THE GROWTH OF CORN AND SUNFLOWERS IN RELATION TO CLIMATIC CONDITIONS.

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INTRODUCTION

The importance of environmental conditions in determining the nature of plant growth has long been recognized. The process of natural selection which is continually going on is but an expression of the effectiveness of these conditions to react upon plant life. In many cases the distribution of various types of vegetation is clearly due to the different climatic factors which have been at work. For example, the distribution of genera and species within that broad belt of coniferous forest which stretches across Canada, while in some cases influenced by competition, variations in soil type, and differences in altitude, is very often directly related to such climatic conditions as precipitation, wind velocity, temperature, atmospheric humidity and sunlight. But these results have been brought about by the constant application of such elements over long periods of time. Of the fluctuations which occur in the growth rate of an individual plant from day to day and from hour to hour, due to the accelerating or retarding influence of climatic changes, but little is known. The ordinary records of climate, useful though they may be in some respects, are of limited value in interpreting plant growth unless coupled with data for corresponding physiological activities in the form of growth measurements. A knowledge, therefore, of the manner in which the growth of economic plants is affected by fluctuations in climate should be of considerable practical value.

The relation of corn and sunflower plants to the climatic environment of this particular district is of singular interest, espec-

[*] Report of an investigation carried out in the Department of Field Husbandry, University of Alberta, under the direction of Professor R. Newton.

ially in connection with the optimum dates of seeding these crops. If seeded too early in the season the young corn plants are liable to be killed by frost when only a few inches above the ground. This not only results in the extra cost of a second seeding, but in most years makes the resulting crop so late that it is unable to attain that stage of maturity necessary for the production of the best quality silage. There is good reason to believe that sunflowers can withstand lower temperatures than corn without being killed, but the optimum date of seeding this crop has never been accurately determined for this district. While the sunflower plants may not actually be frozen by temperatures in the neighborhood of 0°C, it does not necessarily follow that such low temperatures do not have a retarding influence on their subsequent growth.

A study of the geographical distribution of any plant gives a rough indication of the relation which it bears to its environment. In this respect, the clearly marked distribution of corn, Zea mays, suggests at once that quite high temperatures during the growing season is one of the conditions necessary for its successful culture. The sunflower, Helianthus annuus, has no such distinct zone of culture. Although considered by most authorities as being a native of the Great Plains Region from Nebraska to Mexico, it has now quite a scattered distribution as an agricultural crop. In 1615 Champlain[x] observed it being cultivated by the Hurons in Canada. About the middle of the sixteenth century the plant was introduced into Spain from America. It is now grown extensively throughout North America, Russia and Hungary, and to a limited extent in China, Australia, New Zealand, South Africa, Egypt and India. While the location of its

x Gilmore. Uses of Plants by the Indians of the Missouri River Region, 1919.

original habitat suggests that the plant thrives best in regions of high temperature, its present distribution shows that it can be grown successfully under a great variety of conditions.

REVIEW

Growth Measurements

The manner in which growth measurements are carried out is of considerable importance. If stem elongation over a relatively short period of time is taken as a measure of growth, it will, in most cases, be found that the maximum amount of growth takes place in the absence of light. In this case growth is but a measure of the rate at which materials already elaborated by the plant are translocated and rearranged. Prescott (25), working on the growth of maize in Egypt, found that the growth rate, measured by increase in height, exhibited two maxima during the twenty-four hours, one a short time after sunrise and the other in the late afternoon about sunset. The total growth however, during the twelve night hours from 8 p.m. to 8 a.m. was generally found to be greater than that during the remaining twelve hours of daytime. If, on the other hand, increase in dry weight is taken as a measure of growth, or even stem elongation over a period of several days, the former must give an accurate, and the latter an approximate measure of the plants ability to produce new materials, from the compounds present in air and soil.

Internal Factors

Before considering the probable influence of external factors such as climate upon the rate of growth, a clear conception is necessary regarding the part played by certain tendencies resident within the plant itself - the internal factors. Lying dormant

within the seed are certain genetic tendencies, which when expressed later during the life of the growing plant, tend to produce under any given set of external conditions, a certain definite form of growth. It is only reasonable to believe then, that the role of external conditions is merely that of accelerating or retarding the manner in which the internal factors tend to express themselves. F.F. Blackman (2) in pointing out the power which protoplasm possesses of renewing and increasing itself, has compared the growth of an organism to the process of autocatalysis. In the multiplication of bacteria, this author points out, the increase in number, which is a fair measure of the increase in their total mass, assumes for a time the form of a strictly logarithmic curve. In the higher plants, however, the extreme degree of differentiation and specialization in tissue prevents any such regular increase in mass. Reed and Holland (26) however, found that the rate of stem elongation in Helianthus, as determined by weekly measurements, followed strictly the course of an autocatalytic reaction as expressed by the formula

$$\log \frac{x}{A-x} = K(t-t_1)$$

where A represents the final mass of the plant, x the size of the plant at any time t, t_1 the time at which the mass of the plant is half the final mass, and K a constant. The close similarity between the observed and calculated values in this work is indeed striking, and led the authors to conclude that the growth rate is governed by constant internal factors rather than by external factors. Reed (27) has applied the same formula to the growth of pear shoots (Pyrus communis) and young walnut trees (Juglans nigra and Juglans regia) with good results. The formula was also found

to be applicable to data on maize collected by Kreusler, the calculated values bearing a similarity with those observed whether mean height, mean green height, or mean dry weight was taken as a measure of growth. Finally, Reed (27) employed the formula successfully in connection with certain data published by Eckles and Swett (11) on the growth of heifers. But, as pointed out by West, Briggs and Kidd (28) the above formula involves the assumption that the falling off in growth per unit of dry weight is due to the disappearance of a catalyst. In the absence of evidence to support this view they contend that this decrease in the growth rate is possibly due to an increasing differenciation into productive and non-productive tissue. Working recently with Helianthus (17), they have shown that the respiration index of the meristematic tissue as well as that of the whole plant falls off with age. The curve for respiration, moreover, follows closely the falling growth rate curve. This suggested that the decrease in growth towards the end of the life cycle is not wholly due to an increase in water conducting and mechanical tissue.

The "compound interest law" of growth has been put forward by V.H. Blackman (3,4) as expressed by the formula

$$W_1 = W_0 e^{rt}$$

when W_1 is the dry weight of the plant at the end of time t, W_0 the initial seedling or seed weight, r, the rate of interest, and e, the base of the natural logarithms. The value of r has been termed by Blackman as the "efficiency index" of dry weight production, representing the efficiency of the plant as a producer of new material. According to this formula the increase in dry weight takes place exponentially and all of the new material added by the plant is equally effective in producing new growth.

For the data originally examined by Blackman fairly constant values of r were found during the active growing period of the plant. But Kidd, West and Briggs (16) have applied this formula in examining the growth rates of several plants, and find that not only does the efficiency index fluctuate from week to week, but that it tends generally to decrease in value from a period quite early in the growing season. An examination of the data presented by Brenchley (6) for the growth of peas also shows that the value of r undergoes quite violent fluctuations.

Briggs, Kidd and West (7,8) in carrying out an analysis of data collected by Kreusler on the growth of maize, calculated the growth rate by means of the following formula

$$\frac{R}{100} = \frac{W_2 - W_1}{W_1}$$

where W_1 and W_2 are the dry weights of the plants at beginning and end of the week, respectively. This is essentially a simple interest method of calculating growth rate. It gives the rate of increase in dry weight for the period, as a percent of the dry weight at the beginning of the period. Fisher (12) has criticized the use of this formula and pointed out that in some cases it introduced errors up to one hundred percent. He maintained that Blackman's compound interest formula expresses correctly the growth rate of the plant. Should it be necessary to express growth as taking place on the linear basis, he believed that the growth rate should be calculated as a percent of the mean value for the period according to the formula

$$\frac{R}{100} = \frac{2(W_2 - W_1)}{(W_1 + W_2)}$$

Both the simple and the compound interest formulae are based on the assumption that the new material produced by the plant is employed as capital in a certain definite manner, in the former case at stated intervals, and in the latter continuously. In neither instance does the method of calculation give more than an approximation.

The relative growth rate curve for maize presented by Briggs, Kidd and West (7,8) from Kreusler's data, shows that for the two or three weeks following germination the growth rate is either very small or negative in quantity. Following this period there is a rapid increase in the growth rate until it reaches a maximum, when it falls again to a very low value at the end of the season. In the falling part of the curve, however, are two subsidiary maxima which are found, in general, to be coincident with the appearance of male and female flowers, an event probably preceded by increased respiration which resulted in the minima immediately preceding the subsidiary maxima. When the curve for leaf area, ie., the ratio of leaf area to dry weight, is plotted for the same date it is found to follow closely the form of the growth rate curve. This similarity in the form of the two curves suggested to the authors that the increase in dry weight per unit of leaf area was approximately constant throughout the life cycle of the plant. In order to test this supposition the "unit leaf rate", ie., the increase in dry weight per square centimeter of leaf surface, was calculated for the same period. On the assumption that leaf area is a measure of the active growing tissue, the capital, so to speak, which the plant employs, the unit leaf rate curve should have been a straight line parallel to the time axis. But the authors point out that the assimilation

of young seedling leaves is relatively small per unit of surface; also the dry weight per unit of leaf area falls at first and then rises to a maximum at the end of the life cycle. These two tendencies coupled with the fact that respiration per unit of dry weight decreases with age, would have the effect of making the unit leaf rate curve assume a concave form relative to the time axis. The curve obtained follows this general form in the early period of growth, but subsequently fluctuates violently and fails to show any particular tendency. This, the authors have shown to be due in all probability to errors in sampling.

While this work leaves the problem of plant growth formulas still unsolved, it marks a distinct advance by unraveling some of the many internal factors responsible for plant growth.

External Factors

Of the climatic conditions influencing growth, precipitation, atmospheric humidity, temperature and light are probably the most important. In most of the investigations carried out on this subject, the conditions in regard to moisture have been kept in excess either by irrigation or by growing the plants in water culture, so that little information is available regarding the effect of precipitation at different periods in the life cycle of the plant. An examination of the charts prepared by Prescott (25) on the growth of maize in Egypt shows the immediate response which the plant makes to irrigation during the period of rapid growth, when soil moisture has become a limiting factor. The work of Briggs and Shantz (10) emphasized the great variations which different groups of plants exhibit in respect to water requirement. They have reported the results obtained by Wollny at Munich, who found the water requirements of corn and sunflowers

to b- 233 and 490 respectively.

Atmospheric humidity or more properly, the evaporating power of the air, is one of the factors chiefly responsible for water loss by the plant through transpiration. But, with a constant amount of water vapour in the air, the degree of saturation must vary inversely with temperature. The important thing to consider therefore, is the vapour tension deficit of the atmosphere for the particular temperature considered. Livingston and Shreve (19) give a thorough review of this topic and suggest certain methods of employing data on evaporation for the study of plant growth and distribution. McLean (20) in studying the growth of soybean cultures as a measure of the growth producing power of the climate of Maryland, found that the ratio of evaporation to rainfall became quite often a limiting factor for growth. This was especially noticeable towards the end of the growth period, when high temperatures prevailed. The general methods employed by McLean have been adopted by Johnston (15) in a study of the growth of buckwheat, Fagopyrum esculentum, under greenhouse conditions. He found that the high evaporation rates of late summer occurring with high temperature and transpiration values, were responsible for low rates of increase in dry weight and in leaf area.

Besides furnishing energy for the photosynthetic activity of the plant, light is undoubtedly one of the most important external factors influencing transpiration. While only about 0.5 percent of the radiant energy falling upon the leaf is utilized in the process of carbon assimilation, Palladin (24) states that 27.5 percent is used up in transpiration. A close correlation between assimilation and light of high intensity is therefore scarcely to be expected. Brenchley (6)

experimenting with the growth of pea plants under greenhouse conditions, found good correlation between bright sunshine and the rate of increase in dry weight calculated by Blackman's (3) compound interest formula, provided the food supply was adequate. Briggs, Kidd and West (8) found the closest correlation between unit leaf rate (increase in dry weight per unit of leaf area per week) and light, when intensities up to one fifth full sunlight were considered as limiting. The correlation with total hours of sunshine was insignificant. The value for real assimilation was calculated from the unit leaf rate, after adding the loss due to respiration, and deducting the gain due to salt uptake. When the value obtained was compared with light intensity, there seemed to be little correlation, no matter how light was measured. This led the authors to suppose that under natural conditions, light limits the growth rate not by its direct action upon photosynthesis but indirectly through its effect upon stomatal openings. Recent experiments by Garner and Allard (13) have shown that the relative length of night and day is of great importance in determining the amount of vegetative growth and the time of reproduction. This brings up the question of the dates of seeding of different crops in order to obtain maximum yields of fodder or seed.

Temperature has the effect of accelerating most chemical reactions. The acceleration in reaction velocity, moreover, is logarithmic in nature. This phenomenon has been summed up in the rule known as the Van't Hoff principle, which, in brief, states that for every rise of 10°C the reaction velocity is approximately doubled. This principle has been found to hold true in the case of many vital reactions. F.F. Blackman (1) discusses this principle in relation to assimilation and respiration, and points out

the necessity of considering also the time factor. Especially is this true in the case of assimilation, as the initial rate falls off rapidly at high temperatures. It has generally been supposed that a certain optimum temperature exists for the process of growth in a given organism. But Blackman (1) shows the futility of considering a single limiting factor such as temperature unless in relation to other possible limiting factors. Probably the most careful work on the problem of temperature and growth has been carried out by Lehenbauer (18) in his study of the growth of maize seedings. In general, he found that the amount of growth increase per unit of time at a given temperature was influenced by the duration of the exposure to that temperature. With an exposure period of twelve hours the optimum temperature was found to be 32°C. One noticeable feature of these measurements is that for most of the temperatures up to and including 31°C. the growth rate per period of time increases quite regularly from hour to hour. This suggests that had the increase for each period been expressed as relative growth rate, a more constant series of values would have been obtained. McLean (20), Hildebrandt (14), Prescott (25) and Briggs, Kidd and West (8), all found a high correlation existing between temperature and growth under field conditions. Brenchley (6) and Johnston (15) obtained similar results when investigating greenhouse conditions. The failure of Reed and Holland (26) to establish any intimate relation between temperature and the rate of stem elongation in <u>Helianthus</u> may have been due to the fact that in California where temperatures would naturally be uniformly high, other factors might have been limiting growth. The relation of temperature accumulations expressed as degree days, to time of blossoming in the apple and peach, has been studied by Bradford (5). He found that the

agreement in temperature accumulations to blossoming from year to year at any one place, varies with the length of the time for which they are measured, indicating that ordinary temperatures are not always effective, or that temperature is not always a limiting factor. Mosier (22), in his study of the climate of Illinois, has used degree hours to express temperature accumulations for the frost free periods, considering 49°F. as the point of unit growth rate for corn. Although lower yields occurred during the years of high temperature, he found that high temperatures could be correlated with low rainfall. In a recent work Livingston and Shreve (19) have made use of various temperature indices in an attempt to correlate different vegetational regions in the United States with environmental conditions. Summations of temperature for numerous stations, according to the different indices, were obtained, by employing the information accumulated in meteorological literature. In some cases the temperature indices were employed in connection with similar data on evaporation and precipitation, thus giving a series of combined indices. The whole country was then divided into zones according to the magnitude of the various summations obtained. While this work was essentially a study of plant distribution as related to climatic conditions, the methods employed promise to be of considerable value in connection with any general study of climatic conditions and the rate of plant growth.

In general, while each individual plant has its particular form of growth as influenced by various groups of internal factors, it is only reasonable to expect distinct fluctuations in the growth rate curve from day to day, brought about by changes in climatic environment. Moreover, the magnitude of the effect produced by climatic changes will depend to a considerable extent upon the stage of development reached by the plant. That is, the effect of

any single climatic factor such as temperature, is influenced in its action upon the plant by its relation to other climatic factors, and to the internal condition of the plant.

PROBLEM

The primary purpose of this work is to ascertain if possible the optimum dates of seeding corn and sunflowers. In view of the intimate relation existing between climatic conditions and the growth of a plant at any particular stage of its development, it becomes of interest to measure, if possible, the effect of the climate in promoting plant growth. The final yield is in most cases the only matter considered in dates of seeding experiments. But such data are of value only if collected for a considerable number of years. They are also of value only inthe particular district in which the work is carried out. In the present study, records for growth-rate, climatic conditions, and yields have all been kept. It is hoped by careful mathematical analysis of the data thus accumulated to derive fundamantal information as to the growth adaptations of these crops, which may throw light on their suitability to various parts of the country.

EXPERIMENTAL

Outline

The general method employed was that of seeding standard varieties of the sunflower Helianthus annuus and corn Zea Mays, at a number of dates, beginning quite early in the spring and continuing until about the first week in June. Growth measurement of a certain number of plants in each plot were taken at regular intervals. At the same time accurate meteorological records were kept, and careful observations were made after all spring and fall frosts. The varieties employed in the experiment were Mammoth Russian sunflower and North Western Dent corn. Both of these varieties are regarded as standard and are employed extensively in the experimental work of this station. The work was carried out during two years, 1920 and 1921. The land used for the 1920 experiments sloped slightly to the south and west. In 1919 this land was seeded to spring rye. In 1921 the experiment was carried out on land which produced a heavy crop of sunflowers in 1920. The slope of this land was from north to south.

Seeding

In 1920, five plots of corn and five of sunflowers were seeded, the plots of corn and sunflowers alternating with each other. The numbers of the plots and dates of seeding are given in Table 1. Plots 1, 2, 9, and 10 were seeded on the same date, May 14th, so as to act as checks in calculating the final yields. There were, therefore, four dates of seeding, at intervals of roughly ten days, from May 14th to June 10th. Each plot consisted of five rows, 50 links long and 3 feet apart. The rows were seeded east and west. A small hand seeder was employed for drilling in the seed, it being set so as to drop one seed about every

inch. Later, when the plants were about 6 inches high, they were thinned so as to leave 8 inches between plants.

In 1921 five plots of corn and six plots of sunflowers were seeded, one plot of sunflowers being seeded on May 3, to try the effect of a very early seeding. The numbers of the plots and dates of seeding are given in Table 2. In this year the plots of corn and sunflower did not alternate with each other as in 1920, but were planted in adjacent strips of land. This change in method of planting was made to eliminate, if possible, the factor of unequal competition between adjacent plots of corn and sunflowers. Plots 1, 5, 6 and 10 were seeded on the same date, May 10th, and were used as checks. This gave four dates of corn and five of sunflowers, arranged at ten day intervals. Each plot consisted of 4 rows, 130 links long, rows being 3 feet apart. Rows were seeded north and south. The methods of seeding and thinning out were the same as those used in 1920. In the early morning of May 28th the temperature dropped to 24°F. killing the corn plants of plots 1 and 5. These plots were reseeded May 30th.

Growth Measurements.

Increase in dry weight is generally taken as a measure of plant growth. This method is only accurate if a large number of plants are taken for each sample, a procedure which necessitates the seeding of quite a large area. Since the labor involved is also considerable, it was not found possible to follow such a method in this experiment. It was therefore decided to measure the rate of increase in height of the plants. This method has been followed by numerous investigators, including Reed and Holland (26), working with sunflowers and Prescott (25) working with corn.

In 1920 ten normal plants were selected in each plot, the use of border plants, or any having an accidental advantage in regard to

spacing, being avoided. A small wooden stake about the size of a pencil was driven into the ground about six inches from each plant so as to have the top of the stake level with the surface of the ground. The ten selected plants in each plot were then given numbers from one to ten, and records were kept throughout the season of their heights at different dates. The sunflower plants were measured from the top of the stake to the apex of the stem. In measuring the corn plants the height from the top of the stake to the highest leaf tip was taken, the measurements thus representing a combination of internode elongation of the plant itself, and of leaf growth. Measurements were taken for three day periods, and were carried out as nearly as possible immediately after noon each day. Measurements were begun June 5, but frost on the morning of June 13 badly injured the leaves of the corn plants, so measurements were discontinued until June 23. From this date they were continued at three day intervals until Sept. 9, with the exception of one period of six days, from Aug. 25 to 31st. In plot 8 measurements were kept of only nine plants, as one plant was found to be a dwarf and was discarded. Table 3 gives the mean heights (cm.) of the selected plants in each plot at the different dates. The mean actual growth in height (cm.) of these plants for the three day periods from June 23 to Sept. 9, is presented in Table 5.

In 1921 the general method outlined for 1920 was followed, but two changes must be noted. First, measurements were carried out for two days, instead of for three day periods. Second, the corn plants were measured from the top of the stake to the tip of the longest leaf, when the leaves had been stretched out to their full extent. In this way a more constant measure of growth was obtained than was possible in 1920, when the leaves tended to droop and appear shorter on very hot days. Measurements were begun June 20th

and were continued until Sept. 9. In a few instances measurements could be taken only after four day periods. The mean heights (cm.) of the selected plants in each plot at the different dates are presented on Table 4. The mean actual growth in height of the plants (cm.) for the different periods is given in Table 6.

Relative Growth

For the purpose of calculating the relative growth rates of corn and sunflowers in 1920, the heights of plants in plots 1, 3, and 9 of corn, and plots 2, 4, and 10 of sunflowers have been averaged for the different dates. These three plots in each group were considered to be at about the same stage of development. This gives two series of values, one representing the mean height (cm.) of thirty corn plants at different dates, while the other gives the same information for thirty sunflower plants. These averages are given in the last two columns of Table 3, while the corresponding growth increases are presented in the last two columns of Table 5. In 1921 plots 1, 2 and 3 of corn and plots 6, 7 and 10 of sunflowers have been treated in the same way. The mean height (cm.) of the two groups of plants at different dates are given in the last two columns of Table 4, while the corresponding growth increases are given in the last two columns of Table 6. Plot 5, although seeded on the same date as plot 1, was considerably shaded by the adjoining plot of sunflowers, and was therefore not used in making up this average.

The relative growth rate for these averages has been calculated for the two years from Blackman's (3) formula

$$H_2 = H_1 e^{rt}$$

or employing the common system of logarithms, and expressing the result as a percent

$$\frac{R}{100} = \frac{\log_{10} H_2 - \log_{10} H_1}{t \times 0.4343}$$

where $\underline{H_1}$ is the height of the plant at the beginning of the period, $\underline{H_2}$ its height at the end of the period, and $\underline{t}$, the length of the growth period - in 1920, 3 days and in 1921, 2 days. Calculated in this way $\underline{R}$. is the percent increase in height per day, per unit of height, for the whole period. The results for the two years are given in Table 7.

Harvesting and Yields

In 1920 the corn was injured to some extent by frost on Aug. 31, but as some growth was still taking place it was not cut until Sept. 20, when corn and sunflowers were harvested, both having been damaged by the low temperature of 28°F on Sept. 19th. The two outer rows of the plots were discarded, the yield for each plot being taken from the three central rows only. Thus, the plots as harvested each consisted of three rows, 50 links long. The green weight of fodder was obtained by weighing the plants as soon as they were cut. At the same time a representative sample was taken from each plot and the percent dry matter determined. Corrected yields per acre were calculated by the method outlined by Newton (23). The actual yields of the plots, together with the percent dry matter, and corrected yields in dry matter are given in Table 1.

In 1921 the corn was frozen on Sept.2, and was cut the following day. The sunflowers were not touched by this frost, but were injured by a frost on Sept. 10th. They were cut on Sept. 15th. In the case of plots 5, 6, 9 and 10 yields were taken from two rows, 100 links long. This was necessary as there was a noticeable competition between the four neighboring rows of corn and sunflowers in plots 5 and 6, and between the early and late seedings of sunflowers in the case of plots 9 and 10. The actual yields of these

plots given in Table 2 have been multiplied by two, in order to make them comparable with the yields of the other plots which consisted of four rows, 100 links long. The percent dry matter and corrected yields calculated as in 1920, are given in Table 2.

Temperatures

Temperature data for the two years were obtained from a self recording atmospheric thermograph situated close to the plots. The thermograph records were checked with daily readings of maximum and minimum thermometers. Since the growth measurements were made from noon to noon for the different periods, it becomes necessary to calculate the temperature values for similar periods. For this purpose the mean bi-hourly temperatures (Fahrenheit) from noon of one day until noon of the following day have been taken from the thermograph records. Table 20 (Appendix) gives the mean bi-hourly temperatures from noon June 23rd until noon Sept. 9th, 1920. Table 21 gives the corresponding data for 1921 from noon, June 20th until noon, Sept. 9th. From these values the mean temperatures (Fahrenheit) for the twenty-four hour periods from noon of one day until noon of the following day have been calculated. These temperatures have been translated to the corresponding centigrade readings and are presented in Table 8 for the two years. In this way a series of values have been obtained which are based upon not only the magnitude of the temperature, but upon its duration as well. In other words, they represent a series of weighted averages. These readings should be of infinitely greater use in interpreting plant growth than any average based upon maxima and minima readings for the day.

The mean temperatures (centigrade) for the three and two-day periods of growth, during 1920 and 1921 respectively, have been calculated from the mean temperatures for the twenty-four hour periods. The means for these periods of growth in 1920 are given in Table 12, those for 1921 in Table 13.

Temperature Indices

The problem of how best to express temperature in the interpretation of growth processes has been thoroughly discussed by Livingston and Shreve (19). They have employed a number of temperature indices in their zonation studies of the various types of vegetation in the United States. It has been decided to express the temperature data collected for this work in the form of some of the indices given by these authors. The five following temperature efficiency indices have therefore been calculated as described, for each of the periods of growth in 1920 and 1921, and are presented in Tables 10 and 11 respectively. The indices employed by Livingston and Shreve (19) were in the Fahrenheit scale. In the present work the centigrade basis has been used. Exponential indices have been obtained from Fahrenheit readings, but as will be seen, the numerical value of these indices is independent of the scale used.

(1) Direct Temperature Efficiency Indices.

This method assumes that above 0°C the rate of plant growth is directly proportional to temperature. The indices for each growth period have been obtained by summing the mean twenty-four hour temperatures (centigrade) for each two or three day period.

(2) Remainder Temperature Efficiency Indices. (Growth at 4.5° centigrade as unity).

These indices are really a modification of the direct

temperature indices, the difference being that the zero point of growth is moved from 0°C to up to 3.5°C, while at 4.5°C the rate of growth is assumed to be equal to unity. In calculating these indices, 3.5° has been subtracted from each mean twenty-four hour temperature (centigrade) and the remainders have been summed for the periods of growth.

(3) Remainder Temperature Efficiency Indices: (Growth at 10° centigrade as unity).

These indices are similar to those preceding except that 10°C has been chosen as the point at which unit growth takes place.

(4) Exponential Temperature Efficiency Indices:

The calculation of these indices is based on the assumption that at 40°F plant growth takes place at unit rate, and that for each increase of 18°F above this point, the rate of growth is doubled, according to the Van't Hoff-Arrhenius principle. The relation between temperature and the corresponding index of temperature efficiency is expressed by the equation

$$I = 2^{\frac{t-40}{18}}$$

where t is the mean twenty-four hour temperature (Fahrenheit) and I the corresponding efficiency index for plant growth. These indices have been calculated by Livingston and Livingston for all temperatures between 41°F and 100°F and are reproduced by Livingston and Shreve (19). The efficiency index for each mean twenty-four hour temperature (Fahrenheit) has been read from this table and the values obtained are presented in Table 8 for the two years. The indices for each period of growth were then summed.

(5) Physiological Temperature Efficiency Indices:

Lehenbauer's (18) data for the growth rates of maize seedlings at various temperatures when exposed for twelve hour periods,

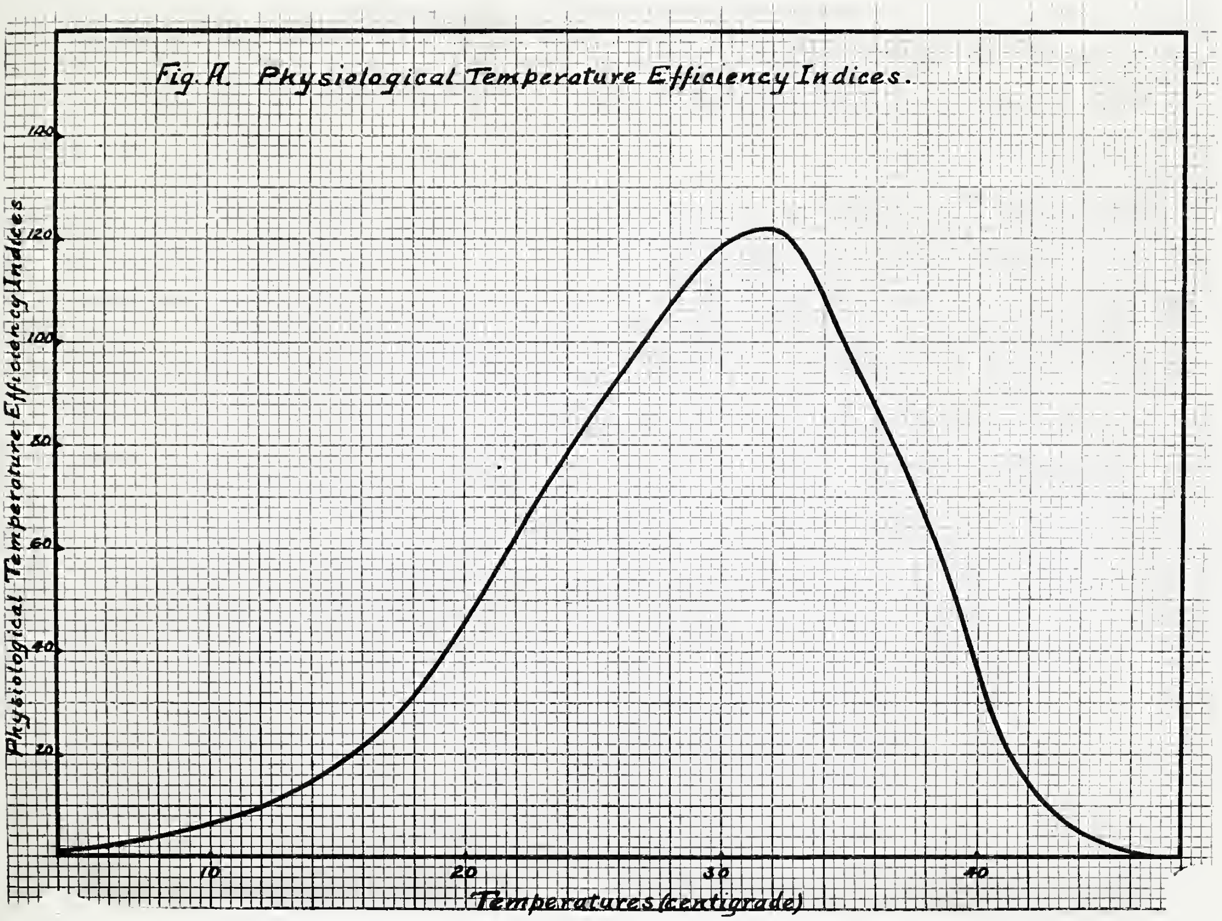

FIGURE A

Physiological Temperature Efficiency Indices based on Lehenbauer's twelve-hour exposures with Maize Seedlings.

has been used by Livingston in preparing these indices. Plotting growth rates as ordinates and temperatures as abscissae, a curve was obtained giving indices ranging from zero at 2°C through a maximum of 122.3 at 32°C to zero again at 48°C. These indices have been reproduced by Livingston and Shreve (19) in their work , and from them the curve given in Figure A has been prepared. In this way it was possible to read directly from the curve the index corresponding to each mean twenty-four hour temperature. These values are given in Table 8 for the two years. The indices for each period of growth were then summed.

Degree Hours:

This method of expressing temperature accumulations has been employed by Mosier (22) in his study of the climate of Illinois. He considered that the zero point of growth for corn was 49°(Fahrenheit), and calculated the degree hours for different periods by multiplying the number of hours during which the temperature is above 49°F by the number of degrees the average temperature is above that point. (Merriam (21) chose 6°C (43°F), as the lower limit for physiological activity in plants and reproductive activity in animals. Livingston and Shreve (19) have made quite general use of 40°F as the point of unit rate of growth in plants. Degree hours have been calculated from 40°F in this study, although it is realized that the position of the point of unit growth rate may not be exactly the same for both of the plants under consideration. The bi-hourly temperatures given in Tables 20 and 21 (Appendix) have been used in calculating the degree hours for each twenty four hour period for the two years, as presented in Table 8. From these values the degree hours for each period of growth have been obtained, as shown in Tables 10 and 11 for the years 1920 and 1921 respectively.

Finally, the values for each of the six temperature indices considered above have been summed from June 25 in 1920 and June 20 in 1921, to the end of each period of growth. Tables 14 and 15, therefore, give the summation of each of these indices to different dates, for the two years.

Relative Humidity

Records for relative humidity were not kept at the experimental plots but were obtained from the Monthly Record of Meteorological Observations issued by the Meteorological Service of Canada. The readings given for Edmonton were recorded about two miles from the experimental plots, and while probably not the same as those obtaining about the plants, will serve as a measure of the fluctuations from day to day. The hourly relative humidity for each day of July and August, 1920, and June, July, August and September of 1921, are given in these records. Relative humidity for June and September of 1920 were not given. The mean daily relative humidity, calculated from the hourly readings, and given in the records mentioned above, are reproduced in Table 9. The mean relative humidity for each period of growth was obtained by averaging all of the hourly readings for the corresponding periods. These means are given in Table 12 for 1920 and in Table 13 for 1921.

Temperature x Relative Humidity

With low atmospheric relative humidity, the water strain may become so great during the hotter part of the day that plants are unable to make use of the high growth possibilities of the existing temperatures. Growth under these conditions necessarily takes place at a slow rate, as the plant cells are unable to maintain their turgidity. Prescott (25), working on the growth of maize in Egypt,

found that the growth rate fell distinctly during the hours of great heat, due to the low atmospheric relative humidity. A high temperature combined with high relative humidity, should give conditions most favorable for rapid growth. The value

$$\frac{TR}{10}$$

has been employed in this study in an attempt to express a combination of temperature and relative humidity favourable to plant growth. Here, T is the mean temperature (centigrade) for the period of growth, and R the mean relative humidity for the corresponding period. The large products which resulted have been reduced by dividing by 10 in each case. The resulting values have been presented for 1920 in Table 12; those for 1921 are given in Table 13.

Precipitation

In 1921 the rain gauge recording daily precipitation was situated close to the plots. In 1920 records were kept in another field about one quarter of a mile distant. The daily precipitation in inches from June 23 to September 9 in 1920, and from June 20 to Sept. 9 in 1921, is given in Table 9.

Sunshine

The duration of sunshine for each hour of daylight from June 20 until September 9 of both years was obtained from the Dominion Government Meteorological Station in Edmonton. The readings were taken by means of a Campbell Stokes Sunshine Recorder. This information has been reproduced in Tables 22 and 23 (Appendix). The hours of sunfhine for each day of the two years from June 20 to September 9 are given in Table 9. The total hours of sunshine for each growth period, as given in Tables 12 and 13 for the years 1920 and 1921 respectively, were obtained from Tabler 22 and 23 (Appendix). The mean daily hours of sunshine for the growth periods for the two years are given in Tables 12 and 13.

Maximum Solar Radiation

The maximum solar radiation (Fahrenheit) for each day, obtained from a black bulb *in vacuo*, is given in Table 9, for the period from July 4 to September 8, 1921. These records were supplied by the Dominion Government Meteorological Station at Edmonton. Records for 1920 and for the remainder of 1921 were not available. Since the readings for 1921 are maximum readings for each day, they cannot be accurately translated into corresponding means for the two day periods of growth. But, since the maximum reading would probably occur for most days about or shortly after noon, it has been decided to treat the maximum for each day as being that for the twenty-four hour period which begins at noon of that day. For example, the mean daily maximum solar radiation for the growth period noon July 4 to noon July 6, has been found by averaging the readings for July 4 and July 5. The means calculated in this way are given in Table 13.

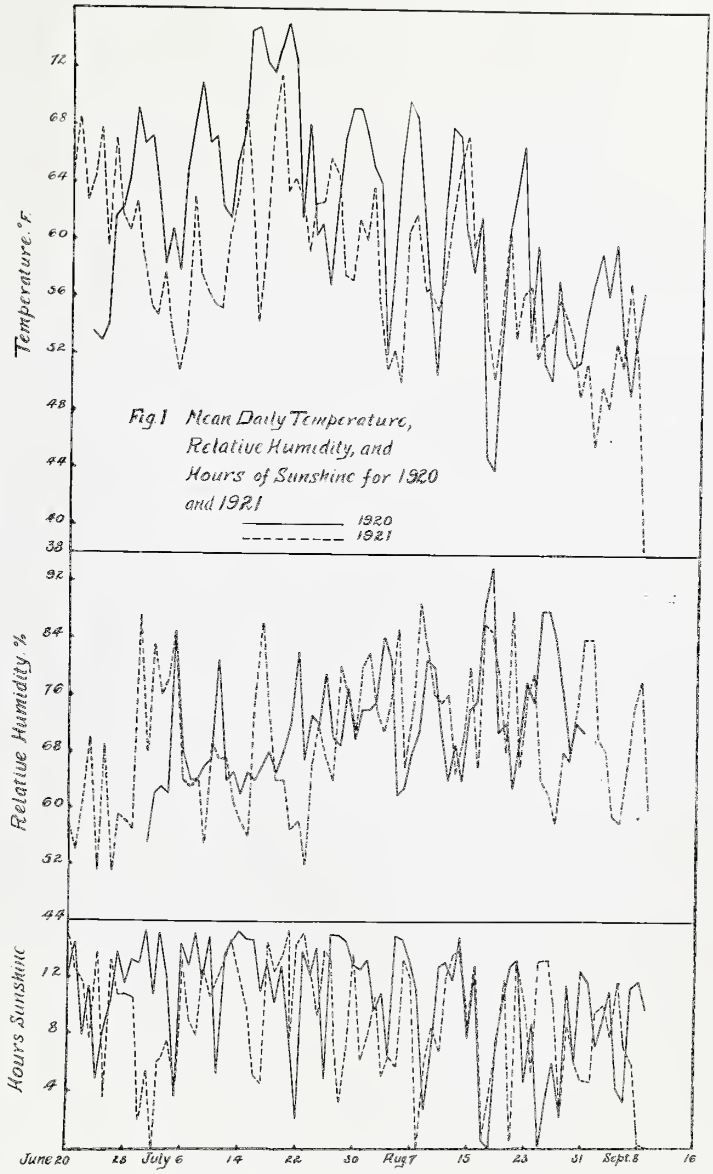

FIGURE 1

Mean Daily Temperature (Fahrenheit), Mean Daily Relative Humidity, and Daily Hours of Sunshine for 1920 and 1921.

DISCUSSION

Climate

In figure 1, the daily temperature, daily relative humidity and daily hours of sunshine for the growing seasons of 1920 and 1921 are shown for the purpose of comparing the climatic changes during the two years. The temperatures are those given in columns 2 and 7 of Table 8. The mean daily relative humidity, and total daily hours of sunshine are taken from Table 9. An examination of the data presented in this figure shows, first of all, that the three elements considered undergo quite violent fluctuations from day to day. The temperatures rise until the highest values are attained about the middle of July, then fall off gradually towards the end of the summer. The temperatures for 1920 are generally higher than those for 1921 and seem to rise and fall less frequently. From June 23 to Sept. 9 of 1920 there were 40,292 degree hours. From June 20 to Sept. 9 of 1921, a slightly longer period, there were only 35,302 degree hours.

Unlike temperature, the relative humidity for the two years rises gradually as the season advances. The curve for 1920 is generally higher than that for 1921, and until the end of July is more uniform and contains fewer sudden drops.

The curve for daily hours of sunshine follows fairly closely the temperature curve. The 1920 readings, moreover, are for a great part of the time considerably higher than those for 1921. Table 16 which gives the total hours of sunshine for the months of June, July and August of the two years brings out this difference more clearly.

Table 16 - Total hours of sunfhine for June, July and August of 1920 and 1921.

Month	1920	1921
June	257.7	301.0
July	376.5	311.1
August	276.6	252.9
Total	910.8	865.0

It will be readily seen that the differences in July and August are responsible for the higher total during 1920.

The precipitation for the two seasons has been purposely omitted from figure 1, as the growing plants draw not only upon the rainfall which they receive during the summer months, but from the supply stored up in the soil as well. The total precipitation from the end of the growing season of the previous year should be a fair measure of the moisture which is available to the growing plant when it begins growth. This information is presented in Table 17, together with the rainfall for the months of July and August.

TABLE17

Precipitation from Sept. 1, 1919 to Aug. 31, 1921.

Year	Month	Rain	Snow	Total
1919	Sept.	1.38	0.2	1.40
1919	Oct.	0.47	18.1	2.28
1919	Nov.	0.04	18.5	1.89
1919	Dec.	---	8.2	0.82
1920	Jan.	0.03	19.9	2.02
1920	Feb.	0.01	2.9	0.30
1920	March	----	12.6	1.26
1920	Apr.	0.45	3.9	0.84
1920	May	2.00	4.3	2.43
1920	June	4.49	----	4.49
	Total	8.87	88.6	17.73
1920	July	2.23	----	2.23
1920	Aug.	1.12	----	1.12
	Total	12.22	88.6	21.08
1920	Sept.	1.31	----	1.31
1920	Oct.	0.62	1.6	0.78
1920	Nov.	0.01	1.7	0.18
1920	Dec.	----	2.5	0.25
1921	Jan.	----	7.9	0.79
1921	Feb.	----	13.6	1.36
1921	March	0.07	15.8	1.65
1921	Apr.	0.08	2.5	0.33
1921	May	1.03	2.4	1.27
1921	June	3.08	----	3.08
	Total	6.20	48.0	11.00
1921	July	3.13	----	3.13
1921	Aug.	1.52	----	1.52
	Total	10.85	48.0	15.65

while the precipitation for July and August of 1921 was greater than for the same period of 1920, it will be readily seen that 1920 was characterised by a heavy precipitation in June, which brings the total for June, July and August slightly higher than for the same three months in 1921. In addition to this the precipitation for Sept. 1, 1919 to the end of May 1920 is considerably higher than that for the same period during 1920 and 1921. This difference was largely due to the heavy fall of snow in the winter of 1919-1920.

In brief, then, the summer of 1920 was marked by high temperatures during the three growing months, combined with favorable soil moisture conditions. In 1921 temperatures were considerably lower, while the amount of moisture stored in the soil at the beginning of June must have been much less than at the same time in 1920.

Growth

An examination of Tables 1and 2 shows that the time from seeding to appearance of the plants above ground, decreases with each date of seeding. In 1920, in the case of the first seeding of corn, eighteen days elapsed between the time of seeding and the appearance of the plants, while sunflowers seeded the same date required only eleven days. At the last seeding these times are reduced to eight days and seven days respectively. In 1921 the results are much the same. This shortening in the length of time for germination is probably due to the higher soil temperatures which obtain as the season advances. No soil thermograph records were kept in the spring of 1920, but the readings for 1921 show that the soil temperature increased from 53° F. on May 14 to 65° F on June 9. The soil temperatures at this time, therefore, have

PLATE I

Effect of frost injury on the growth of sunflowers.
Left to right; two branching plants, two plants with leaves curled, normal plant.

an important bearing upon the dates of seeding these two crops. In 1921, corn and sunflowers seeded on May 30, twenty days after the first seeding on May 10, were only fourteen days later than the first seeding in appearing above the ground. This is equivalent to a gain in time of nearly a week.

In 1920 the temperature dropped to 29°F. on the morning of June 15, doing considerable injury to the first and second seedings of corn. These plants recovered, however, and a second seeding was not necessary. The sunflowers were not noticably injured by this frost. Corn seeded on May 31 escaped this frost as it did not appear above the ground until June 14.

In 1921 the first seeding of corn was killed by frost on May 28, when the thermometer registered 24°F. It was necessary to reseed these plots. In this year, then, the earliest seeding of corn, which escaped frost injury, was that of May 20. The sunflowers while not killed by the frost seemed to have suffered injury. The leaves of some were later seen to curl slightly, and a number of the plants assumed a branching form, possibly due to injury of the growing point. In Plate 1 four of these plants are shown beside one uninjured plant. It is well known that in most of the common varieties of sunflower, plants can be found which show this branching habit. Strains have been selected which breed true for this factor. But of the many forms which appeared after this frost, probably only a few were due to any hereditary differences in the plants. This is brought out by the following count of the abnormal plants in different plots taken on June 23rd, 1921.

Plot 6	76
Plot 7	17
Plot 10	79
Plot 11	98

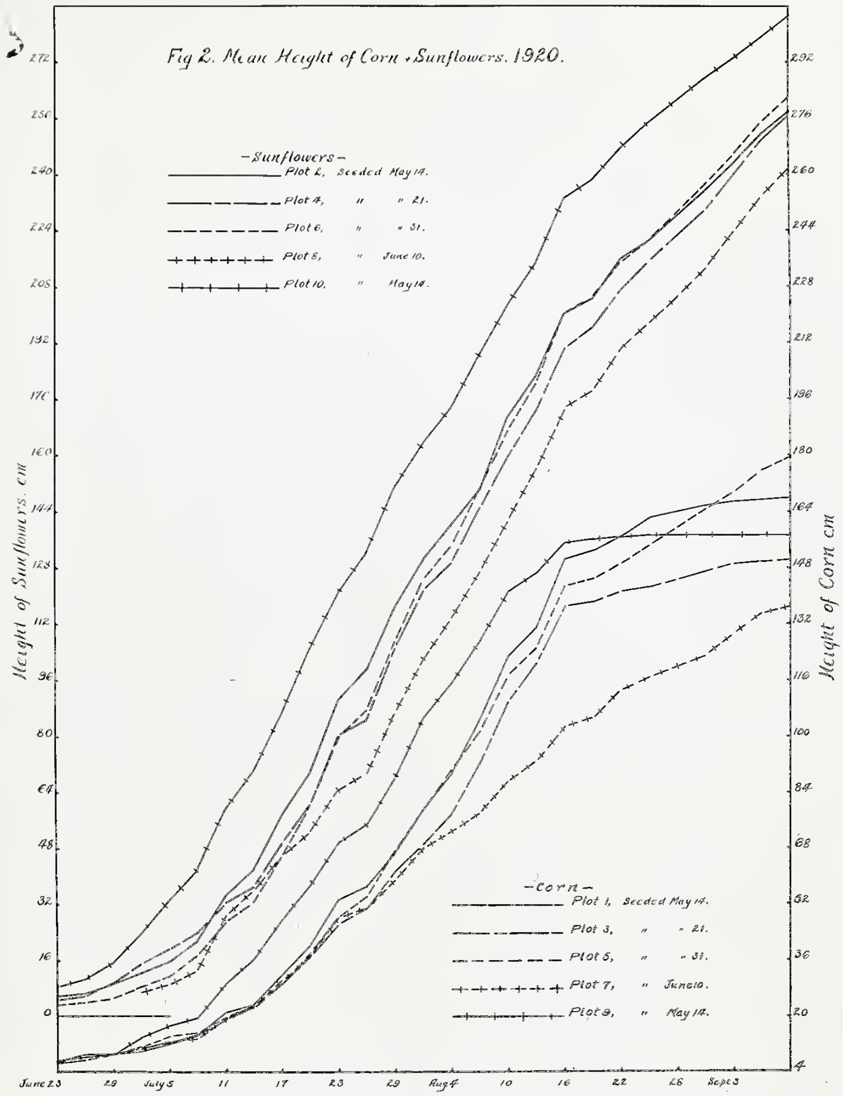

FIGURE 2

Mean Height (cm.) of Corn and Sunflower Plants at Different Dates in 1920.

Since plants of plot 7 did not appear above the ground until June 1, they could not have been affected by this frost. Plot 11 which was seeded on May 3, was injured most of all.

It therefore appears that a temperature of 29°F. in 1920 did considerable injury to the corn, but apparently had no effect upon the sunflowers. In 1921 a temperature of 24°F. completely killed the corn plants and slightly injured the sunflowers.

Thus far it has been shown that the earliest seeding of corn to escape frost injury in 1920, was that of May 31, which appeared above the ground on June 14. In 1921 the seeding of May 20, which appeared June 4, was the earliest safe date. But in some years it is possible that corn seeded at either of these dates might be frozen. Data collected for a number of years must be made use of in studying this part of the problem. Records of the late frosts at Edmonton kept for the years 1894 to 1917 inclusive, have been referred to in this connection. According to these records corn above the ground on June 4 would have been frozen in six years out of the twenty-four years considered, while corn seeded so as to be above the ground not before June 14, would have been frozen only in three years out of twenty-four. In other words, the seeding of corn at the end of May would greatly reduce the danger from late spring frosts.

The mean heights of the ten plants in each plot at different dates in 1920, are shown in figure 2. The most noticeable thing in this figure is the much greater height attained by the sunflowers. This may have been to a slight extent due to the method used in measuring the corn in 1920. In the case of the sunflowers the best growth as measured by height, was made by plot 10, which was seeded on May 14. The other plot of sunflowers, seeded on this date, did

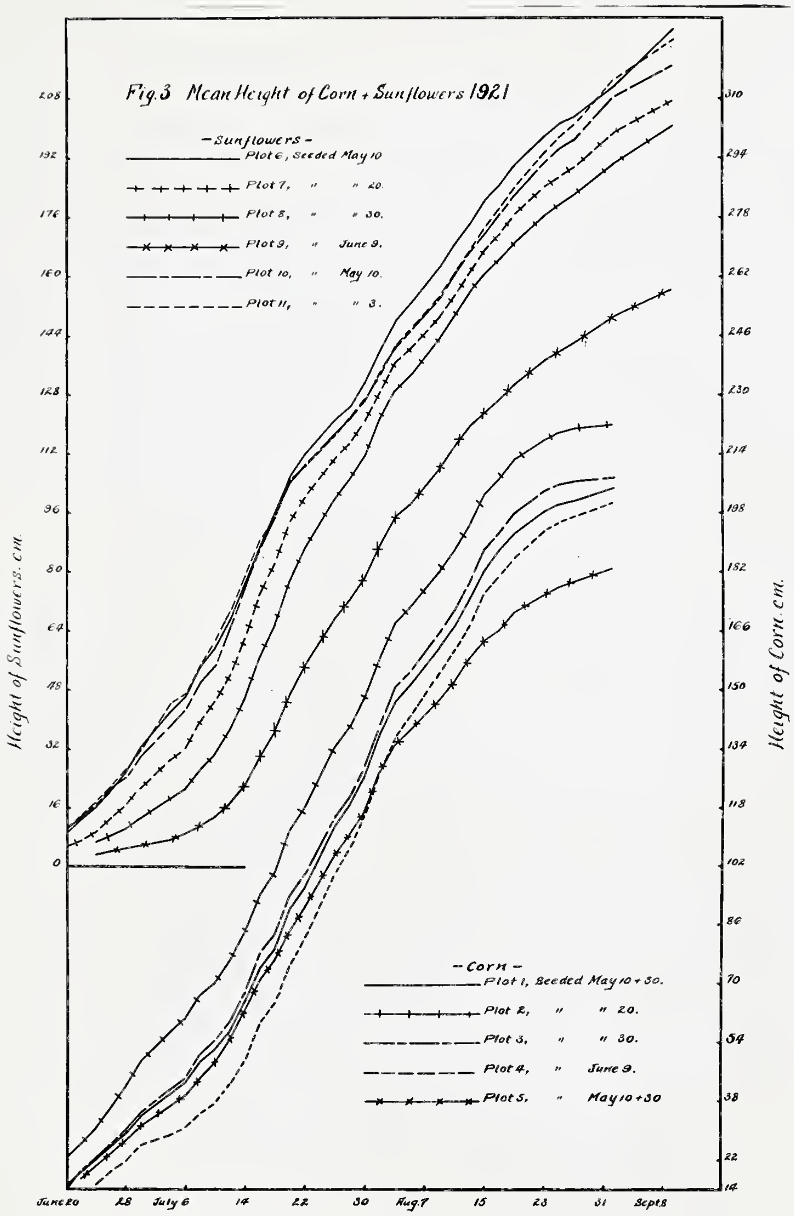

FIGURE 3

Mean Height (cm.) of Corn and Sunflower Plants at Different Dates in 1921.

not make such good growth, probably because it was situated at the south end of the block, on lower ground. Plot 8, the last seeding, made the poorest growth of all. None of the plots of sunflowers had reached maturity at the end of the season, as all were still growing rapidly when the last measurement was taken.

Of the plots of corn shown in figure 2, the best growth was made by the seeding of May 31, while the poorest growth was made by plot 7, seeded only ten days later. It therefore appears that a difference of ten days in the date of seeding at this time, has, in the case of both corn and sunflowers, an important influence upon the ultimate height which the plants attain. The most mature plots of corn as judged by these growth curves, were those seeded May 14 and May 21. Plots 5 and 7, seeded May 31, and June 10 respectively, were still growing when the last measurements were taken.

The same fluctuations in the growth rate from day to day can be noticed in all of the plots, showing that environmental conditions have affected all of the plants of both corn and sunflowers in much the same way. Plot 10 which made the most rapid growth has apparently been influenced by these changing conditions less than any other plot. Most of the growth has been made by all of the plots during the month of July and the first half of August. Between August 15 and 18 the growth was suddenly checked, and from that point onwards proceeds at a much slower rate.

The mean heights of the ten plants in each plot, at different dates in 1921 are shown in figure 3. It will be remembered that in this year a new method of measuring the corn plants was adopted. But the final heights recorded for the plants in 1921 were not greatly affected by the method of measurement, as in both years the last height measurements were taken to the tip of the stam-

enate inflorescences which remained quite erect and generally exceeded the leaves in length.

An examination of the curves presented in Figure 3, shows that the growth made by the sunflowers in 1921 was much less than during the season of 1920. Corn on the other hand seems to have made better growth. The early seedings of sunflowers have attained the greatest height, while as in 1920 the late seeding of June 9 has made a very poor showing. The corn of plot 2, seeded on May 20, has made very rapid growth. Plot 3, seeded on May 30, has also reached a good height. Some of the plants of plot 5 were shaded by the adjoining plot of sunflowers, and for that reason the mean height of this plot has been reduced. While the corn had nearly ceased growth at the last measurements, the sunflowers, as in 1920, show no sign of any retardation in the growth rate.

A study of the growth curves presented for the two years shows that the early seeding of sunflowers seems to be advisable, while corn seeded from May 20 to May 31 gave the best results. Earlier maturing varieties of both corn and sunflowers are necessary if the plants are to complete their life cycles during the growing season at their disposal, While the sunflowers made much better growth in 1920 than 1921, conditions for the growth of corn seem to have been better in the latter year.

Yields

The corrected yields in tons of dry matter per acre are given in Tables 1 and 2, together with the per cent dry matter for each plot as determined by drying in an electric oven at 100°C. The dry matter content of the corn remained roughly the same for the two years, the highest value being 18.4% for plot 5 in 1920, and the lowest 13.9 % for plot 4 in 1921. The very high dry matter content of plot 5 in 1920 and plot 3 in 1921, was very probably due to the fact that both of these plots were

growing very rapidly when injured by the fall frosts. Injury to the leaves in such a case would be very severe, with the result that they would quickly lose their moisture content. In 1920 it was noticed that the frost of Aug. 31 caused more damage to plot 5 than to any other plot of corn. The high dry matter content of 17.9% for plot 9 in 1920 is unquestionable, due to the favorable state of maturity of this plot, which was situated on the warm dry land at the north end of the block.

The dry matter content of the sunflowers is appreciably lower than that of the corn in 1920, while in 1921 their relations in this respect are reversed. The favorable dry matter content of the sunflowers in 1921 seems to have been associated with poor growth and low yield.

It has been already stated that the method outlined by Newton (23) was used in calculating corrected yields. In 1920 the block of ground used for the experiment sloped gently from plot 10 to plot 1. The slope, however, was uniform throughout, as will be seen from an examination of the actual yields in green weight for that year. In the 1921 experiment, the only slope was north and south, the direction in which the plots were seeded. The use of this method of calculating corrected yields is therefore justifiable.

The yields of sunflowers in 1920, given in Table 1, are about double those for corn during the same year, notwithstanding the lower dry matter content of the sunflowers. The highest yield of sunflowers was given by the early seedings, and the yields tend to fall as the dates of seeding become later. The best corn yield was produced by the May 31 seeding, although the seedings of May 14 also gave quite good yields. The poorest yield of corn was given by the late seeding of June 10.

In 1921 the yields of sunflowers have fallen off greatly, while the corn yields are considerably higher than in 1920. Plot 11, the very early seeding of sunflowers, has given the highest yield of the block, but with this exception, the sunflower yields are slightly below those of the corn. The highest yield of corn is again given by the plot seeded at the end of May, while the lowest yield is given by the late seeding of June 9. Plots 1 and 5 of corn which were reseeded on May 30, have given slightly lower yields than plot 3, while theoretically, all should have the same percent dry matter and yield. This may be due to the fact that a few plants in plots 1 and 5 which were frozen off, came up again before the new plants were thinned out. It is also possibly due to the experimental error of the work. In any case, the conclusions which may be drawn from this work are not seriously affected by this difference. Since the frost of May 28, 1921 caused some injury to the sunflowers which were above the ground at that time, it is only reasonable to believe that the yield of these plots would be reduced accordingly. An examination of the yields given in Table 2, however, shows that plots 7, 8 and 9, which were not subjected to this frost, have also given much lower yields than the corresponding dates of seeding in 1920. The low sunflower yields for 1921 must have been due to some other cause than frost injury. The probable cause for this reduction in yield will be considered later.

From the discussion of frost observations, growth measurements, and final yields in the foregoing pages, some decision may now be arrived at regarding the optimum dates of seeding these crops.

Dates of Seeding

Data collected for two years show that corn seeded about May 31 germinates and starts growth quickly, makes rapid growth, and attains a good height, as shown by the growth measurements, and at the same time has given the best yield of dry matter per acre. According to the records of late frosts kept at Edmonton, corn appearing above the ground June 14, might be expected to receive frost injury one year in every eight. Nothing would be gained by delaying the seeding of corn much beyond May 31 for two reasons. First, the yields from the June 9 and June 10 seedings have been low in both years. Second, of the three spring frosts which occurred after June 14, two came on June 24. At this time, corn seeded even after June 10 would be subject to frost. Therefore, the danger from frost would be only very slightly reduced by seeding after May 31. It appears, then, that the optimum date of seeding corn for this district is about May 31.

In both years the early seedings of sunflowers have given the most rapid growth and the best yields. In 1921 the May 3 seeding gave the highest yield of the block, notwithstanding the fact that some of the plants had been injured by frost. The data at hand, therefore, show that the seeding of sunflowers as early as May 3 is profitable.

The need for earlier maturing varieties of both corn and sunflowers is emphasized by this study. The ability of the sun-flowers to withstand light spring and fall frosts gives them a slightly longer growing season than the corn, but even with this advantage the variety of sunflower employed in this work failed to reach that stage of maturity necessary for the production of good quality silage.

Growth and Climate

The relative growth taken from Table 7, and actual growth,

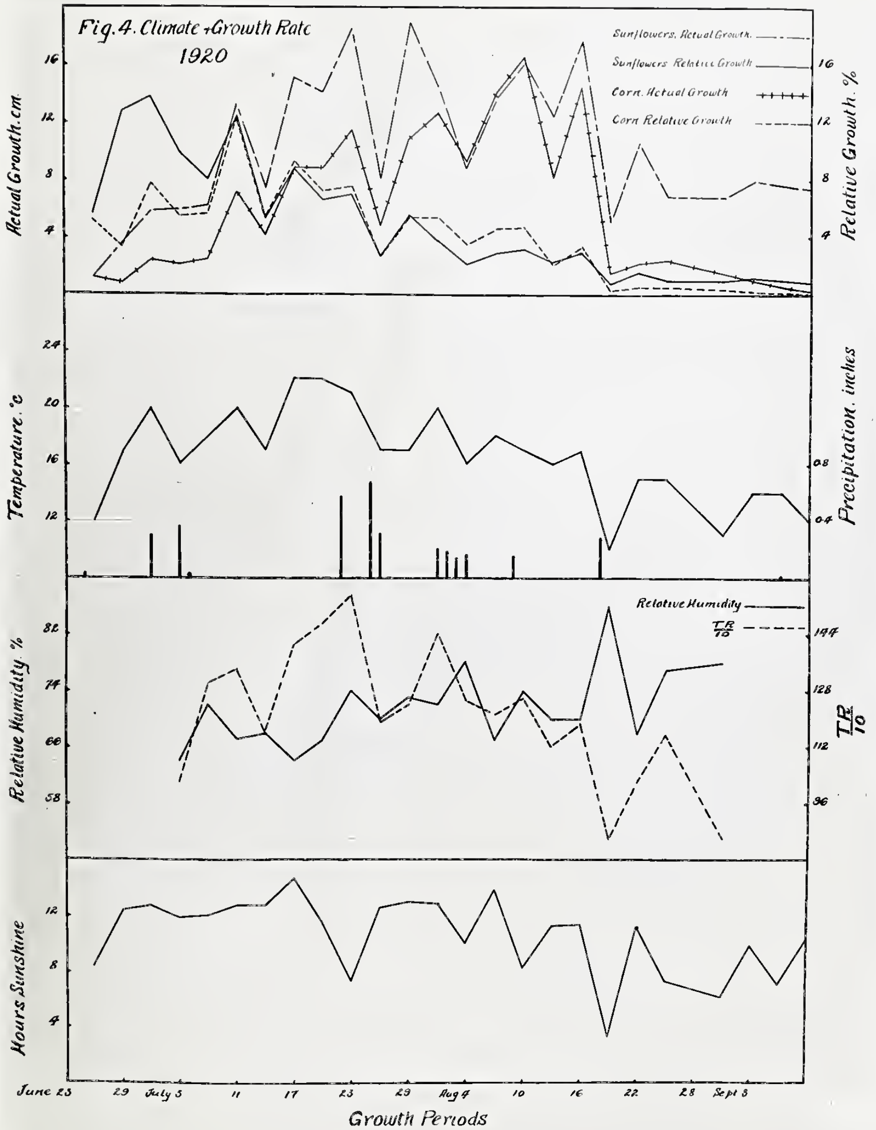

FIGURE 4

Actual and Relative Growth of Corn and Sunflower Plants for three-day periods in 1920, together with Mean Temperature (centigrade), Precipitation (inches), Mean Relative Humidity; the product $\frac{TR}{10}$ and Mean Daily Hours of Sunshine for corresponding periods.

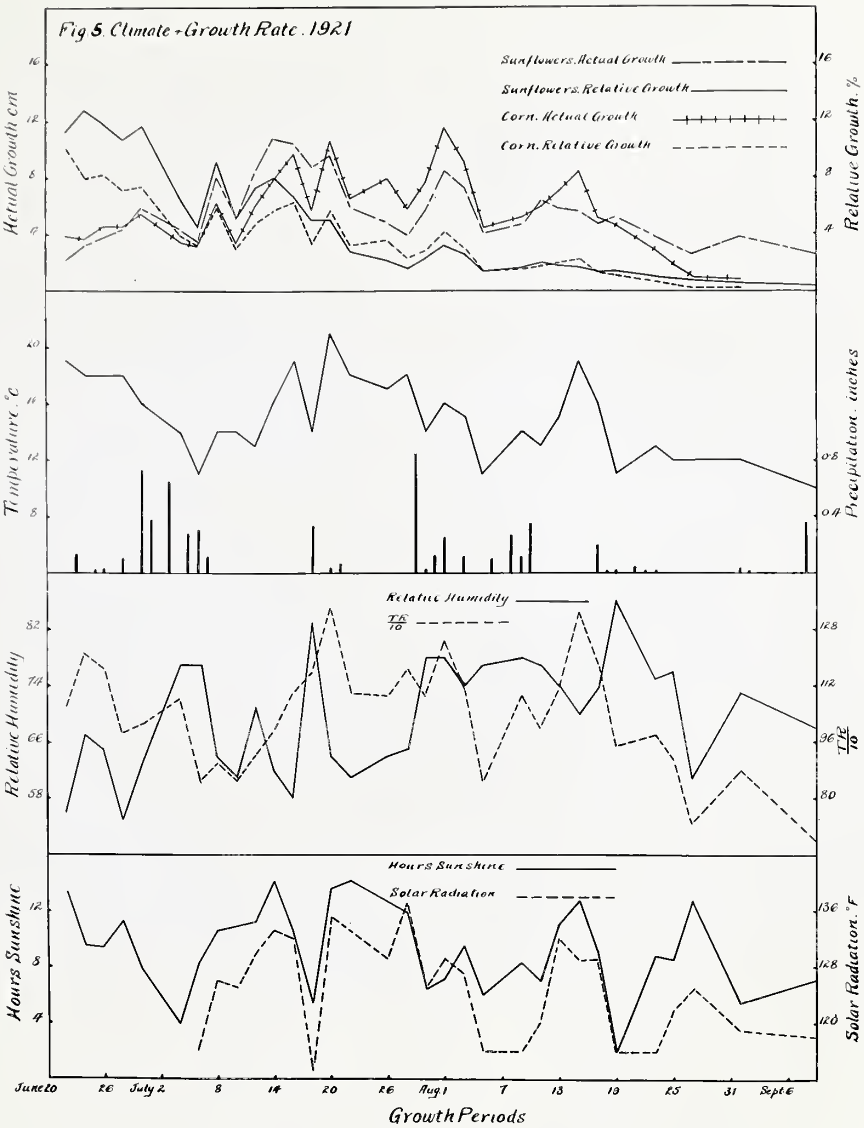

FIGURE 5

Actual and Relative Growth of Corn and Sunflower Plants for two-day periods in 1921, together with Mean Temperature (centigrade) Precipitation (inches), Mean Relative Humidity; the product $\frac{TR}{10}$, Mean Daily Hours of Sunshine, and Mean Maximum Solar Radiation (Fahrenheit).

taken from the last two columns of Tables 5 and 6, for the years 1920 and 1921, together with the corresponding climatic data, is presented in figures 4 and 5. It will be seen by referring to Tables 5 and 6 that once in 1920, and six times in 1921, the growth measurements were taken after longer than the regular periods. For the purpose of avoiding any confusion in the presentation of the actual growth in these charts, the growth for these periods has been reduced to a mean for the two or three day period, according as the year is 1921 or 1920. For example, the growth given in the tables for a six day period in 1920 or a four day period in 1921, has been divided by two and the resulting values have been plotted in the two figures. The relative growth rate calculated by Blackman's (3) formula is independent of the length of the period of growth. Precipitation taken from Table 9 is presented in inches for the days on which it fell. All of the other climatic data have been presented as means for the periods of growth, as taken from Tables 12 and 13.

In 1920 the relative growth rate is quite high at the beginning of the season, but falls considerably towards the latter part of July, while at the end of the season it takes the form of a straight line almost parallel to the time axis. In 1921 the curve has much the same form. The fluctuations from day to day in both years follow those of the actual growth rate curve, but from about the end of July the relative growth rate seems to be unaffected by environmental factors. The growth in height, then, of corn and sunflowers, seems to ha ve no strict relationship to the height which the plants have already attained, but falls in an irregular manner from the beginning to the end of the season.

The actual growth rate for the two years fluctuates from day to day with the environmental conditions. In 1920 the actual growth

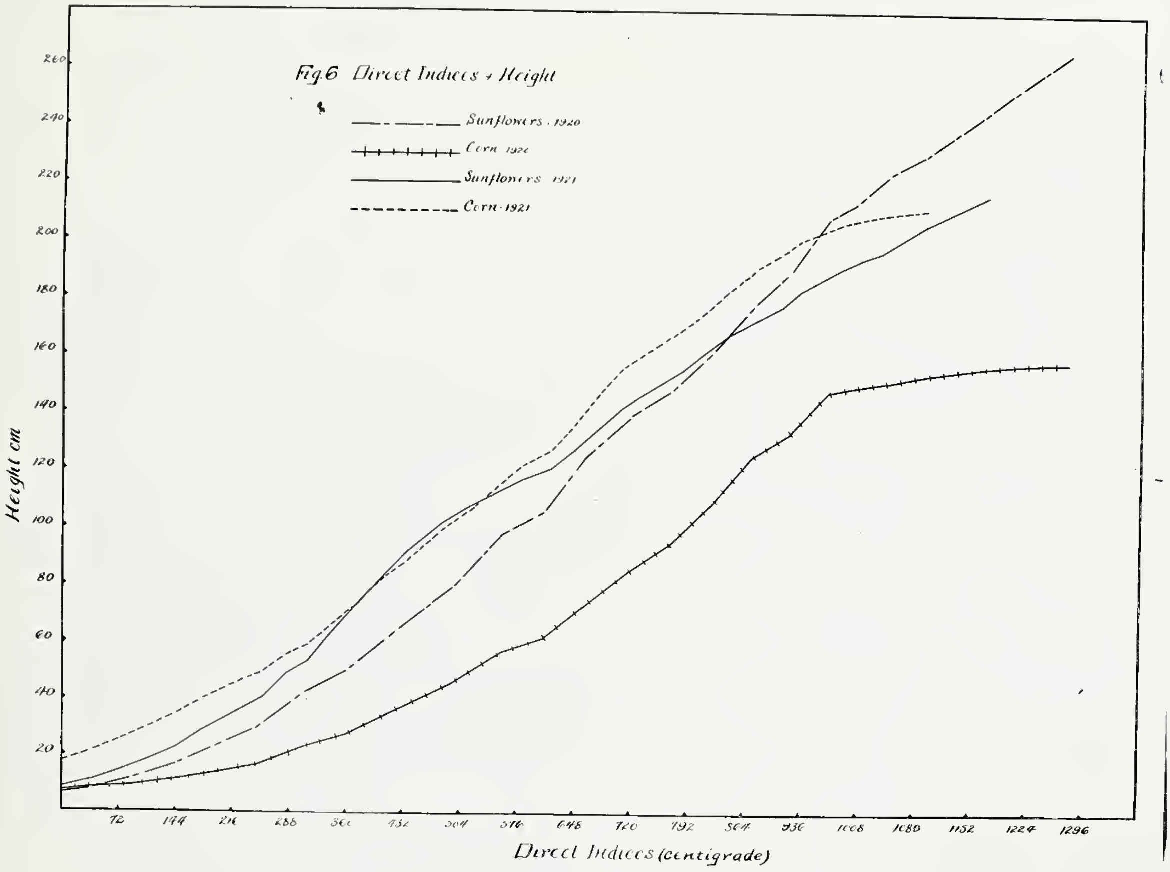

FIGURE 6

Direct T mperature Efficiency Indices (centigrade) and the Growth in Height of Corn and Sunflowers in 1920 and 1921.

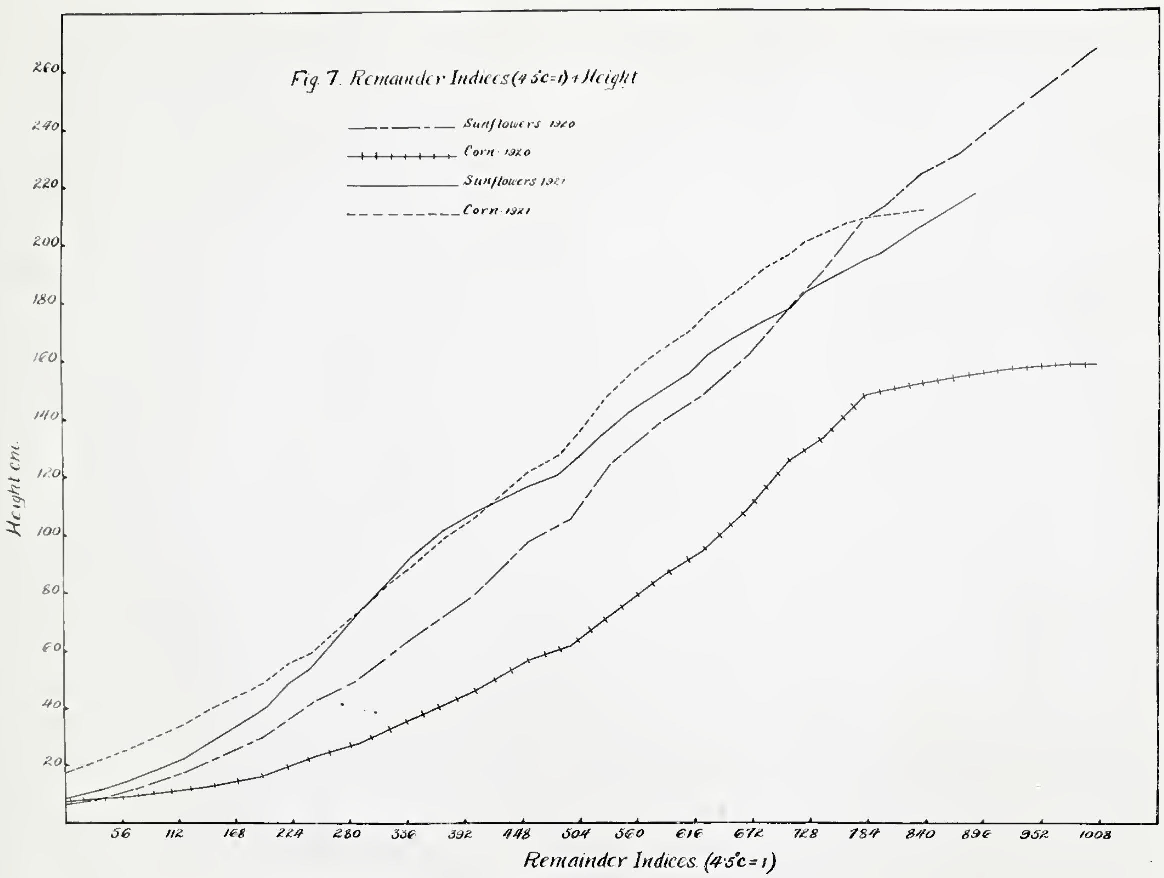

FIGURE 7

Remainder Temperature Efficiency Indices (4.5°D = 1) and the Growth in Height of Corn and Sunflowers in 1920 and 1921.

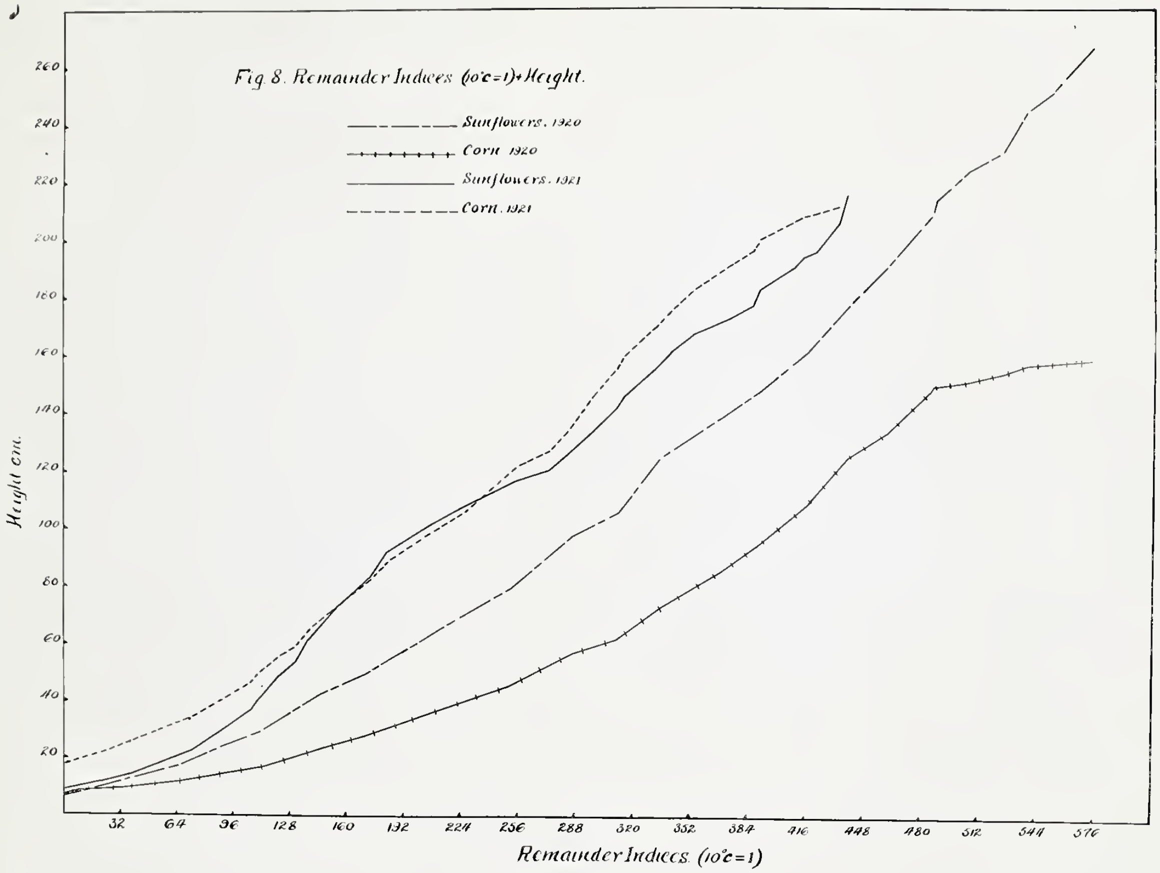

FIGURE 8

Remainder Temperature Efficiency Indices (10°C = 1) and the Growth in Height of Corn and Sunflowers in 1920 and 1921.

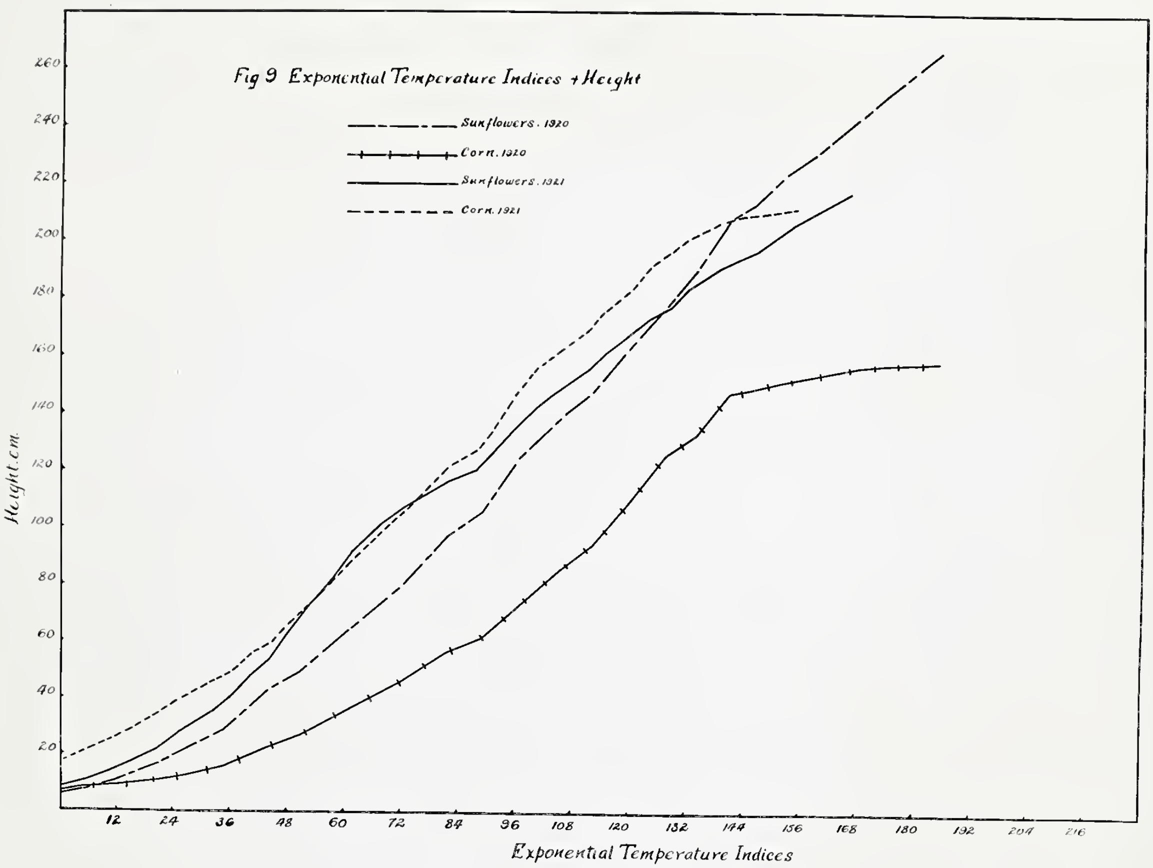

FIGURE 9

Exponential Temper ture Efficiency Indices and the Growth in Height of Corn and Sunflowers in 1920 and 1921.

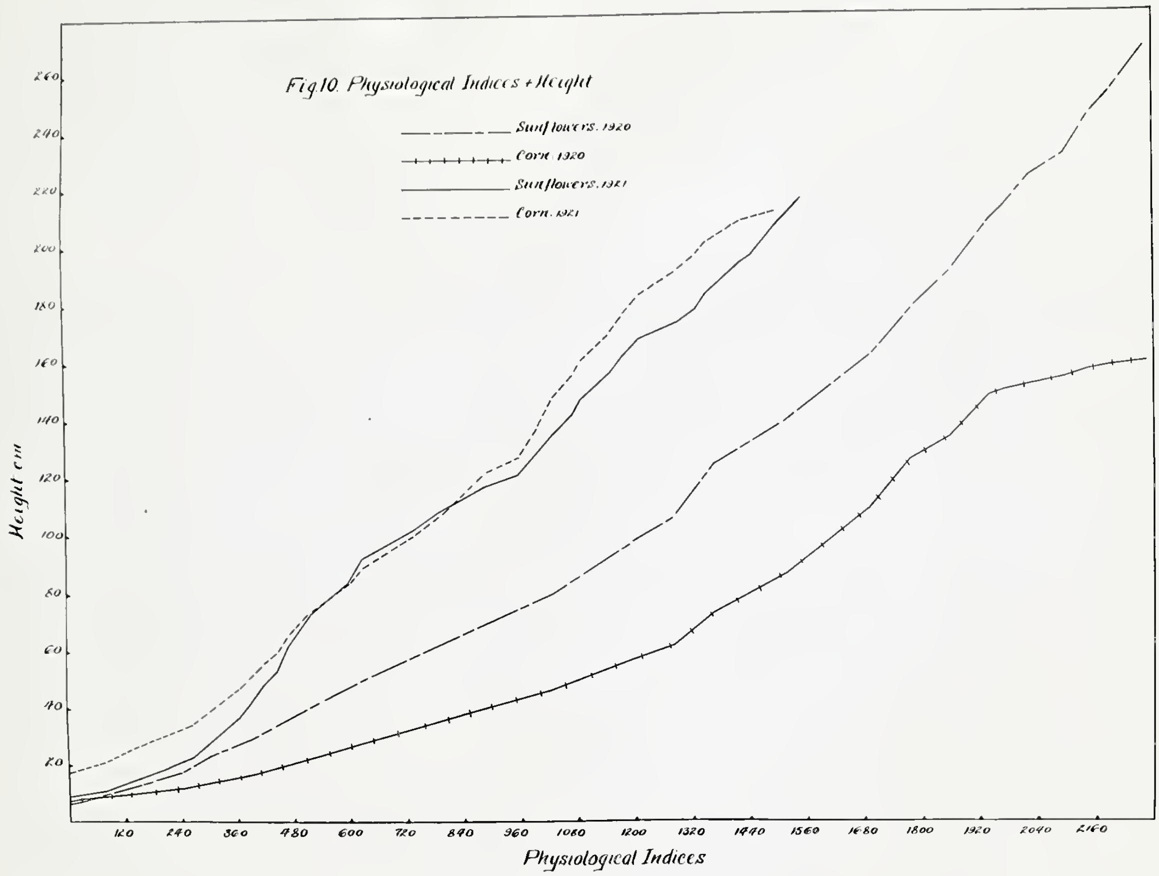

FIGURE 10

Physiological Temperature Efficiency Indices and the Growth in Height of Corn and Sunflowers in 1920 and 1921.

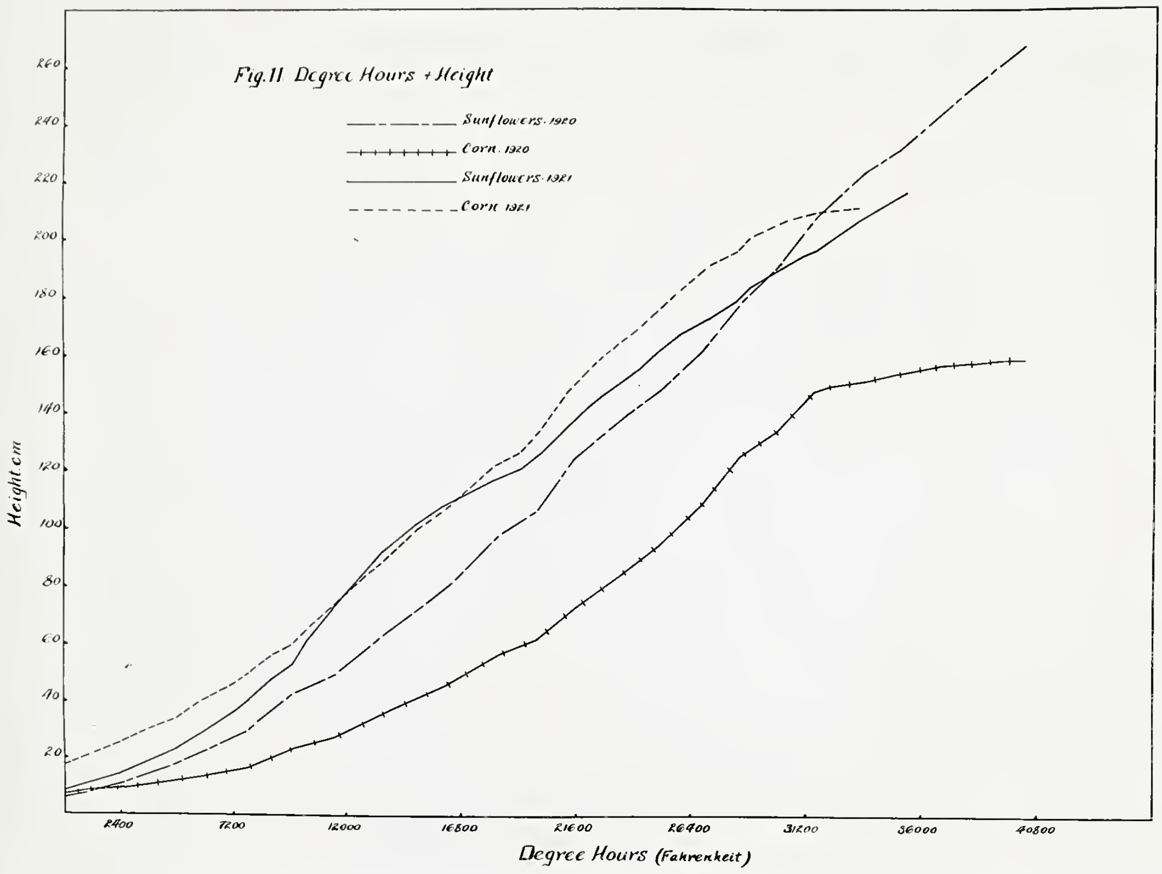

FIGURE 11

Degree Hours (Fahrenheit) above 40° F. and the Growth in Height of Corn and Sunflowers in 1920 and 1921.

rate of corn is considerably lower than that of the sunflowers. This is probably due to the method used in measuring the corn, as towards the middle of August, when the tassel of the corn plant was being measured, the growth of the corn is about equal to that of the sunflowers. In 1921 the actual growth rate of the corn is quite often higher than that of the sunflowers. This is especially noticeable at high temperatures, suggesting that at high temperatures the corn makes more favorable growth than the sunflowers. The time during which the most rapid growth was made extended from about July 11 to Aug. 19 in both years. This period coincides with a time of quite high temperatures. The sudden drop in temperature about August 19 in both years is accompanied by a sudden drop in the growth rate after which neither of the plants make very rapid growth. The corn almost ceases growth at this point, while the sunflowers continue to make considerable growth, but at a much reduced rate.

In some cases precipitation has accelerated the growth rate even where the temperature remained the same or has fallen. The best growth has been made where precipitation was followed by increasing temperatures. There seems to be little relations between growth and relative humidity. The product $\frac{TR}{10}$ does not seem to have as close a relation to growth as does the temperature curve. The hours of sunshine, and solar radiation naturally show quite a close correlation with each other, and with the temperature curve.

Since the relation between temperature and growth seems to be so intimate, it is of interest to consider the coefficients of correlation for a few of these plots. The coefficients of of correlation with the direct indices of Tables 10 and 11, have been calculated for each date of seeding of corn and sunflowers

for the two years. The method of Ayres has been used.

TABLE 18
Correlation Coefficients for Direct Indices and Growth

1920

Corn	r	Sunflowers	r
Plot 1	.3613 ± .1173	Plot 2	.5184 ± .0987
Plot 3	.3389 ± .1194	Plot 4	.4184 ± .1113
Plot 5	.3479 ± .1186	Plot 6	.4729 ± .1047
Plot 7	.4793 ± .1108	Plot 8	.2864 ± .1320
-	---	-	---

1921

Corn	r	Sunflowers	r
Plot 2	.4564 ± .0959	Plot 6	.6496 ± .0689
Plot 3	.4000 ± .1017	Plot 7	.4854 ± .0911
Plot 4	.4814 ± .0963	Plot 8	.5427 ± .0869
--	---	Plot 9	.4778 ± .0951
--	---	Plot 11	.6655 ± .0664

From the correlation coefficients given in Table 18, it will be seen that the relation between the rate of growth of corn in 1920, and changes in temperature as measured by direct indices, is very obscure. With the exception of the value for plot 7, these correlations lack any particular significance, especially when considered in relation to their probable errors. In 1921 the correlations for corn are slightly higher, but this may be due to the fact that a different method of measuring was used. The early seedings of sunflowers in both 1920 and 1921 show the existence of a relationship between growth and temperature as measured by direct indices. This correlation becomes quite distinct in the cast of plot 11, seeded May 3, 1921. It will also be noticed that in 1921 the values given for sunflowers are generally higher than those for 1920. This difference may to a

certain extent reflect the lower temperatures which prevailed in 1921, as expressed by degree hours. In other words, temperature in 1921, had slightly limited growth.

From the growth rate and temperature curves of figures 4 and 5, it is obvious that there exists quite a close relationship between fluctuations in the growth rate and changes in temperature. The direct temperature indices seem to bring this out in the case of the sunflowers, especially for the early plots in 1921. The growth of corn, however, seems to bear a different relationship to temperature, as the correlation of its growth with direct temperature indices, is slight in both years.

In figures 6 to 11 the mean heights of the thirty plants given in columns 11 and 12 of Table 3, for 1920, and columns 12 and 13 of Table 4 for 1921, have been plotted as ordinates. The various summations of temperature efficiency indices as given in Tables 14 and 15, are plotted as abscissae. If the heights reached by the plants on the various dates had been in any way proportional to the temperature accumulations for the corresponding periods of growth, a definite form of curve might have been expected, depending upon the nature of the relationship. The curves obtained from the various indices are all very similar in form, and suggest that the relationship between growth and temperature as measured by any of these methods, is a linear one. In all cases, the fall in the slope of the curve at the beginning and end of the season, shows that temperatures at those times have been less effective in promoting growth in height.

In order to measure, if possible, the accuracy with which the various temperature indices express the relationship between temperature and growth, a few correlation coefficients have been calculated. Plot 2 (1921) of corn and plot 11 (1921) of sun-

flowers, have been chosen, as they both showed some evidence of correlation with the direct indices and were also the two earliest seedings for the year. The coefficients given in Table 19 are those between the growth of the plants in these plots, and the five temperature indices, degree hours, total hours of sunshine, the product $\frac{TR}{10}$ and mean relative humidity. The temperature indices and degree hours used are those given in Table 11. The total hours of sunshine, $\frac{TR}{10}$ and mean relative humidity, will be found in Table 13.

TABLE 19 - Correlation Coefficients for Plots 2 and 11 (1921) and Temperature Indices, Degree Hours, Total hours of Sunshine $\frac{TR}{10}$, and mean Relative Humidity.

	Plot 2 Corn	r	Plot 11 Sunflowers	r
Direct Indices	.4564	± .0959	.6655	± .0664
Remainder Indices (4.5°C)	.5292	± .0872	.6469	± .0693
Remainder " (10°C)	.6407	± .0714	.2571	± .1113
Exponential Indices	.4582	± .0957	.6387	± .0706
Physiological Indices	.5798	± .0804	.0355	± .1190
Degree Hours	.5380	± .0861	.6207	± .0733
Hours Sunshine	.4322	± .0985	.4100	± .0992
$\frac{TR}{10}$	.6606	± .0683	.3991	± .1002
Relative Humidity	-.0910	± .1201	-.0600	± .1188

The best correlation between the growth of sunflowers and temperature is obtained when direct temperature indices are employed. With the remainder indices above 10°C and also with the physiological indices, there is no correlation whatever. The relation with hours of sunshine and the product $\frac{TR}{10}$ is very slight, while the value for relative humidity is a minus quantity.

The correlation between the growth of corn and temperature is considerably better with the remainder indices of 4.5^{o} C, than with direct indices. It is still higher with remainder indices of 10°C, while the best correlation with the growth of corn has been obtained with the products $\frac{TR}{10}$. The correlation between the growth of corn and physiological indices is comparatively good when compared with the corresponding figure for sunflowers. Since the physiological indices were actually derived from Lehenbauer's (18) data on maize seedlings, it is not surprising to find that the corn plants in their growth show a much closer relationship to these indices than do sunflowers. It, therefore, appears that physiological temperature efficiency indices for expressing plant growth can be of little value unless derived from observations on each particular plant under consideration.

Although too much reliance cannot be placed upon the correlations in the above table, there seems to be considerable evidence to support the view that while sunflowers make good growth at medium or quite low temperatures, corn responds most closely to high temperatures, and is particularly influenced by favorable conditions of temperature and relative humidity.

From a study of the climatic data growth measurements and yields for the two years, certain conclusions may be drawn regarding the climatic adaptations of these two crops. The outstanding difference in the climate for the two seasons, was the low precipitation from Sept.1, 1920 to the end of June 1921, as compared with the same period during the previous year. This difference in precipitation for the two years was associated with a reduction in the yield of sunflowers for 1921. The corn on the other hand suffered no such reduction in yield. Sunflowers

have germinated and started growth more rapidly than corn, when seeded at the early dates. They have not been seriously injured by late spring and early fall frosts, and for that reason have a considerably longer growing season. Corn has been very susceptible to frost injury and gives evidence of good growth at high temperatures. Sunflowers, therefore, should be well suited to those parts of the country where precipitation is ample, but where there is a short growing season with low temperatures in spring and fall, and danger of frost injury. Corn should give good results where the season is longer, temperatures higher, and where soil moisture is not sufficient for the successful culture of sunflowers.

SUMMARY

1. During 1920 and 1921 a study has been made of the growth of corn, *Zea Mays*, and Sunflowers, *Helianthus annuus*, seeded at different dates, in relation to their climatic environment. The varieties used were Northwestern Dent corn and Mammoth Russian sunflowers.

2. Early seedings of sunflowers were found to germinate and appear above ground sooner than the early seedings of corn, while the late seedings of both plants required much the same time for this purpose. Both were retarded by the lower soil temperatures obtaining early in the season, but the corn to a greater degree than the sunflowers.

3. A temperature of 29°F. in the spring of 1920 injured the corn but did not affect the sunflowers. In 1921 a temperature of 24°F. killed the corn and slightly injured the sunflowers.

4. Because of resistance to late spring and early fall frosts, sunflowers have a longer growing season than corn.

5. Corn seeded at the end of May begins growth quickly, will in most years escape injury from late spring frosts, and gives a good yield of dry matter. Seeded at this date its time of active growth capacity synchronizes with that part of the season most favorable for vegetative growth.

6. The seeding of sunflowers early in May seems advisable if the best yields of dry matter are to be obtained.

7. In 1920 the corn had a higher dry matter content than the sunflowers. In 1921 this order was reversed but the high dry matter of the sunflowers was associated with slow growth and low yield.

8. The growth in height of corn and sunflowers fluctuates greatly

from day to day. The per cent relative growth is not constant but falls in an irregular manner from the beginning to the end of the season.

9. An effort has been made to correlate the growth of corn and sunflowers, with five temperature efficiency indices used by Livingston and Shreve, as well as with degree hours, total hours of sunshine, the product $\frac{TR}{10}$, and mean relative humidity.

10. The growth of both corn and sunflowers has shown closer correlation with temperature than with any other single climatic factor. Corn gave the best correlation with temperature when remainder indices derived from temperatures above 10°C were employed. Sunflowers gave the best correlation with temperatures above 0°C. This indicates a greater capacity in sunflowers than corn for growth at low temperatures.

11. Physiological temperature indices derived from Lehenbauer's observations on the growth of maize, have shown no relation to the growth of sunflowers, but have given a distinct correlation with the growth of corn.

12. The sudden drop in temperature about Aug. 19th in both years was accompanied by a distinct check in the growth rate of corn and sunflowers. The sunflowers continued to grow steadily at the low temperatures which followed this date, but the growth made by the corn was very slight.

13. Lack of sufficient soil moisture in 1921 was undoubtedly responsible for the low yields of sunflowers in that year. Corn showed no reduction in yield due to this cause.

14. Corn promises to give better yields of fodder than sunflowers in the southern areas of the province where the growing season is comparatively long, temperatures are high, and soil moisture is limited. Sunflowers should be well suited to the northern sections where moisture is more abundant, temperatures at the beginning and end of the growing season are low, and where there is danger from spring and fall frosts.

15. The need for earlier maturing varieties of both corn and sunflowers is emphasized by this study.

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TABLE I - PLAN OF SEEDING, OBSERVATIONS AND YIELDS FOR 1920

Date of Seeding	Plot	Crop	Date appearance of plants above ground	Days from seeding to appearance of plants	Date Harvested.	Actual yield per plot (lbs. green wt.)	Per-cent dry matter	Corrected yield per ac. (Tons of dry matter
May 14	1	Corn	June 1	18	Sep.20	134.6	15.8	1.95
May 14	2	Sunflower	May 25	11	" "	350.7	14.2	4.33
May 21	3	Corn	June 7	17	" "	139.7	14.9	1.69
May 21	4	Sunflower	June 4	14	" "	368.2	14.8	4.33
May 31	5	Corn	June 14	14	" "	154.6	18.4	2.08
May 31	6	Sunflower	June 10	10	" "	405.4	14.1	4.19
June 10	7	Corn	June 18	8	" "	144.8	15.8	1.53
June 10	8	Sunflower	June 17	7	" "	387.5	14.3	3.77
May 14	9	Corn	June 1	18	" "	177.8	17.9	1.95
May 14	10	Sunflower	May 25	11	" "	451.5	15.1	4.33

TABLE 2 - PLAN OF SEEDING, OBSERVATIONS AND YIELDS FOR 1921

Date of Seeding	Plot	Crop	Date appearance of plants above ground	days from seeding to appearance of plants	Date Harvested	Actual yield per plot (Lbs. green wt.)	Per-cent dry matter	Corrected yield per acre (Tons of dry matter)
May 10 ⌧	1	Corn	May 25	15	Sep. 3	707.5	15.3	2.95
May 20	2	"	June 4	15	" 3	699.5	15.8	3.02
May 30	3	"	June 8	9	" 3	726.0	16.4	3.27
June 9	4	"	June 17	8	" 3	693.5	13.9	2.67
May 10 ⌧	5	"	May 25	15	" 3	654.0	16.2	2.95
May 10	6	Sunflower	May 23	13	" 15	549.0	20.3	2.94
May 20	7	"	June 1	12	" 15	399.0	22.9	2.46
May 30	8	"	June 8	9	" 15	502.0	21.6	2.98
June 9	9	"	June 17	8	" 15	424.0	20.4	2.43
May 10	10	"	May 23	13	" 15	484.0	21.1	2.94
May 3	11	"	May 18	15	" 15	588.0	21.7	3.75

⌧ Corn of plots 1 and 5 killed by frost on morning of May 28, and seeded again May 30. Plants of second seeding appeared above ground June 8.

TABLE 3 - MEAN HEIGHT OF PLANTS (cm.) AT DIFFERENT DATES, 1920.

Date	Plot 1 Corn	Plot 3 Corn	Plot 5 Corn	Plot 7 Corn	Plot 9 Corn	Plot 2 Sunflowers	Plot 4 Sun-flowers	Plot 6 Sun-flowers	Plot 8 Sun-flowers	Plot 10 Sun-flowers	Ave. of plots 1,3 & 9 Corn	Ave. of plots 2, 4 and 10. Sun-flowers
June 5	3.9				4.6	1.7				1.9		
" 8	5.2				5.9	2.2				2.9		
" 11	6,4				6.5	3.0				3.6		
" 12		4.7					2.5					
" 14						3.6				4.6		
" 15							2.8					
" 17												
" 20												
" 23	7.5	6.6	7.3		7.3	5.9	5.2	3.6		8.4	7.1	6.5
" 26	8.8	7.9	8.4		8.1	6.6	5.9	4.0		10.5	8.3	7.7
" 29	9.3	9.0	9.1		9.2	9.2	9.4	5.6		15.2	9.2	11.3
July 2	10.0	11.0	11.3	10.9	13.9	12.4	15.4	8.5	7.0	23.5	11.6	17.1
" 5	12.0	12.0	14.1	12.3	17.2	15.9	19.6	11.9	9.0	33.6	13.7	23.0
" 8	14.5	14.3	15.1	13.9	19.7	21.3	24.0	17.4	13.7	42.2	16.2	29.2
" 11	21.0	19.4	19.8	19.7	29.5	34.9	32.5	27.8	29.2	59.9	23.3	42.4
" 14	23.8	22.3	23.4	22.3	36.4	42.0	37.2	32.7	36.4	70.3	27.5	49.8
" 17	31.9	29.2	29.3	30.1	48.1	57.9	50.0	46.5	46.1	86.7	36.4	64.9
" 20	40.4	37.3	38.1	37.5	58.0	70.3	61.4	60.7	53.1	105.2	45.2	79.0
" 23	53.6	46.8	48.7	48.2	69.8	91.1	80.1	80.0	65.1	121.2	56.7	97.5
" 26	57.4	51.6	54.5	51.5	75.6	99.5	85.0	88.0	70.0	132.3	61.5	105.6
" 29	67.1	62.0	67.6	59.5	88.3	117.0	105.2	107.6	87.0	151.2	72.4	124.5
Aug. 1	79.9	69.7	79.9	68.4	105.7	131.2	121.9	124.6	102.2	163.8	85.1	139.0
4	89.8	77.9	90.8	73.4	115.5	140.3	129.7	134.7	113.9	173.6	94.4	147.9
7	105.5	92.5	102.2	78.4	127.4	150.8	144.9	151.2	127.6	189.0	108.5	161.6
10	123.2	110.4	117.3	87.7	141.7	170.9	159.4	167.8	141.6	203.1	125.1	177.8
13	131.6	121.3	125.6	93.3	147.0	182.9	172.7	180.2	155.9	215.2	133.3	190.3
16	150.8	137.2	143,2	103.6	155.5	200.1	190.5	200.3	173.8	233.5	147.8	208.0
19	153.0	138.6	144.8	105.8	156.2	204.7	196.2	205.1	178.8	238.5	149.3	213.1
22	156.6	141.2	149.3	113.5	156.8	216.0	207.3	215.4	190.3	247.7	151.5	223.7
25	162.1	142.6	154.2	117.0	156.9	221.4	215.4	221.4	197.8	254.9	153.9	230.6
31	165.8	147.0	164.7	123.4	156.9	235.2	229.5	236.9	213.3	267.6	156.6	244.1
Sept. 3	166.9	148.9	169.5	129.4	156.9	243.3	239.6	245.0	223.7	273.0	157.6	252.0
6	167.4	149.9	175.9	134.9	157.0	251.7	249.6	254.9	233.2		158.1	
9	167.7	150.1	179.0	136.7	157.0	257.9	257.0	262.1	241.7	285.1	158.3	266.7

TABLE 4 - MEAN HEIGHT OF PLANTS (cm.) AT DIFFERENT DATES, 1921.

Date	Plot 1 Corn	Plot 2 Corn	Plot 3 Corn	Plot 4 Corn	Plot 5 Corn	Plot 6 Sun-flowers	Plot 7 Sun flowers	Plot 8 Sun-flowers	Plot 9 Sun-flowers	Plot 10 Sun-flowers	Plot 11 Sun-flowers	Ave. of plots 1, 3 and 5. Corn	Ave. of plots 6, 7, and 10 Sunflowers
June 20	15.8	22.6	14.2	----	----	9.7	6.1	----	----	10.6	10.7	17.5	8.8
22	18.9	26.2	19.0	----	17.4	12.4	7.6	----	----	13.0	13.2	21.4	11.0
24	22.2	30.9	22.2	14.7	20.5	16.1	9.9	6.3	3.4	16.6	17.2	25.1	14.2
26	25.8	36.6	26.3	19.0	23.8	20.4	12.9	8.4	4.1	20.8	21.5	29.6	18.0
28	29.5	42.7	30.2	21.9	26.9	25.7	16.6	10.4	4.8	24.7	26.2	34.1	22.3
30	34.0	49.1	35.3	26.1	31.4	32.5	21.4	13.3	5.7	30.4	32.0	39.5	28.1
July 4	40.2	57.3	41.5	28.9	37.0	42.5	28.9	18.7	7.6	38.6	44.5	46.3	36.7
6	43.1	60.8	44.4	31.0	39.8	46.2	32.1	21.2	8.7	42.3	46.5	49.4	40.2
8	48.9	67.3	50.7	34.5	45.2	54.6	39.8	26.9	11.4	50.2	55.4	55.6	48.2
10	52.2	70.4	54.4	37.4	49.0	59.7	45.0	31.4	13.6	55.6	61.6	59.0	53.4
12	57.5	77.1	60.4	42.8	55.3	67.5	52.1	37.1	17.1	65.9	69.2	65.0	61.8
14	65.9	84.5	68.3	49.5	63.0	77.3	62.7	46.0	22.2	77.9	79.2	72.9	72.6
16	74.6	94.6	78.5	59.5	71.6	87.7	74.3	57.3	30.1	87.0	88.4	82.6	83.0
18	80.0	101.0	83.8	65.0	76.9	97.0	83.0	65.9	36.9	95.3	94.9	88.3	91.8
20	90.6	112.1	94.1	75.2	85.1	106.2	94.0	77.5	46.4	104.1	104.4	98.9	101.4
22	96.8	118.6	100.7	82.2	91.2	112.1	100.5	86.8	55.3	109.4	109.1	105.4	107.3
26	113.3	134.9	115.8	99.8	105.4	121.5	111.1	99.9	67.8	117.8	117.6	121.3	116.8
28	118.9	140.2	121.8	107.2	110.7	125.4	115.0	105.1	72.5	121.6	121.3	127.0	120.7
30	126.7	148.1	129.4	116.3	117.2	131.9	120.8	111.6	78.8	126.6	126.4	134.7	126.4
Aug. 1	138.2	159.4	141.0	127.9	127.6	140.7	129.4	121.7	87.8	134.4	134.1	146.2	134.8
3	146.5	168.5	150.8	137.6	134.9	148.3	136.6	129.2	95.0	141.3	141.5	155.3	142.1
5	151.4	172.5	155.3	142.7	139.1	152.8	140.3	133.4	98.4	145.3	145.3	159.7	146.1
9	161.6	182.4	165.8	154.7	147.0	162.7	149.3	143.0	108.1	154.4	154.5	169.9	155.5
11	167.4	188.3	171.8	161.2	152.2	169.0	155.6	149.6	114.4	160.8	161.0	175.8	161.8
13	174.4	194.8	179.1	167.8	158.6	174.5	161.5	156.0	119.9	166.7	167.1	182.8	167.6
15	182.3	202.8	188.4	176.4	163.7	180.4	167.2	160.6	123.5	171.9	173.0	191.2	173.2
17	188.4	207.3	193.1	181.1	166.1	184.8	171.9	164.4	127.0	177.0	178.6	196.3	177.9
19	192.6	212.2	198.0	185.8	171.0	190.3	176.7	169.4	131.4	182.3	184.1	200.9	183.1
23	198.3	217.8	204.0	192.9	176.2	197.9	184.1	176.4	137.3	190.7	193.6	206.7	190.9
25	200.2	219.4	205.9	195.0	178.0	200.9	187.0	179.5	139.8	194.4	197.4	208.5	194.1
27	201.3	220.5	206.6	197.5	179.4	203.4	189.3	182.1	142.0	197.3	200.8	209.4	196.7
Sept. 1	204.5	221.8	207.4	200.8	182.8	211.7	198.8	190.1	149.0	208.0	212.8	211.2	206.2
9	----	----	----	----	----	226.2	207.4	200.1	156.3	216.4	223.9	-----	216.7

TABLE 5 - MEAN ACTUAL GROWTH OF PLANTS (cm.) FOR PERIODS, 1920

Date	Plot 1 Corn	Plot 3 Corn	Plot 5 Corn	Plot 7 Corn	Plot 9 Corn	Plot 2 Sunflowers	Plot 4 Sun-flowers	Plot 6 Sun-flowers	Plot 8 Sun-flowers	Plot 10 Sun-flowers	Ave. of plots 1, 3 & 9. Corn	Ave. of plots 2, 4 and 10. Sunflowers
June 23-26	1.3	1.3	1.1	---	0.8	0.7	0.7	0.4	---	2.1	1.2	1.2
June 26-29	0.5	1.1	0.7	---	1.1	2.6	3.5	1.6	---	4.7	0.9	3.6
" 29-July 2	0.7	2.0	2.2	---	4.7	3.2	6.0	2.9	---	8.3	2.4	5.8
July 2-5	2.0	1.0	2.8	1.4	3.3	3.5	4.2	3.4	2.0	10.1	2.1	5.9
July 5-8	2.5	2.3	1.0	1.6	2.5	5.4	4.4	5.5	4.7	8.6	2.5	6.2
July 8-11	6.5	5.1	4.7	5.8	9.8	13.6	8.5	10.4	15.5	17.7	7.1	13.2
July 11-14	2.8	2.9	3.6	2.6	6.9	7.1	4.7	4.9	7.2	10.4	4.2	7.4
July 14-17	8.1	6.9	5.9	7.8	11.7	15.9	12.8	13.8	9.7	16.4	8.9	15.1
July 17-20	8.5	8.1	8.8	7.4	9.9	12.4	11.4	14.2	7.0	18.5	8.8	14.1
July 20-23	13.2	9.5	10.6	10.7	11.8	20.8	18.7	19.3	12.0	16.0	11.5	18.5
July 23-26	3.8	4.8	5.8	3.3	5.8	8.4	4.9	8.0	4.9	11.1	4.8	8.1
July 26-29	9.7	10.4	13.1	8.0	12.7	17.5	20.2	19.6	17.0	18.9	10.9	18.9
July 20-Aug.1	12.8	7.7	12.3	8.9	17.4	14.2	16.7	17.0	15.2	12.6	12.7	14.5
Aug.1-4	9.9	8.2	10.9	5.0	9.8	9.1	7.8	10.1	11.7	9.8	9.3	8.9
Aug. 4-7	15.7	14.6	11.4	5.0	11.9	10.5	15.2	16.5	13.7	15.4	14.1	13.7
Aug. 7-10	17.7	17.9	15.1	9.3	14.3	20.1	14.5	16.6	14.0	14.1	16.6	16.2
Aug. 10-13	8.4	10.9	8.3	5.6	5.3	12.0	13.3	12.4	14.3	12.1	8.2	12.5
Aug. 13-16	19.2	15.9	17.6	10.3	8.5	17.2	17.8	20.1	17.9	18.3	14.5	17.7
Aug. 16-19	2.2	1.4	1.6	2.2	0.7	4.6	5.7	4.8	5.0	5.0	1.5	5.1
Aug. 19-22	3.6	2.6	4.5	7.7	0.6	11.3	11.1	10.3	11.5	9.2	2.2	10.6
Aug. 22-25	5.5	1.4	6.9	3.5	0.1	5.4	8.1	6.0	7.5	7.2	2.4	6.9
Aug. 25-31	3.7	4.4	10.5	6.4	000	13.8	14.1	15.5	15.5	12.7	2.7	13.5
Aug.31-Sep.3	1.1	1.9	4.8	6.0	0.0	8.1	10.1	8.1	10.4	5.4	1.0	7.9
Sept. 3-6	0.5	1.0	6.4	5.5	0.1	8.4	10.0	9.9	9.5	---	0.5	---
Sept. 6-9	0.3	0.2	3.1	1.8	0.0	6.2	7.4	7.2	8.5	12.1	0.2	14.7

TABLE 6 . MEAN ACTUAL GROWTH OF PLANTS (cm.)FOR PERIODS,1921

Date	Plot 1 Corn	Plot 2 Corn	Plot 3 Corn	Plot 4 Corn	Plot 5 Corn	Plot 6 Sunflowers	Plot 7 Sun-flowers	Plot 8 Sun-flowers	Plot 9 Sun-flowers	Plot 10 Sun-flowers	Plot 11 Sun-flowers	Ave.of plots 1-2-3 Corn	Ave.of plots 6-7-10 Sunflowers
June 20-22	3.1	3.6	4.8	---	---	2.7	1.5	----	----	2.4	2.5	3.9	2.2
22-24	3.3	4.7	3.2	---	3.1	3.7	2.3	---	----	3.6	4.0	3.7	3.2
24-26	3.6	5.7	4.1	4.3	3.3	4.3	3.0	2.1	0.7	4.2	4.5	4.5	3.8
26-28	3.7	6.1	3.9	2.9	3.1	5.3	3.7	2.0	0.7	3.9	4.7	4.5	4.3
28-30	4.5	6.4	5.1	4.2	4.5	6.8	4.8	2.9	0.9	5.7	5.3	5.4	5.8
30-July 4	6.2	8.2	6.2	2.8	5.6	10.0	7.5	5.4	1.9	8.2	12.5	6.8	8.6
July 4-6	2.9	3.5	2.9	2.1	2.8	3.7	3.2	2.5	1.1	3.7	2.0	3.1	3.5
6-8	5.8	6.5	6.3	3.5	5.4	8.4	7.7	5.7	2.7	7.9	8.9	6.2	8.0
8-10	3.3	3.1	3.7	2.9	3.8	5.1	5.2	4.5	2.2	5.4	6.2	3.4	5.2
10-12	5.3	6.7	6.0	5.4	6.3	7.8	7.1	5.7	3.5	10.3	7.6	6.0	8.4
12-14	8.4	7.4	7.9	6.7	7.7	9.8	10.6	8.9	5.1	12.0	10.0	7.9	10.8
14-16	8.7	10.1	10.2	10.0	8.6	10.4	11.6	11,3	7.9	9.1	9.2	9.7	10.4
16-18	5.4	6.4	5.3	5.5	5.3	9.3	8.7	8.6	6.8	8.3	6.5	5.7	8.8
18-20	10.6	11.1	10.3	10.2	8.2	9.2	11.0	11.6	9.5	8.8	9.5	10.6	9.6
20-22	6.2	6.5	6.6	7.0	6.1	5.9	6.5	9.3	8.9	5.3	4.7	6.5	5.9
22-26	16.5	16.3	15.1	17.6	14.2	9.4	10.6	13.1	12.5	8.4	8.5	15.9	9.5
26-28	5.6	5.3	6.0	7.4	5.3	3.9	3.9	5.2	4.7	3.8	3.7	5.7	3.9
28-30	7.8	7.9	7.6	9.1	6.5	6.5	5.8	6.5	6.3	5.0	5.1	7.7	5.7
30-Aug.1	11.5	11.3	11.6	11.6	10.4	8.8	8.6	10.1	9.0	7.8	7.7	11.5	8.4
Aug. 1-3	8.3	9.1	9.8	9.7	7.3	7.6	7.2	7.5	7.2	6.9	7.4	9.1	7.3
3-5	4.9	4.0	4.5	5.1	4.2	4.5	3.7	4.2	3.4	4.0	3.8	4.4	4.0
5-9	10.2	9.9	10.5	12.0	7.9	9.9	9.0	9.6	9.7	9.1	9.2	10.2	9.4
9.11	5.8	5.9	6.0	6.5	5.2	6.3	6.3	6.6	6.3	6.4	6.5	5.9	6.3
11-13	7.0	6.5	7.3	6.6	6.4	5.5	5.9	6.4	5.5	5.9	6.1	7.0	5.8
13-15	7.9	8.0	9.3	8.6	5.1	5.9	5.7	4.6	3.6	5.2	5.9	8.4	5.6
15-17	6.1	4.5	4.7	4.7	2.4	4.4	4.7	3.8	3.5	5.1	5.6	5.1	4.7
17-19	4.2	4.9	4.9	4.7	4.9	5.5	4.8	5.0	4.4	5.3	5.5	4.6	5.2
19-23	5.7	5.6	6.0	7.1	5.2	7.6	7.4	7.0	5.9	8.4	9.5	5.8	7.8
23-25	1.9	1.6	1.9	2.1	1.8	3.0	2.9	3.1	2.5	3.7	3.8	1.8	3.2
25-27	1.1	1.1	0.7	2.5	1.4	2.5	2.3	2.6	2.2	2.9	3.4	0.9	2.6
27-Sept.1	3.2	1.3	0.8	3.3	3.4	8.3	9.5	8.0	7.0	10.7	12.0	1.8	9.5
Sept. 1-9	---	---	---	---	---	14.5	8.6	10.0	7.3	8.4	11.1	---	10.5

Table 7 - MEAN RELATIVE GROWTH OF PLANTS (percent per day)
1920-1921

1920 Date	Ave. Plots 1-3-9 Corn	Ave. Plots 2-4-10 Sunflowers
June 23-26	5.2	5.6
26-29	3.4	12.8
June 29		
July 2	7.7	13.8
July 2-5	5.5	9.9
5-8	5.6	8.0
8-11	12.1	12.4
11-14	5.5	5.4
14-17	9.3	8.8
17-20	7.2	6.6
20-23	7.6	7.0
23-26	2.7	2.7
26-29	5.4	5.5
July 29		
Aug. 1	5.4	3.7
Aug. 1-4	3.5	2.1
4-7	4.6	2.9
7-10	4.7	3.2
10-13	2.1	2.3
13-16	3.4	3.0
16-19	0.3	0.8
19-22	0.5	1.6
22-25	0.5	1.0
25-31	0.3	1.0
Aug. 31		
Sept. 3	0.2	1.1
Sept. 3-6	0.1	0.9
6-9	0.04	0.9

1921 Date	Ave. Plots 1-2-3 Corn	Ave. Plots 6-7-10 Sunflowers
June 20-22	10.1	11.2
22-24	8.0	12.8
24-26	8.2	11.9
26-28	7.1	10.7
28-30	7.3	11.6
June 30		
July 4	4.0	6.7
July 4-6	3.2	4.5
6-8	5.9	9.1
8-10	3.0	5.1
10-12	4.8	7.3
12-14	5.7	8.0
14-16	6.3	6.7
16-18	3.3	5.0
18-20	5.7	5.0
20-22	3.2	2.8
22-26	3.5	2.1
26-28	2.3	1.6
28-30	2.9	2.3
July 30		
Aug. 1	4.1	3.2
Aug. 1-3	3.0	2.6
3-5	1.4	1.4
5-9	1.5	1.6
9-11	1.7	2.0
11-13	2.0	1.8
13-15	2.2	1.6
15-17	1.3	1.3
17-19	1.1	1.4
19-23	0.7	1.0
23-25	0.4	0.8
25-27	0.2	0.7
Aug. 27		
Sept. 1	0.2	0.9
Sept. 1-9	--	0.6

TABLE 8. MEAN TEMPERATURES, EXPONENTIAL AND PHYSIOLOGICAL TEMPERATURE EFFICIENCY INDICES AND DEGREE HOURS FOR TWENTY-FOUR HOUR PERIODS. 1920-1921

Date	1920					1921				
	Degrees F.	Degrees C.	Exponential Indices	Physiological Indices	Degree Hours	Degrees F.	Degrees C.	Exponential Indices	Physiological Indices	Degree Hours
June 20-21	---	---	---	---	---	64.3	17.9	2.5	31	584
21-22	---	---	---	---	---	68.5	20/3	3.1	48	684
22-23	---	---	---	---	---	62.8	17.1	2.4	26	548
23-24	53.5	11.9	1.7	9	324	64.3	17.9	2.5	31	584
24-25	52.9	11.6	1.6	9	310	67.7	19.8	2.9	44	666
25-26	54.0	12.2	1.7	10	336	59.7	15.4	2.2	19	472
26-27	61.6	16.4	2.3	23	518	67.0	19.4	2.8	41	648
27-28	62.2	16.8	2.3	25	534	61.8	16.6	2.3	24	524
28-29	64.2	17.9	2.5	31	580	60.7	15.9	2.2	21	496
29-30	69.1	20.6	3.1	51	698	62.6	17.0	2.4	26	542
June 30 July 1	66.7	19.3	2.8	40	642	58.8	14.9	2.1	17	452
July 1-2	67.2	19.6	2.8	43	652	55.4	13.0	1.8	12	370
2-3	63.4	17.4	2.4	28	562	54.7	12.6	1.8	11	352
3-4	58.3	14.6	2.0	17	440	57.6	14.2	2.0	15	422
4-5	60.8	16.0	2.2	22	500	53.7	12.1	1.7	10	330
5-6	57.9	14.4	2.0	16	430	50.9	10.5	1.5	7	262
6-7	64.9	18.3	2.6	34	598	53.1	11.7	1.6	9	314
7-8	68.2	20.1	2.9	46	678	63.0	17.2	2.4	27	552
8-9	70.9	21.6	3.3	60	742	57.6	14.2	2.0	15	422
9-10	66.8	19.3	2.8	40	644	56.2	13.4	1.9	13	390
10-11	67.1	19.5	2.8	42	650	55.5	13.1	1.9	12	372
11-12	62.2	16.8	2.3	25	532	55.2	12.9	1.8	12	366
12-13	61.5	16.4	2.3	23	516	60.3	15.7	2.2	20	488
13-14	65.6	18.7	2.7	36	614	62.9	17.2	2.4	27	550
14-15	67.8	19.9	2.9	45	668	69.0	20.6	3.1	51	696
15-16	74.3	23.5	3.7	75	824	63.3	17.4	2.4	28	560
16-17	74.7	23.7	3.8	77	832	54.2	12.3	1.7	10	344
17-18	72.3	22.4	3.4	66	776	59.2	15.1	2.1	18	460
18-19	71.7	22.1	3.4	64	762	68.2	20.1	2.9	46	678
19-20	73.3	22.9	3.6	70	800	71.5	21.9	3.4	62	756
20-21	75.0	23.9	3.8	78	840	63.4	17.4	2.4	28	562

Date	1920 Degrees F.	1920 Degrees C.	1920 Exponential Indices	1920 Physiological Indices	1920 Degree Hours	1921 Degrees F.	1921 Degrees C.	1921 Exponential Indices	1921 Physiological Indices	1921 Degree Hours
July 21-22	72.5	22.5	3.6	67	780	64.3	17.8	2.5	30	584
22-23	61.6	16.4	2.3	23	518	62.8	17.1	2.4	26	548
23-24	68.1	20.1	2.9	46	674	59.2	15.1	2.1	18	460
24-25	60.3	15.7	2.2	20	488	62.5	16.9	2.4	26	540
25-26	61.2	16.2	2.2	22	510	62.6	17.0	2.4	26	542
26-27	56.9	13.8	2.2	14	406	65.7	18.7	2.7	36	616
27-28	62.8	17.1	2.4	26	548	64.8	18.2	2.6	33	596
28-29	67.2	19.6	2.8	43	654	57.6	14.2	2.0	15	422
29-30	69.2	20.7	3.1	52	700	57.2	14.0	1.9	15	412
July 30-31	69.2	20.7	3.1	52	702	61.3	16.3	2.2	23	512
July 31										
Aug. 1	67.4	19.7	2.8	44	658	60.0	15.6	2.2	20	480
Aug. 1-2	65.1	18.4	2.6	34	602	63.6	17.6	2.5	29	566
2-3	64.0	17.8	2.5	30	576	55.6	13.1	1.9	12	374
3-4	52.0	11.1	1.6	8	288	51.0	10.6	1.5	8	264
4-5	57.7	14.3	2.0	16	424	52.2	11.2	1.6	8	294
5-6	66.0	18.9	2.7	38	624	50.0	10.0	1.5	6	240
6-7	69.7	20.9	3.2	54	712	60.7	15.9	2.2	21	496
7-8	68.6	20.3	3.1	48	686	61.8	16.6	2.3	24	524
8-9	62.6	17.0	2.4	26	542	56.4	13.6	1.9	14	394
9-10	56.0	13.3	1.9	13	384	56.7	13.7	1.9	14	402
10-11	50.7	10.4	1.5	7	256	55.1	12.8	1.8	12	362
11-12	62.2	16.6	2.3	25	532	57.1	13.9	1.9	15	410
12-13	68.0	20.0	2.9	46	672	61.3	16.3	2.2	23	512
13-14	67.3	19.6	2.8	43	656	65.0	18.3	2.6	34	600
14-15	60.7	15.9	2.2	21	498	67.2	19.5	2.8	42	650
15-16	57.9	14.4	2.0	16	430	59.6	15.3	2.2	19	470
16-17	61.8	16.6	2.3	24	524	61.2	16.2	2.2	22	510
17-18	44.7	7.1	1.2	3	114	54.0	12.2	1.7	10	336
18-19	43.9	6.6	1.2	2	110	50.3	10.2	1.5	7	248
19-20	52.8	11.6	1.6	9	316	54.7	12.6	1.8	11	354
20-21	60.9	16.1	2.2	22	502	60.5	15.8	2.2	21	492
21-22	63.5	17.5	2.5	23	564	53.2	11.8	1.6	9	316

Date	1920					1921				
	Degrees F.	Degrees C.	Exponential Indices	Physiological Indices	Degree Hours	Degrees F.	Degrees C.	Exponential Indices	Physiological Indices	Degree Hours
Aug. 22-23	66.7	19.3	2.8	40	642	56.1	13.4	1.9	13	386
23-24	53.0	11.7	1.6	9	322	56.8	13.8	1.9	14	404
24-25	59.6	15.3	2.2	19	470	51.8	11.0	1.6	8	288
25-26	51.3	10.7	1.5	8	270	53.2	11.8	1.6	9	330
26-27	50.2	10.1	1.5	6	244	53.7	12.1.	1.7	10	338
27-28	57.2	14.0	1.9	15	412	55.9	13.3	1.9	13	382
28-29	52.2	11.2	1.6	8	294	54.7	12.6	1.8	11	354
29-30	51.2	10.7	1.5	8	278	53.1	11.7	1.6	9	336
30-31	51.5	10.8	1.6	18	304	49.2	9.6	1.4	6	242
Aug. 31										
Sept. 1	54.8	12.7	1.8	11	358	51.3	10.7	1.5	8	272
Sept. 1-2	57.0	13.9	1.9	15	408	45.6	7.6	1.3	3	206
2-3	59.1	15.1	2.1	18	458	49.7	9.8	1.5	6	244
3-4	56.2	13.4	1.9	13	388	48.3	9.1	1.4	5	250
4-5	59.9	15.5	2.2	20	478	52.9	11.6	1.6	9	310
5-6	53.2	11.8	1.6	9	318	51.0	10.6	1.5	8	278
6-7	49.2	9.6	1.4	6	252	57.1	13.9	1.9	15	410
7-8	53.2	11.8	1.6	9	336	51.6	10.9	1.6	8	278
8-9	56.4	13.6	1.9	14	408	38.3	3.5	0.0	0.5	22

TABLE 9. MEAN DAILY RELATIVE HUMIDITY, TOTAL DAILY HOURS OF SUNSHINE, AND DAILY PRECIPITATION (inches) FOR 1920 AND 1921, AND DAILY MAXIMUM SOLAR RADIATION (F) FOR 1921.

	1920			1921			
Date	Relative Humidity	Hours Sunshine	Precipitation	Relative Humidity	Hours Sunshine	Precipitation	Solar Radiat.
June 20	---	12.2	---	58	15.4	---	---
21	---	14.4	---	54	12.5	---	---
22	---	7.9	---	61	11.6	---	---
23	---	11.3	---	70	7.6	0.13	---
24	---	4.9	---	51	13.7	---	---
25	---	8.2	0.03	69	3.6	0.03	---
26	---	10.4	---	51	13.2	0.02	---
27	---	13.8	---	59	10.7	---	---
28	---	11.6	---	58	10.7	0.10	---
29	---	13.3	---	57	10.5	---	---
30	---	13.0	---	87	2.0	0.72	---
July 1	55	15.4	---	68	5.4	0.38	---
2	62	10.8	0.30	83	0.0	---	---
3	63	15.2	---	76	6.2	0.65	---
4	62	11.9	---	78	7.4	---	123
5	85	3.6	0.36	85	4.6	0.27	108
6	68	14.4	0.01	64	13.2	0.31	123
7	64	12.9	---	63	9.0	0.11	129
8	64	15.1	---	64	7.9	---	125
9	66	11.9	---	55	12.4	---	124
10	67	14.9	---	69	10.6	---	129
11	81	5.3	---	67	11.9	---	130
12	64	13.7	---	67	13.3	---	133
13	65	14.5	---	61	14.7	---	132
14	62	15.3	---	58	12.3	---	132
15	65	14.8	---	56	10.1	---	132
16	64	14.7	---	75	5.1	---	98
17	66	11.0	---	86	4.5	---	127
18	68	13.0	---	73	14.4	0.33	134
19	65	10.3	---	64	12.3	---	136
20	68	12.8	---	64	13.4	0.03	137
21	72	7.7	---	57	15.3	0.06	128

Date		1920 Relative Humidity	1920 Hours Sunshine	1920 Precipitation	1921 Relative Humidity	1921 Hours Sunshine	1921 Precipitation	1921 Solar Radiation
July	22	82	2.1	0.57	58	14.3	---	132
	23	67	13.9	---	52	15.1	---	132
	24	73	12.3	---	66	12.1	---	131
	25	72	14.1	0.68	72	9.3	---	119
	26	79	4.8	0.31	67	13.8	---	139
	27	70	15.1	---	64	13.1	---	134
	28	69	15.0	---	80	3.2	---	124
	29	77	14.6	---	76	6.6	0.85	125
	30	70	12.9	---	71	13.5	0.02	129
	31	74	12.5	---	80	6.1	0.12	129
Aug.	1	74	13.3	0.20	82	7.8	0.25	122
	2	75	9.7	0.18	74	10.6	---	132
	3	84	10.8	0.14	71	5.0	0.12	111
	4	81	6.5	0.16	75	6.3	---	120
	5	62	15.0	---	85	5.7	---	108
	6	63	14.8	---	66	13.3	0.10	127
	7	68	13.1	---	74	12.0	---	130
	8	71	11.1	---	89	0.0	0.27	99
	9	81	2.7	0.15	83	6.0	0.12	122
	10	80	6.5	---	76	8.4	0.35	118
	11	71	12.8	---	75	6.8	---	135
	12	64	13.1	---	76	12.0	---	129
	13	69	11.9	---	65	13.7	---	127
	14	64	14.9	---	70	13.9	---	131
	15	74	7.7	---	89	8.6	---	129
	16	75	12.2	---	66	12.9	---	128
	17	89	0.5	---	86	0.5	0.20	127
	18	94	0.0	0.29	85	3.5	0.01	105
	19	71	7.5	---	79	6.5	0.01	119
	20	72	10.4	---	68	11.8	---	128
	21	63	12.8	---	88	0.5	0.05	97

3

Date		1920 Relative Humidity	1920 Hours Sunshine	1920 Precipitation	1921 Relative Humidity	1921 Hours Sunshine	1921 Precipitation	1921 Solar Radiat.
Aug.	22	70	13.3	--	66	13.0	0.02	120
	23	78	4.7	--	76	10.3	0.02	124
	24	75	9.7	--	79	5.3	--	119
	25	88	0.1	--	64	13.2	--	125
	26	88	3.3	--	62	13.2	--	125
	27	84	6.0	--	58	10.2	--	127
	28	77	2.2	--	68	2.5	--	98
	29	68	11.5	--	67	8.5	--	124
	30	72	6.0	--	74	6.1	--	126
	31	71	12.5	--	84	4.8	--	119
Sept.	1	--	11.7	--	84	4.7	0.04	102
	2	--	7.2	-	70	9.6	0.02	124
	3	--	8.8	--	68	10.1	--	122
	4	--	11.0	--	59	7.9	--	127
	5	--	4.3	--	58	11.6	--	126
	6	--	3.3	0.005	65	7.1	--	131
	7	--	11.3	--	74	6.0	--	126
	8	--	11.7	--	78	0.2	0.36	85
	9	--	9.8	--	60	0.0	--	--

T ABLE 10. SUMMATION OF TEMPERATURE EFFICIENCY INDICES AND DEGREE HOURS FOR PERIODS OF GROWTH, 1920.

TABLE 10. SUMMATION OF TEMPERATURE EFFICIENCY INDECES AND DEGREE HOURS FOR PERIODS OF GROWTH, 1920.

Date	Direct Indices	Remainder Indices (4.5°c)	Remainder Indices (10°c)	Exponential Indices	Physiological Indices.	Degree Hours.
June 23-26	35.7	25.2	8.7	5.0	28	970
26-29	51.1	40.6	24.1	7.1	79	1632
June 29 July 2	59.5	49.0	32.5	8.7	134	1992
July 2-5	48.0	37.5	21.0	6.6	67	1502
5-8	52.8	42.3	25.8	7.5	96	1706
8-11	60.4	49.9	33.4	8.9	142	2036
11-14	51.9	41.4	24.9	7.3	84	1662
14-17	67.1	56.6	40.1	10.4	197	2324
17-20	67.4	56.9	40.4	10.4	200	2338
20-23	62.8	52.3	35.8	9.7	168	2138
23-26	52.0	41.5	25.0	7.3	88	1672
26-29	50.5	40.0	23.5	7.4	83	1608
29- Aug. 1	61.1	50.6	34.1	9.0	148	2060
Aug. 1-4	47.3	36.8	20.3	6.7	72	1466
4-7	54.1	43.6	27.1	7.9	108	1760
7-10	50.6	40.1	23.6	7.4	87	1612
10-13	47.2	36.7	20.2	6.7	78	1460
13-16	49.9	39.4	22.9	7.0	80	1584
16-19	30.3	19.8	3.3	4.7	29	748
19-22	45.2	34.7	18.2	6.3	59	1382
22-25	46.3	35.8	19.3	6.6	68	1434
25-31	67.5	46.3	13.5	9.6	53	1802
31- Sept. 3	41.7	31.2	14.7	5.8	44	1224
Sept. 3-6	40.7	30.2	13.7	5.7	42	1184
6-9	35.0	24.5	8.0	4.9	29	996

TABLE 11. SUMMATION OF TEMPERATURE EFFICIENCY INDICES AND DEGREE HOURS FOR PERIODS OF GROWTH. 1921.

Date	Direct Indices	Remainder Indices (4.5°C)	Remainder Indices (10°C)	Exponential Indices	Physiological Indices	Degree Hours
June 20-22	38/2	31.2	20.2	5.6	79	1268
22-24	35.0	28.0	17.0	4.9	57	1132
24-26	35.2	28.2	17.2	5.1	63	1138
26-28	36.0	29.0	18.0	5.1	65	1172
28-30	32.9	25.9	14.9	4.6	47	1038
June 30						
July 4	54.7	40.7	18.7	7.7	55	1596
July 4-6	22.6	15.6	4.6	3.2	17	592
6-8	28.9	21.9	10.9	4.0	36	866
8-10	27.6	20.6	9.6	3.9	28	812
10-12	26.0	19.0	8.0	3.7	24	738
12-14	32.9	25.9	14.9	4.6	47	1038
14-16	38.0	31.0	20.0	5.5	79	1256
16-18	27.4	20.4	9.4	3.8	28	804
18-20	42.0	35.0	24.0	6.3	108	1434
20-22	35.2	28.2	17.2	4.9	58	1146
22-26	66.1	52.1	30.1	9.3	96	2090
26-28	36.9	29.9	18.9	5.3	69	1212
28-30	28.2	21.2	10.2	3.9	30	834
July 30						
Aug. 1	31.9	24.9	13.9	4.4	43	992
Aug. 1-3	30.7	23.7	12.7	4.4	41	940
3-5	21.8	14.8	3.8	3.1	16	558
5-9	56.1	42.1	18.1	7.9	65	1654
9-11	26.5	19.5	8.5	3.7	26	764
11-13	30.2	23.2	12.2	4.1	38	922
13-15	37.8	30.8	19.8	5.4	76	1250
15-17	31.5	24.5	13.5	4.4	41	980
17-19	22.4	15.4	4.4	3.2	17	584
19-23	53.6	39.6	17.6	7.5	54	1548
23-25	24.8	17.8	6.8	3.5	22	692
25-27	23.9	16.9	5.9	3.3	19	668
Aug. 27						
Sept. 1	57.9	40.4	12.9	8.2	47	1586
Sept. 1-9	77.0	49.0	5.0	10.5	54.5	1998

TABLE 12. MEAN TEMPERATURE (Centigrade), MEAN RELATIVE HUMIDITY, $\frac{TR}{10}$, TOTAL HOURS OF SUNSHINE, AND MEAN DAILY HOURS OF SUNSHINE, FOR PERIODS OF GROWTH. 1920.

Date	Mean Temp. (Centigrade)	Mean Relative Humidity	$\frac{TR}{10}$	Total Hours Sunshine	Mean Daily Hours Sunshine
June 23-26	12	--	--	25.3	8.4
26-29	17	--	--	36.8	12.3
June 29 July 2	20	--	--	38.2	12.7
July 2-5	16	64	102	35.8	11.9
5-8	18	72	130	36.0	12.0
8-11	20	67	134	38.1	12.7
11-14	17	68	116	38.0	12.7
14-17	22	64	141	44.1	14.7
17-20	22	67	147	34.4	11.5
20-23	21	74	155	21.9	7.3
23-26	17	70	119	37.4	12.5
26-29	17	73	124	38.7	12.9
July 29 Aug. 1	20	72	144	38.4	12.8
Aug. 1-4	16	78	125	29.9	10.0
4-7	18	67	121	41.8	13.9
7-10	17	74	126	24.7	8.2
10-13	16	70	112	33.9	11.3
13-16	17	70	119	34.5	11.4
16-19	10	86	86	9.8	3.3
19-22	15	68	102	33.7	11.2
22-25	15	77	116	22.0	7.3
25-31	11	78	86	36.4	6.1
Aug. 31 Sept. 3	14	--	--	29.3	9.8
3-6	14	--	--	21.0	7.0
6-9	12	--	--	30.7	10.2

TABLE 13. MEAN TEMPERATURE (Centigrade), MEAN RELATIVE HUMIDITY, $\frac{TR}{10}$, TOTAL HOURS OF SUNSHINE, MEAN DAILY HOURS OF SUNSHINE, AND MEAN MAXIMUM SOLAR RADIATION (Fahrenheit) FOR PERIODS OF GROWTH IN 1921.

Date	Mean Temp. (Centigrade)	Mean Relat. Humidity	$\frac{TR}{10}$	Total Hours Sunshine	Mean Daily Hours Sunshine	Mean Max. Solar Rad. (Fahrenheit)
June 20-22	19	56	106	26.7	13.4	--
22-24	18	67	121	19.0	9.5	--
24-26	18	65	117	18.7	9.4	--
26-28	18	55	99	22.6	11.3	--
28-30	16	63	101	15.5	7.8	--
June 30 July 4	14	77	108	15.5	3.9	--
July 4-6	11	77	85	16.6	8.3	116
6-8	14	64	90	21.1	10.6	126
8-10	14	61	85	21.7	10.9	125
10-12	13	71	92	22.4	11.2	130
12-14	16	62	99	28.1	14.1	133
14-16	19	58	110	20.8	10.4	132
16-18	14	83	116	10.8	5.4	113
18-20	21	64	134	27.2	13.6	135
20-22	18	61	110	28.1	14.1	133
22-26	17	64	109	50.3	12.6	129
26-28	18	65	117	23.8	11.9	137
28-30	14	78	119	12.8	6.4	125
July 30 - Aug. 1	16	78	125	14.2	7.1	129
Aug. 1-3	15	74	111	18.9	9.5	127
3-5	11	77	85	11.9	6.0	116
5-9	14	78	109	33.0	8.3	116
9-11	13	77	100	13.9	7.0	120
11-13	15	74	111	21.9	11.0	132
13-15	19	70	133	25.5	12.8	129
15-17	16	74	118	18.1	9.1	129
17-19	11	86	95	4.0	2.0	116
19-23	13	75	98	35.6	8.9	116
23-25	12	76	91	17.2	8.6	122
25-27	12	61	73	25.5	12.8	125
Aug. 27 Sept. 1	12	73	88	27.6	5.5	119
Sept. 1-9	10	68	68	56.9	7.1	118

TABLE 14. SUMMATIONS OF TEMPERATURE EFFICIENCY INDICES AND DEGREE HOURS FROM JUNE 23 TO THE END OF EACH THREE-DAY PERIOD OF GROWTH IN 1920.

Periods ending -	Direct Indices	Remainder Indices (4.5°C.)	Remainder Indices (10°C.)	Exponential Indices	Physiological Indices	Degree Hours
June 26	35.[illegible]7	25.2	8.7	5.0	28	970
29	86.8	65.8	32.8	12.1	107	2602
July 2	146.3	114.8	65.3	20.8	241	4594
5	194.3	152.3	86.3	27.4	308	6096
8	247.1	194.6	112.1	34.9	404	7802
11	307.5	244.5	145.5	43.8	546	9838
14	359.4	285.9	170.4	51.1	630	11500
17	426.5	342.5	210.5	61.5	827	13824
20	493.9	399.4	250.9	71.9	1027	16162
23	556.7	451.7	286.7	81.6	1195	18300
26	608.7	493.2	311.7	88.9	1283	19972
29	659.2	433.2	335.2	96.3	1366	21580
Aug. 1	720.3	583.8	369.3	105.3	1514	23640
4	767.6	620.6	389.6	112.0	1586	25106
7	821.7	664.2	416.7	119.9	1694	26866
10	872.3	704.3	440.3	127.3	1781	28478
13	919.5	741.0	460.5	134.0	1859	29938
16	969.4	780.4	483.4	141.0	1939	31522
19	999.7	800.2	486.7	145.7	1968	32270
22	1044.9	834.9	504.9	152.0	2027	33652
25	1091.2	870.7	524.2	158.6	2095	35086
31	1158.7	917.2	537.7	168.2	2148	36888
Sept. 3	200.4	948.4	552.4	174.0	2192	38112
6	1241.1	978.6	566.1	179.7	2234	39296
9	1276.1	1003.1	574.1	184.6	2263	40292

TABLE 15. SUMMATIONS OF TEMPERATURE EFFICIENCY INDICES AND DEGREE HOURS FROM JUNE 20 TO THE END OF EACH TWO-DAY PERIOD OF GROWTH ON 1921.

Periods Ending-	Direct Indices	Remainder Indices (4.5°C)	Remainder Indices (10°C.)	Exponential Indices	Physiological Indices	Degree Hours
June 22	38.2	31.2	20.2	5.6	79	1268
24	73.2	59.2	37.2	10.5	136	2400
26	108.4	87.4	54.4	15.6	199	3538
28	144.4	116.4	72.4	20.7	264	4710
30	177.3	142.3	87.3	25.3	311	5748
July 4	232.0	183.0	106.0	33.0	366	7344
6	254.6	198.6	110.6	36.2	383	7936
8	283.5	220.5	121.5	40.2	419	8802
10	311.1	241.1	131.1	44.1	447	9614
12	337.1	260.1	139.1	47.8	471	10352
14	370.0	286.0	154.0	52.4	518	11390
16	408.0	317.0	174.0	57.9	597	12646
18	435.4	337.4	183.4	61.7	625	13450
20	477.4	372.4	207.4	68.0	733	14884
22	512.6	400.6	224.6	72.9	791	16030
26	578.7	452.7	254.7	82.2	887	18120
28	615.6	482.6	273.6	87.5	956	19332
30	643.8	503.8	283.8	91.4	986	20166
Aug. 1	675.7	528.7	297.7	95.8	1029	21158
3	706.4	552.4	310.4	100.2	1070	22098
5	728.2	567.2	314.2	103.3	1086	22656
9	784.3	609.3	332.3	111.2	1151	24310
11	810.8	628.8	340.8	114.9	1177	25074
13	841.0	652.0	353.0	119.0	1215	25996
15	878.8	682.8	372.8	124.4	1291	27246
17	910.3	707.3	386.3	128.8	1332	28226
19	932.7	722.7	390.7	132.0	1349	28810
23	986.3	762.3	408.3	139.5	1403	30358
25	1011.1	780.1	415.1	143.0	1425	31050
27	1035.0	797.0	421.0	146.3	1444	31718
Sept. 1	1092.9	837.4	433.9	154.5	1491	33304
9	1169.9	886.4	438.9	165.3	1545.5	35302

APPENDIX

TABLE 20 - Mean Bi-hourly Temperatures (^{o}F) for 24 Hour Periods, from Noon June 23 until Noon Sept. 9, 1920.

Date	12-2	2-4	4-6	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10	10-12
June 23-24	59	62	64	65	54	46	44	47	47	50	50	54
June 24-25	58	62	63	62	54	48	48	45	42	47	52	54
June 25-26	58	60	56	53	49	48	47	48	49	54	61	65
June 26-27	70	71	72	69	63	58	52	49	47	56	64	68
June 27-28	73	75	72	73	66	56	48	45	45	56	66	72
June 28-29	74	76	74	71	65	57	52	49	46	56	72	78
June 29-30	80	80	80	79	73	65	60	58	56	58	68	72
June 30-July 1	75	78	80	80	72	61	54	49	48	64	69	71
July 1-2	74	78	79	79	70	60	56	56	56	58	66	74
June 2-3	77	77	79	76	72	62	56	51	47	51	55	58
July 3-4	62	65	67	67	64	54	48	44	43	55	64	67
July 4-5	70	73	73	72	62	58	54	50	49	52	58	59
July 5-6	61	62	64	56	54	50	49	50	56	60	64	69
July 6-7	71	74	76	76	68	60	54	50	49	57	68	76
July 7-8	80	82	81	74	71	64	58	54	50	58	70	77
July 8-9	81	82	81	78	73	66	62	59	57	62	72	78
July 9-10	82	83	82	74	64	59	56	54	50	58	67	73
July 10-11	78	81	82	78	72	63	58	55	55	58	61	64
July 11-12	67	67	68	67	63	59	55	53	53	58	67	69
July 12-13	72	73	72	70	64	55	50	46	44	54	65	73
July 13-14	77	79	79	78	71	58	53	50	48	54	66	74
July 14-15	79	81	80	77	70	62	58	55	52	56	67	77
July 15-16	84	88	89	85	75	67	66	62	57	64	73	82
July 16-17	88	92	92	91	81	68	61	57	53	59	70	84
July 17-18	92	95	93	70	67	63	61	59	57	61	72	78
July 18-19	83	83	80	82	74	66	61	56	54	63	77	82
July 19-20	87	90	89	83	74	67	64	57	53	63	73	80
July 20-21	86	88	90	84	75	69	64	63	61	64	75	81
July 21-22	88	89	84	80	76	72	65	64	63	63	61	65
July 22-23	69	71	68	65	61	59	56	53	49	54	64	70
July 23-24	74	79	82	77	70	61	58	57	56	61	68	74

Date	12-2	2-4	4-6	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10	10-12
July 24-25	78	80	76	66	54	54	52	49	48	50	56	61
July 25-26	67	71	73	68	60	55	55	54	54	55	58	65
July 26-27	73	74	68	58	52	50	48	47	46	48	56	63
July 27-28	67	70	72	72	66	57	52	50	49	58	66	75
July 28-29	79	81	80	80	70	58	54	51	49	57	68	80
July 29-30	85	83	78	72	66	63	61	60	57	61	66	78
July 30-31	80	79	79	77	70	65	63	62	58	59	66	73
July 31-Aug.1	77	82	81	74	69	65	63	58	56	57	62	65
Aug. 1-2	70	77	83	83	70	57	52	48	47	54	68	72
Aug. 2-3	80	85	84	74	63	56	53	50	49	50	58	66
Aug. 3-4	58	54	57	58	53	50	50	49	47	50	49	49
Aug. 4-5	53	60	67	71	60	52	48	48	46	52	63	72
Aug. 5-6	75	79	81	81	66	56	52	49	48	57	70	78
Aug. 6-7	83	87	88	86	74	60	56	52	50	56	66	78
Aug. 7-8	85	85	82	80	68	62	56	53	51	56	70	75
Aug. 8-9	79	78	74	68	64	58	55	54	54	54	55	58
Aug. 9-10	61	64	64	62	55	51	51	51	48	48	56	61
Aug. 10-11	64	64	60	57	50	45	40	40	40	42	45	61
Aug. 11-12	68	73	76	72	60	54	51	49	49	54	65	75
Aug. 12-13	80	83	85	84	66	60	55	53	52	55	67	76
Aug. 13-14	83	86	84	79	68	62	56	52	52	56	62	68
Aug. 14-15	75	78	77	68	56	52	49	49	50	52	58	65
Aug. 15-16	67	70	69	64	56	53	50	49	47	49	58	63
Aug. 16-17	68	73	73	68	62	61	59	58	57	56	54	53
Aug. 17-18	51	52	50	46	42	41	40	40	42	43	45	45
Aug. 18-19	44	44	44	44	42	38	37	38	39	49	52	56
Aug. 19-20	60	64	67	62	51	47	43	39	37	46	56	62
Aug. 20-21	70	75	76	72	56	50	48	47	47	50	64	76
Aug. 21-22	80	82	81	80	60	54	51	48	46	47	60	73
Aug. 22-23	80	85	82	78	70	63	56	54	50	52	65	68
Aug. 23-24	67	62	59	69	54	48	42	38	37	41	57	62
Aug. 24-25	69	72	73	68	60	56	54	52	52	51	54	54

Date	12-2	2-4	4-6	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10	10-12
Aug. 25-26	55	56	55	52	51	51	49	49	48	49	50	50
Aug. 26-27	53	58	61	60	52	47	46	44	43	44	46	48
Aug. 27-28	63	70	70	66	60	56	52	46	43	43	53	64
Aug. 28-29	64	60	56	55	51	50	47	45	42	43	54	60
Aug. 29-30	65	68	65	58	50	44	42	39	37	40	50	57
Aug. 30-31	62	65	66	65	55	48	42	38	34	34	49	60
Aug.31-Sept.1	68	71	71	69	56	46	43	41	40	39	53	61
Sept. 1-2	64	66	64	58	54	54	54	49	52	53	54	62
Sept. 2-3	68	74	74	68	58	54	52	51	46	47	56	61
Sept. 3-4	62	68	72	68	55	50	44	43	41	45	58	68
Sept. 4-5	75	77	78	70	58	52	52	52	42	49	56	58
Sept. 5-6	61	62	64	57	52	51	49	47	46	46	50	54
Sept. 6-7	60	62	65	61	47	41	38	36	34	37	48	62
Sept. 7-8	68	70	72	65	48	44	41	39	36	36	54	66
Sept. 8-9	73	77	77	69	53	48	48	42	36	37	53	64

APPENDIX

TABLE 21 - Mean Bi-hourly Temperatures (°F.) for 24 hour Periods from Noon June 20 until Sept. 9, 1921.

Date	12-2	2-4	4-6	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10	10-12
June 20-21	73	77	79	77	70	53	51	50	50	54	63	75
June 21-22	78	83	82	78	70	64	61	58	56	58	64	70
June 22-23	73	78	78	72	59	58	56	53	51	54	59	63
June 23-24	70	74	74	72	66	61	60	55	54	55	63	68
June 24-25	74	78	80	75	68	65	62	61	60	58	64	68
June 25-26	72	75	64	65	60	52	46	44	43	57	66	72
June 26-27	76	80	80	74	70	64	60	54	49	57	68	72
June 27-28	76	79	76	69	60	57	53	48	46	54	60	64
June 28-29	70	76	76	70	63	54	51	48	48	52	57	63
June 29-30	68	74	76	70	66	60	58	56	55	55	56	57
June 30-July 1	62	68	70	67	62	57	55	54	53	52	53	53
July 1-2	56	61	65	65	60	52	53	52	52	51	49	49
July 2-3	52	57	61	58	56	53	50	49	51	54	56	59
July 3-4	62	64	66	64	60	54	52	50	46	49	60	64
July 4-5	67	71	64	57	55	49	45	44	43	46	51	53
July 5-6	57	59	57	55	53	48	43	44	44	45	50	56
July 6-7	60	63	60	55	53	50	46	44	43	47	54	62
July 7-8	68	72	74	70	64	60	58	54	53	56	62	65
July 8-9	68	70	71	66	56	50	48	47	49	52	56	58
July 9-10	63	66	69	65	55	52	48	44	44	50	57	62
July 10-11	66	70	63	60	54	50	48	44	41	47	59	64
July 11-12	68	71	68	60	54	47	43	39	40	47	60	65
July 12-13	70	73	74	74	60	53	49	46	45	50	60	70
July 13-14	74	77	77	72	61	58	51	47	45	56	64	73
July 14-15	77	80	80	74	67	64	64	62	56	62	68	74
July 15-16	78	81	76	71	60	57	54	52	51	54	60	66
July 16-17	68	63	58	57	53	49	50	49	49	50	52	53
July 17-18	57	65	69	68	61	56	50	47	48	56	64	69
July 18-19	75	78	80	75	67	61	60	60	60	62	68	73
July 19-20	78	83	85	82	72	68	66	64	59	60	67	74
July 20-21	83	87	82	64	59	56	55	53	50	51	57	64
July 21-22	69	74	78	82	76	57	53	52	49	51	61	70
July 22-23	73	78	76	72	64	57	55	53	51	52	59	64
July 23-24	70	73	75	75	64	48	44	41	40	50	63	67
July 24-25	66	70	71	69	63	60	58	53	50	56	64	70

Date	12-2	2-4	4-6	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10	10-12
July 25-26	72	71	77	74	65	59	53	50	46	50	63	71
July 26-27	75	78	81	80	70	60	55	51	50	54	64	70
July 27-28	75	81	80	78	69	58	53	51	54	56	58	65
July 28-29	67	70	66	57	55	54	53	52	52	52	54	59
July 29-30	62	65	68	69	65	55	50	46	44	46	54	62
July 30-31	70	72	75	77	66	56	52	50	50	51	55	62
July 31-Aug.1	69	73	70	67	62	57	53	51	50	51	56	61
Aug. 1-2	68	72	73	70	60	58	57	56	56	57	65	71
Aug. 2-3	73	77	70	52	51	49	48	47	48	49	50	53
Aug. 3-4	55	62	64	59	50	43	42	41	42	45	50	59
Aug. 4-5	64	61	60	54	50	49	48	48	46	48	49	50
Aug. 5-6	51	52	58	58	50	47	42	41	40	44	54	63
Aug. 6-7	68	72	76	74	60	52	49	49	48	51	61	68
Aug. 7-8	70	73	77	65	57	55	55	55	55	55	62	63
Aug. 8-9	62	51	59	59	57	54	55	52	49	54	59	66
Aug. 9-10	72	73	70	61	54	52	49	47	46	49	53	55
Aug. 10-11	58	61	62	62	52	46	47	49	49	53	58	64
Aug. 11-12	67	67	65	62	58	53	48	47	43	50	60	65
Aug. 12-13	68	71	73	70	58	51	50	48	44	58	70	75
Aug. 13-14	79	83	82	76	64	58	54	50	45	51	65	73
Aug. 14-15	79	82	82	78	68	62	57	52	48	57	68	72
Aug. 15-16	74	76	70	66	60	56	52	49	43	46	57	66
Aug. 16-17	70	73	73	70	62	59	57	55	54	54	52	56
Aug. 17-18	58	62	60	57	54	52	51	50	49	50	52	53
Aug. 18-19	57	59	58	55	49	48	47	45	42	41	49	54
Aug. 19-20	60	64	65	62	52	50	47	42	42	50	58	65
Aug. 20-21	70	76	78	70	60	55	56	53	51	50	51	56
Aug. 21-22	58	64	62	56	53	51	48	45	45	44	53	59
Aug. 22-23	64	68	69	68	56	48	47	48	47	47	52	59
Aug. 23-24	66	71	71	64	57	53	53	50	48	47	50	52
Aug. 24-25	56	63	65	63	54	47	46	42	38	40	50	58
Aug. 25-26	64	69	70	66	53	43	38	38	38	39	56	64
Aug. 26-27	69	71	70	62	48	42	39	38	38	45	56	66
Aug. 27-28	71	74	70	64	51	48	46	45	45	46	52	59
Aug. 28-29	63	66	67	61	51	47	45	45	45	47	58	62

Date	12-2	2-4	4-6	6-8	8-10	10-12	12-2	2-4	4-6	6-8	8-10	10-12
Aug. 29-30	69	73	72	65	50	44	39	36	34	43	52	60
Aug. 30-31	70	72	65	55	44	41	37	37	36	40	46	48
Aug.31-Sept.1	53	60	67	60	52	47	45	44	45	45	49	49
Sept.1-2	50	59	61	57	46	36	33	31	29	35	50	60
Sept.2-3	65	70	64	53	49	44	41	40	39	39	37	56
Sept.3-4	62	67	67	60	45	38	33	32	33	39	47	57
Sept.4-5	61	68	68	56	50	46	44	43	41	42	56	60
Sept.5-6	64	65	67	60	45	40	39	37	37	40	52	66
Sept.6-7	71	71	67	62	54	55	53	47	44	47	53	61
Sept.7-8	66	68	64	57	53	51	49	46	43	40	41	41
Sept.8-9	43	44	43	41	40	39	37	35	33	31	34	40

APPENDIX

TABLE 22 - Duration of Sunshine for Each Hour of the Day from June 20 to Sept. 9, 1920.

Day of month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours	Total possible Hrs. Lat.
JUNE, 1920																				
20		0.5	1.0	0.6	0.4	0.9	0.9	1.0	0.8	0.7	0.8	0.9	0.8	0.5	0.6	0.9	0.7	0.2	12.2	16.9
21		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4			14.4	16.9
22		0.1	0.0	0.3	0.6	1.0	0.9	0.6	0.1	0.0	0.0	0.0	0.8	1.0	1.0	0.9	0.6		7.9	16.9
23		0.6	0.0	0.8	0.8	1.0	0.9	0.8	0.5	0.3	0.8	0.8	0.6	0.9	0.9	1.0	0.6		11.3	16.9
24											0.4	0.4	1.0	1.0	0.9	1.0	0.2		4.9	16.8
25		0.5	1.0	1.0	1.0	0.9	0.9	0.3	0.5	0.8	0.5	0.7	0.1						8.2	16.8
26			0.8	1.0	1.0	1.0	1.0	1.0	0.7	0.7	0.8	0.2	0.4	0.6	0.4	0.7	0.1		10.4	16.8
27		1.0	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.8	1.0	1.0	0.5			13.8	16.8
28	0.1	1.0	0.8	0.9	0.9	0.8	0.7	0.8	1.0	1.0	0.6	0.6	0.2	0.6	1.0	0.6			11.6	16.8
29		0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.8	0.9	1.0	0.8	0.5	0.5	0.3		13.3	16.8
30		0.2	0.1	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	0.4		13.0	16.8
Total	0.1																			
JULY, 1920																				
1	0.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		15.4	
2					0.4	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.6			10.8	
3		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	1.0	0.9	1.0	1.0	1.0	0.5		15.2	
4			0.9	1.0	0.7	0.7	0.8	0.9	0.9	1.0	1.0	0.9	0.7	0.8	0.5	0.8	0.3		11.9	
5		0.1	0.0	0.5	0.6	0.0			0.2	0.2	0.4		0.5	0.2		0.6	0.3		3.6	
6		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	1.0	1.0	1.0	1.0	1.0	0.9	0.3		14.4	
7		0.7	0.9	1.0	1.0	1.0	1.0	1.0	0.8	0.6	1.0	1.0	1.0	0.5	0.1	1.0	0.3		12.9	
8		0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6		15.1	
9		0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.3		0.1	0.1		11.9	
10		0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5		14.9	
11		0.6	1.0	0.8			0.1		0.1	0.2		0.1		0.7	0.8	0.8	0.1		5.3	
12			0.7	0.9	1.0	1.0	1.0	1.0	1.0	0.8	0.7	0.8	0.9	0.9	1.0	1.0	1.0		13.7	
13		6.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.9	1.0	0.9	1.0	1.0	1.0	0.3		14.5	
14		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		15.3	
15		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		14.8	
16		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2		14.7	
17		0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7						11.0	

TABLE 22 (continued)

TABLE 22 (continued)

July, 1920 (continued)

Day of month	Hours Ending																	Total Hours	Total Possible Hrs. Lat.
	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9		
18		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5	0.3	1.0	1.0	0.1		13.0	
19		0.1	0.5	1.0	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.1					10.3	
20		0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4				12.8	
21			0.1	0.9	0.6	0.8	1.0	1.0	1.0	1.0	1.0	0.3							7.7	
22								0.2	0.7	0.6	0.3	0.3							2.1	
23			0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2		13.9	
24		0.7	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	1.0	1.0	1.0	0.9					12.3	
25			0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6		14.1	
26				0.1	0.4	0.7	1.0	0.6	0.2	0.7	0.3	0.5	0.2	0.1					4.8	
27		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6		15.1	
28		0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		15.0	
29		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.1		14.6	
30		0.3	0.9	1.0	1.0	1.0	1.0	1.0	0.8	0.3	1.0	1.0	1.0	1.0	1.0	0.5	0.1		12.9	
31		0.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	1.0	1.0	1.0	1.0	0.7				12.5	
Total	0.1	12.4	24.2	27.2	26.6	27.1	27.8	27.6	27.6	26.2	27.5	26.4	24.8	22.8	20.4	20.2	7.4	0.2	376.5	
AUGUST, 1920																				
1			0.3	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		13.3	
2		0.1	0.8	0.8	0.6	0.9	1.0	0.6	1.0	1.0	1.0	1.0	0.5	0.3	0.1				9.7	
3		0.3	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.3	0.2	0.1	0.4	0.9	1.0	1.0	0.4		10.8	
4			0.8	0.3	0.0						0.6	0.6	0.9	1.0	1.0	1.0	0.3		6.5	
5		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4		15.0	
6		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		14.8	
7		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	0.7	0.7	0.9	0.7	0.6	0.1		13.1	
8		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.5	0.4	0.1				11.1	
9											0.1	0.1	0.3	0.4	1.0	0.8			2.7	
10			0.5	0.7	1.0	1.0	0.7	0.5	0.6	0.5	0.3		0.2			0.2	0.3		6.5	
11		0.1	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4			12.8	
12		0.3	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9		0.1		13.1	
13			0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		0.3	0.7			11.9	
14		0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0			14.9	
15							0.3	0.2	1.0	0.6	0.8	1.0	1.0	1.0	1.0	0.8			7.7	
16			0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5				12.2	
17									0.1	0.1				0.3					0.5	

TABLE 22 - continued

August, 1920

Day of Month	4	5	6	7	8	9	10	11	Hours Ending Noon	1	2	3	4	5	6	7	8	9	Total Hours
18																			
19			0.7	1.0	0.8	0.3			0.2	0.4	0.8	1.0	0.9	0.1	1.0	0.3			7.5
20					0.5	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.6	1.0	1.0	0.7			10.4
21			0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5			12.8
22			0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5			13.3
23			0.5	0.4	0.2	0.3	0.3	0.3	0.3		0.1			0.5	1.0	0.8			4.7
24			0.4	1.0	1.0	0.9	0.7	0.8	0.8	0.9	1.0	0.4	0.8	0.8	0.2				9.7
25					0.1														0.1
26												0.6	0.9	0.4	0.8	0.6			3.3
27								0.6	0.9	1.0	1.0	1.0	0.8	0.7					6.0
28						0.4	0.8	0.8	0.1	0.1									2.2
29				0.1	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5			11.5
30						0.4	0.8	1.0	0.7	0.2	0.5	0.3		0.8	1.0	0.3			6.0
31			0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3			12.5
Total		3.9	14.0	18.0	19.1	20.2	20.6	20.8	20.9	20.1	21.2	20.0	20.5	20.5	20.6	14.1	12.2		276.6

SEPTEMBER, 1920

Day of Month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours
1				0.7	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6			11.7
2							0.1	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.2				7.2
3				0.2	0.3	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7					8.8
4				0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8				11.0
5				0.1	1.0	1.0	0.6	0.1	0.4	0.3	0.0	0.0	0.6	0.2					4.3
6									0.3	0.1		0.4	1.0	1.0	0.5				3.3
7				0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9				11.3
8				0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9				11.7
9				0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	0.6					9.8
Total																			

APPENDIX

TABLE 23 - Duration of Sunshine for Each Hour of the Day from June 20 to Sept. 9, 1921.

JUNE, 1920

Day of Month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours
								Hours Ending											
20		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0	0.5		15.4
21		1.0	1.0	0.4	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8				12.5
22			0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	0.8	0.1				11.6
23								0.8	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.1			7.6
24		0.3	0.6	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	1.0	1.0	1.0	0.3		13.7
25				0.8	0.2	0.1				0.7			0.5	0.2		0.8	0.3		3.6
26		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2				13.2
27		1.0	1.0	1.0	1.0	0.7	0.8	0.7	1.0	1.0	1.0	0.9	0.6						10.7
28		1.0	1.0	0.8	1.0	0.2	0.7	1.0	1.0	1.0	0.5	1.0	1.0	0.4	0.1				10.7
29					0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8				10.5
30									0.2	0.2	0.5	0.3	0.8						2.0
31																			
Total																			

JULY, 1920

Day of Month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours
1											0.1	0.8	1.0	1.0	1.0	1.0	0.5		5.4
2													0						
3						0.2	0.5	0.7	0.4	0.4	0.2	0.7	0.7	1.0	0.6	0.6	0.2		6.2
4		0.4	0.3	0.2	0.2	0.1		0.7	1.0	1.0	1.0	1.0	0.2		0.2	0.8	0.3		7.4
5				0.8	0.3				0.1	0.2		0.7	0.4	0.5	1.0	0.6			4.6
6		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		0.9	1.0	0.5		13.2
7		0.3		0.8	0.3	0.7	1.0	1.0	1.0	1.0	1.0	0.7	0.9	0.3					9.0
8		0.1	0.9	1.0	1.0	1.0	0.4	1.0	0.4	0.6	0.4	0.4	0.4		0.5				7.9
9			0.2	0.2	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2		12.4
10		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.1						10.6
11		0.8	1.0	1.0	1.0	1.0	0.7	1.0	1.0	0.9	1.0	0.7	0.5	0.6	0.7				11.9
12		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.4	1.0	0.8	0.3	0.4		13.3
13		0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9			14.7
14		0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	005				12.3
15		0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6							10.1

TABLE 23 - continued

JULY, 1920

Day of month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours
						Hours ending													
16		0.3	1.0	1.0	1.0	1.0	0.5	0.2	0.1										5.1
17										0.1	0.8	0.5	0.5	0.2	1.0	1.0	0.4		4.5
18		0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	0.3		14.4
19			0.6	0.1	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.6	0.2		12.3
20		0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9				13.4
21		0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	0.7		15.3
22		0.6	0.8	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.3		14.3
23		0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		15.1
24			0.8	1.0	1.0	1.0	1.0	0.9	0.5	1.0	0.6	1.0	1.0	1.0	1.0	0.3			12.1
25		0.3	1.0	1.0	1.0	0.8	1.0		0.5				0.7	1.0	1.0	0.8	0.2		9.3
26			0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	0.3		13.8
27			0.3	0.4	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		13.1
28		0.1	0.1	0.1	0.3	0.5	0.9	0.5	0.2	0.1	0.3	0.1							3.2
29						0.3	0.9	0.9	0.5	1.0	1.0	1.0	0.3	0.7					6.6
30			0.7	0.8	1.0	1.0	1.0	1.0	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	0.3		13.5
31					0.3	0.9	1.0	1.0	1.0			0.7		0.1	0.8	0.2	0.1		6.1
Total		8.9	18.5	19.9	21.5	23.5	23.9	23.9	22.5	22.2	22.4	23.7	19.0	18.5	20.5	16.0	6.2		311. 1
				AUGUST, 1920															
1				0.1					0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.3		7.8
2			0.6	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	0.8	0.7	0.5	0.2				10.6
3								0.6	0.1		0.5	0.5	1.0	1.0	1.0	0.3			5.0
4				0.2	0.1	0.1	0.2	0.3	0.8	0.9	0.7	0.5	0.8	0.8	0.7	0.1	0.1		6.3
5			1.0	0.2								0.4	1.0	1.0	0.9	0.9	0.3		5.7
6			0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	1.0	1.0	0.2		13.3
7		0.4	1.0	1.0	1.0	1.0	0.8	0.8	0.8	0.2	1.0	1.0	1.0	1.0	0.4	0.6			12.0
8																			
9					0.6	0.6	1.0	1.0	1.0	1.0	0.2	0.3	0.3						6.0
10						0.1	0.1	0.5	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1		8.4
11					0.8	0.2	0.8	0.9	1.0	0.9	0.7	0.5	0.3	0.2	0.5				6.8
12			0.6	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	0.8	0.1	1.0	1.0	0.7			12.0
13			0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9			13.7
14			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9			13.9

TABLE 23 - continued

AUGUST, 1920

Day of Month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours
								Hours Ending											
15			0.3	0.5	0.4	0.9	0.9	0.7	1.0	0.6	0.9	1.0	0.7	0.1	0.3	0.3			8.6
16			0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2			12.9
17			0.1	0.1		0.1								0.2					0.5
18									0.1	0.6	0.5		0.3	0.4	0.8	0.8			3.5
19						0.2		0.1	0.1	0.6	1.0	1.0	1.0	1.0	1.0	0.5			6.5
20			0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	Q.2				11.8
21												0.3		0.2					.5
22			0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5			13.0
23			0.1	0.3	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.3	0.2			10.3
24				0.1	0.1			0.1		0.3	0.7	1.0	1.0	0.7	0.9	0.4			5.3
25			0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5			13.2
26			0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4			13.2
27				0.8	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.6	0.6	0.7	0.8				10.2
28									0.1			0.7	0.7	0.4	0.6				2.5
29				0.3	1.0	1.0	1.0	1.0	0.5	0.7	0.6	0.9	0.8	0.4	0.1	0.2			8.5
30			0.2	0.2					0.3	0.7	0.4	0.8	0.9	1.0	1.0	0.6			6.1
31										0.5	1.0	1.0	1.0	1.0	0.3				4.8
Total		0.4	9.3	13.8	15.7	16.2	16.8	17.8	18.6	21.0	21.7	23.1	23.2	22.3	20.0	12.0	1.0		252.9

SEPTEMBER, 1920

Day of Month	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	Total Hours
1				0.1		0.1		0.1			0.2	1.0	1.0	0.8	0.9	0.5			4.7
2			0.1	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.1					9.6
3				0.3	0.7	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6				10.1
4						0.2	0.6	1.0	1.0	1.0	1.0	1.0	1.0	0.6	0.5				7.9
5			0.4	1.0	0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	0.1			11.6
6				0.4	1.0	1.0	0.9	1.0	1.0	1.0	0.7	0.1							7.1
7						0.2	0.1	0.8	0.7	1.0	1.0	1.0	1.0	0.2					6.0
8										0.2									0.2
9																			
Total																			