UNIVERSITY OF MANITOBA

EVALUATION OF THE CORN HEAT UNIT
FOR SOUTH WESTERN MANITOBA

by

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A THESIS

SUBMITTED TO

THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT

OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

DEPARTMENT OF SOIL SCIENCE

WINNIPEG, MANITOBA

February, 1974

AKNOWLEDGEMENTS

The author wishes to express his appreciation to:

Dr. C.F. Shaykewich, Department of Soil Science, under whose supervision this investigation was carried out, for his assistance during the course of this project and his helpful criticism during the writing of this thesis;

Dr. R.I. Hamilton, Canada Department of Agriculture, Brandon, for his helpful co-operation during the term of this project;

The research staff of the Canada Department of Agriculture, Research Station, Brandon, for their help with the field work for this project;

The staff of the University of Manitoba Soil Science Department for their assistance in the completion of this project;

Mr. J.G. Mills for his generous help in processing data from this project;

Dr. R.A. Hedlin, Department of Soil Science, and Dr. S.B. Helgason, Department of Plant Science, for serving on the examining committee;

The staff of Soil Survey, University of Manitoba, for their help in plot selection;

Canada Department of Agriculture, Manitoba Corn Committee, Seagrams of Canada,Ltd., Manitoba Department of Agriculture, Geigy Chemicals, for their financial assistance.

ABSTRACT

The effectiveness of the Corn Heat Unit as an agrometerological index for corn (Zea mays L.) was studied at eight locations in South- Western Manitoba in 1971 and 1972. Corn development(as measured by leaf stage, tasseling, silking, and kernel moisture) was related to corn heat unit accumulation. It was found that there were significant statistical differences between locations and years in the number of heat units required for tasseling and silking for each hybrid. There was a range of approximately 400 heat units in the number of corn heat units necessary for the attainment of physiological maturity(40 per cent kernel moisture) between the eight locations for individual hybrids. Therefore it was concluded that the the corn heat unit is not a satisfactory parameter for predicting corn development in South Western Manitoba.

Kernel moisture levels during the harvest period (early October) were found to be near the level(30 per cent) required for mechanical harvesting of grain. This was the case for the majority of the eight locations for the early maturing hybrids in both years.

Analysis of the soil temperature measurements at the 20 and 50 cm depths at the eight locations indicated that soil temperature was an important factor in corn emergence and development.

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INTRODUCTION

There is a general belief that the South Western portion of Manitoba is not particularily well suited to corn production. The belief is that the climate of this region is not favourable for corn production because of a relatively short growing season, insufficient heat unit accumulation and low rainfall. However long term data on corn (Zea mays L.) production at the Canada Research Station in Brandon, indicates that there is a good potential for grain and silage production in the region. Since there did not exist any survey of the climatic regime of this region, a study was initiated to determine whether the conflicting observations could be explained and to determine the relationship between climate and corn production for South Western Manitoba.

Increased corn production, made possible by better knowledge of the climate's influence on corn growth, may have several advantages:

1) There would be economic benefits from diversification into corn production.

2) Grain corn has a large local market in the distilling industry of Manitoba.

3) Most of the land, with a well drained medium to coarse textured soil, in the South West now supporting cereal crops should be suitable for either grain or silage

corn production.

4) Corn, as silage, has proven to be a desirable feed for cattle because of its high yield potential and nutrional value. Thus it could be used as an alternative or addition to the existing feeds, used in the large livestock industry in South Western Manitoba.

Corn could serve as a supplement or alternative for some of the crops grown in the South Western region of the Province.

To evaluate the suitability of a climate for a crop, in particular corn, Several different systems have been developed. Among these are degree days, frost free period, and corn heat units. The system which seems most successful for corn is the "Corn Heat Unit" system developed for Ontario by Brown (1963, as referred to by Gamble, 1971). The corn heat unit system is a modified degree day system which allows for the specific requirements of corn.

A map of South Western Manitoba with the corn heat unit ratings for each area (Figure 1) indicates that the levels of corn heat units are generally not high enough for grain corn production. The earliest available hybrid grain corn presumably requires 2300 to 2500 corn heat units to mature while existing levels seem to range from 2100 to 2300 heat units. It was the purpose of this project to evaluate the Corn Heat Unit as to its use as a criteria for predicting grain corn maturity in South Western Manitoba.

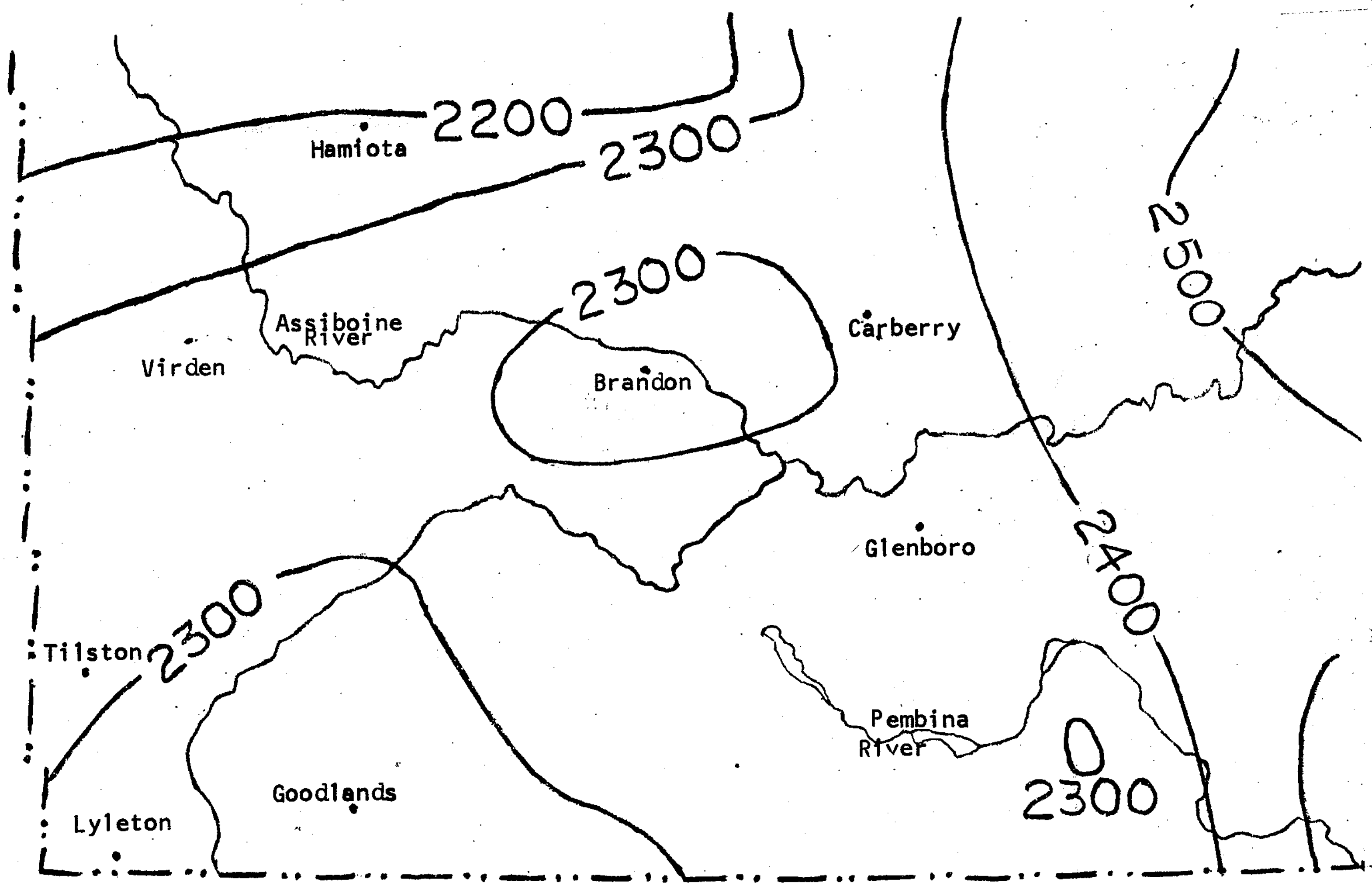

Figure 1. Corn heat unit map of South Western Manitoba. (Corn heat units were calculated from the 15th of May to the first fall frost(-2C), on the basis of long term weather data.) 3

LITERATURE REVIEW

The emphasis of this project has been placed on the relationship between temperature and corn growth and development. Some of the factors which influence corn growth, such as moisture and fertility, can be controlled. The influence of temperature is an important factor in corn growth, but temperature influences cannot readily be controlled under field conditions. For these reasons this review is mainly concerned with temperature effects on corn growth, although the effects of solar radiation on maturity are also discussed. Since criteria for determining the stage of maturity of corn plants are important in assessing the usefulness of certain agrometerological indices, a discussion of maturity criteria is also included.

Soil Temperature And Corn Development

The root zone temperature has been found to be important to corn development. These findings may be attributed to the effects of temperature on plant metabolism and nutrition.

There is considerable evidence that corn seedling emergence is controlled by soil temperature. Blacklow (1972) found that the time required to initiate growth of the corn seedling radicle and shoot increased from 20 hours to 200 hours when the soil temperature was lowered from 30C to 10C. His studies also showed that the rate of elongation, for the shoot and radicle, was maximum at 30C and virtually ceased at 10C. Ketcheson (1970) noted that an increase in the soil temperature at 10 to 15 cm depth to 22C over an average temperature of 15C, resulted in a three day decrease in time to emergence. Alessi and Power (1971) found the time required for emergence of 80 per cent of corn seedlings increased from 4 days at 26.7C to 24 days at 13.3C, at a seeding depth of 12.7 cm. Chirkov (1964) suggests a temperature of 8C is the minimum for germination.

Torssel *et al.* (1959) pointed out the necessity of developing corn hybrids which are able to germinate quickly in cold, moist soils of cooler climates. These observations emphasize the importance of soil temperatures to corn germination. It is clearly seen that if germination is delayed by cool soil temperatures, time to maturity may be increased. The plant will not be able to utilize the entire growing season because of delayed germination.

In corn, the critical period for soil temperature effects extends from germination to emergence of the apical meristem (growing point) of the seedling above the soil surface. Because the apical meristem is below the soil surface its development is controlled by soil temperature during this early stage of growth (from germination to the 7 to 10 leaf stage). Soil temperature can also influence the growth of the corn plant after emergence.

Beauchamp and Lathwell (1966a) observed that root growth was significantly slower at 15C than at 20C and 25C. It was noted that cell division processes were dominant over cell elongation at the lower temperature but that the opposite occurred at the higher temperature regime. They reported that the protophloem elements matured closer to the apex of the plant roots when grown under higher temperatures. This indicates that the lower temperatures delayed the maturation of the roots. There was also a decrease in the number of metazylem vessels at the 15C temperature although the diameter of these vessels did not change.

Beauchamp and Lathwell (1966b) reported a reduction in the rate of leaf initiation and maximum number of leaves initiated per plant when corn was grown at 15C versus 20C root zone temperature. They interpreted the results as a direct effect of root zone temperature on the meristematic region. Watts (1971, as referred to by Cal and Obendorf, 1972) measured leaf extension continously while the temperature of the root system was altered rapidly. The relative rate of leaf extension in the young corn plants was dependent upon the temperature applied to the meristem. Rate of leaf extension approximately doubled with each 10C rise in temperature from 0C to 30C.

Beauchamp and Lathwell (1967) studied the effect of changes in root zone temperature on the subsequent growth and development of young corn plants. They found that generally dry weights of shoots and roots at specific morphological stages of development decreased significantly with increasing root zone temperature. This occurred even though the rate of development increased with higher temperature. Root zone temperatures almost totally regulated the rate of development even though aerial temperatures were always high enough to allow rapid development. These observations were made during the period from emergence to the six leaf stage. The low temperature treatment was 15C and the higher temperatures 20C and 25C. It was also pointed out that the optimum temperature for dry matter accumulation seemed to decrease with development. They suggest that a proportionately greater number of cells might be involved in a specific mechanism for the utilization of carbohydrates. While these cells respire, they may have a limited function in promoting plant development. This system might allow for a maximum utilization of carbohydrates for growth at lower temperatures by cells not directly involved in growth.

Cal and Obendorf (1972) observed the growth of four hybrids of corn at 12, 16, and 20C initial root zone temperatures. They found that leaf number increased with sequential increases in root zone temperatures. At nine weeks after seeding at 16C, leaf blade areas were 43 to 74 per cent of the control plants' blades for the four hybrids, while after the same period the 12C blade areas were 10 to 24 per cent of the control. There were significant differences among the hybrids in their responses to below optimum soil temperatures.

The influence of soil temperatures on the corn plant may not be limited to the below ground portion of the plant. Beauchamp and Torrance (1969) pointed out that since the corn stalk is mainly composed of water, it may be assumed that there may be a significant amount of heat transferred along the corn stalk under a thermal gradient. Their study was concerned with the relative contributions of aerial temperatures and soil temperatures within the corn stalk. They found that the soil temperature could signficantly affect the stalk temperature up to the 6 and 8 leaf stages. These findings would have significance during the early period of growth of the corn seedling.

There are experimental results which indicate that soil temperature can be directly related to the time required for corn plants to reach maturity. Ketcheson (1968) found a soil temperature of 21C hastened maturity more than a temperature of 17C (with a constant air temperature). Plants at 21C reached the 50 per cent tassel stage 9 days before plant at the 17C soil temperature regime. Ketcheson (1970) studied the effects of heating and insulation of the soil on corn growth. The 10 to 15 cm depth of soil was maintained at higher temperatures (2 to 3C higher than normal) during May and June. Corn in the treatment which received both heating and insulation (2.5 cm thick polystrene board placed on the soil surface) showed a three day decrease in the time required for silking. Also it was found that ear moisture content was 2 to 4 per cent lower for corn plants which were in the heated treatment.

A decrease in time to maturity due to higher soil temperature was also reported by Cal and Obendorf (1972). Time to silking was found to be 2 weeks shorter under the 20C soil temperature regime than under the 16C temperature regime (fluctuating air temperature). Tasseling also occurred earlier under the higher temperature conditions. They related the increase in time to maturity under lower temperatures to be due partially to effect of soil temperature on the activity of the meristematic region during early growth.

Soil temperature may also influence nutrient uptake by corn plants. Ketcheson (1957) studied the effects of low soil temperature on phosphorous uptake of young corn plants. Phosphorous uptake was measured at 20C and 13C growth media temperatures. The results indicated that phosphorous might be lacking in plants subjected the lower temperature. It was suggested that a decrease in root activity at the lower temperature might be the cause of the decrease in phosphorous uptake.

Hough (1971) studied the effects of soil temperature on the time required for emergence of the corn hybrid Inra 200. The average daily rate of development 1/D (where D is the days from sowing to emergence) was plotted against the soil temperature (at 5 cm). The regression equation had a correlation coefficient of +0.90:

$$1/D = 0.0093\ (T - 5.9)$$

Results indicate that a soil temperature of 5.9C at 5 cm gives the best fit to emergence data. This base temperature of 5.9C is below the physiological threshold temperature of 10C, below which there is not any measurable growth. Hough suggests that the value for the threshold temperature and may vary with the soil moisture conditions and cannot be taken as an absolute value.

Ketcheson (1968) examined the effects of air and soil temperature as well as those of a starter fertilizer on growth and nutrient composition of corn. It was noted that the total days to maturity was decreased by higher soil and air temperatures (26-16C high and 22-12C low, air-soil temperatures). Concentrations of nitrogen and potassium were higher in the plants which received the lower soil temperature treatments. There was no significant difference in the final phosphorous content of the plants. Ketcheson pointed out that the effects on early nutrient uptake by the plant were not studied in his experiment.

Air Temperature Effects On Corn Growth And Development

Minimum Temperature

The lowest air temperature at which normal growth ceases is given as approximately 10C (Lehenbauer, 1914, as cited by Gamble, 1971). Chirkov (1964) reported that corn growth virtually stopped at 10-20C. The 10C temperature is generally accepted as the base temperature for daytime growth of corn.

Corn plants may be damaged by temperatures ranging from 0-7C, according to the work of Harper (1955, as referred to by Torsell *et al*. 1959). Johansson and Torsell (1956, as referred to by Torsell et al.1959) found that a temperature of ± 0.0C to ± 0.5C, maintained for 6 hours, produced a visible deleterious effect upon young corn plants. They also found that yield was reduced by a temperature treatment of -2C to -3C imposed for 6 hours.

Optimum Temperature For Corn Development

Increasing the air temperature above the 10C minimum causes an increase in rate of chemical reactions within the plant. According to Wilsie (1962), Lehenbauer (1914) found a Q10 for corn of 6.56 from 12C to 22C and 0.06 between 33C and 43C. These results indicate that an increase in temperature is only useful in the lower temperature range (20-30C). Lehenbauer (1914, as referred to by Wilsie 1962) defined the optimum temperature as the one at which maximum sustained growth occurs. The optimum temperature for corn is generally accepted as being approximately 30C based on the work of Lehenbauer (1914, as referred to by Wilsie 1962).

Maximum Temperature

Temperatures above the 30C optimum may not be beneficial to corn plant growth and may in fact be harmful. As noted by Lehenbauer (1914, as referred to by Wilsie 1962) the average Q10 value for reactions within the plant drops rapidly from 33 to 43C. This indicates that temperatures from 30 to 40C decrease the rates of growth processes. Devlin (1969) indicates that thermal death occurs for leaves of most plants at 55 to 60C. He also states that temperatures below the thermal death temperature can stop or destroy photosynthetic mechanisms. However with short exposure time, stimulation of photosynthesis above the optimum can occur, suggesting that temperature may cause deactivation of photosynthetic enzymes (Rabinovich,1956, as reported by Devlin, 1969). Thus corn plants may survive high temperature exposure for a short time but exposure for several hours may cause irreversible damage to photosynthetic mechanisms. Gamble (1972) indicates that growth rates of corn plants may decrease at temperatures above 33C.

Effects of Night Temperature on Corn Growth

Went (1958, as referred to by Gamble 1971) found that most plants generally have a lower optimum temperature at night than they have during the daytime. Peters (1971) found that yield was reduced by 40 per cent when a night air temperature of 29.4C was applied from anthesis to maturity as compared to a control of 18.3C. Although yield was reduced it was also found that maturity was hastened by high night temperatures. Ketcheson (1968) reported that a day-night temperature regime of 26-16C resulted in a 5 day decrease in time to tassel over a 22-12C day-night temperature regime. A decreased yield also seemed to result from the higher temperature regime.

Solar Radiation And Corn Development

The importance of solar radiation in determining the rate of corn development is not well documented. However there does exist some evidence to indicate that solar radiation does affect corn development. Hough (1971) observed that early growth of corn, to the flowering stage, depends on the rate of dry matter accumulation per unit leaf area. If his observations are correct, solar radiation could be important. This conclusion follows from the fact that dry matter accumulation is controlled mainly by temperature and solar radiation effects on photosynthesis. Hough studied the influences of climatic factors on corn development from sowing to flowering. He found that air temperature and solar radiation combined to give a better correlation with daily plant development than either factor