain filling period, will help in interpreting regional maize yield differences.

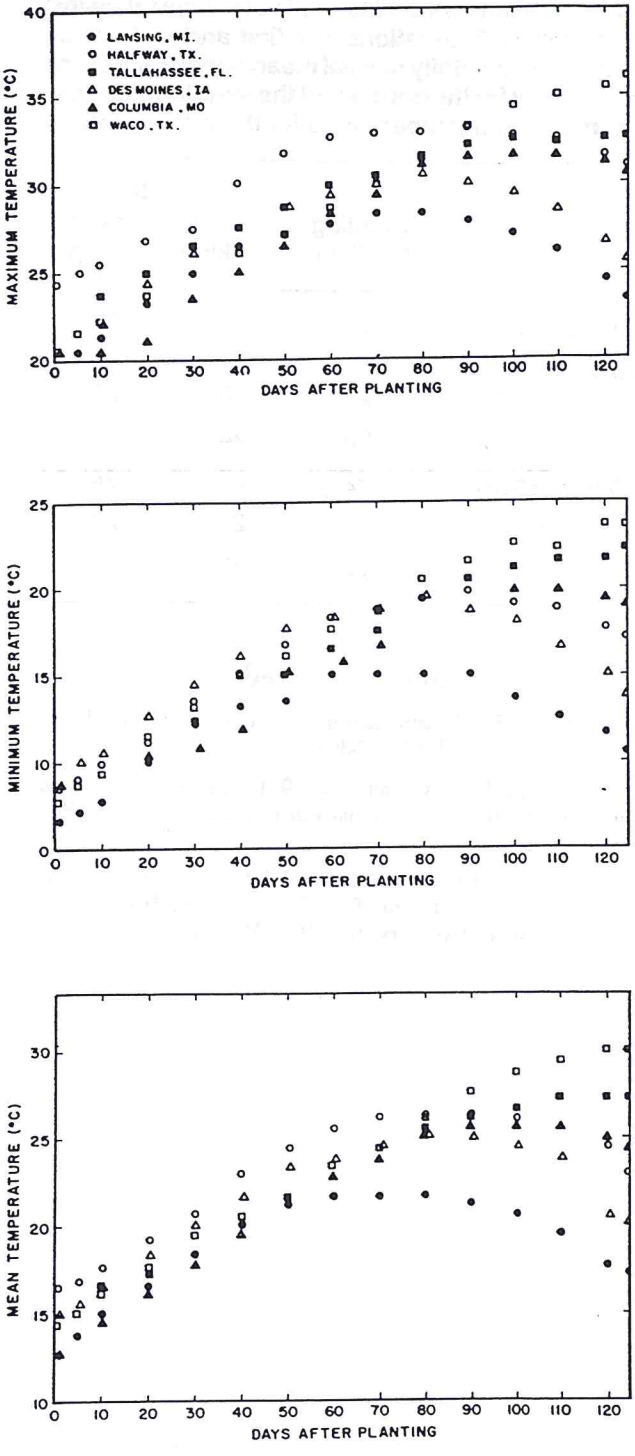

Figure 1. Normal daily maximum, minimum, and mean temperatures for six U.S. locations during the maize growing season. Values are shown for every tenth day. The range across locations of 50 percent silking (solid arrows) and physiological maturity (dashed arrows) dates are shown.

Table 3. Normal daily mean temperatures (°C) from planting to silking, at silking, and at 40 days following silking at six U.S. locations; the first and last values are a mean of the daily normal mean temperatures for every fifth day for the period and the middle values are the normal mean temperatures for the silking date

Location	Planting to silking	At silking	40 days following silking
Lansing, MI	18	22	21
Lubbock/ Amarillo, TX	22	26	26
Tallahassee, FL	20	24	26
Des Moines, IA	22	25	24
Columbia, MO	21	22	24
Waco, TX	20	26	28

Literature Cited

Bates, R.P. 1955. Climatic factors and corn yields in Texas Blacklands. Agron. J. 47:367-369.

Duncan, W.G., D.L. Shaver, and W.A. Williams. 1973. Insolation and temperature effects on maize growth and yield. Crop Sci. 13:187-191.

Erdmann, M.H., E.C. Rossman, and L.S. Robertson. 1981. Fourteen steps to profitable corn production in Michigan. Mich. Ext. Serv. Bul. 1P-15M, 8 pp.

Hanway, J.J. and W.A. Russell. 1969. Dry-matter accumulation in corn (*Zea mays* L.) plants: Comparisons among single-cross hybrids. Agron. J. 61:947-951.

Kiniry, J.R. and M.E. Keener. 1982. An enzyme kinetic equation to estimate maize development rates. Agron. J. 74:115-119.

Kiniry, J.R. and J.T. Ritchie. 1985. Shade-sensitive interval of kernel numbers of maize. Agron. J. 77:711-715.

Major, D.J. and G.B. Schaalje. 1985. Effect of temperature on *in vitro* kernel growth of the flint and dent maize hybrids. Crop Sci. 25:732-735.

McCree, K.J. and J.H. Silsbury. 1978. Growth and maintenance requirements of subterranean clover. Crop Sci. 18:13-18.

National Oceanic and Atmospheric Administration. 1982. Daily normals of temperature, heating, and cooling degree days and precipitation, 1951-1980. National Climatic Data Center. Asheville, North Carolina.

Peters, D.B., J.W. Pendleton, R.H. Hageman, and C.M. Brown. 1971. Effect of night air temperature on grain yield of corn, wheat, and soybeans. Agron. J. 63:809.

Quin, F.M. 1981. Night respiration of a maize crop in the lowland tropics. J. Appl. Ecol. 18:497-506.

Rossman, E.C., K. Dysinger, M. Chamberlain, and R.H. Leep. 1985. Hybrids compared 1985. Mh. Ext. Serv. Bul. E-431. 27 pp.

Stacey, S.V., O. Steanson, L.S. Jones, and W.J. Forman. 1957. Joint effects of maximum temperatures and rainfall on corn yields, Experiment, Georgia. Agron. J. 49:26-29.

Thompson, L.M. 1969. Weather and technology in the production of corn in the U.S. Corn Belt. Agron. J. 61:453-456.

Wright, D.L. and F.M. Rhoads. 1981. Management practices for 300 bushel corn. Florida Ext. Serv. Bul. 108. 7 pp.

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