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.

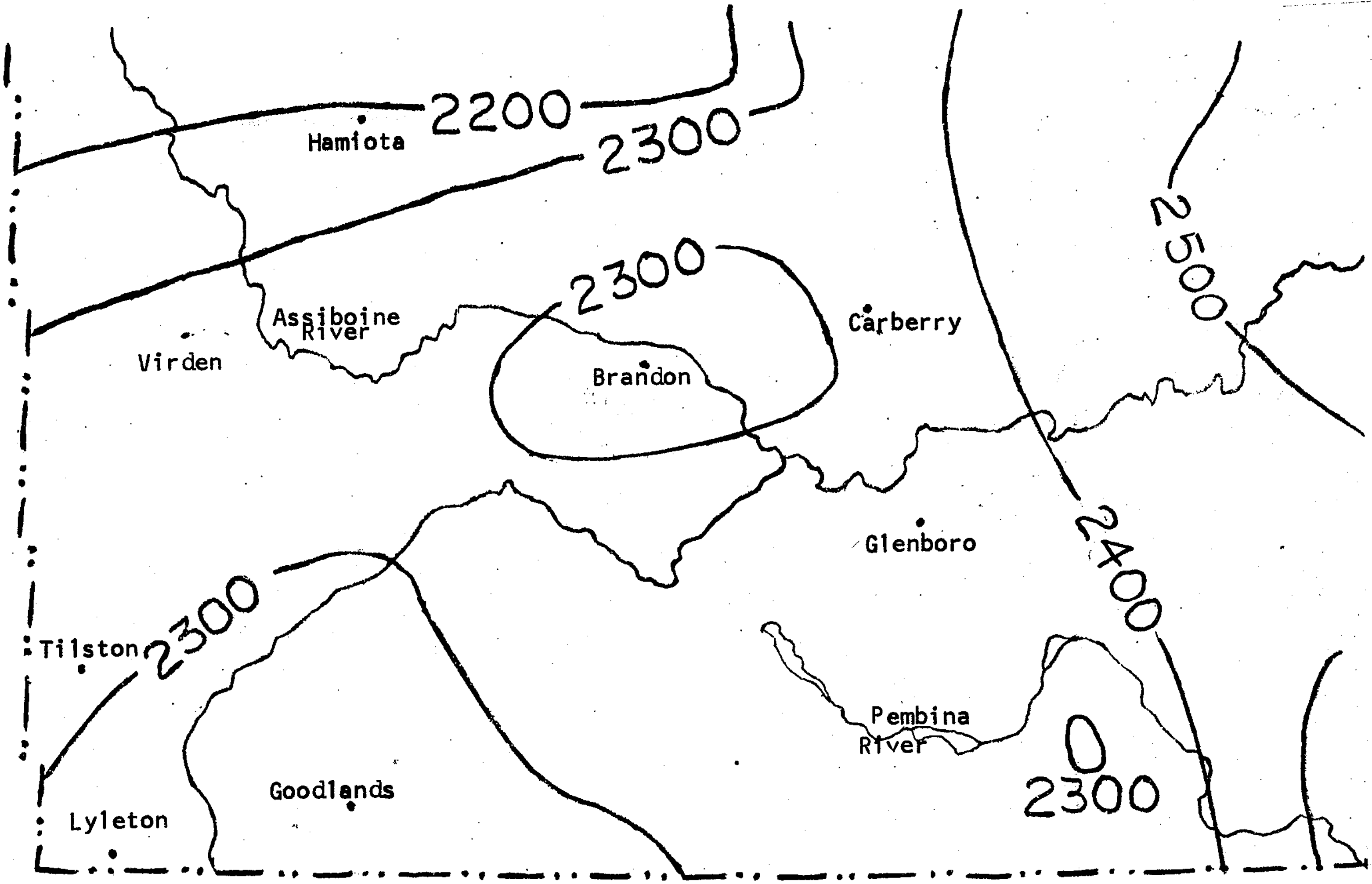

Figure 1. Corn heat unit map of South Western Manitoba. (Corn heat units were calculated from the 15th of May to the first fall frost(-2C), on the basis of long term weather data.)

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 alone. Solar radiation alone showed the poorest correlation with phenological development. Hough stated that this lack of correlation between solar radiation and development might be due to the fact that the values for solar radiation he used were only estimates based on the hours of sunshine.

Clements and Kubota (1943, as cited by Wilsie, 1962) found that sugar cane matured more rapidly under higher solar radiation conditions at one of two sites. Other climatic factors were identical at each site. They found that a heat unit system incorporating solar radiation measurements gave a better prediction of maturity than heat units based only on aerial temperatures.

Allen *et al*. (1973) recorded the number of langleys(1) of solar and sky radiation from planting to tasseling. There was no significant variation in the accumulated solar radiation, although there was a large difference in the number of days, between planting and tasseling for the two seasons. Mean days to tassel varied from 64.6 to 48.8 (greenhouse and field, respectively). Solar radiation accumulation varied from 19,500 langleys to 25,400 langleys for the early and late varieties respectively.

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1 Gram calorie/(cm x cm)= 1 langley.

Agrometerological Indices And Crop Production

Researchers have sought various means by which the agricultural potential of a climate in a region could be evaluated. An agrometerological index was sought which could be used to determine whether a certain crop would mature in that region. This can be accomplished by taking weather measurements and applying these to known climatic limits for a certain crop.

Perhaps the earliest criterion used for climatic evaluation was that of the number of frost free days or the length of the growing season. This index has been widely used and is useful in determining the limits of the growing season. This method only provides qualitative and not quantitative information. Because this index does not provide information on the intensity of the temperature or light regime, a more detailed system is required.

Since aerial temperature is critical to crop production, indices were developed based on air temperature. The simplest system utilized a base temperature below which it was assumed that plant growth was negligible. In this system if the base temperature was set at 10C a temperature of 25C would contribute 15 degrees. These degrees were accumulated for each day throughout the growing season. This is the basis for the "Degree Day" system.

Wiggans (1956) found that the number of heat units (specific degree days) required for a variety of oats to reach maturity varied little from year to year. He also noted that early or late planting had no influence on the number of heat units required for the crop to reach maturity.

Torsell (1959) stated that Seeley (1917) showed that for a period of 27 years the heat units required for the growth of corn, from sprouting to flowering, varied from 1232 to 1919(Heat units were based on a summation of degrees above a base temperature.). The corresponding data for heat units accumulated from flowering to maturity, varied from 897 to 1601. Torsell suggests that these results reflect the inadequacy of the degree day approach when degree days are calculated on the basis of a linear growth curve for corn response to temperature. He suggested that it would be more suitable to use a curvilinear growth curve which would reflect the relative efficiency of temperatures below and above the optimum.

The basic model of the degree day or heat unit system has been modified to adapt it to different circumstances. Reath and Wittwer (1952, as cited by Wilsie, 1962) used a multiple of the degree day summations and the average duration of the daylight period. They found that this system was more satisfactory for prediction of pea development than degree days alone.

Nuttonson (1953, 1955, 1957, as cited by Wilsie,

1962) reported the result of an analysis of data gathered over many years from the United States, Czechoslovakia, and the U.S.S.R. He reported that the use of the photothermal unit (degree days multiplied by daylength) was more satisfactory for predicting the dates of heading and maturity for rye, wheat, and oats than the summation of degree days alone.

Wilsie (1962) presented the results of Clements and Kubota(1943) which indicated that solar radiation is an important factor in climatic evaluation. They found that a better estimate of yield could be obtained from an equation which included both degree days and solar radiation.

The growing degree day system, as it applies to corn, was reviewed by Baker(1970, as referred to by Gamble, 1971). The growing degree day system uses 10C as the base temperature. Daily maximum and minimum temperatures are averaged for each day to provide a daily mean from which the 10C base is subtracted. Growing degree days are accumulated for the entire growing season.

The "Corn Heat Unit" system (also referred to as the Ontario Corn Heat Unit system) developed by Brown (1963, referred to by Gamble, 1971) was adopted in Ontario in 1964 and was subsequently accepted for all of Canada as method of delineating corn growing areas. This system was also widely used to rate corn hybrids for maturity or earliness. The corn heat unit system is based on daily maximum and minimum temperatures. The effects of daytime maximum temperature on plant growth are evaluated in a quadratic function which incorporates a lower limit for growth at 10C (50F) and a maximum of 30C (86F). The detrimental effects of temperatures above 30C are included in the quadratic function. The daily minimum temperature is used as the nighttime contribution to corn heat units. It was assumed that the nighttime temperature required for corn development was lower than the daytime requirement. 4.5C was used as the base for the minimum temperature.

Corn heat units based on degrees fahrenheit, are accumulated from this equation:

$$(1.85(Tmax - 50F) - (0.026(Tmax - 50F)^2))/2 + (Tmin - 40F)/2$$

The period of heat unit accumulation must be defined by certain criteria. Brown (1972) suggests that corn heat unit accumulation should begin on the day in the spring when the daily mean air temperature reaches 12.5C (55F). He also suggests the adoption of some indication of plant maturity, such as the attainment of a certain kernel moisture by a corn hybrid. To enable one to map a region for corn heat units before corn is grown in that area, Brown (1972) advocates the use of the fall date on which there is a 10 per cent chance of frost (0C).

Gamble (1971) stated that any rating of areas in terms of corn heat units, should be done on the basis of long term weather records of maximum and minimum temperatures.

Brown (1972) included values for corn heat unit ratings in Southern Ontario. These values were based on isolines in increments of 200 heat units. Brown suggests that there may be a variation of approximately 100 corn heat units from year to year in the accumulation of heat units at any one location. Long term weather data for Manitoba indicates that there is a standard deviation of approximately 200-300 corn heat units from year to year at any one location in Manitoba (2).

An evaluation of various methods of computing thermal units was conducted by Cross and Zuber (1972). They tested 22 methods for accuracy in predicting the time required for several corn hybrids to reach the flowering stage (50 per cent anthesis) from planting. The best estimate of days to flowering was provided by the systems which used thermal unit with a minimum base temperature of 10C and a maximum of 30C. The criterion used for evaluating the system was the coefficient of determination value of the regression equation for predicting the date of flowering.

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2 A personal communication from Dr. C.F. Shaykewich, Soil Science Department, University Of Manitoba.

In the heat stress system which Cross and Zuber stated gave the best fit, temperatures in excess of 30C were subtracted to allow for high temperature stress. There was no allowance made for the effects of nightime temperatures in this system. It was also noted that a better relationship existed between flowering date and an hourly stress equation than that of a daily stress equation. The heat unit system developed by Brown was tested and found to be only slightly inferior to the heat stress system. Cross and Zuber suggest that the disagreement between the corn heat unit system and the heat stress system may be due to the use of the lower minimum temperature in the corn heat unit system.

Gilmore and Rogers (1958) evaluated fifteen methods of calculating heat units required to bring four varieties of hybrid corn to 50 per cent silking. Using the minimum coefficient of variation as the criterion, the best method appeared to be the one which used daily mean temperature minus 10C. Gilmore and Rogers made adjustments for temperatures below the 10C minimum for growth, and above the 30C optimum (They subtracted the degrees of variation.). The number of heat units required for silking remained relatively constant for crops with different planting dates, while calendar days to silking showed a wide variation.

Criteria For Corn Maturity

There is some discussion as to the parameters which should be used to determine grain corn maturity. One method was suggested by Daynard and Duncan (1972) which would utilize the formation of the corn kernel abscission layer (black layer) as the criterion for maturity. They noted that the black layer may be formed as a result of maturity or because of physiological stress upon the corn plant, such as frost or drought. These factors indicate that its uses are limited to qualitative observations.

Another parameter which might be used as an indication of maturity is bushel weight. A plant may be considered to have reached maturity when its corn kernels have reached a certain density or bushel weight. However, Hall and Hill(1971) showed that test weight or bushel weight can vary as much as 15 per cent, depending on the method of drying, initial moisture at harvest, and hybrid.

The most widely accepted method of determining physiological maturity is the kernel moisture of the grain corn. This method is suggested to be the most reliable and accurate parameter (3). The exact point which is referred to as the point of physiological maturity is 40 per cent, calculated on a wet weight basis.

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3 Personal communication from Dr. L. Donovan Canada Department of Agriculture, Ottawa and Dr. R.I. Hamilton, Canada Department Of Agriculture, Brandon.

Summary

Soil Temperature

Early development of the corn plant is usually governed by soil temperature in the germination zone. The time required for emergence of the corn seedling may be increased by a temperature in the soil below the optimum (30C). Soil temperatures below 10C may prevent germination and emergence of the corn plant. Its growth is still influenced by soil temperature at the depth of the apical meristem (until the meristem emerges) and the soil temperature of the root zone. Low temperatures in the former zone can cause a decrease in leaf initiation rate and affect the dry matter accumulation rate of the young corn plant. Low root zone temperatures can decrease root growth and morphological development. Below optimum root zone temperatures may also cause nutrient deficiencies to occur during early stages of corn growth.

The cumulative effects of these soil temperature influences can cause an increase in the time to flowering under below optimum temperatures. Plant maturity may be delayed by below optimum soil temperatures.

Air Temperature

Generally corn (*Zea mays* L.) has an optimum day temperature of 30C, a minimum of 10C and a maximum of approximately 40C. The relationship betwen corn growth and air temperature is best illustrated by a growth response curve for corn in terms of aerial temperature(Figure 2). The optimum night temperature for corn is lower than the optimum daytime temperature. High night temperatures(above 30C)may decrease yield but can also hasten maturity.

Solar Radiation

The vegetative stage of growth is important in the development of the corn plant. Dry matter accumulation is the process which is probably directly connected to solar radiation intensity and accumulation.

Agrometerological Indices And Crop Production

Agrometerological indices are parameters which can be used evaluate crops for their climatic requirement and relate the characteristics of climate to a crop's requirement.

Indices which have been used include the length of the growing season, as measured by frost free days, accumulated degree days (daily mean temperature minus a base temperature for plant growth accumulated per day throughout the entire growing season) and the modified degree day system designated as the heat unit system. The latter is the most specific system as the growth-temperature relationship for a certain crop is used as the basis for the calculation of the heat unit. The corn heat unit system

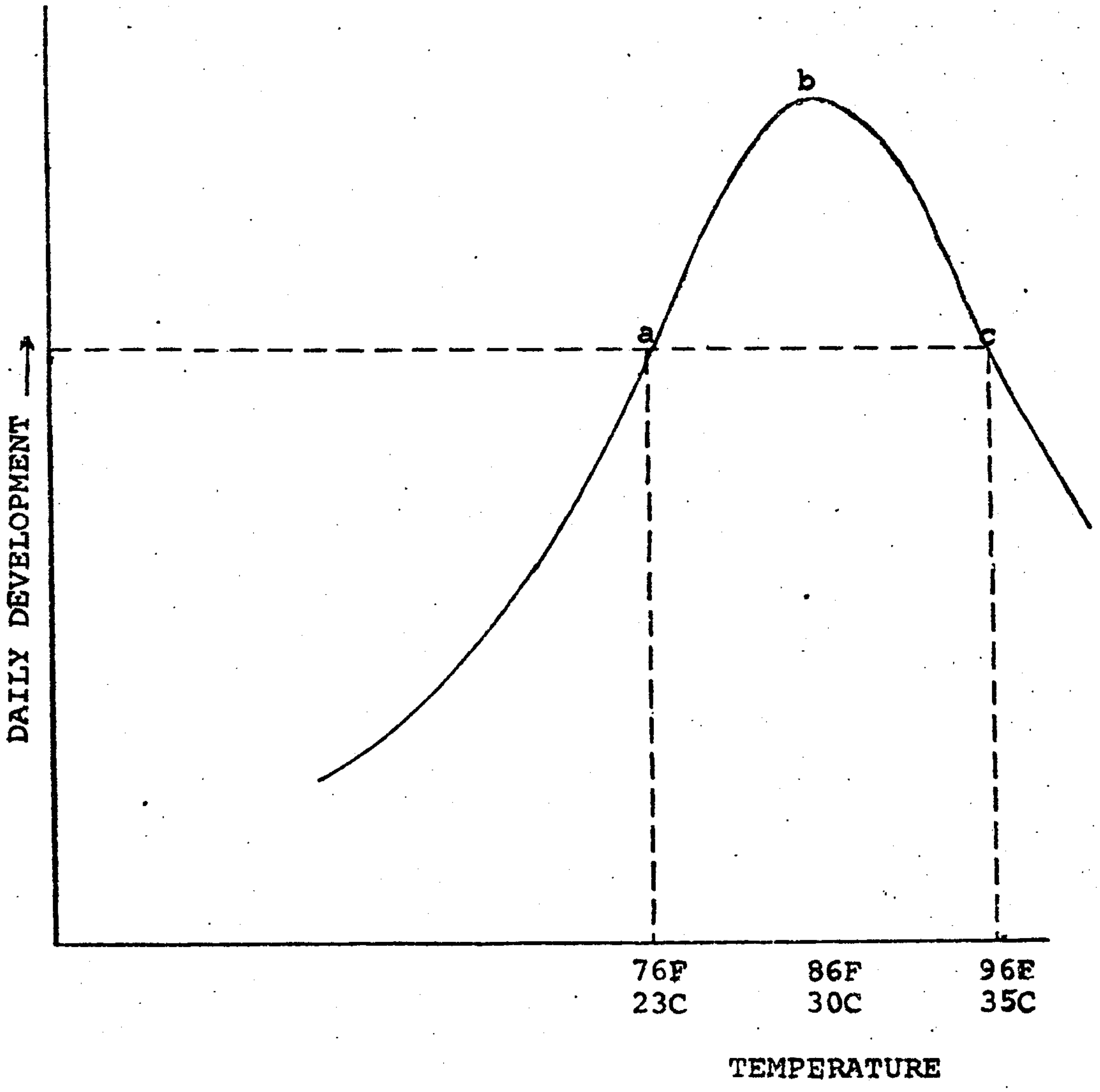

Figure 2. Hypothetical growth response of corn to temperature. Reproduced from Cross and Zuber (1972).

has been developed for corn.

Criteria For Corn Maturity

The criterion most widely accepted for a measure of corn maturity is kernel moisture. The level for physiological maturity is generally regarded as 40 per cent.

METHODS AND MATERIALS

Plot Selection And Description

The field work for this project was conducted at eight sites during the summers of 1971 and 1972. Each site was chosen on the basis of climatic region, soil, and geographic features which were deemed to be of importance to corn production. Seven of the major Manitoba soil associations are represented in the plot site locations, so that most of the soils which might be suitable for corn production in the South West were included. Specific plot locations were also selected using the criterion of a well drained, medium textured clay loam surface soil. The plot site's location, soil association, surface texture, latitude, and elevation are given in Table 1.

Plot Design

To simulate actual field conditions, under which corn would be grown commercially, each experimental plot was centered in a two acre field of grain corn (field size was larger than two acres in some cases). The actual dimensions of the plot and the experimental design are given in Figure 3.

Meterological Measurements

Measurement of daily maximum and minimum temperature

TABLE 1

PLOT DESIGNATION, LEGAL DESCRIPTION ELEVATION, LATITUDE AND SOIL ASSOCIATION

Plot Designation	Legal Description	Elevation(m)	Latitude	Soil Association
Brandon	SW-12-10-19W	360.5	49° 52'	Assiniboine
Carberry(71)	NE-19-12-14W	378.5	50° 00'	Wellwood
Carberry(72)	NE 3-11-15W	375.5	49° 54'	Wellwood
Glenboro	SW 2- 7-14W	369.5	49° 34'	Glenboro
Goodlands	SW 15- 2-24w	492.5	49° 09'	Waskada
Hamiota	SW 26-13-24W	503.0	50° 10'	Newdale
Lyleton	SE 16- 1-28W	462.5	49° 03'	Souris
Tilston	NE 20- 5-29W	495.5	49° 25'	Oxbow
Virden	SW 23-10-28W	495.5	49° 52'	Oxbow

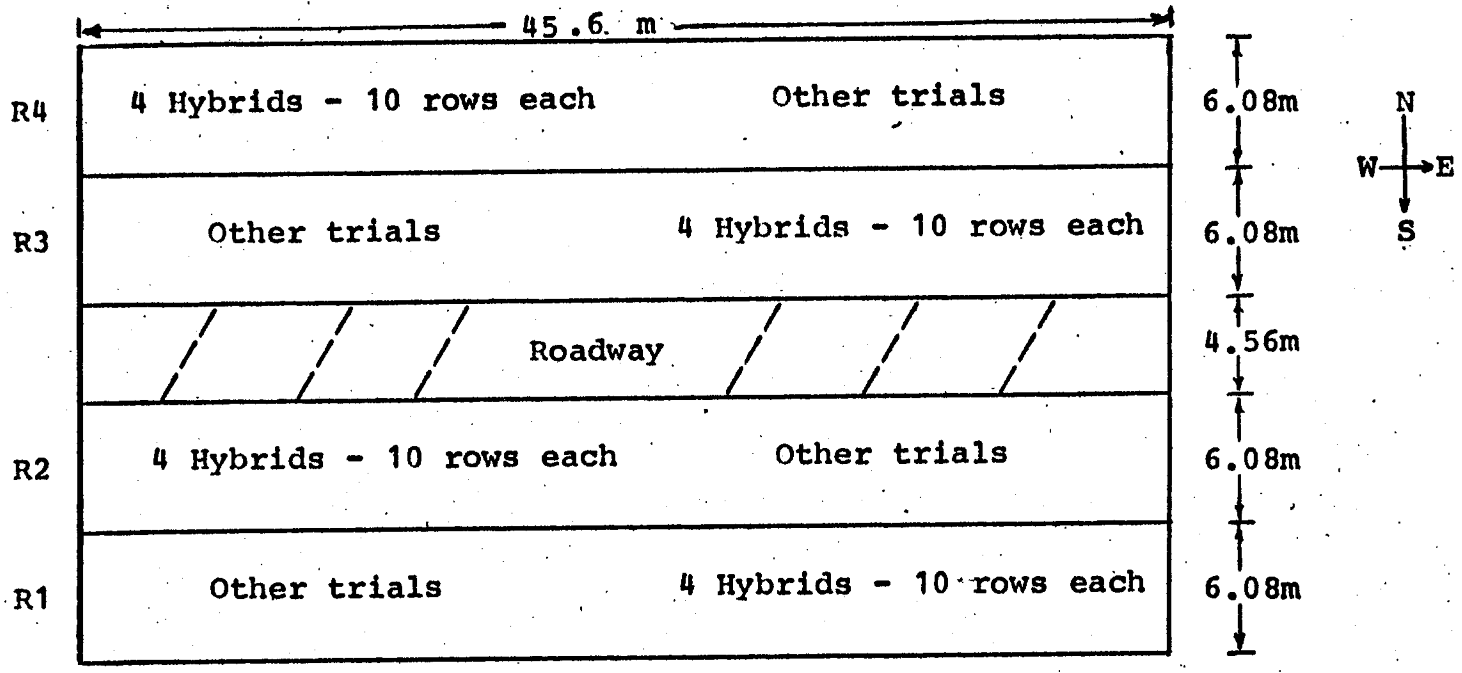

Figure 3. Plot design (randomized block with four replicates).

was accomplished either through the use of maximum and minimum thermometers(4) or with a seven day recording thermograph(5) installed in a Stevenson weather screen(6). Rain guages were installed at each weather station site so that rainfall could be recorded(7). In 1972 recording pyroheliometers were installed on top of the weather screens, at Hamiota, Brandon, and Lyleton(8). Weather stations were located within a mile of the plot site.

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4 MSC 5, Stock nos. 0026-3788 (Maximum), 0026-2722 (Minimum), Atmospheric Enviroment Service, Ottawa, Ontario, Canada.

5 Lambrecht recording Thermograph, No. 251.

6 Refer to form 0063-9059 "Temperature" Atmospheric Enviroment Service Ottawa, Ontario, Canada.

7 Refer to form AE 0063-9057 "Precipitation" Atmospheric Enviroment Service, Ottawa, Ontario, Canada.

8 Belfort Instrument Company, 4 N. Central Ave. Baltimore, Maryland, U.S.A.

The pyroheliometers recorded the rate at which solar radiation was reaching the earth's surface. The accumulated daily solar radiation was calculated by measuring the area under the intensity curve recorded on the pyroheliometer charts(9).

At each plot site soil temperature was monitored at approximately ten day intervals throughout the growing season. Thermocouples were placed at 2.5, 5.0, 10.0, 20.0, 50.0, 100.0 and 150.0 cm below the soil surface. The soil temperature probes were placed near the centers of the plots beside corn plants, so that the recorded temperatures would be those experienced by the corn roots. The temperatures were read(to the nearsest 0.1C) through the use of a Multi-mite potentiometer(10).

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9 The area under the solar radiation curve was found by determining the weight of the chart paper under the curve and relating this measurement to the weight per unit area of the chart paper.

10 Thermo-Electric,(Canada) Ltd., Brampton, Ontario, Canada.

Hybrid Selection

Four hybrids were selected for the trials: Stewart's 2300, Morden 88, OX-402, UH-106. The first three varieties were selected for their earliness (each was rated very early maturing),while UH-106 is generally considered to be a later maturing variety. OX-402 is an experimental variety while the others are grown commercially. The seed used was obtained from commercial and research sources.

Fertilizer

To optimize soil fertility, each site received nitrogen, phosphorous, and potassium as recommended from soil test analysis. The target yield was set at more than 6,000 kgms per hectare. The rates of fertilizer applied are shown in Table A2. Application of fertilizer was by broadcast spreading before seeding and/or sidebanding after emergence.

Planting Procedure

To insure the utilization of the entire growing season, the plot area was cultivated as early as possible in the spring (April 25 to May 10). A uniform seedbed was prepared. Excessive cultivation was avoided so that soil moisture could be conserved. Seeding was completed in the shortest period possible so that the seeding date would not favour any of the eight sites. In both years it was possible to seed the eight plots in a 7 to 10 day period (Table 2).

In 1971 the seeding was done with hand planters. In 1972 seeding was done with a two row, tractor mounted John Deere corn planter. The seeds were planted to a depth of 5 to 7.5 cm, depending on moisture conditions at each plot. The initial population was set at approximately 126,00 plants per hectare, with a row spacing of 75 cm. After emergence population was reduced to 63,000 plants per hectare by hand rogueing.

Weed Control

A chemical weed control system was utilized. In 1971 Atrazine(12) at 2.2 kgm per hectare and Sutan(13) at 3.3 kgm per hectare were used as a pre-emergence treatment and were incorporated into the soil. In 1972 a post-emergence application of 2.2 kgm per hectare Atrazine, 1.1 kgm

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12 Atrex Atrazine (2-cloro-4 ethylamino 6 isopropylamino 1,3,5 Triazine). Supplied by C.I.B.A. Geigy chemicals, Winnipeg, Manitoba.

13 Sutan 7.2E, "S-ethyl diissobutylthiocarbamate". Obtained from Chipman Chemicals, Winnipeg, Manitoba.

TABLE 2

SEEDING DATES IN 1971 AND 1972

Location	1971	1972
Brandon	May 10	May 8
Carberry	May 12	April 27
Glenboro	May 11	April 28
Goodlands	May 5	May 3
Hamiota	May 7	April 29
Lyleton	May 3	May 3
Tilston	May 4	May 4
Virden	May 6	May 4

per hectare of Bladex(14), and 6.5 liters per hectare of Booster Plus(15) was used for weed control. An application of 0.9 liters per hectare of Banvel 3(16) was used to control weeds not erradicated by primary chemicals. Hand weeding was used in some instances where chemical weed control was not effective.

Plant Development

Several criteria were used to define development stages in corn plant growth. Seedling emergence, leaf development, tassel emergence , silking, and kernel moisture were used as indicators of plant development.

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14 " 2- ((4-chloro-6-(ethylamino)-s-triazine2-yl)amino) -2-methyl proionitrite", obtained from Shell Canada Ltd., Winnipeg, Manitoba.

15 Oil surfactant, obtained from Shell Oil Company, Winnipeg, Manitoba.

16 Combination of dicamba, " 3,6-dichloro-o-anisic acid", 2-4-D, 2,4 dichlorophenoxy, acetic acid", megaprop, "2-((4-chloro-o-toly) oxy) propionic acid ", obtained from Shell Oil Ltd., Winnipeg, Manitoba.

Seedling Emergence

The date of seedling emergence was designated as the approximate date on which 50 to 75 per cent of the corn seedlings had emerged above the soil surface. The recorded observations were based on the average of three rows per variety for each replicate. If counts were not taken at the emergence date, the approximate emergence date was determined from an extrapolation of existing observations during the emergence period. Two to three readings were taken during the emergence period.

Leaf Stage

The method of determining leaf stage consisted of counting the total number of leaves which had emerged from the leaf whorl. The emerging leaf was counted if it was visible in the whorl. Observations were made from the three to the thirteen leaf stage.

Tasseling And Silking

The approximate dates when 50 to 75 per cent of the corn plants had emerged tassels (visible above the leaf whorl) and visible silking. Observations were made on 10 plants from three rows for each variety in each replication. Tasseling and silking dates are approximations made from two to three observations during these stages of development.

Kernel Moisture

Five cobs were picked from randomnly selected corn plants, within intact rows (other than end rows) of each replicate of each variety. The intact cobs were placed in plastic bags and packed in containers which contained ice for cooling. This procedure was followed to prevent moisture loss before kernel moisture determinations could be made. If the samples could not be processed the day they were collected, they were kept frozen until they could be processed. Samples were collected at approximately 10 day intervals from August 15 to September 15 and at a final harvest in October.

Kernel moisture was determined from a minimum of 30 gm (wet weight basis) of corn kernels taken from a five centimeter portion of the cob, 4.0 t0 9.0 cm from the base of the corn cob. The sample plus container was then weighed and dried at 40C for a minimum of 48 hours. The dry weight of the corn kernels was then determined and the percentage moisture determined (on a wet weight basis).

Grain Yield Determination

Grain yields were determined from a measured length of corn row which corresponded to 0.0004 hectare of plot area. The total weight of the cobs from this section was determined. The total weight of grain was found by determining the ratio of the grain weight to the total weight of the cob. The yield per hectare was then determined by multiplying the section yield by 2,500. The final yields were adjusted to give the yield at 15 per cent kernel moisture.

Bushel Weight

The bushel weight (pounds per bushel) of each variety, for each site was determined from the yield sample of the final harvest(17). The bushel weight samples were dried at 40C for approximately one week or until negligble moisture loss could be detected. The samples were then cleaned (chaff and shattered material removed) before bushel weight was determined. The bushel weight was found by weighing the amount of grain in a plastic cylinder (approximately 6 cm in height and 4 cm in diameter) with a volume of 155.33 cc. This weight in grams was then multiplied by 0.5 to convert the measurement to pounds per bushel.

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17 In 1971 the samples were bulked from four replicates for each variety at each location as sample size was not sufficient for determinations of individual replicates. In 1972 determinations were made for each replicate.

RESULTS AND DISCUSSION

Corn Emergence

Corn emergence dates (50 per cent emergence) during 1971 and 1972, varied from May 16 to May 25 (Table 3). The Carberry emergence date in 1971 was the only exception, with an emergence date in June. Emergence dates during 1971 appeared to show more variation than those recorded for 1972.

The emergence period found in this study coincides with the generally accepted seeding period for grain corn in Manitoba. Corn which has emerged from the ground at the time when weather conditions are generally favourable for corn growth (approximately May 15), has an advantage over corn which must remain in the ground for about a week until emergence. Even though later sown corn may emerge in a shorter period of time, the advantages gained by early emergence may not be overcome.

Bunting (1968) found that the corn planted on May 11th silked 5 days earlier than corn planted on May 19th. He also found that sowing on May 2nd only decreased time to silking by one day as compared to sowing on May 11th. The conclusion that can be drawn from Bunting's results that there is an optimum date for seeding of grain corn and a delay causes significantly increased time to maturity.

TABLE 3

DATE OF CORN EMERGENCE
AND TIME FROM SEEDING TO EMERGENCE IN THE SPRING

Location	Emergence Date		Time To Emergence(Days)	
Brandon	23/5*	24/5	13	16
Carberry	2/6	21/5	20	24
Glenboro	25/5	21/5	14	23
Goodlands	21/5	21/5	16	20
Hamiota	24/5	20/5	17	21
Lyleton	16/5	20/5	13	17
Tilston	20/5	21/5	16	17
Virden	25/5	23/5	19	19

* Date of approximately 50% emergence.

It has been found that this general relationship between seeding date and emergence can be applied to Manitoba as well as to England, where Bunting's studies were conducted. Experiments studying the influence of seeding date on corn development by the Canada Department of Agriculture Research Station, at Brandon Manitoba, support Bunting's findings (18). It was found that there was an optimum date for early maturity characterized by early tasseling and silking, as well as lower kernel moisture and a date which maturity was not significantly affected.

Frequently weather conditions during the optimum seeding period are unfavourable. Sowing before the optimum date would have the effect of extending the sowing period for optimum early maturity.

The early emergence dates, as a probable result of early sowing in this study, may be important in explaining the relatively high levels of maturity in comparison to farmers' results.

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18 Unpublished data from Dr. R.I. Hamilton, Canada Department Of Agriculture, Brandon, Manitoba.

The time required for emergence after sowing varied from 13 days at Lyleton in 1971 (Table 3) to 24 days at Carberry and Glenboro in 1972. While the short time required for emergence at Lyleton is indicative of early emergence(May 16), the time required for corn to emerge at Carberry and Glenboro in 1972 was not related to later sowing. Seeding dates for Carberry and Glenboro were earlier than for Lyleton in 1972(Table 3). These results indicated that there was a larger variation in seeding dates than emergence dates in 1972.

A further discussion of emergence data and time to emergence will be given in the soil temperature section of results and discussion.

Soil Temperature And Corn Development

Since soil temperature can have a significant effect on growth of the corn plant, it is reasonable to assume that it may explain some of the differences in plant development between locations. Differences in soil temperature between locations may partially account for differences in the effects of aerial temperatures, as measured by the corn heat unit's effect on maturity.

In order to determine whether there might have been differences in soil temperature between locations, soil temperature measurements recorded during the growing season were analyzed. Fourth order polynomial regression curves for the 20 cm and 50 cm depths were drawn for both years(Figures 4-11).

Soil temperatures at 20 cm were higher for Lyleton(during the growing season) in 1971(Figures 4-5). Carberry appeared to have the lowest soil temperature at 20 cm for 1971. The 20 cm soil temperatures for other locations were intermediate to the extremes at Lyleton and Carberry. The higher soil temperatures at Lyleton corresponded to the early grain corn maturity at Lyleton, while the low temperatures at Carberry paralleled the unsatisfactory maturity at Carberry. In 1972 the 20 cm temperatures varied little among locations during May and June but did show some variation during July and August (Figures 6-7). Glenboro, Brandon, and Goodlands appeared to have somewhat lower 20 cm soil temperatures than the other locations during July and August(3-4C lower than the rest of the plot sites). There did not appear to be any relationship between the soil temperatures at 20 cm for the entire growing season and grain corn maturity, however the soil temperature during the emergence period may have more significance than the overall soil temperature.

The soil temperatures at 50 cm in 1971(Figures 8-9) were highest at Lyleton on the basis of the entire growing season. Virden and Hamiota had the lowest soil temperatures at 50 cm in 1971(Figures 8-9) with temperatures 4-5C lower than those at Lyleton. The lower soil

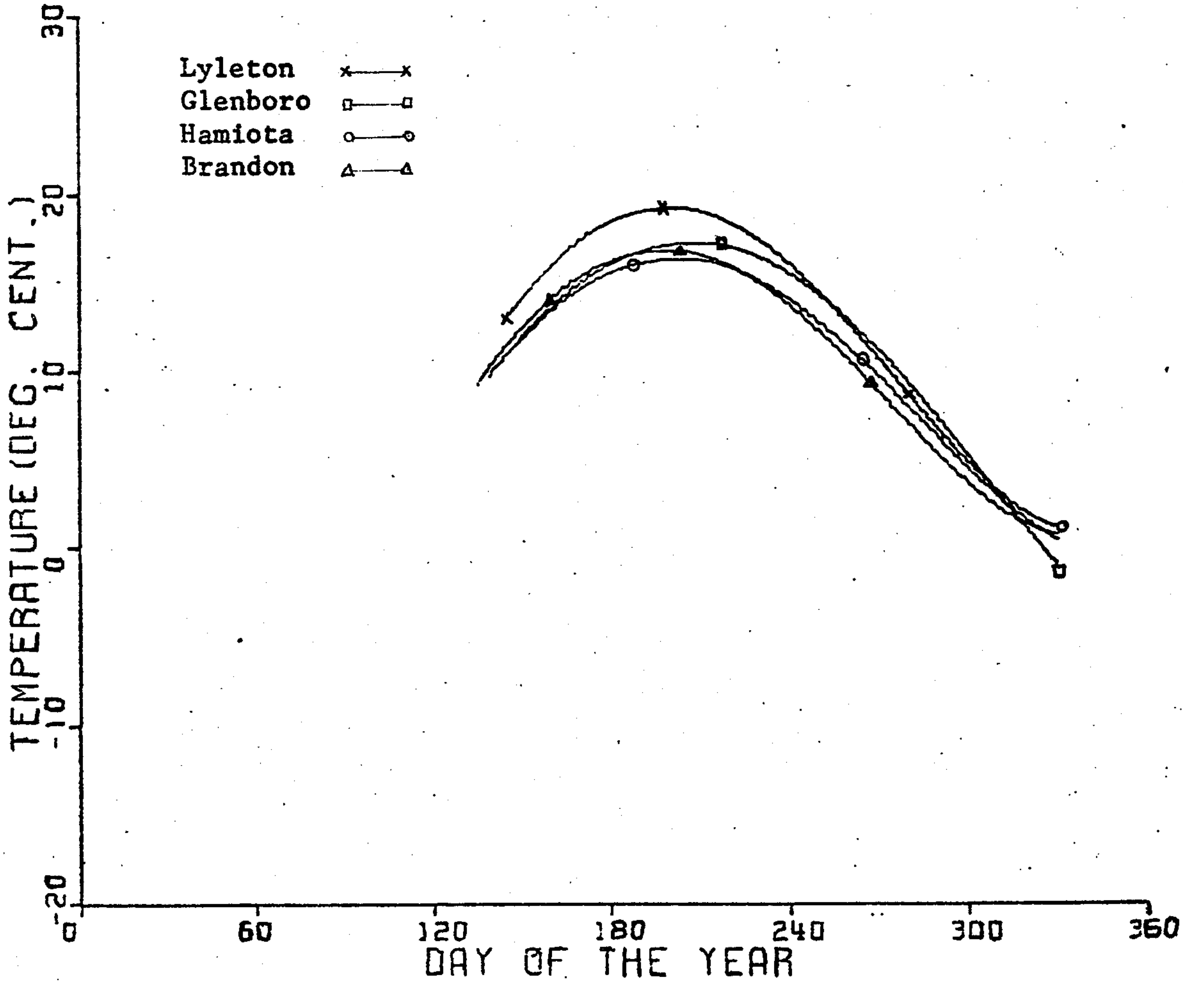

Figure 4. Regression curves of 20 cm soil temperature in 1971 for Lyleton, Glenboro, Hamiota, and Brandon. (Symbols do not represent actual data points.)

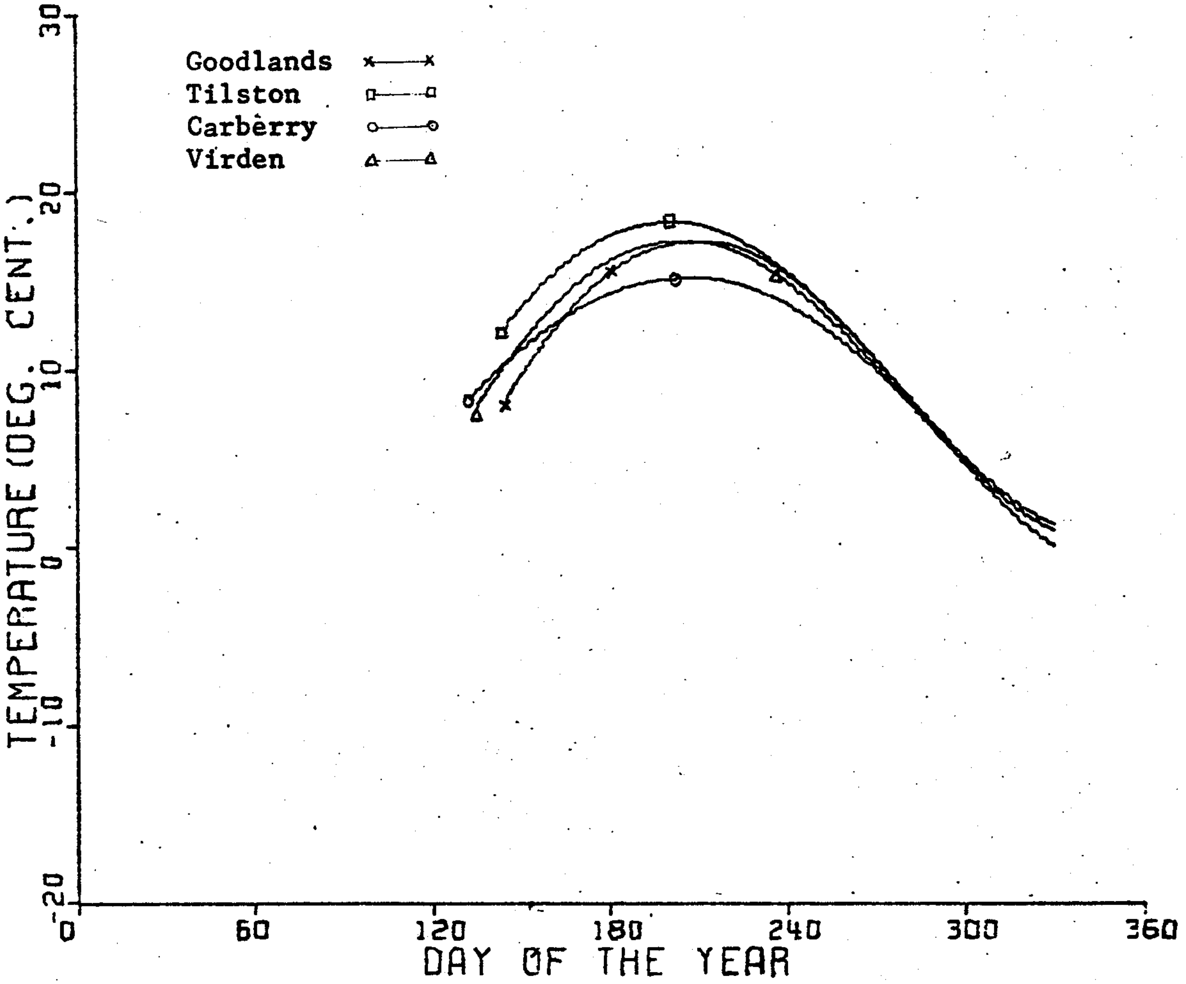

Figure 5. Regression curves of 20 cm soil temperature in 1971 for Goodlands, Tilston, Carberry, and Virden. (Symbols do not represent actual data points.)

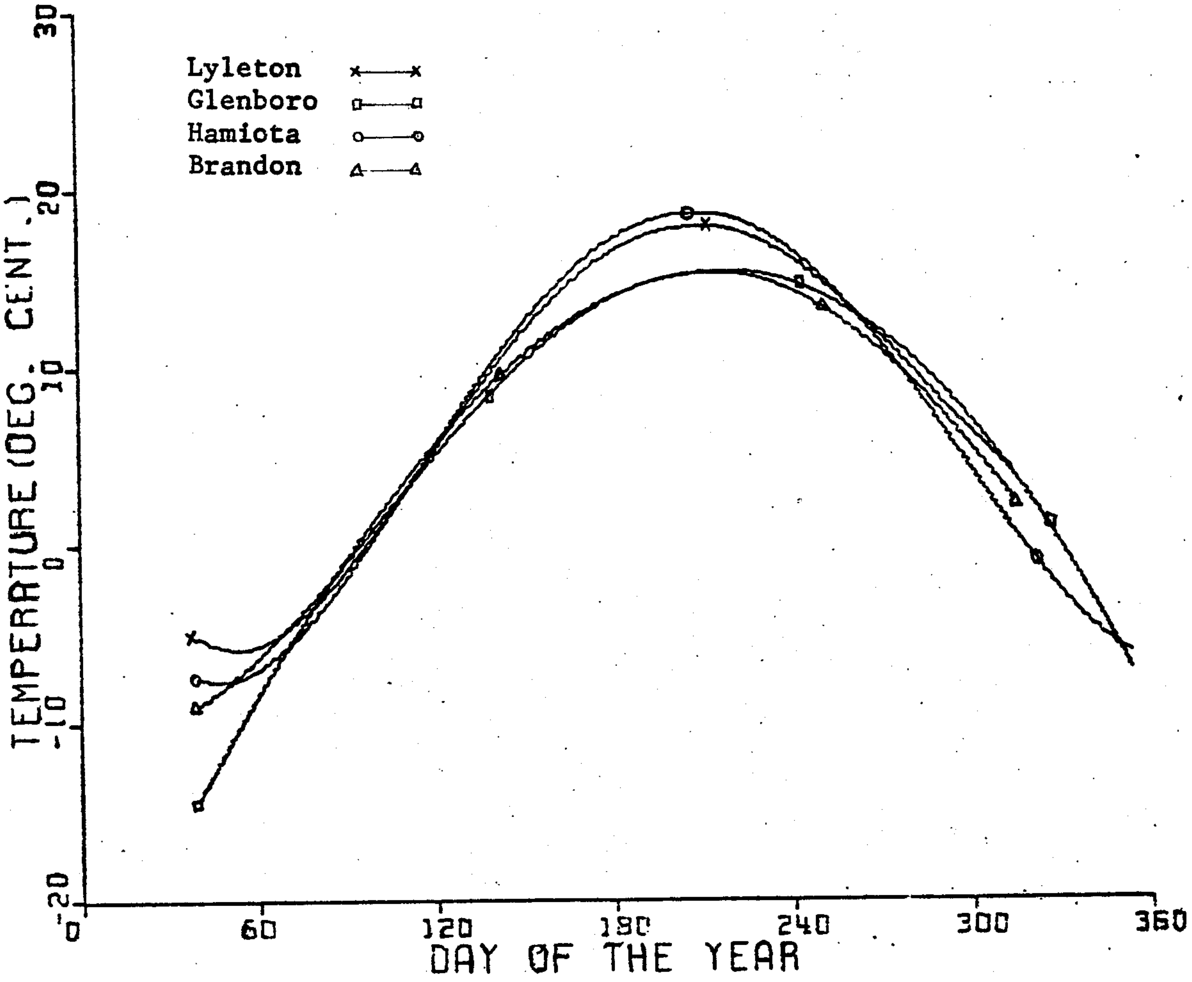

Figure 6. Regression curves of 20 cm soil temperature in 1972 for Lyleton, Glenboro, Hamiota, and Brandon. (Symbols do not represent actual data points.)

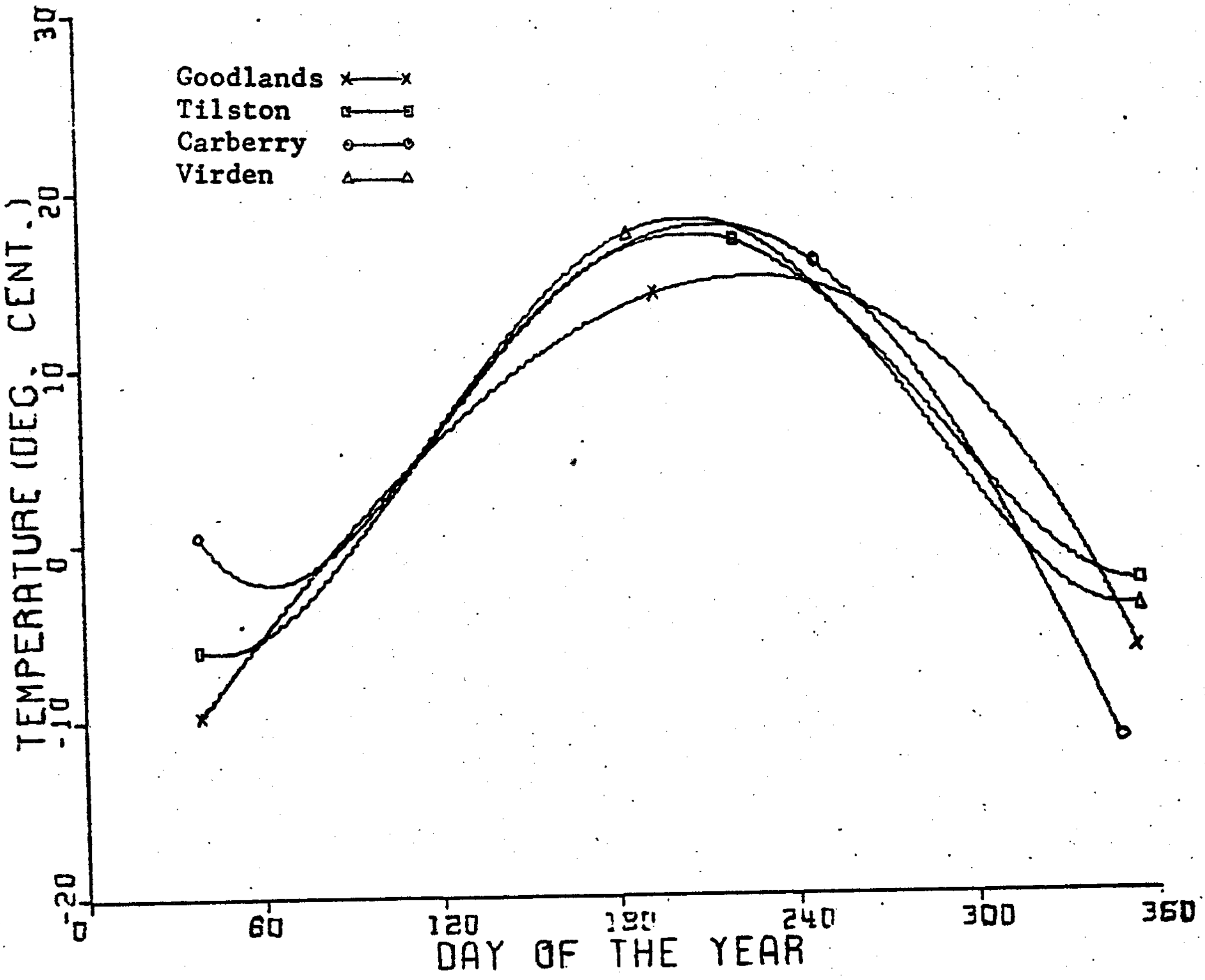

Figure 7. Regression curves of 20 cm soil temperature in 1972 for Goodlands, Tilston, Carberry, and Virden. (Symbols do not represent actual data points.)

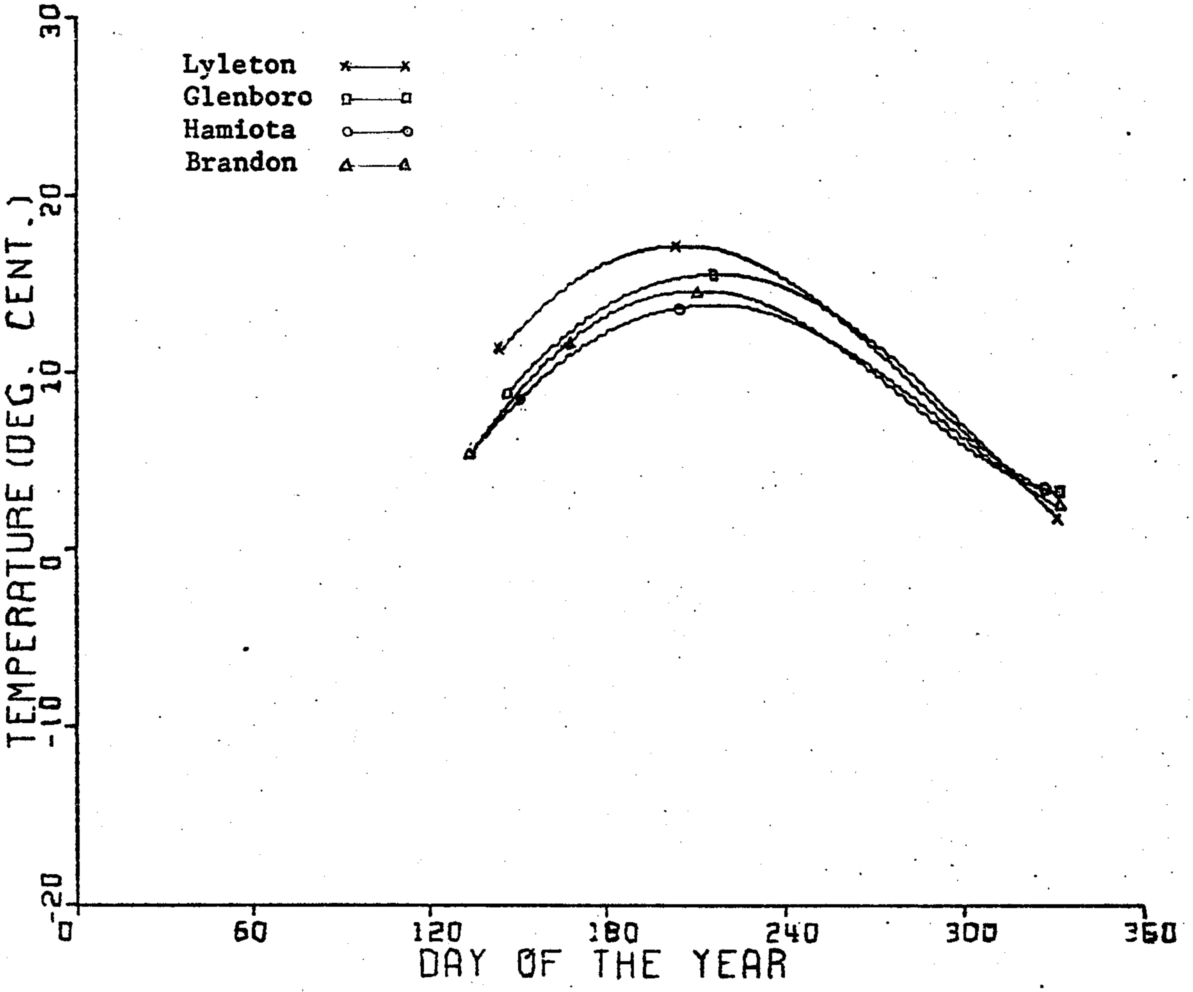

Figure 8. Regression curves of 50 cm soil temperature in 1971 for Lyleton, Glenboro, Hamiota, and Brandon. (Symbols do not represent actual data points.)

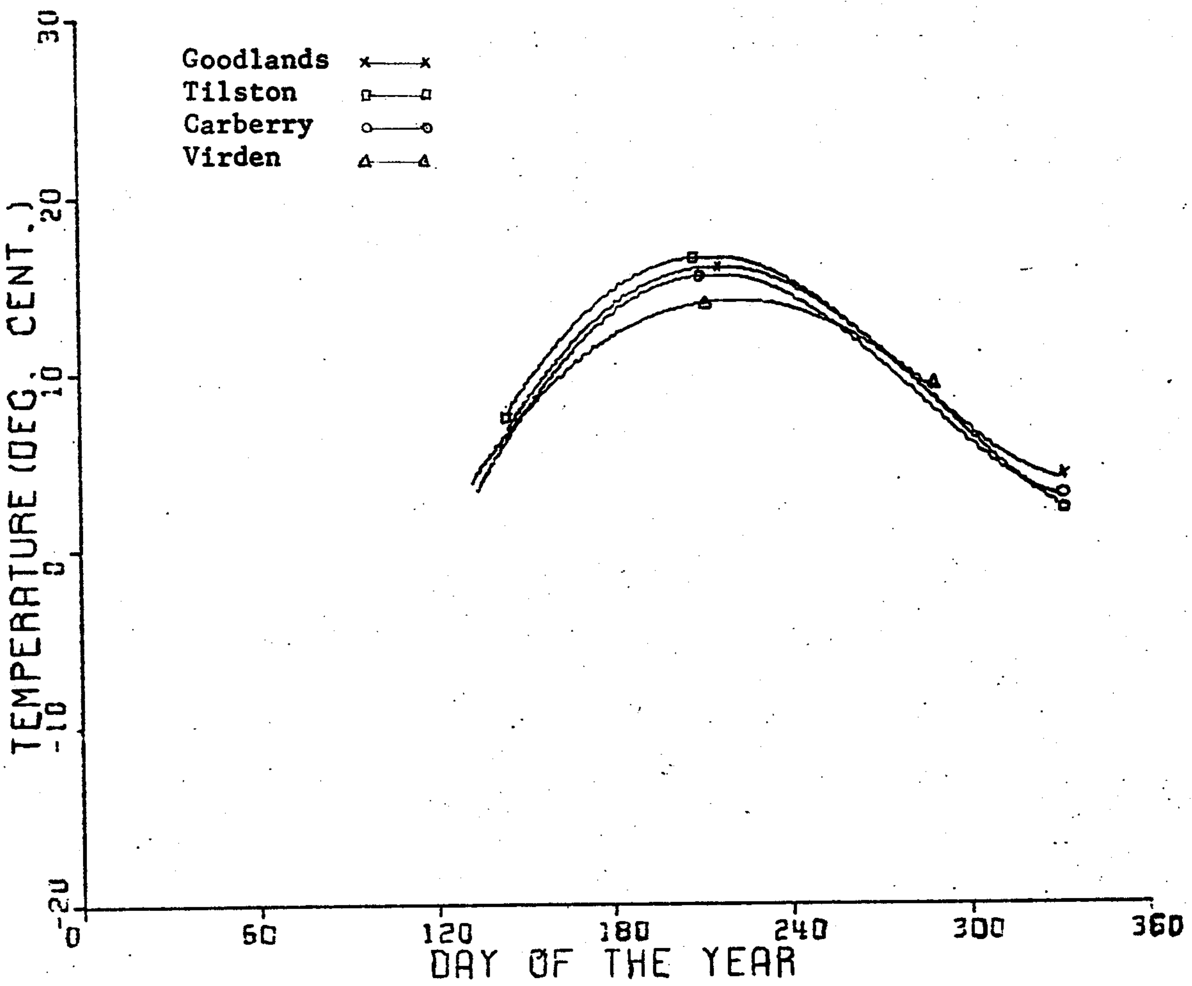

Figure 9. Regression curves of 50 cm soil temperature in 1971 for Goodlands, Tilston, Carberry, and Virden. (Symbols do not represent actual data points.)

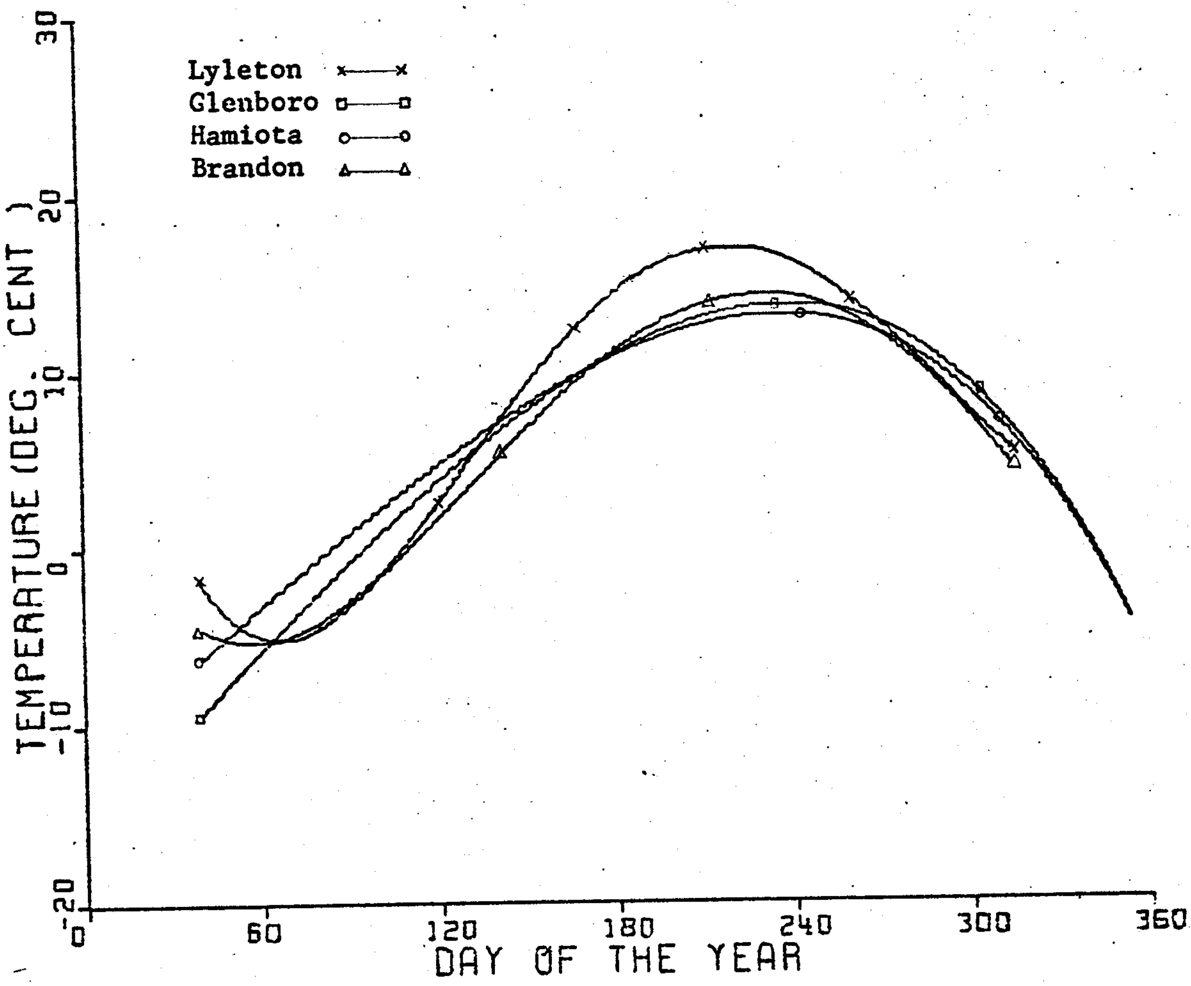

Figure 10. Regression curves of 50 cm soil temperature in 1972 for Goodlands, Tilston, Carberry, and Virden. (Symbols do not represent actual data points.)

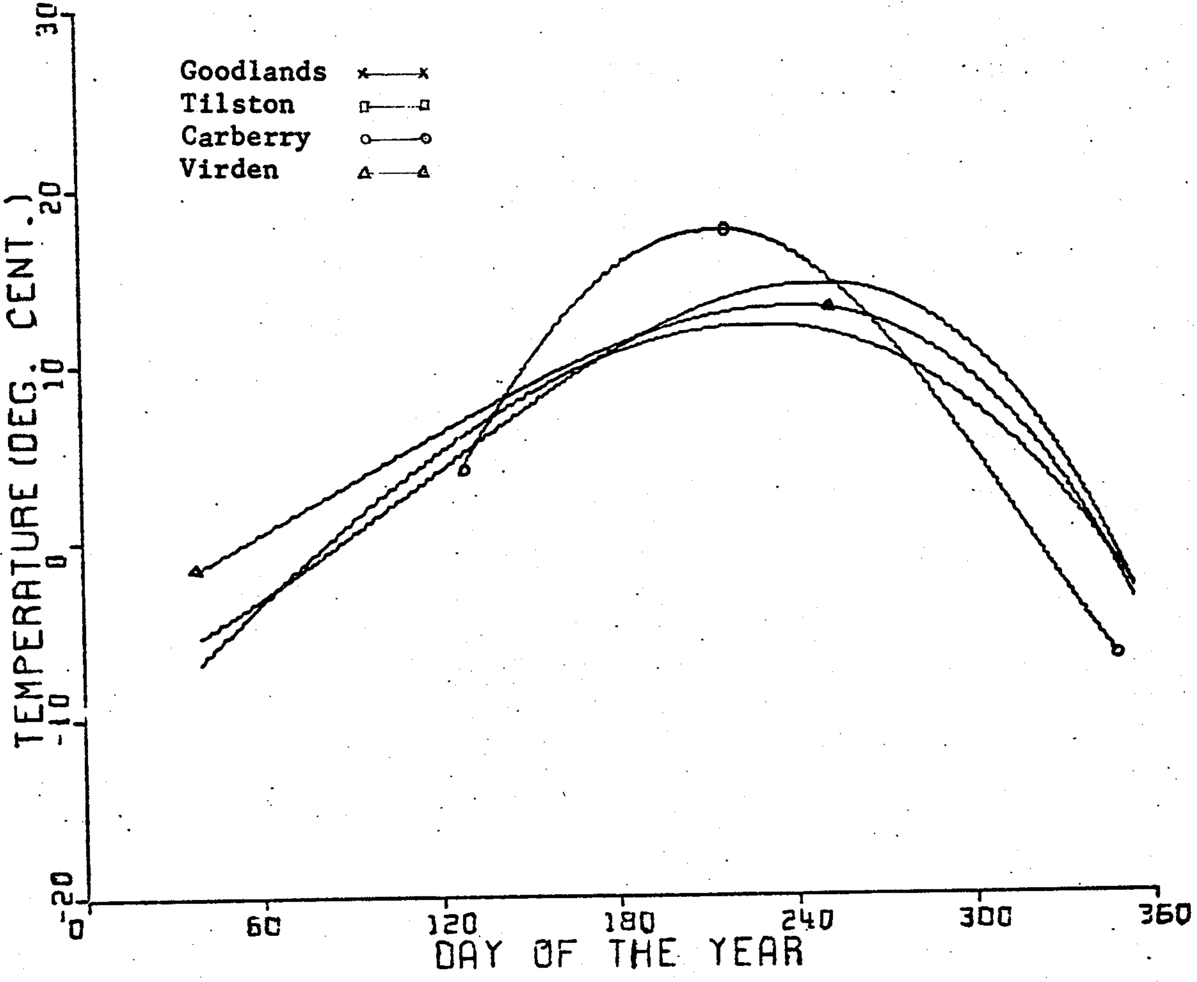

Figure 11. Regression curves of 50 cm soil temperature in 1972 for Goodlands, Tilston, Carberry, and Virden. (Symbols do not represent actual data points.)

temperatures at Virden and Hamiota corresponded to poor grain maturity at these locations, while the higher soil temperatures at Lyleton corresponded to good grain maturity at that location. In 1972 the 50 cm soil temperatures appeared to increase rapidly at Lyleton and Carberry during May and June. Soil temperatures at 50 cm at Lyleton and Carberry were 4-5C higher than the other locations for most of the growing season. The high soil temperatures at 50 cm at Lyleton were indicative of grain corn maturity at that location while the high soil temperatures at Carberry did not correspond as well to early grain corn maturity.

The 20 cm soil temperature was chosen to represent the temperature which would influence germination and emergence of the corn plant. The temperature at 20 cm fluctuates daily but is constant enough to have an effect on the corn plant as well as being practical for observational purposes. A plot of time to emergence from planting as a function of the logarithm of the mean 20 cm soil temperature during this period(Figure 12) shows that there is a general relationship between the two measurements. The coefficient of determination for the linear regression is 0.249, with a 't' value of 2.15, df.= 14, which is significant at P=.10. Since there are a large number of factors which influence corn emergence it would be expected that soil temperature would not explain a large proportion of the variation in time to emergence. It does seem that the 20 cm temperature

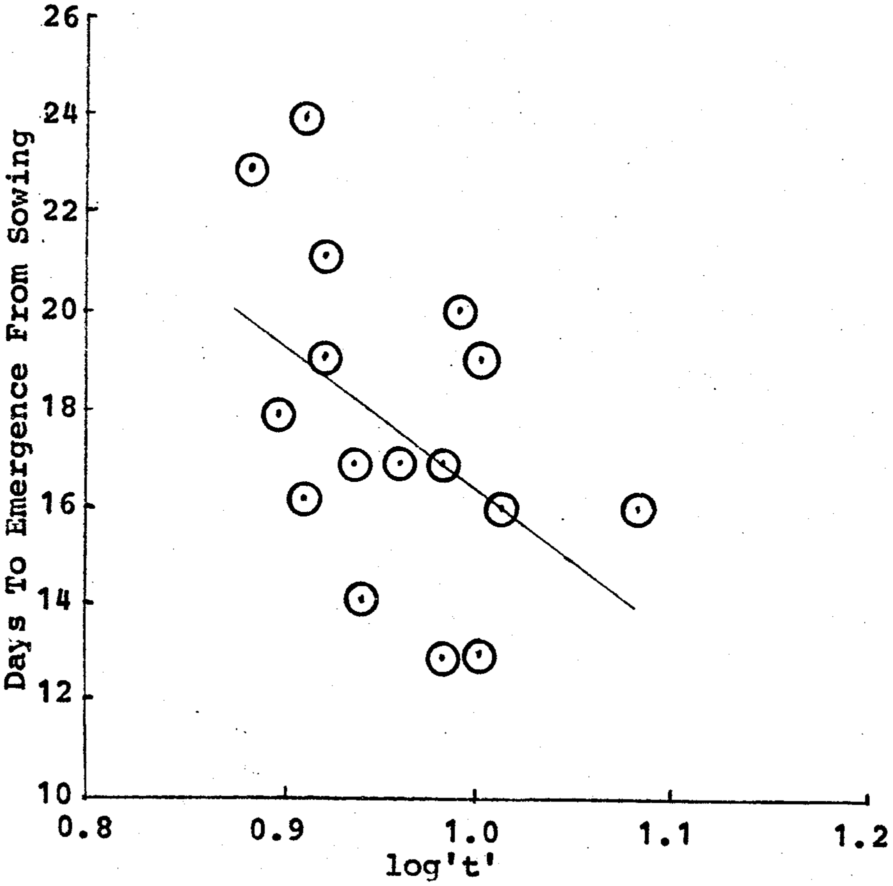

Figure 12. Days from sowing to emergence as a function of log't'(mean soil temperature at the 20 cm depth from sowing to emergence), for all locations in 1971 and 1972.

is a factor in time to emergence.

Soil temperatures at 50 cm remain relatively constant from a day to day basis as opposed to the 20 cm temperature. Clayton (1973) suggests that the 50 cm depth temperature of 5C should be used as the starting point of the growing season in the spring. The soil temperature at 50 cm is important to the plant in terms of root development and nutrient uptake, mainly during the vegetative stage of growth. Root growth during the latter stage of plant development may extend beyond the 100 cm depth. Thus the 50 cm soil temperature may be used as a general indicator of the suitability of the soil enviroment during the entire growing season.

In order to evaluate the use of the 50 cm 5C soil temperature as an indication of the beginning of the growing season, the date of the 5C 50 cm soil temperature was related to the emergence date for corn seedlings. A linear regression model with a coefficient of determination of 0.40 and t= 3.0, with 14 df., is represented in Figure 13. Since the "t" value is significant at P=.05, it does appear that the 50 cm 5C temperature point is related to emergence date of the corn plant.

Leaf Stage And Development

Corn leaf development (as measured by the number of emerged leaves) was observed at all plots. These

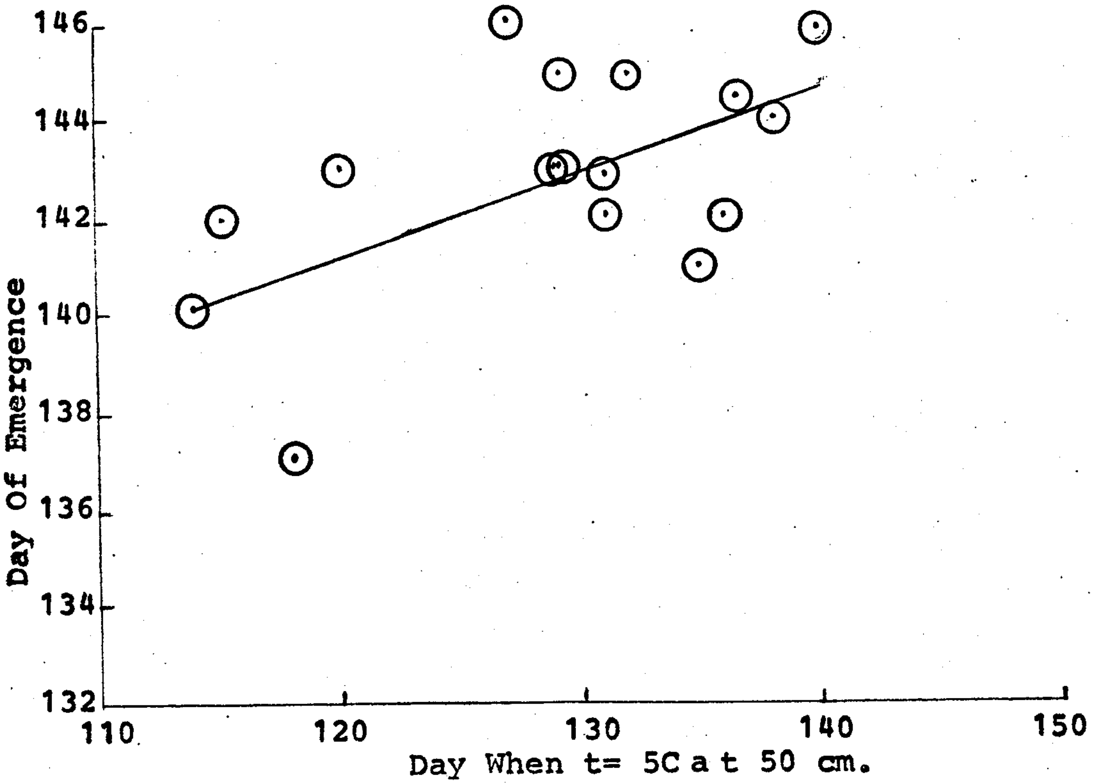

Figure 13. Day of emergence as a function of day of the year when the soil temperature at 50 cm reaches 5C, for all locations in 1971 and 1972.

observations may provide a measure of plant development (Allen et al., 1973). The most useful comparisons to be made for leaf development at different plots is of the same hybrid, since final leaf number may vary with hybrids.

If there was a difference in leaf stage development, it should have been evident at the locations which showed the largest difference in maturity for corn. Lyleton and Hamiota exhibit a large difference in grain corn maturity, so a comparison in leaf stage development was made for those locations. A comparison of the leaf stage development at Lyleton and Hamiota for Morden 88(Figure 14), shows that leaf development was more rapid for Lyleton than Hamiota in 1971. The Lyleton corn had approximately one to two more leaves at most points during vegetative development. In 1972 the differences between Lyleton and Hamiota were not as noticeable. In 1972 there did not seem to be any difference in leaf stage between the locations until early June. At this point leaf development at Lyleton moved ahead of that at Hamiota.

It is possible that in 1971 the early emergence at Lyleton, contributed to its advanced leaf stage. In 1972 both plots had similar emergence dates with correspondingly similar leaf development. The decrease in leaf development rate at Hamiota in 1972 was probably due to drought stress during late May and early June.

Results of this leaf development study seem to

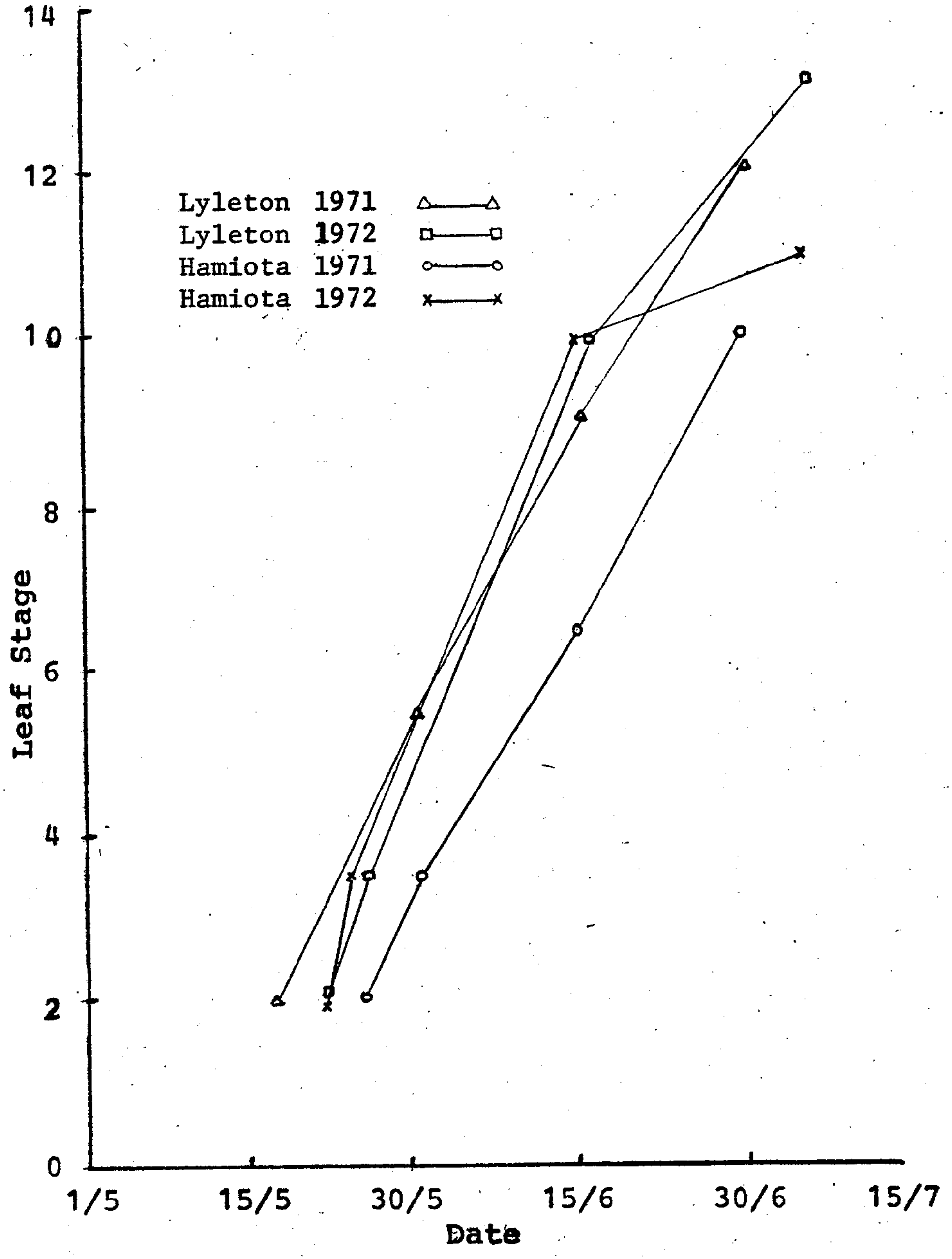

Figure 14. Leaf stage as a function of date.

indicate that leaf development does not necessarily coincide with grain corn maturity, but that it may be used as a observation of early vegetative development.

To relate leaf development observations to the corn heat unit theory, the leaf development of Morden 88 at Hamiota and Lyleton was compared with heat unit accumulation from corn emergence (Figure 15). From these graphs it may be surmised that there seems to be very little variation in the number of heat units required to reach a particular leaf stage. It appears that there is a smaller variation in accumulated heat units during the vegetative stage of growth than during the reproductive stage of corn development.

Tassel Emergence

The observed tasseling dates (date of 50 per cent tassel emergence) appear to vary considerably among hybrids and locations (Table 4). Tasseling dates for Morden 88 varied from July 5th at Lyleton in 1972, to July 24 at Virden and Carberry in 1971. Stewart's 2300 showed similar tasseling date variation to that for Morden 88. Tasseling date for the later maturing hybrid, UH-106, varied from July 10th at Lyleton in 1972 to August 1st at Virden in 1971.

Earliest tasseling dates for both years were recorded at Lyleton for all hybrids. The dates of tassel emergence remained relatively constant from year to year at Lyleton for individual hybrids. This was in contrast to the

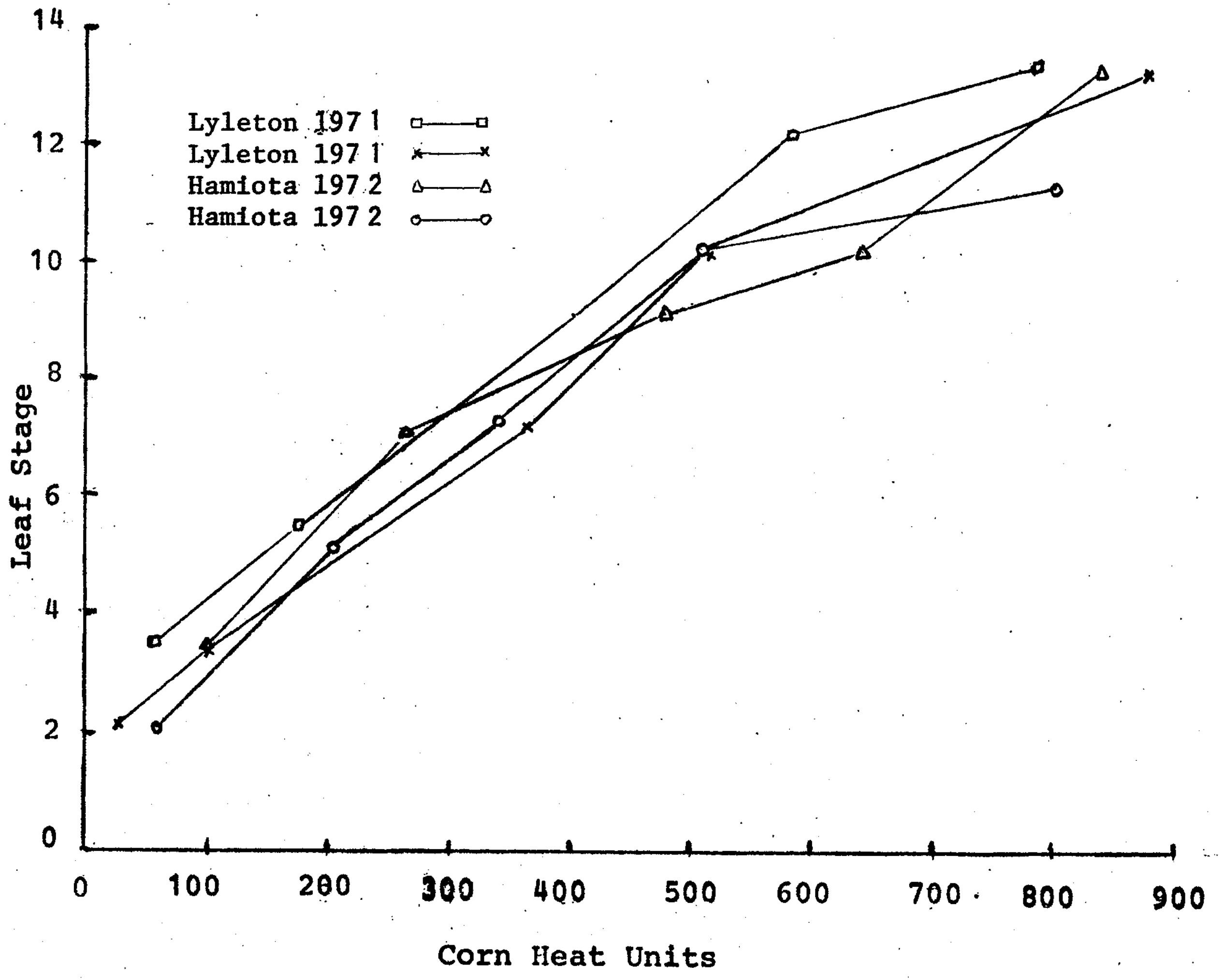

Figure 15. Leaf stage as a function of corn heat units accumulated from emergence, for Lyleton and Hamiota in 1971 and 1972.

TABLE 4

TASSELING DATES FOR STEWART'S 2300, MORDEN 88, OX-402, AND UH-106 IN 1971-1972

Location	Morden 88		Stewart's 2300		UH-106		OX-402
	1971	1972	1971	1972	1971	1972	1972
Brandon	18/7*	15/7	18/7	17/7	25/7	19/7	17/7
Carberry	24/7	10/7	25/7	13/7	30/7	16/7	13/7
Glenboro	16/7	8/7	16/7	12/7	20/7	16/7	11/7
Goodlands	12/7	8/7	12/7	8/7	20/7	12/7	8/7
Hamiota	20/7	10/7	20/7	11/7	30/7	16/7	12/7
Lyleton	6/7	5/7	6/7	6/7	11/7	10/7	6/7
Tilston	20/7	10/7	21/7	12/7	30/7	16/7	12/7
Virden	24/7	21/7	23/7	22/7	1/8	27/7	20/7

* Tasseling date based on approximately 50% tassel emergence.

relatively large variation in the date of tassel emergence at other locations. Tilston, Hamiota, and Carberry showed variations of up to two weeks between 1971 and 1972 (Tasseling occurred earlier in 1972.). The remaining locations showed variations in tasseling date of from one day to one week. It appears that the largest differences in tasseling date occurred with UH-106 from 1971 to 1972. Tasseling date among hybrids was the latest for UH-106 for both years at all locations. Tasseling occurred latest at Virden in both years. Tassel emergence was generally earlier at all locations in 1972 than in 1971. Early tasseling corresponded to early maturity at Lyleton. The trend is most noticeable in 1971, as the corn at locations where tasseling occurred during or before the second week in July(Lyleton and Goodlands), showed early maturity of grain corn. The tasseling stage is important in the early phase of reproductive growth of the corn plant.

In South Western Manitoba, it seems to be essential for corn to tassel on or before the second week in July in order that the grain corn mature during the growing season before the first fall frost.

To study the relationship of corn heat units to the time of tasseling, calculations were made to determine the number of corn heat units accumulated from corn emergence to tassel emergence (Table 6). Statistical analysis(Table 7) shows the number of corn heat units required for tassel

TABLE 5

SILKING DATES
FOR STEWART'S 2300, MORDEN 88, AND UH-106 IN 1971-1972

Location	Morden 88		Stewart's 2300		UH-106		OX-402
	71	72	71	72	71	72	72
Brandon	30/7*	24/7	30/7	24/7	4/8	29/7	24/7
Carberry	8/8	20/7	9/8	25/7	13/8	28/7	25/7
Glenboro	25/7	19/7	26/7	23/7	30/7	24/7	22/7
Goodlands	29/7	19/7	29/7	20/7	30/7	24/7	20/7
Hamiota	4/8	27/7	2/8	29/7	7/8	3/8	29/7
Lyleton	18/7	16/7	19/7	19/7	22/7	22/7	19/7
Tilston	2/8	22/7	2/8	24/7	6/8	30/7	22/7
Virden	4/8	29/7	8/8	30/7	11/8	6/8	27/7

* Silking date based on approximately 50% silk emergence.

TABLE 6

CORN HEAT UNITS ACCUMULATED TO SILKING AND TASSELING DATES*

Location	Year	Stewart's 2300		Morden 88		OX-402**		UH-106	
		Tassel	Silk	Tassel	Silk	Tassel	Silk	Tassel	Silk
Brandon	71	992	1206	992	1208	----	----	1117	1292
	72	987	1109	987	1109	987	1109	1047	1233
Carberry	71	997	1266	981	1245	----	----	1076	1350
	72	931	1172	905	1084	931	1172	1081	1230
Glenboro	71	1066	1263	1044	1247	----	----	1150	1331
	72	1030	1242	947	1172	998	1210	1112	1282
Goodlands	71	972	1320	972	1320	----	----	1158	1338
	72	986	1226	986	1208	986	1226	1068	1303
Hamiota	71	1103	1351	1147	1393	----	----	1288	1459
	72	963	1304	942	1266	984	1304	1066	1383
Lyleton	71	872	1153	872	1131	----	----	955	1216
	72	858	1103	831	1055	858	1103	934	1151
Tilston	71	1208	1446	1230	1446	----	----	1399	1523
	72	947	1177	907	1137	947	1137	1037	1295
Virden	71	1116	1426	1134	1338	----	----	1259	1500
	72	1081	1208	1047	1208	1013	1154	1154	1319

* Corn Heat Units were accumulated from emergence date, at each location to dates of silking(50% silk emergence) and tasseling(50% emergence).

** OX-402 was not grown in 1971, so data was not available.

TABLE 7

"F" VALUES FOR CORN HEAT UNITS ACCUMULATED TO TASSELING AND SILKING

Source	d.f.	"F"for Tasseling	"F" for Silking
Year	1	10.88**	17.06**
Variety	2	7.57**	4.73**
Location	7	3.79**	3.87**
Variety x Location	14	0.05	0.06
Error	24		

** Significant at P= .01.

emergence varied from year to year and location to location for each hybrid. Morden 88 required only about 850 heat units to reach tassel emergence stage at Lyleton in both years while the same hybrid required over 1100 corn heat units at Hamiota, Tilston, and Virden in 1971 and about 1000 in 1972. Corn heat unit requirements seemed to follow the same pattern for Stewart's 2300 and OX-402. UH-106 also showed variation similar to the earlier hybrids, but at each location required about 100 heat units more than the earlier hybrids.

The conclusion that may be drawn from these results is that the same hybrid may require different amounts of corn heat units to reach tassel emergence.

Silking Date

Silking dates follow a similar pattern to tasseling dates(Table 5). There was a wide variation in the silking dates from location to location and among hybrids. Silking was earliest at Lyleton in both years for all varieties. Latest silking occurred at Carberry for UH-106 in 1971. Silking dates ranged from July 22nd at Lyleton in 1972, to August 13th at Carberry in 1971. Silking was generally earlier in 1972 than in 1971. Silking dates for UH-106 were usually 3 days to a week later than for other hybrids at all locations.

The importance of silking parallels that of tasseling as a sign of plant development during the reproductive phase of growth. If corn plants are able to silk earlier in the growing season, kernel development would proceed sooner. This would lead to earlier maturity of the grain. It has also been established that if there is a longer period available after silking for grain development, yield potential is usually increased(Duncan,1967). This observation might partially explain the high yields observed at Lyleton. Early silking is also desirable to prevent stress during the crucial fertilization period. There is usually a drought stress during the first two weeks in August, so that silking before this period would be advantageous for corn yield.

Under the corn heat unit system it should be possible to determine the standard quantity of heat units required for silking to occur. To evaluate the corn heat unit system on this basis the number of heat units accumulated from corn emergence to silk emergence were determined(Table 6). Statistical analysis(Table 7) indicates that there were significant differences between locations as well as differences between years for the same hybrid.

A significant point which can be noted from the data on heat unit accumulation to silking, is that silking seemed to require fewest corn heat units at Lyleton in both years for all hybrids.

It is clear that the corn heat unit system cannot fully explain the observed differences in heat unit accumulation on the basis of the climatic variables measured by this system. It is conceivable that there would exist a variation in the dates of silking from year to year as heat unit accumulation rates may vary, however the quantity of heat units accumulated from corn emergence to silking should remain relatively stable if the corn heat unit system is accurate. Since it was found that the number of heat units accumulated to silking varied from year to year and from location to location the reliability of the corn heat unit sytem may be questioned.

Kernel Moisture

Development of the corn plant after kernel development has begun, may be assessed by kernel moisture levels. Kernel moisture decreases correspond to dry matter accumulation until maturity. The kernel moisture level which is generally accepted as being an indication of maturity is approximately 40 per cent on a wet weight basis.

In order to evaluate the relationship of corn heat units to corn development, it is necessary to determine the accumulation of heat units to a certain level of kernel moisture. The results of these calculations are expresssed in Figures 16 to 21. These plots of kernel moisture versus corn heat units from emergence are representative of the results but do not show individual relationships for each

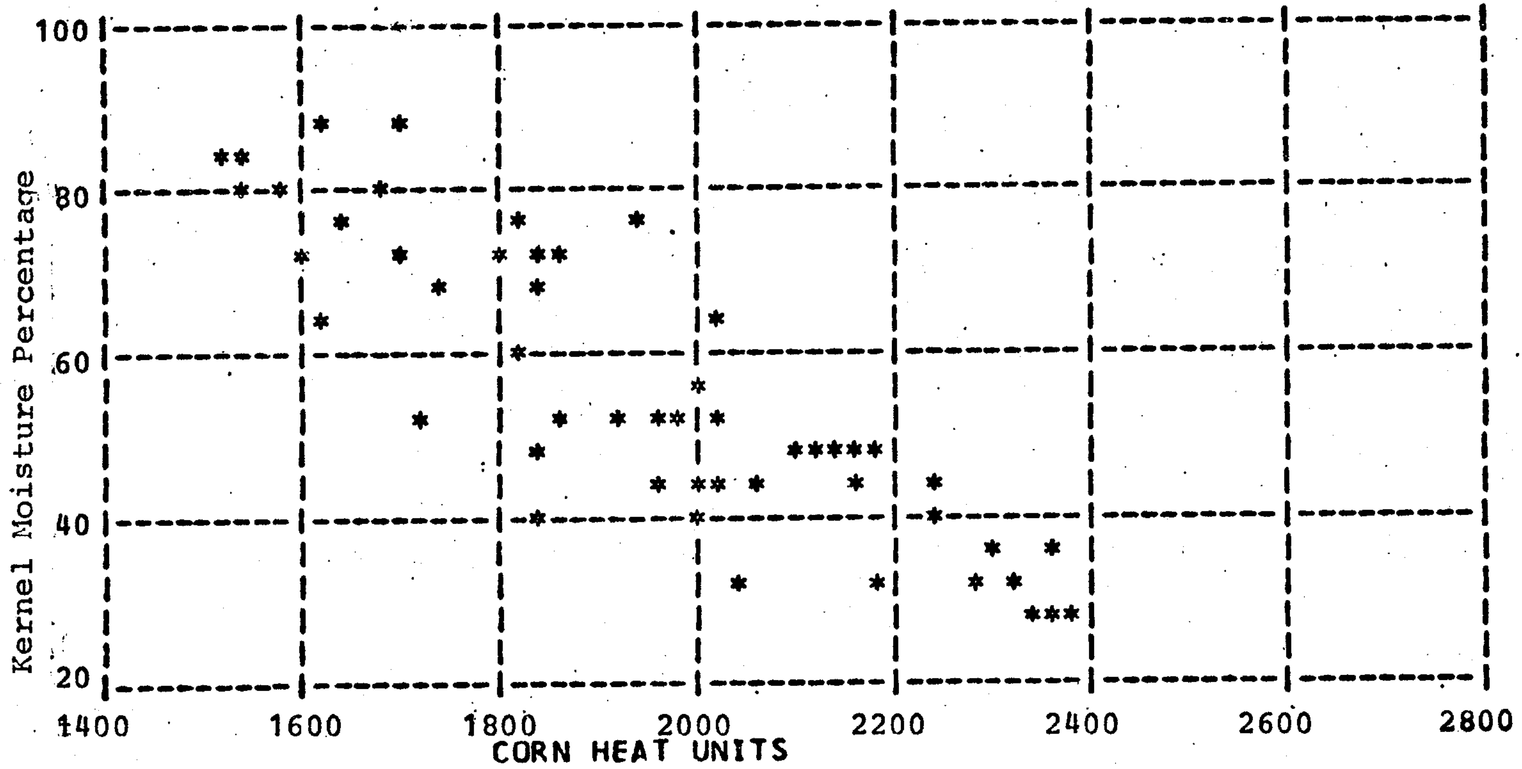

Figure 16. Kernel moisture percentage(calculated on a wet weight basis) of Stewart's 2300 as a function of corn heat units accumulated from emergence date, for all locations in 1971 and 1972.

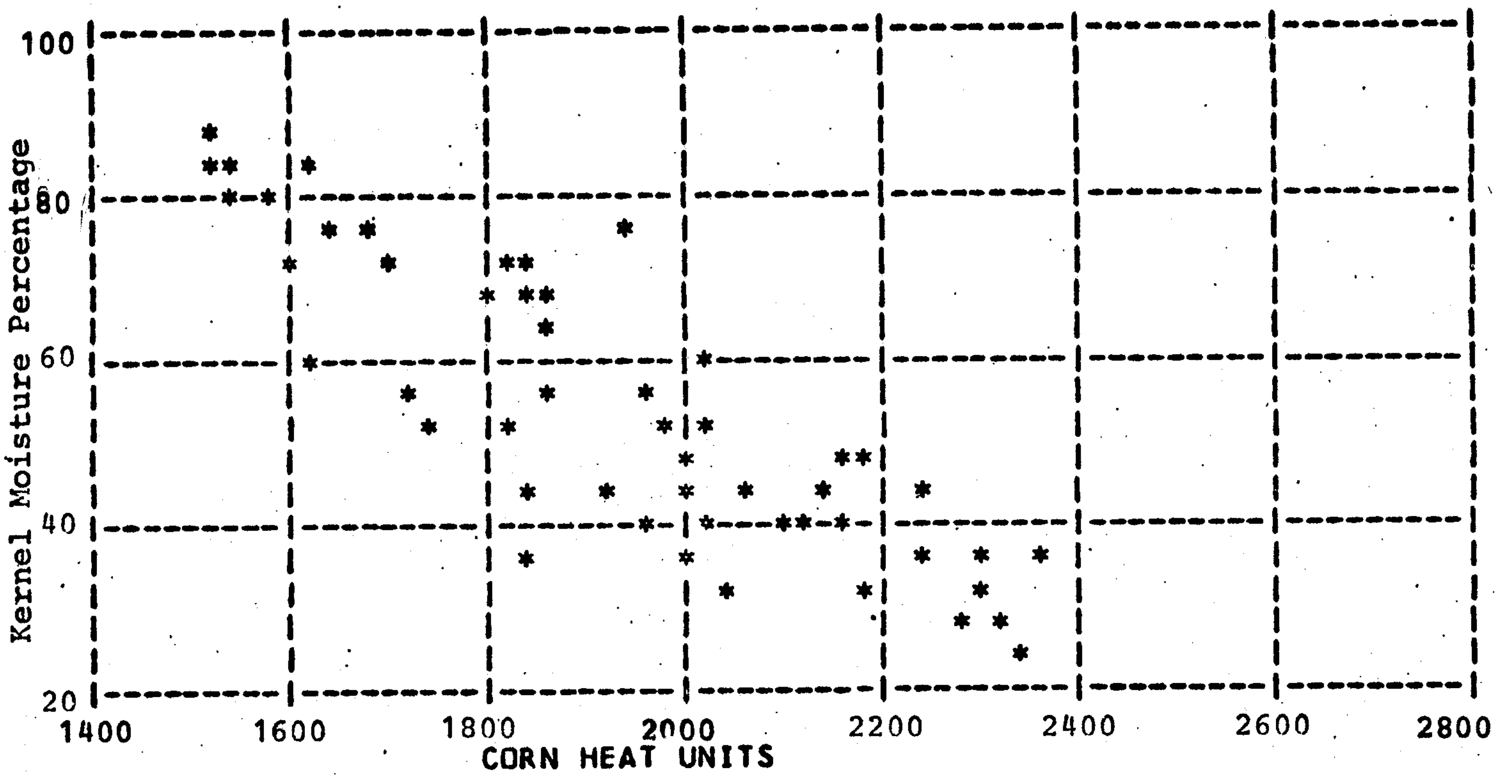

Figure 17. Kernel moisture percentage(calculated on a wet weight basis) of Morden 88 as a function of corn heat units accumulated from emergence date, for all locations in 1971 and 1972.

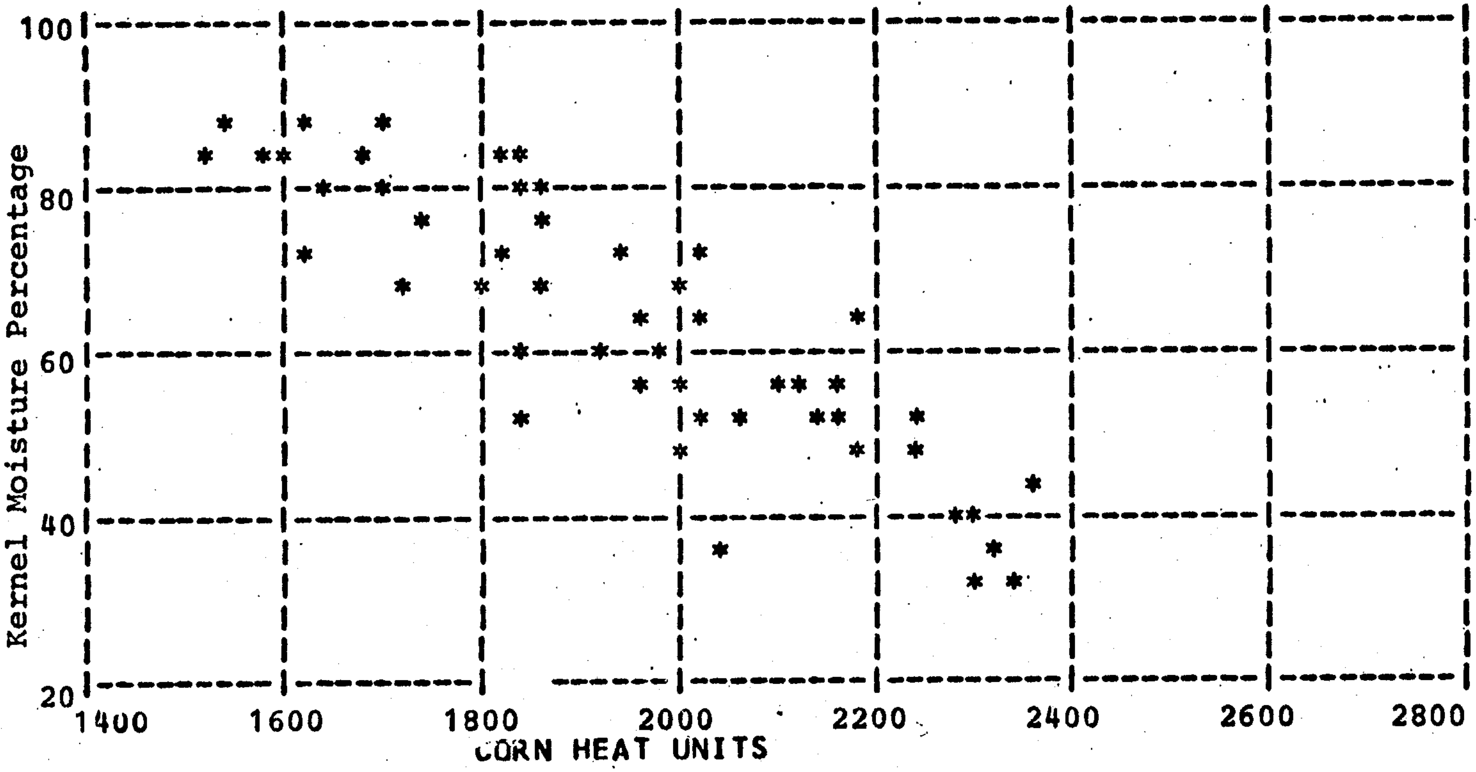

Figure 18. Kernel moisture percentage(calculated on a wet weight basis) of UH-106 as a function of corn heat units accumulated from emergence date, for all locations in 1971 and 1972.

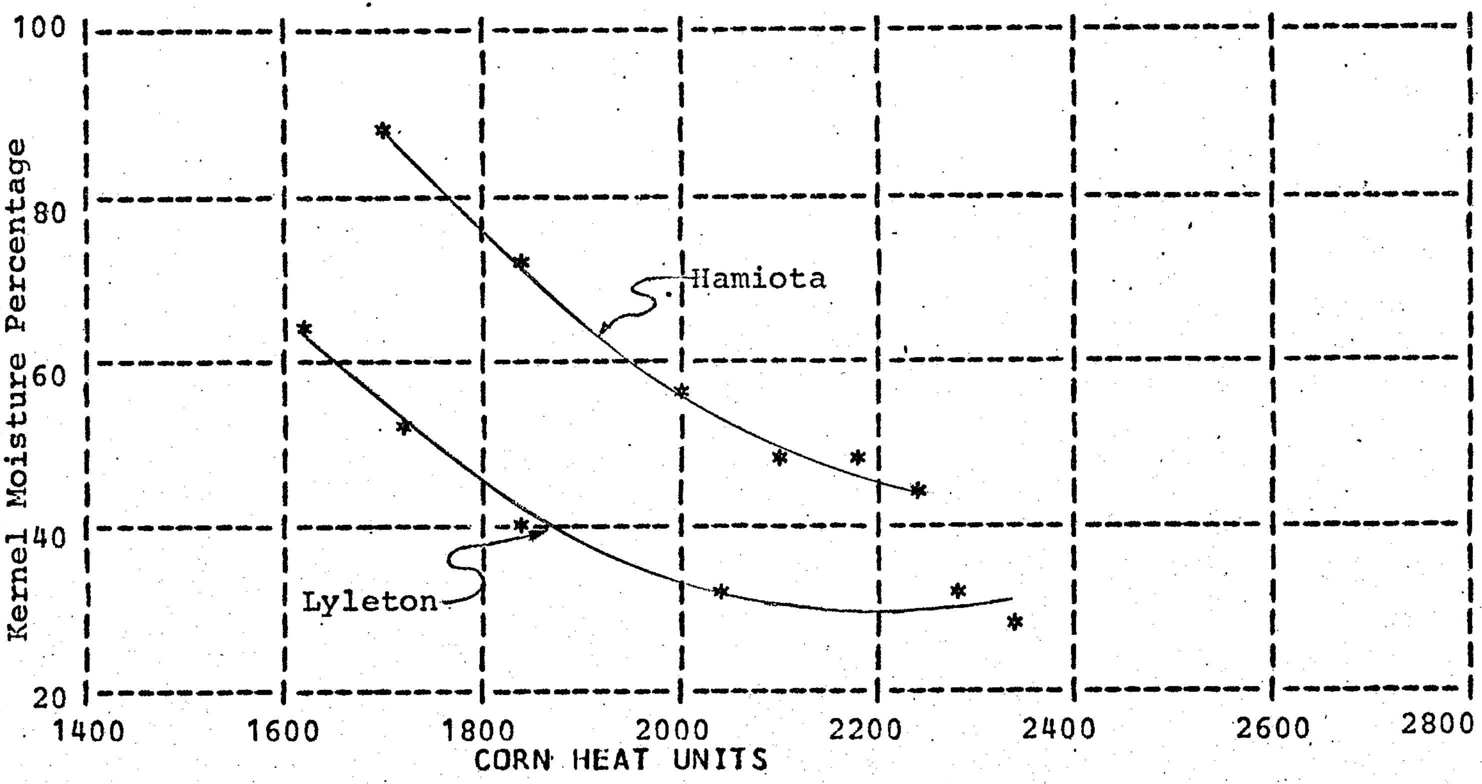

Figure 19. Kernel moisture percentage (calculated on a wet weight basis) of Stewart's 2300 as a function of corn heat units accumulated from emergence date, for Hamiota and Lyleton in 1971 and 1972.

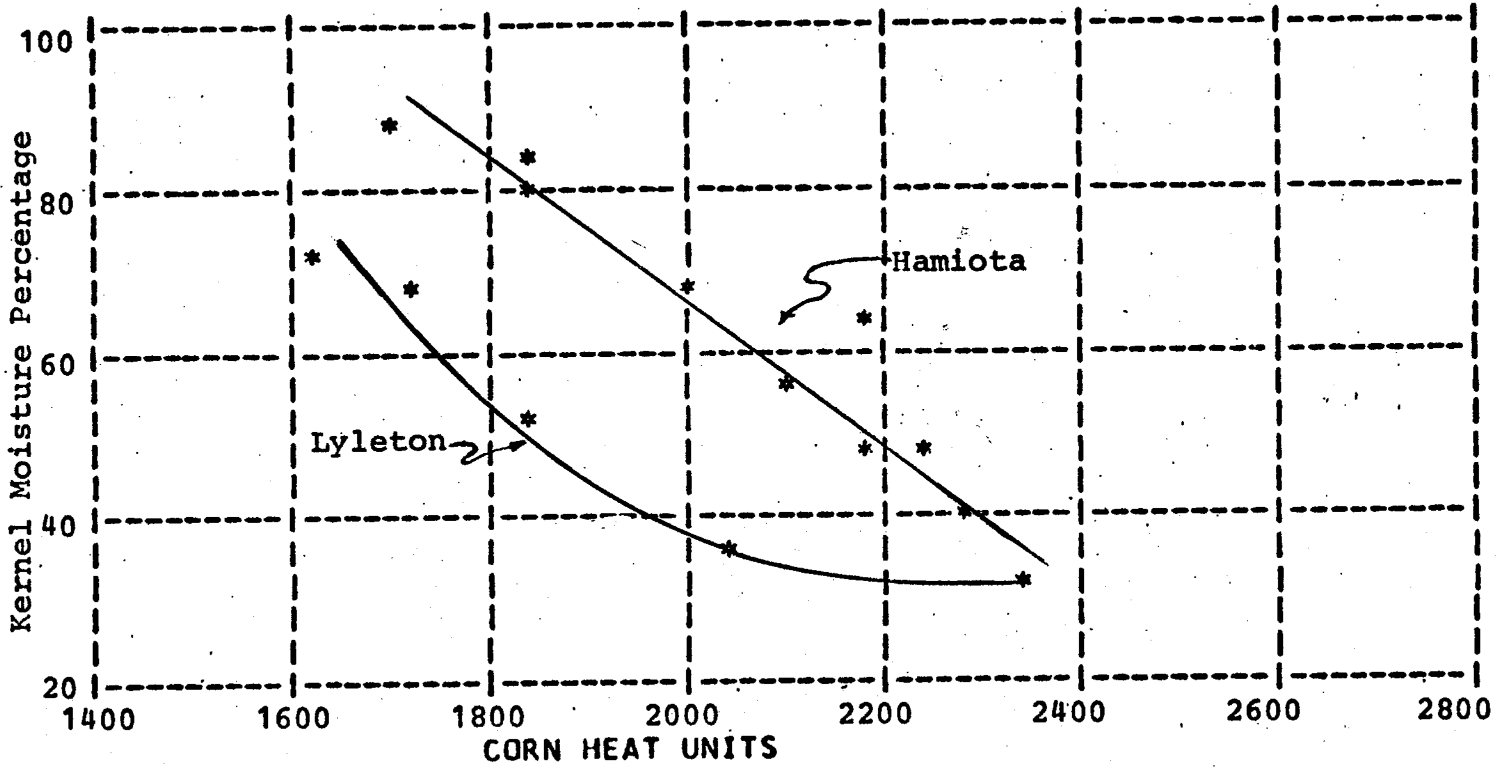

Figure 20. Kernel moisture percentage(calculated on a wet weight basis) of Morden 88 as a function of corn heat units accumulated from emergence date, for Hamiota and Lyleton in 1971 and 1972.

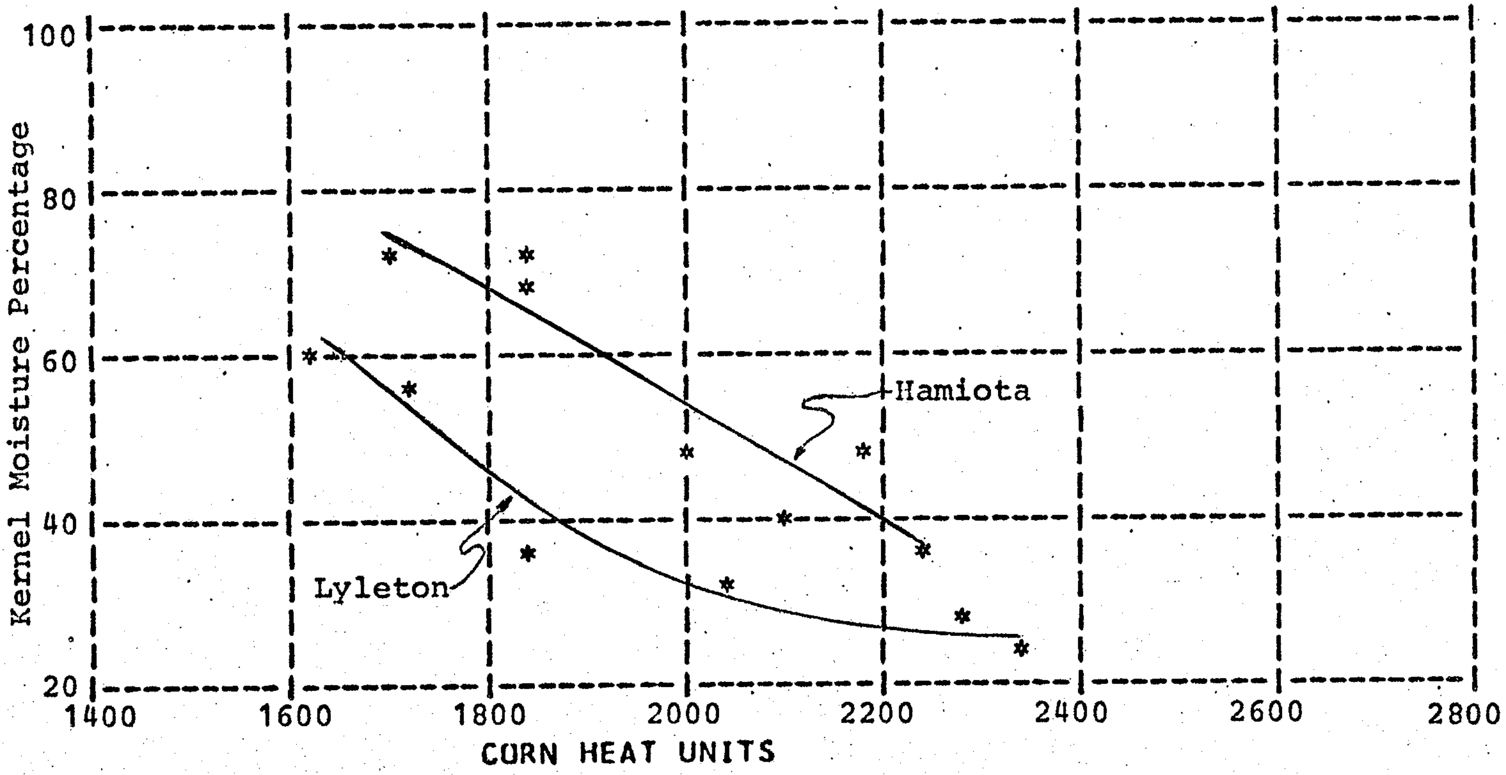

Figure 21. Kernel moisture percentage(calculated on a wet weight basis) of UH-106 as a function of corn heat units accumulated from emergence date, for Hamiota and Lyleton in 1971 and 1972.

location. Only the most significant graphs have been included.

The corn heat unit theory predicts that the number of corn heat units required for grain corn to reach maturity should remain relatively constant from year to year and among locations. To determine if this is what has occurred in this study, one should examine the the graph of corn heat units versus kernel moisture for each hybrid for all locations in both years(Figures 16-18).

In Figure 16 the relationship of kernel moisture to corn heat units for Stewart's 2300 for both years at eight sites is displayed. There seems to be a very large scatter of points which indicates that a single curve could not fit these points adequately. Kernel moisture levels varied from 20 to 85 per cent, so that a large range of corn development was represented. The approximate point where the general pattern of points cross the 40 per cent kernel moisture level is about the 2100 to 2200 corn heat units. The accepted corn heat unit rating for Stewart's 2300 is 2300, about a hundred higher than than the observed total.

The pattern of kernel moisture versus corn heat units is for Morden 88 similar to that of Stewart's 2300(Figure 17). Moisture levels vary from 20 to 85 per cent and heat units range from 1500 to 2400. The corn heat unit level which corresponds to 40 per cent kernel moisture is approximately 2000 to 2200.

UH-106 was the latest maturing hybrid used in this study, and is rated at approximately 2500 corn heat units(requires 2500 corn heat units to reach physiological maturity). The relationship between corn heat units and moisture levels indicates that although UH-106 requires more heat units to reach maturity than other hybrids in this study, it required less than 2300 (Figure 18). It was significant to note that the long term average heat unit accumulation for the experimental sites is below the level believed required for UH-106 to reach maturity(Figure 1). UH-106 did reach maturity at several locations(Lyleton, Goodlands, Glenboro).

In 1972 OX-402 was included in the study. The data for this hybrid was not included in the corn heat unit - kernel moisture graphs, but results obtained for this hybrid were similar to those of Morden 88 and Stewart's 2300.

The general conclusion to be reached from this data is that the corn heat unit hypothesis does not agree with observed results. The number of corn heat units required for a specific hybrid to reach maturity does not remain constant from location to location or from year to year. In order to subject this conclusion to closer scrutiny, several comparisons were made between locations on a single hybrid basis. Two locations were chosen to represent the extremes in grain corn maturity in this study. Lyleton had mature grain corn for all varieties while Hamiota exhibited poorer maturity.

When one examines the graph of kernel moisture versus corn heat units at Lyleton and Hamiota for Stewart's 2300 in both years(Figure 19), it is evident that Stewart's 2300 reached maturity with less heat units at Lyleton than at Hamiota. Stewart's 2300 required approximately 1800 to 1900 heat units at Lyleton and about 2200 at Hamiota to reach maturity. According to the corn heat unit theory there should not have been a difference in the number of heat units accumulated to maturity.

Similar results were obtained for Morden 88 and UH-106 at Hamiota and Lyleton for both years(Figures 20-21). Morden 88 required about 400 more heat units to reach maturity at Hamiota than at Lyleton. UH-106 reached maturity at Lyleton but not at Hamiota, although both locations received similar amounts of heat units(Table A5).

The kernel moisture curves for each location followed approximately the same pattern from year to year(Figures 19-21) for the same hybrid. This is in disagreement with the effect of corn heat units on tassel and silk emergence, where there was yearly variation in accumulated corn heat units. It seems that corn heat units affect the processes of tasseling and silking differently than kernel moisture decrease. This leads one to conclude that there may be some other factor, besides heat units, which determines whether grain corn will reach maturity.

Solar Radiation

Solar radiation levels for Lyleton, Brandon, and Hamiota indicate that Lyleton received the largest total amount during the growing season(Table 8). Hamiota received the least solar radiation of the three locations. Lyleton received larger amounts of solar radiation during May and June than the other sites. This resulted in a larger overall total for Lyleton. Brandon received more solar radiation than Hamiota in July and August but received about the same amount during the rest of the growing season. Solar radiation levels for South Western Manitoba in June, July, and August are comparable to those of Lafayette Indiana (Table 8). Since there is only data from one year and only three locations it is difficult to draw definite conclusions, however the highest solar radiation total at Lyleton did coincide with the best grain corn maturity. Also the low solar radiation levels at Hamiota paralleled the lower grain corn maturity at that location. This would seem to suggest that there may be an important relationship between solar radiation levels and corn development rates. More data is required to test this relation and determine the influence of solar radiation on plant development.

Kernel Moisture At Final Harvest

The importance of kernel moisture is its value as a factor in mechanical harvesting operations. It is usually

TABLE 8

SOLAR RADIATION MEASUREMENTS FOR HAMIOTA BRANDON, LYLETON, IN 1972, AND THE LAFAYETTE 15 YEAR AVERAGE

	Solar Radiation (langleys)					
Location	May	June	July	August	September	Totals
Hamiota	10,836.7	12,050.6	9,669.9	10,847.6	6,919.3	50,324.1
Brandon	10,933.0	12,671.8	12,512.1	11,259.5	7,201.8	54,578.6
Lyleton	12,321.3	13,923.5	12,657.5	10,704.8	7,579.2	57,386.0
Lafayette*	---	11,400	12,349	9,858	7,290	---

* Normal monthly solar radiation at Lafayette Indianna(determined over a 15 year period, Rumwas, Blair, and Bula, 1971).

necessary to have corn at the 30 per cent kernel moisture level for harvest(Aldrich and Leng, 1965). Corn which is to be harvested for grain should reach this critical level early in the fall, while weather conditions are favourable to allow harvesting to be completed.

The kernel moisture attained in both years were satisfactory for all hybrids at Lyleton and Goodlands(Tables 9-10). The earlier varieties, Stewart's 2300, Morden 88, and OX-402, attained moisture levels below 30 per cent at Brandon in 1972. At Glenboro kernel moistures were near the 30 per cent level in 1972 for all hybrids. Kernel moisture levels for all hybrids except UH-106, were near the 30 per cent level at Carberry in 1972. Kernel moistures were well above the 30 per cent level at other locations in 1972. In 1971 Stewart's 2300 and Morden 88 reached 30 per cent moisture at all locations except Carberry, Virden, and Hamiota. UH-106 only reached the critical level at Goodlands and Lyleton in 1971.

Grain Corn Yields

Yields (Tables 12 and 13) in both years were satisfactory as they were generally above the average yields in Manitoba. Yields in 1972 were higher than in 1971 for most locations although yields at Hamiota and Virden did not seem to vary substantially from year to year. The increased yields in 1972 can probably be attributed to more favourable

TABLE 9

KERNEL MOISTURE PERCENTAGE AT FINAL HARVEST IN 1971*

Location	Stewart's 2300	Morden 88	UH-106
Brandon	28.9b-f**	28.3b-f	37.9j
Carberry	35.8f-j	34.0f-i	46.8k-l
Glenboro	28.9b-f	23.8a-d	40.6h-k
Goodlands	23.8a-d	20.9ab	21.5abc
Hamiota	33.8e-h	30.0d-g	46.3j-l
Lyleton	21.6abc	19.9a	22.8a-d
Tilston	26.8a-e	29.5c-g	42.7i-l
Virden	41.9i-k	35.9h-j	49.8l

* Calculated on a wet weight basis.

** Duncan's multiple range test. Kernel moistures followed by the same letter(s) are not significantly different at P=.05.

TABLE 10

KERNEL MOISTURE PERCENTAGE AT FINAL HARVEST IN 1972*

Location	St.2300	Morden 88	OX-402	UH-106
Brandon	25.9a-c**	24.6a-b	23.5a	31.6e-i
Carberry	32.5e-j	28.9b-g	30.4c-h	36.7i-m
Glenboro	29.9b-g	32.4e-i	32.2e-i	33.8f-k
Goodlands	26.5a-d	27.7a-e	29.7b-g	30.6d-h
Hamiota	42.5n	31.8d-i	39.1n-l	48.1b-g
Lyleton	25.5a-c	26.1a-c	26.3a-d	29.7o
Tilston	39.7l-n	34.9h-l	34.4g-l	35.8h-l
Virden	42.1mn	38.9k-n	38.0j-n	50.2o

* Calculated on a wet weight basis.

** Duncan's multiple range test. Kernel moistures followed by the same letter(s) are not significantly different at P=.05.

TABLE 11

GRAIN CORN YIELDS IN 1971 (KGM/HA)*

Location	Stewart's 2300	Morden 88	UH-106
Brandon	4296a-e**	3924a-e	2597a
Carberry	4277a-e	3855a-e	3616a-e
Glenboro	3819a-e	3843a-e	2793ab
Goodlands	2610a	3327a-d	3295abc
Hamiota	4670cde	4659cde	4019a-e
Lyleton	4939de	4727cde	5135e
Tilston	4278a-e	3824a-e	3264abc
Virden	4278a-e	3824a-e	3264abc

* Yields were calculated at 15 % kernel moisture.
** Duncan's multiple range test. Yields followed by the same letter(s) are not significantly different at P= .05.

TABLE 12

GRAIN CORN YIELDS IN 1972(KGM/HA)*

Location	Stewart's 2300	Morden 88	OX-402	UH-106
Brandon	4898a-g**	5250c-i	5136b-h	5362d-j
Carberry	5652e-i	5960g-n	6343h-p	6324h-p
Glenboro	6928m-q	6620k-q	6066g-o	7199o-q
Goodlands	6406i-p	6564j-q	7702q	7790q
Hamiota	4175a-c	3810a	3860a	4256a-d
Lyleton	7456p-q	6851l-q	7111n-q	8984r
Tilston	6318g-p	5903f-m	6136g-o	6105g-o
Virden	3980a-b	4696a-f	5501e-k	4426a-e

* Yields were calculated at 15% kernel moisture.
** Duncan's multiple range test. Yields followed by the same letter(s) are not significantly different at P= .05.

weather conditions at most locations in 1972. Rainfall was higher in 1972 causing lower soil water deficit at all locations except Virden and Hamiota (Table A4).

In 1971 yields did not seem to vary greatly from location to location. Differences between the yields for these locations may be attributed to the difference in grain corn maturity between locations. Corn grown at Lyleton reached maturity substantially earlier than corn grown at Brandon. Because UH-106 requires the longest growing season as well as the largest number of corn heat units, it is most subject to yield decreases under unfavourable climatic conditions. Thus the lower yield at Brandon may be partially explained. The large variation among replicates resulted in few significant differences in yield between varieties and locations.

There were more apparent differences in yield in 1972. This was partially due to decreased variation between replicates and a wider range between the highest and lowest yields. The highest overall yield was at Lyleton for UH-106. Yields for the other varieties were also the highest at Lyleton. The yields at Lyleton were in excess of the target yield of 6000 kgms per hectare. High yields (above or equal to the target yield) were recorded at all plots except for Virden, Hamiota, and Brandon. The lower yields at these three plots seemed to be due to drought stress caused by low rainfall during May and June.

Comparisons of the yields between hybrids in 1972, indicate that UH-106 had the highest yields of the four hybrids at most of the locations. These results are an indication of the higher yield potential of a later maturing hybrid such as UH-106. This potential was realized to a greater extent in 1972, when growing conditions were more favourable. The five locations where maturity was reached earlier or where the corn developed more fully also displayed higher yields for UH-106. The yields of the other three hybrids did not indicate any large differences in yield at most locations.

Bushel Weights

Bushel weights for all locations are recorded in Tables 13 and 14 for 1971 and 1972, respectively. In 1971 the bushel weights for the early hybrids, Stewart's 2300 and Morden 88, were generally acceptable for grain (56 lbs/bushel or greater) at most locations. Bushel weights for UH-106 were lower at all locations than those of the earlier varieties. Only at Lyleton and Goodlands was UH-106 produced with a bushel weight of over 56 lbs/ bushel.

In 1972 the bushel weights for the early hybrids, Stewart's 2300, Morden 88, and OX-402, were at or above the 56 lbs/bushel requirement at Glenboro, Goodlands, Lyleton, and Tilston (OX-402 was slightly below 56 lbs/bushel at Tilston). At other locations all hybrids appeared to be

TABLE 13

BUSHEL WEIGHTS FOR 1971*

Location	Stewart's 2300	Morden 88	UH-106
Brandon	57.1*	55.7	47.0
Carberry	55.4	53.0	51.5
Glenboro	57.0	57.6	55.5
Goodlands	61.3	59.0	57.3
Hamiota	58.2	56.5	55.5
Lyleton	59.5	58.2	56.9
Tilston	56.4	54.8	52.9
Virden	57.5	56.4	51.6

* Bushel weights are recorded in pounds per bushel and were determined from bulked samples of four replications for each variety at each location.

TABLE 14

BUSHEL WEIGHTS FOR 1972*

Location	Stewart's 2300	Morden 88	OX-402	UH-106
Brandon	54.5e-i**	55.1f-k	52.3d-e	47.1ab
Carberry	54.9f-j	54.5e-i	54.1e-h	49.3b
Glenboro	56.9i-m	56.9i-m	56.3h-k	55.5g-k
Goodlands	60.0n	58.9mn	56.5h-k	55.3g-k
Hamiota	51.4cd	55.0f-j	49.5bc	45.5g-k
Lyleton	58.9mn	57.7k-m	57.4j-m	55.3f-k
Tilston	57.2j-m	56.0g-k	55.7g-k	52.5de
Virden	53.3def	53.3def	53.0def	49.2b

* Bushel weights were recorded in pounds per bushel and were determined for each replicate.

** Duncan's multiple range test. Bushel weights followed by the same letter or letters are not significantly different at P= .05.

below 56 lbs/bushel. UH-106 did not reach required bushel weight at any of the locations in 1972.

The lower bushel weights of UH-106 may be due mainly to its genetic characteristics as well as its higher heat unit requirement. It is signficant to note that the required bushel weight was attained at several locations in both years for the earlier hybrids. This indicates that it is possible to grow grain corn with satisfactory bushel weight in the South-Western region of Manitoba.

The variation of bushel weight from year to year and from location to location can be due to the effects of climatic stress (drought) during critical grain filling periods, reaction of the hybrid to insufficient long growing period or high moisture at harvest.

SUMMARY AND CONCLUSIONS

During the summers of 1971 and 1972 trials were conducted at eight sites to determine whether grain corn production was possible in South Western Manitoba. A corn heat unit map of the area predicts that available hybrids should not be able to mature sufficiently for grain production. Several hybrids of corn (*Zea mays* L.) with different ratings were utilized. Kernel moisture was used as the main basis for evaluating grain corn maturity. Climatological measurements made at each location included daily maximum and minimum temperatures, rainfall, soil temperature, and solar radiation.

Corn emergence occurred primarily in the period from the 15th to the 25th of May during both years. Emergence dates seemed to be more uniform in 1972 than in 1971. The emergence period observed in this study coincided with the normal seeding period for grain corn in Manitoba. The early maturity of the corn (as indicated by kernel moisture) was probably partially a result of early emergence. One would conclude from emergence and maturity results that early seeding and emergence are important factors in determining the stage of maturity attained by the corn plant. The probable cause of this effect would be the more efficient utilization of the entire growing season by an earlier sown crop.

Soil temperature records indicated that there appears to be a relationship between the soil temperature at 20 cm during the period from seeding to emergence and the time required for emergence after planting. It was also found that the 50 cm soil temperature was related to the date of emergence. It appeared that the 50 cm soil temperature reflected the general climatic potential of the plot location as the locations which had the higher soil temperature at 50 cm throughout the growing season usually showed early grain corn maturity.

Tasseling dates for all locations during the two years ranged from the first week in July to the last week in July. Locations that recorded late tassel emergence showed later maturity. In order that corn reach maturity early in the growing season in South Western Manitoba, it should tassel before the second week in July.

Tassel emergence was not found to be significantly related to accumulated corn heat units from corn emergence to tasseling. The accumulated corn heat units to silk emergence date did not show that a definite relationship between corn heat units and silking date exists. This is in disagreement with corn heat unit theory which predicts that the number of corn heat units accumulated to a specific stage of development should remain the same for each location and each year.

Kernel moisture measurements were in agreement with tassel and silking - corn heat unit relationships. The corn heat unit system did not appear to explain observed differences in kernel moisture levels at different locations during the grain filling stage. The large variation in the number of corn heat units needed for corn to reach the 40 per cent kernel moisture maturity level made it appear evident that the corn heat unit was not a good criterion of grain corn maturity potential.

Final kernel moisture results at harvest indicate that in most locations it is possible to grow corn which has a kernel moisture which is low enough for mechanical harvesting in the fall.

A preliminary investigation of solar radiation at Lyleton, Brandon, and Hamiota in 1972, revealed a trend in the relation of solar radiation to grain corn maturity. The largest accumulation of solar radiation occurred at the Lyleton location, coinciding with the early grain corn maturity at Lyleton.

One can conclude from the results of this study that the corn heat unit, in its present form, cannot be used as a reliable estimate of climatic potential for corn production in South Western Manitoba. The observed conflict between the results of this project and the corn heat unit approach may be a result of a combination of factors such as soil temperature and solar radiation. Further research into the causes of these discrepancies appears to be warranted.

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APPENDIX

TABLE A1

SOIL CHARACTERISTICS

Location	Year	Surface Texture	pH	Conductivity*
Brandon	71-72	clay loam	6.6-7.0	0.5-0.8
Carberry	71	sandy clay loam	5.9-6.2	0.2-0.3
Carberry	72	fine sandy clay loam	6.4-6.7	0.1-0.3
Glenboro	71-72	clay loam	5.7-5.8	0.2-0.3
Goodlands	71-72	clay loam	7.3-7.7	0.3-0.5
Hamiota	71-72	clay loam	7.0-7.7	0.4-0.6
Lyleton	71-72	clay loam	6.8-7.7	0.4-0.6
Tilston	71-72	clay loam	7.0-7.9	0.2-0.5
Virden	71-72	clay loam	7.6-7.8	0.3-2.7

* Conductivity measured in mmhos. Conductivity determined from a saturated paste.

TABLE A2

SOIL FERTILITY

Location	Year	Nitrate N (ppm)			Available P (ppm)		K (ppm)
		0-6	6-12	12-24	0-6	6-12	0-6
Brandon	71	---	---	---	---	---	---
Brandon	72	25-82 *	20-60	44-90	14-82	30-39	675-700
Carberry	71	---	---	---	---	---	---
Carberry	72	1-3	1-2	1-2	0-1	---	120-152
Glenboro	71	9-18	1-9	---	6-36	---	375-546
Glenboro	72	19-45	45-82	5-14	12-24	2-5	273-700
Goodlands	71	4-15	4-7	1-2	2-27	0-4	---
Goodlands	72	10-28	2-4	1-3	10-28	2-4	255-292
Hamiota	71	7-8	7-20	---	11-21	---	291-990
Hamiota	72	4-26	32-60	1-32	9-21	2-7	255-700
Lyleton	71	1-6	0-3	---	4-18	---	220-360
Lyleton	72	1-21	6-25	15-29	6-52	1-3	207-380
Tilston	71	7-8	29-97	---	3-52	---	475-664
Tilston	72	4-11	6-51	11-26	8-47	1-16	305-620
Virden	71	23-30	28-130	---	6-17	6-11	287-397
Virden	72	8-22	3-8	1-21	8-21	2-7	209-391

* Range of four replicates.

TABLE A3

FERTILIZER APPLICATION*

Location	Nitrogen		P_2O_5		K_2O	
	1971	1972	1971	1972	1971	1972
Brandon	---**	---	---	---	---	---
Carberry	---	165	---	110	---	110
Glenboro	310	60	90	0	0	0
Goodlands	150	150	150	0	0	0
Hamiota	310	60	44	60	0	0
Lyleton	330	60	150	0	0	0
Tilston	70	0	44	40	0	0
Virden	80	80	130	25	0	0

* Kgm/ha

** Data not available.

TABLE A4

WATER DEFICIT*
ON JULY 16 AND AUGUST 13 FOR 1971-1972

	July 16		August 13	
Location	1971	1972	1971	1972
Brandon	-3.33	4.87	0.87	7.19
Carberry	-0.76	4.81	2.58	8.23
Glenboro	-1.70	3.40	1.47	4.89
Goodlands	-1.16	3.30	2.38	3.07
Hamiota	-1.13	6.38	3.64	8.47
Lyleton	-0.97	3.48	3.56	3.00
Tilston	-0.06	2.41	4.80	4.80
Virden	1.21	6.10	5.16	8.49

* Water Deficit = Potential Evapotranspiration - Precipitation - Available Soil Water On May 1st(assumed to be 4 inches). As water deficit increases water availability decreases, so that a negative water deficit shows greater water availability.

TABLE A5

CORN HEAT UNITS*
AND FROST FREE DAYS**IN 1971-1972

Location	1971	1972	1971	1972
Brandon	2207	1957	102	74
Carberry	2012	2006	111	77
Glenboro	2385	2395	125	114
Goodlands	2437	2410	133	138
Hamiota	2247	2158	122	80
Lyleton	2384	2164	120	136
Tilston	2368	2231	122	125
Virden	2232	2067	123	138

* Corn Heat Units calculated in degrees fahrenheit from emergence to date of first fall frost(-2C).

** Maximum number of days during the growing season without a frost(0C).