

3-1932

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### Recommended Citation

Puhr, L.F. and Hume, A.N., "Variations in Amounts of Carbohydrates in the Leaves of Corn" (1932). *Bulletins*. Paper 270.  
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# **Variations In Amounts of Carbohydrates In The Leaves of Corn**

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# Variations In Amounts of Carbohydrates (Sugar and Starch) In The Leaves of Corn

Leo F. Puhr and A. N. Hume

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## INTRODUCTION

The present study conducted as a research project with the use of Purnell funds was designed to acquire information concerning the diurnal variation in the amounts of carbohydrates in the leaves of corn plants.

It was assumed that the variations of light and temperature between periods when the amounts of carbohydrates were determined might be associated with the conditions of growth of the plants, not only as to light and temperature during the day and night, but likewise by the stage of growth of the plants themselves.

Two strains of corn were therefore employed, one of which had been observed to be of early maturity, and the other of later maturity. Presumably two such different strains might represent different degrees of maturity of corn plants, at a given time when leaf-samples might be taken, for the determination of carbohydrates therein.

The time for taking these leaf samples was somewhat arbitrarily selected when the corn plants were still in active growth, but fairly mature. The early strain in the several seasons whether growing in the greenhouse or field was usually fully tasseled and silked; the later strain evidently not so far advanced.

The computations and discussions in this bulletin are based on the amounts determined quantitatively of photosynthetic products in the leaf-samples taken at periods indicated and analyzed for sugars and starch.

## HISTORICAL

Miller (4) made the following observations concerning the daily variation of the carbohydrates found in the leaves of corn and sorghum. The total sugar in the leaves of corn and sorghums began to increase between 4:00 and 6:00 a. m., reaching a maximum at a time varying from 12 to 5 p. m. After the maximum was reached the sugar disappeared rapidly until 10 p. m., after which the decrease was very gradual until daylight again appeared. In three comparative experiments with Pride of Saline corn the maximum percentage of sugar in the leaves was respectively 6.03, 6.33, and 6.44.

The insoluble carbohydrates estimated as starch generally reached a maximum later in the day than the sugars, and after they had reached a maximum showed little decrease until about midnight, after which they decreased rapidly until daylight. The non-reducing sugars in the leaves of the plants studied were with the exception of Dwarf milo and Red Amber sorgho, always in excess of the reducing sugars. The non-reducing sugars increased markedly during the day and decreased during the night.

Brown and Morris (1) in their work on the carbohydrates of nasturtium considered that dextrose and laevulose present in the leaves was a product of the hydrolysis of cane sugar. On account of the relative amount of cane sugar found in the leaves and the manner in which it fluctuates during the day, they concluded it is the first sugar formed in photosynthesis.

Davis, W. A., Daish, A. G., Davis and Sawyer, C. C. (2 and 3) concluded from their investigations with potatoes and marigold that cane sugar is apparently the first sugar formed in the leaves of potatoes and marigold and is transferred into hexoses for translocation. They also concluded that cane sugar is gradually inverted on its way through the veins, midribs, and stalks. In the same investigation they observed that the amount of sucrose in the leaves reached a maximum at 2:00 p. m., following approximately the curve of temperature. It then fell during the rest of the day and the hexose sugars began to increase in the leaf due to the hydrolysis of the sucrose to invert sugar. The starch reached its maximum two hours after sunset.

## PLAN OF EXPERIMENT

### Cultural Methods

The corn plants were grown both in the greenhouse and in the field.

The greenhouse plants were grown in galvanized cylindrical cans sixteen inches wide and thirty-six inches deep. The cans were filled from a bin of Barnes sandy loam soil that had been thoroughly mixed and pulverized. Four corn plants were grown in each can. The cans were arranged in the greenhouse so each one received as nearly as possible the same amount of sunlight. The greenhouse is located on the south side of a brick building. The temperature of the greenhouse was maintained as nearly as possible as the temperature would be outside during the growing season.

The plants grown under field conditions were planted in hills forty-

four inches apart. Two plants were grown in each hill. The soil was kept free from weeds by hoeing and cultivating.

### History of Seed

The early and late maturing strains were selected for earliness and lateness from the variety known as Brookings 86. The selection for earliness and lateness was made on the basis of the time of the appearance of the silks. Each strain of corn had been self-fertilized since 1925. Both field and greenhouse plants of either strain were planted from the same ear. Seed from the same ear from which the greenhouse and outdoor corn plants were produced was planted in the field and self-fertilized. Thus the seed for the next year's plants was produced. Both strains of corn were grown as continuous self-fertilized lines throughout the experiment.

### Collection of Material

The corn leaves were sampled at intervals of three hours each with a Sachs-Genung punch. One hundred discs having a diameter of a centimeter were taken from six corn plants of each strain. The samples were immediately taken to the laboratory and dried in a vacuum oven at a temperature of 65 degrees Centigrade to prevent any changes of the sugars due to the enzymes present in the leaves.

### Method of Analysis

The sugar determinations were made according to the method of Shaffer-Hartman.

The sample of leaves was thoroughly macerated by placing in a mortar, adding a few cc. of 80 per cent alcohol, some pure silica sand, and grinding with a pestle.

The macerated leaves were refluxed with 80 per cent alcohol. The alcohol was evaporated off and the sugar solution was made up to 25 cc. and clarified with neutral lead acetate solution. The excess lead acetate was precipitated with sodium carbonate and filtered.

Ten cc. aliquots were withdrawn from each sugar solution and placed in 80 cc. centrifuge tubes. Twenty-five cc. of Benedict's solution was added to each tube and then boiled exactly four minutes. The tubes were then cooled and centrifuged six minutes. Ten cc. aliquots were withdrawn from each tube after centrifuging and the copper remaining in solution was determined by the iodide method. The Benedict's solution was standardized in terms of pure glucose.

The residue from the extraction of the sugars was hydrolyzed with 1 per cent HCL. According to Spoehr (6) the insoluble carbohydrates capable of being hydrolyzed with 1 per cent HCL represent very nearly the reserve food material of a plant. The reducing sugars obtained from the starch hydrolysis were determined in the same manner as the soluble sugars.

## RESULTS

The comparative study of the daily variation of the carbohydrates in the leaves of early and late maturing strains of corn was carried on during the years of 1927, 1928, 1929, and 1930. Greenhouse plants were grown in the late winter and spring during the years of 1927 and 1930

and in the fall of 1928. The plants grown in the field were planted as soon as weather conditions permitted. During the year of 1927 sufficient numbers of plants were grown to allow the taking of duplicate samples from each strain but in the following years only one group of samples was taken from each strain. The two strains of corn were grown each year under the same environmental conditions so that any difference in the amount and distribution of carbohydrates could be attributed to specific differences in the strains of corn.

The leaf samples were taken each year when the corn plants were in approximately the same stage of maturity. The early maturing plants were fully tasseled and silked and in the fertilization period at the time of sampling. The late maturing plants were usually a week to ten days behind the early maturing strain, the tassels just completely out and silks beginning to appear. Both strains were sampled on the same day.

The results of the investigation may be summarized according to the years it was conducted.

### Results for 1927

In 1927 leaf samples for analysis were taken from corn plants grown in the field and in the greenhouse. The total sugar for both strains reached a maximum in most of the observations at 4 p. m. In three observations the maximum total sugar occurred at 1 p. m. The minimum total sugar in the leaves for either strain was found most frequently from 1 a. m. to 4 a. m. The distribution of reducing and non-reducing sugars followed approximately the same trend as the total sugar. The insoluble carbohydrates estimated as starch reach a maximum for both strains that varied from 1 a. m. to 4 a. m. The minimum percentage of starch in the leaves occurred during the day time. Refer to Tables 1, 2, 3, 4. Appendix pages 10, 12, 14, 16.

### Results for 1928

For the early strain the maximum quantity of total sugar occurred from 4 p. m. to 7 p. m. and the minimum quantity from 4 a. m. to 7 a. m. A study of the distribution of total sugar for the late strain reveals that the maximum quantity occurs approximately from 4 p. m. to 7 p. m., and the minimum quantity from 4 a. m. to 10 a. m. The non-reducing sugar or sucrose follows very closely the same curve as that of total sugar. Since the reducing sugars occur in such relatively small amounts its fluctuations are not very consistent for either strain. A study of the variation of starch in the early and late strains shows that the maximum percentage of starch for each occurs at approximately 7 p. m. and the minimum at 1 p. m. Refer to Tables 5, 6, 7, 8. Appendix pp. 18, 20, 22, 24.

### Results for 1929

The results for 1929 are based on the analysis of leaf samples taken from plants grown under natural conditions in the field. The total sugar in the leaves of the early strain began to increase at 4 a. m., and reached a maximum at 4 p. m. and then declined quite rapidly until the minimum was reached at 1 a. m. The late strain had a higher percentage of total sugar in the leaves than the early strain. The maximum amount of total sugar was found at 1 p. m. and 4 p. m. respectively for the late



strain while the minimum amount was found at 4 a. m. Since the total sugar consists largely of non-reducing sugar the curves representing the changes in non-reducing sugar are very similar to those representing the change in total sugar.

Due to the very small amount of reducing sugar found in the leaves of both strains, the variations in reducing sugar have no significance. There are no starch determinations available for this year. Refer to Tables 9, 10. Appendix pages 26, 28.

### Results for 1930

In 1930 the carbohydrate determinations were made on leaf samples taken from corn plants grown in the greenhouse. Both early and late strains contained an unusually high percentage of total sugar. For both strains the total sugar began to increase at approximately 4 a. m. and reached a maximum at 4 p. m. After the maximum was reached the sugar disappeared until a minimum was reached between 4 a. m. and 7 a. m. The daily variation of non-reducing sugar is very similar to the daily variation of total sugar for both strains. By consulting Tables XI and XII and the corresponding graphs it will be seen that the changes in reducing sugar are very irregular. The percentage of starch did not vary much throughout the day for either strain, so that no definite conclusions can be made from this series in regard to starch variation. Refer to Tables 11, 12. Appendix pages 30, 32.

## DISCUSSION OF RESULTS

### Total Sugar

The total sugar in the leaves of an early and a late strain of corn increases rapidly during the day time and decreases at night. The maximum amount of sugar for both strains occurred at approximately from 1 to 4 p. m. for the greater number of observations. From the results of twelve observations the maximum total sugar occurred eight times at 4 p. m. for the early strain, and five times for the late strain. The maximum sugar occurred once at 1 p. m. for the early strain, and five times at 1 p. m. for the late strain. In samples taken from plants grown in the greenhouse on November 21 and 22, 1928, the maximum sugar occurred at 7 p. m. for both strains. In no other case did the maximum total sugar occur so late in the day. The shortness of the period of sunshine at this season of the year may account for the maximum sugar occurring at this time. In one sampling of August 6, 1928, the maximum total sugar occurred at 10 a. m. This was the earliest it occurred in either strain for all observations.

A study of the twelve comparative experiments with early and late maturing strains reveals that the maximum percentage of sugar for the early strains varies from 6.70 to 20.17 per cent, and from 6.83 to 16.6 per cent for the late strain. The average maximum per cent of sugar is 11.0 for the early strain, and 11.39 per cent for the late strain.

The time of the occurrence of the maximum per cent of total sugar in the leaves of early and late strains varied from 1 a. m. to 4 a. m. In two comparative observations the minimum total sugar occurred as late as 10 a. m. The average minimum per cent total sugar was 5.00 per cent for the early strain and 5.53 for the late strain.

The curves representing the changes of total sugar in the leaves resemble the curves representing the daily variation of temperature. The higher percentages of sugar occur in the afternoon when the temperature reaches its maximum. Since sugars are presumably the primary products of photosynthesis the greatest amount should occur in the day time when photosynthesis is at its maximum. During the hours of darkness photosynthesis has ceased and the decline in total sugar would be due to translocation and conversion of sugars to starch. A careful study of the twelve comparative experiments with early and late maturing strains of corn reveals that there is no significant difference in the amount and distribution of total sugar in the two strains of corn.

### Reducing and Non-Reducing Sugars

An examination of the graphs and tables representing the diurnal changes in total sugar and non-reducing sugar in the leaves of early and late maturing strains of corn reveals that they are very similar.

The maximum per cent of non-reducing sugar occurs most frequently between the hours of 1 p. m. and 4 p. m. for both strains of corn. The minimum per cent of non-reducing sugar occurs from 1 a. m. to 4 a. m. An examination of the graphs representing the changes in reducing sugars will show that the changes in reducing sugar are not so well defined and as consistent as the changes in total and non-reducing sugar. For most observations the minimum amount of reducing sugar occurred from 1 a. m. to 4 a. m., and the maximum amount from 1 p. m. to 4 p. m. The amount of reducing sugar in the leaves for most of the observations was under three per cent. The non-reducing sugar was always in excess of the reducing sugar. A comparison of the two strains of corn in regard to the daily distribution of non-reducing and reducing sugars in the leaves indicates that there is no significant difference between the two strains.

Since the non-reducing sugar is always in excess of the reducing sugar it might be conceived that non-reducing sugar or sucrose is the primary sugar of photosynthesis. It is also possible that reducing sugars may be the first sugars formed by photosynthesis and are converted to sucrose and temporarily stored in the leaves during the hours of sunshine as such.

### Starch

The insoluble carbohydrates estimated as starch reached a maximum later in the day than the soluble carbohydrates. The maximum percentage of insoluble carbohydrates occurred from 7 p. m. to 1 a. m. The earliest the maximum starch occurred for all observations was 4 p. m. and the latest 4 a. m. The minimum per cent starch in the leaves was found to be from 4 a. m. to 7 a. m. In two observations the minimum starch occurred at 10 a. m. A comparative study of the time of the occurrence of maximum starch and sugar in the leaves of early and late maturing strains reveals that during the hours of sunshine there is an accumulation of sugar. Later in the day when the photosynthetic activities of the plant have been reduced there is a conversion of sugar into starch. After the starch has reached its maximum from 7 p. m. to 1 a. m. there is a rapid decline in the amount of starch found in the leaves of



either strain.

The minimum total sugar and the minimum starch occur at approximately the same time from 1 a. m. to 4 a. m. From the physiological viewpoint the reduction in the amount of sugars and starch previous to the hours of sunshine seems plausible. In order for the leaves of the corn plant to be most efficient in the synthesis of carbohydrates it would be necessary that the residual carbohydrates from the previous day be translocated before photosynthesis begins on the next day. In the above manner the occurrence of the minimum per cent sugar and starch at approximately the same time may be accounted for. A careful study of the twelve comparative experiments shows that there is very little difference in the diurnal distribution of the insoluble carbohydrates in the leaves of early and late maturing strains of corn.

## SUMMARY

1. The total sugar in the leaves of early and late maturing strains of corn increases rapidly during the day time and decreases at night. The maximum amount of sugar for both strains occurs from 1 p. m. to 4 p. m. The minimum amount of total sugar in the leaves is found between 1 a. m. and 4 a. m.

2. The insoluble carbohydrates estimated as starch reach a maximum later in the day than the total sugar. For most observations the maximum amount of insoluble carbohydrates was found between 7 p. m. and 1 a. m. and the minimum amount at approximately 4 a. m. to 7 a. m.

3. The non-reducing sugars were always in excess of the reducing sugars. The non-reducing sugars increased rapidly during the hours of sunshine and decreased at night. The variations in reducing sugars are not so well defined and regular as the variations in non-reducing sugar.

4. There is no significant difference between the early and late maturing strains of corn here employed in regard to the daily variation and quantity of sugars and starch in the leaves.

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## APPENDIX

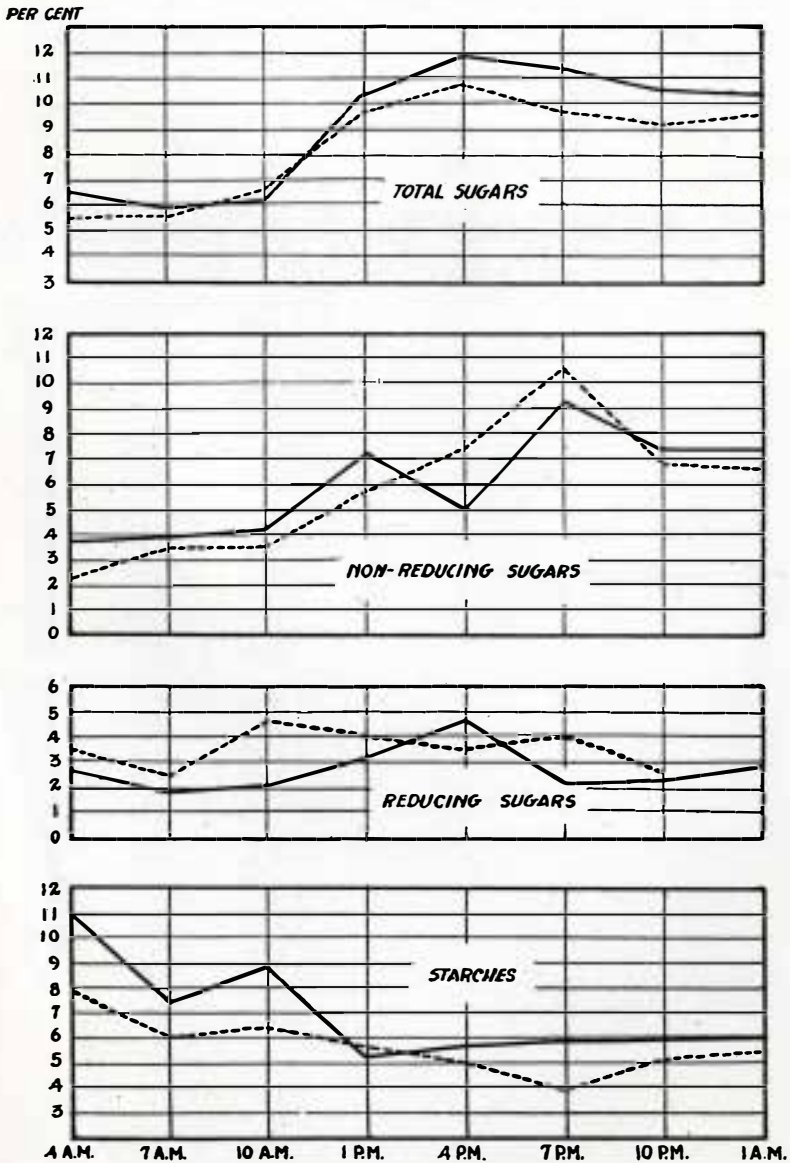
TABLE 1.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE THREE-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, PRODUCED UNDER GREENHOUSE CONDITIONS. LEAF SAMPLES TAKEN APRIL 19, 1927.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	6.50	5.51
	7 a. m.	5.74	5.71
	10 a. m.	6.20	6.35
	1 p. m.	10.25	9.77
	4 p. m.	11.74*	10.87
	7 p. m.	11.44	9.62
	10 p. m.	10.54*	9.26
	1 a. m.	10.31	9.53
Non-reducing Sugars	4 a. m.	3.81	2.08
	7 a. m.	3.89	3.32
	10 a. m.	4.20	3.36
	1 p. m.	7.15	5.60
	4 p. m.	4.85*	7.35
	7 p. m.	9.27	10.47
	10 p. m.	7.44*	6.64*
	1 a. m.	7.35	6.59
Reducing Sugars	4 a. m.	2.69	3.43
	7 a. m.	1.85	2.40
	10 a. m.	2.00	4.67
	1 p. m.	3.10	4.06
	4 p. m.	4.69	3.53
	7 p. m.	2.17	4.14
	10 p. m.	2.35	2.62*
	1 a. m.	2.96	2.94
Starches	4 a. m.	11.01	7.95
	7 a. m.	7.51	6.16
	10 a. m.	8.91	6.41
	1 p. m.	5.19	5.52
	4 p. m.	5.43	5.02
	7 p. m.	5.73	3.70
	10 p. m.	5.86	5.20*
	1 a. m.	5.98	5.47

\*\*—Based on one sample.

\*—Average of two samplings

CHART ONE



GRAPHIC PRESENTATION OF FOREGOING TABLE 1

Percentage of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under greenhouse conditions. Sampled April 19, 1927. — — — — — Late.

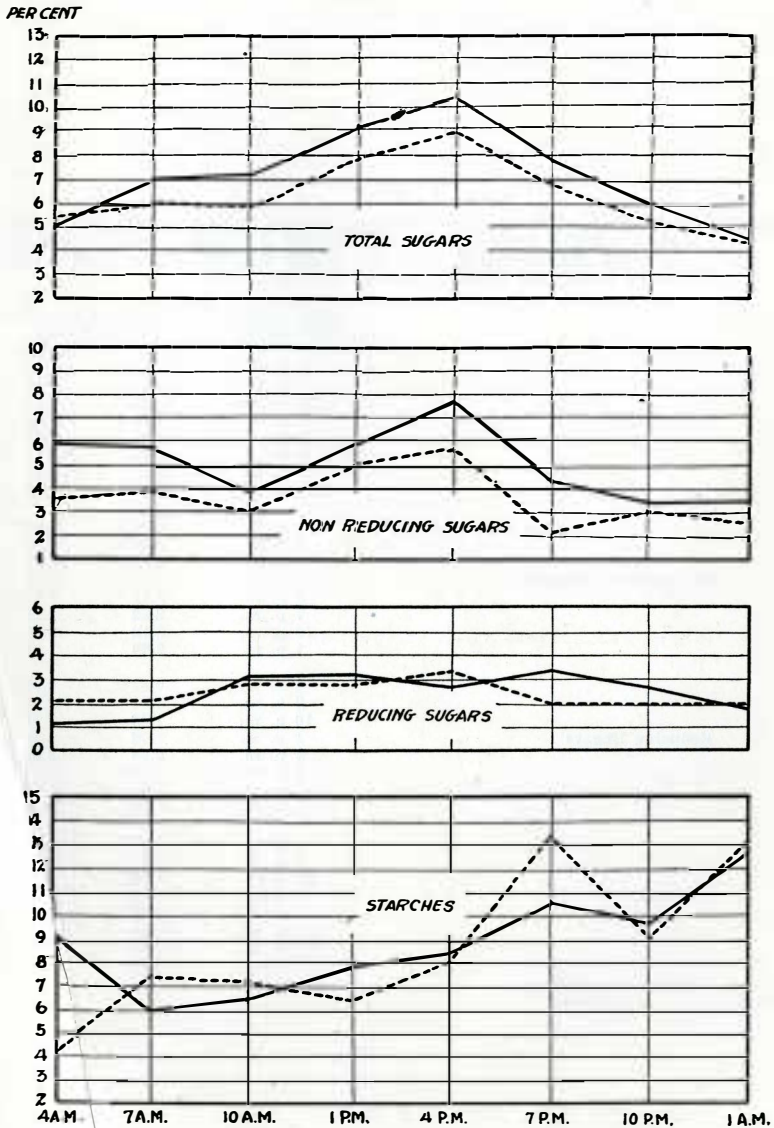
TABLE 2.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER GREENHOUSE CONDITIONS. LEAF SAMPLE TAKEN APRIL 22, 1927.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	4.97	5.61
	7 a. m.	7.06	6.05
	10 a. m.	7.12	5.80
	1 p. m.	9.16	7.68
	4 p. m.	10.45	9.00
	7 p. m.	7.72	6.79
	10 p. m.	6.00	5.12
	1 a. m.	4.78	4.62
Non-reducing Sugars	4 a. m.	5.82	3.53
	7 a. m.	5.64	3.79
	10 a. m.	3.91	3.00
	1 p. m.	5.89	4.89
	4 p. m.	7.71	5.62
	7 p. m.	4.27	2.07**
	10 p. m.	3.37	3.12
	1 a. m.	3.35**	2.57
Reducing Sugars	4 a. m.	1.17	2.08
	7 a. m.	1.43	2.26
	10 a. m.	3.22	2.81
	1 p. m.	3.27	2.79
	4 p. m.	2.75	3.37
	7 p. m.	3.46	2.09**
	10 p. m.	2.63	2.00
	1 a. m.	1.92**	2.05
Starches	4 a. m.	9.33	4.32
	7 a. m.	6.01	7.49
	10 a. m.	6.63	7.28
	1 p. m.	7.87	6.45
	4 p. m.	8.46	8.10
	7 p. m.	10.56	13.39
	10 p. m.	9.57	9.24
	1 a. m.	12.86	13.08

\*—Average of two samplings.

\*\*—Based on one sample.

CHART TWO



GRAPHIC PRESENTATION OF FOREGOING TABLE 2.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under greenhouse conditions. Sampled April 22, 1927. — Early; - - - - - Late.



TABLE 3.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER FIELD CONDITIONS. LEAF SAMPLES TAKEN AUGUST 23, 1927.

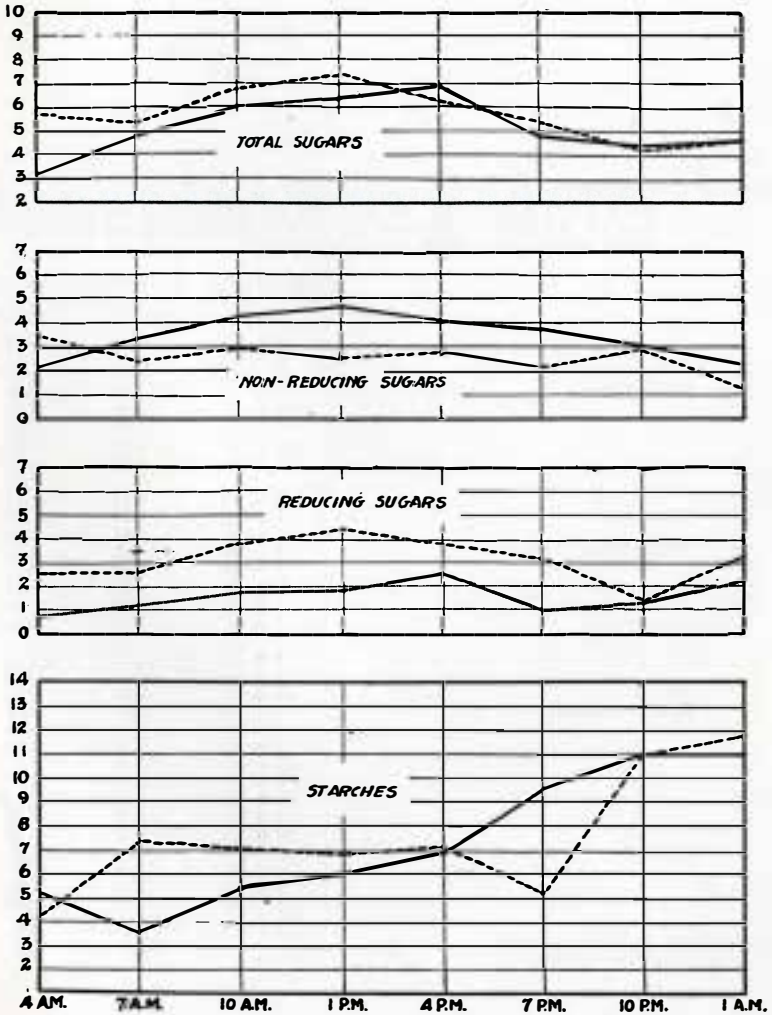
	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	3.21	5.65
	7 a. m.	4.79	5.25
	10 a. m.	6.04	6.70
	1 p. m.	6.42	6.83
	4 p. m.	6.70	6.36
	7 p. m.	4.78	5.33
	10 p. m.	4.43	4.26
	1 a. m.	4.54	4.48
Non-reducing Sugars	4 a. m.	2.27**	3.39**
	7 a. m.	3.49	2.53
	10 a. m.	4.36	2.94
	1 p. m.	4.69	2.46
	4 p. m.	4.11	2.71
	7 p. m.	3.82	2.23
	10 p. m.	3.12	2.91
	1 a. m.	2.29	1.34
Reducing Sugars	4 a. m.	0.62**	2.51**
	7 a. m.	1.30	2.67
	10 a. m.	1.68	3.75
	1 p. m.	1.72	4.36
	4 p. m.	2.58	3.66
	7 p. m.	0.96	3.09
	10 p. m.	1.31	1.35
	1 a. m.	2.25	3.14
Starches	4 a. m.	5.28**	4.22
	7 a. m.	3.61	7.48**
	10 a. m.	5.53	7.12
	1 p. m.	5.95	6.88
	4 p. m.	6.76	7.15
	7 p. m.	9.48	7.19
	10 p. m.	10.98	11.02
	1 a. m.	10.99	11.74

\*—Average of two samplings.

\*\*—Based on one sample.

CHART THREE

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 3.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under field conditions. Sampled August 23, 1927. ——— Early; - - - - - Late.

TABLE 4.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND ALATE MATURING STRAIN OF CORN, UNDER FIELD CONDITIONS. LEAF SAMPLES TAKEN AUGUST 25, 1927.

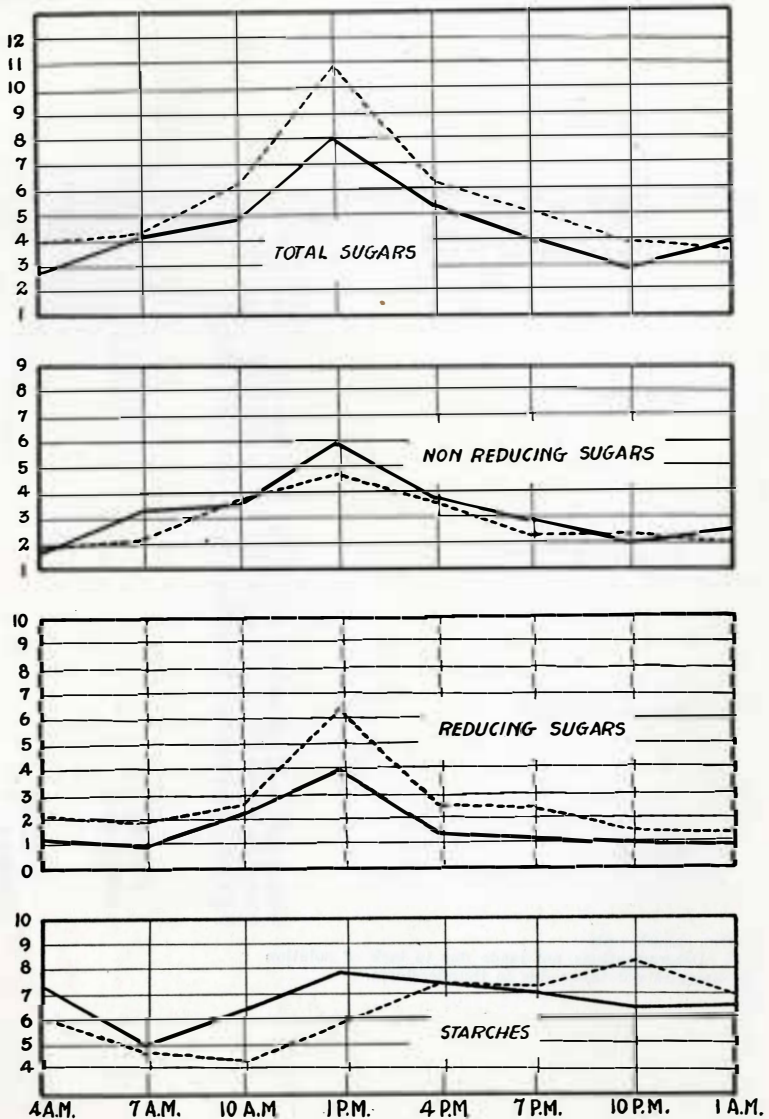
	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	2.71	3.94
	7 a. m.	4.11	4.18
	10 a. m.	4.87	6.34
	1 p. m.	8.07	10.90
	4 p. m.	5.33	6.38
	7 p. m.	4.16	4.99
	10 p. m.	2.90	3.87
	1 a. m.	3.76	3.55
Non-reducing Sugars	4 a. m.	1.64	1.84
	7 a. m.	3.31	2.25
	10 a. m.	3.53	3.75
	1 p. m.	6.02	4.62
	4 p. m.	3.82	3.69
	7 p. m.	2.90	2.43
	10 p. m.	1.95	2.30
	1 a. m.	2.45**	2.11
Reducing Sugars	4 a. m.	1.07	2.10
	7 a. m.	0.80	1.93
	10 a. m.	2.34	2.59
	1 p. m.	4.10	6.28
	4 p. m.	1.51	2.69
	7 p. m.	1.25	2.56
	10 p. m.	0.94	1.57
	1 a. m.	0.86	1.44
Starches	4 a. m.	7.37**	6.12**
	7 a. m.	5.15	4.71
	10 a. m.	6.49	4.26
	1 p. m.	7.96	5.91
	4 p. m.	7.51	7.45
	7 p. m.	7.06	7.35
	10 p. m.	6.54	8.23
	1 a. m.	6.67	7.11

\*—Average of two samplings.

\*\*—Based on one sample.

CHART FOUR

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 4.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under field conditions. Sampled August 25, 1927. ——— Early; - - - - - Late.

TABLE 5.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER FIELD CONDITIONS. LEAF SAMPLES TAKEN AUGUST 22, 1928.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	3.10	3.71
	7 a. m.	4.84	5.35
	10 a. m.	6.47	7.27
	1 p. m.	6.39	7.85
	4 p. m.	6.91	4.84
	7 p. m.	5.18	5.90
	10 p. m.	0	0
	1 a. m.	0	0
	4 a. m.		
Non-reducing Sugars**	7 a. m.		
	10 a. m.		
	1 p. m.		
	4 p. m.		
	7 p. m.		
	10 p. m.		
	1 a. m.		
	4 a. m.		
	7 a. m.		
Reducing Sugars**	10 a. m.		
	1 p. m.		
	4 p. m.		
	7 p. m.		
	10 p. m.		
	1 a. m.		
	4 a. m.	14.17	11.33
	7 a. m.	15.02	13.95
	10 a. m.	13.47	13.13
Starches	1 p. m.	16.01	15.68
	4 p. m.	16.99	17.66
	7 p. m.	15.41	16.66
	10 p. m.	0	0
	1 a. m.	0	0
	4 a. m.		

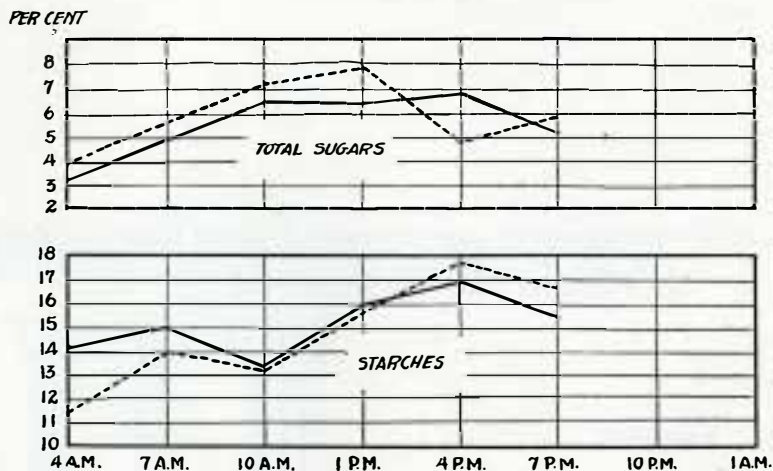
\*—One sample only

\*\*—Determinations not made due to lack of solution

0—Samples not taken due to thunderstorm.



CHART FIVE



## GRAPHIC PRESENTATION OF FOREGOING TABLE 5.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under field conditions. Sampled August 22, 1928. ———— Early; - - - - - Late.

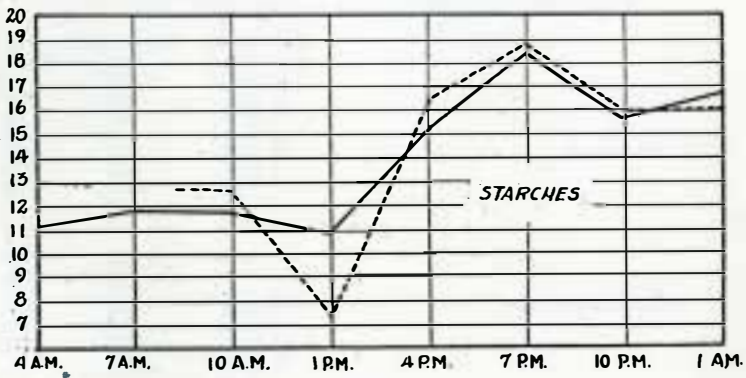
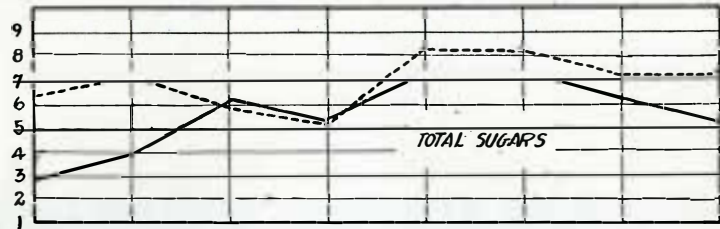
TABLE 6.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER FIELD CONDITIONS. LEAF SAMPLES TAKEN SEPTEMBER 5, 1928.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	2.67	6.38
	7 a. m.	3.77	7.27
	10 a. m.	6.32	5.86
	1 p. m.	5.41	5.27
	4 p. m.	7.30	8.46
	7 p. m.	7.29	8.31
	10 p. m.	6.18	7.39
	1 a. m.	5.20	7.28
Non-reducing Sugars	4 a. m.		
	7 a. m.		
	10 a. m.		
	1 p. m.		
	4 p. m.		
	7 p. m.		
	10 p. m.		
	1 p. m.		
Reducing Sugars	4 a. m.		
	7 a. m.		
	10 a. m.		
	1 p. m.		
	4 p. m.		
	7 p. m.		
	10 p. m.		
	1 a. m.		
Starches	4 a. m.	11.28	12.98
	7 a. m.	11.86	
	10 a. m.	11.76	12.61
	1 p. m.	10.89	7.41
	4 p. m.	15.23	16.41
	7 p. m.	18.50	18.89
	10 p. m.	15.61	15.86
	1 a. m.	16.55	15.97

\*—Based on one sample

CHART SIX

PER CENT



## GRAPHIC PRESENTATION OF FOREGOING TABLE 6.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under field conditions. Sampled September 5, 1928. ——— Early; - - - - - Late.

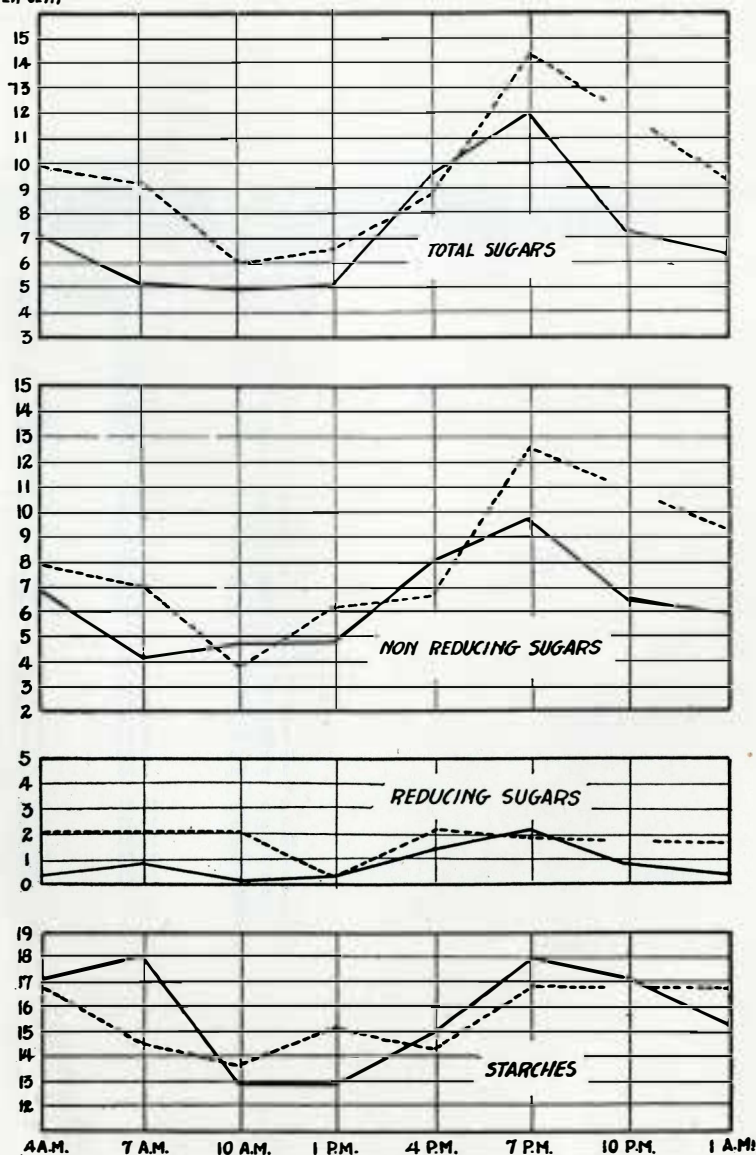
TABLE 7.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER GREENHOUSE CONDITIONS. LEAF SAMPLES TAKEN NOVEMBER 21, 1928.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	7.13	9.86
	7 a. m.	5.06	9.12
	10 a. m.	4.76	6.02
	1 p. m.	4.98	6.53
	4 p. m.	9.52	8.75
	7 p. m.	11.97	14.33
	10 p. m.	7.26	
	1 a. m.	6.32	10.93
Non-reducing Sugars	4 a. m.	6.72	7.81
	7 a. m.	4.14	6.95
	10 a. m.	4.59	3.87
	1 p. m.	4.60	6.13
	4 p. m.	8.06	6.57
	7 p. m.	9.66	12.45
	10 a. m.	6.46	
	1 a. m.	5.93	9.37
Reducing Sugars	4 a. m.	0.41	2.05
	7 a. m.	0.92	2.17
	10 a. m.	0.17	2.15
	1 p. m.	0.38	0.40
	4 p. m.	1.46	2.18
	7 p. m.	2.31	1.88
	10 p. m.	0.80	
	1 a. m.	0.39	1.56
Starches	4 a. m.	17.15	16.81
	7 a. m.	17.96	14.54
	10 a. m.	12.88	13.59
	1 p. m.	12.82	15.17
	4 p. m.	14.99	14.24
	7 p. m.	17.95	16.84
	10 p. m.	17.27	
	1 a. m.	15.43	16.70

\*—Based on one sample

## CHART SEVEN

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 7.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early maturing and a late maturing strain of corn under greenhouse conditions. Sampled November 21, 1928. — Early; — — — — — Late.



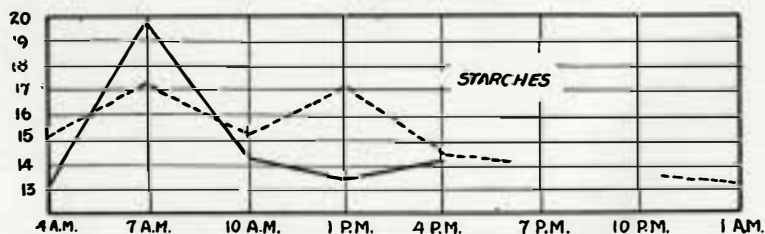
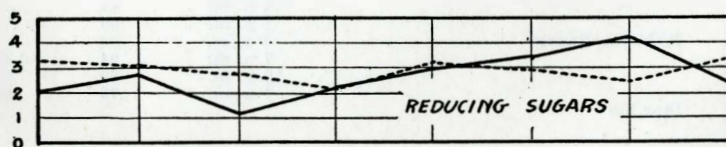
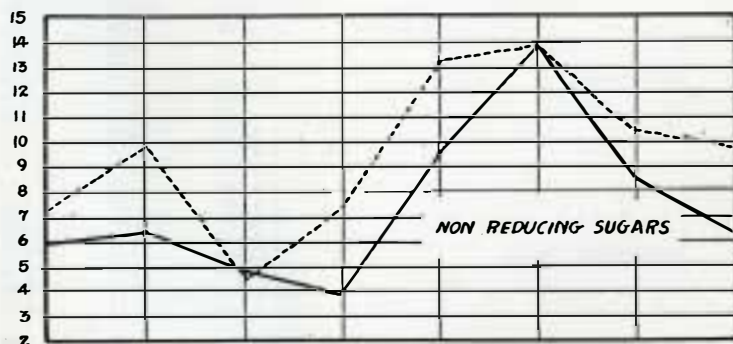
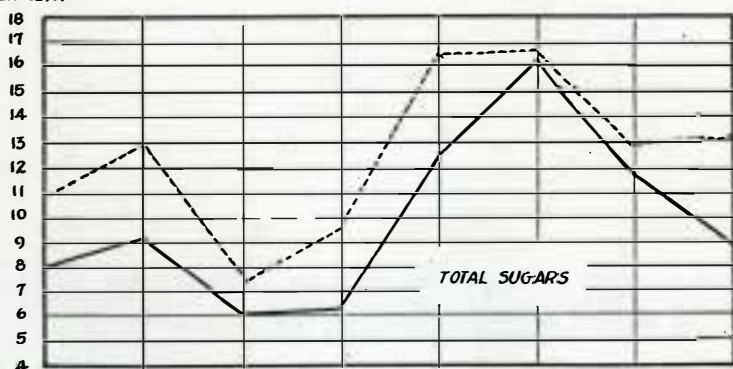
TABLE 8.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER GREENHOUSE CONDITIONS. LEAF SAMPLES TAKEN NOVEMBER 22, 1928.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	7.96	10.79
	7 a. m.	9.25	12.97
	10 a. m.	5.99	7.40
	1 p. m.	6.11	9.57
	4 p. m.	12.61	16.37
	7 p. m.	16.25	16.61
	10 p. m.	11.71	12.85
	1 a. m.	8.93	13.07
Non-reducing Sugars	4 a. m.	5.87	7.33
	7 a. m.	6.48	9.73
	10 a. m.	4.71	4.52
	1 p. m.	3.82	7.36
	4 p. m.	9.00	13.17
	7 p. m.	13.88	13.73
	10 p. m.	8.48	10.35
	1 a. m.	6.38	9.71
Reducing Sugars	4 a. m.	2.09	3.46
	7 a. m.	2.77	3.24
	10 a. m.	1.28	2.88
	1 p. m.	2.29	2.21
	4 p. m.	3.05	3.20
	7 p. m.	2.37	2.88
	10 p. m.	3.23	2.50
	1 a. m.	2.55	3.36
Starches	4 a. m.	13.21	15.05
	7 a. m.	19.77	17.34
	10 a. m.	14.34	15.30
	1 p. m.	13.50	17.33
	4 p. m.	14.21	14.56
	7 p. m.		
	10 p. m.		
	1 a. m.		13.19

\*—Based on one sample.

## CHART EIGHT

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 8.

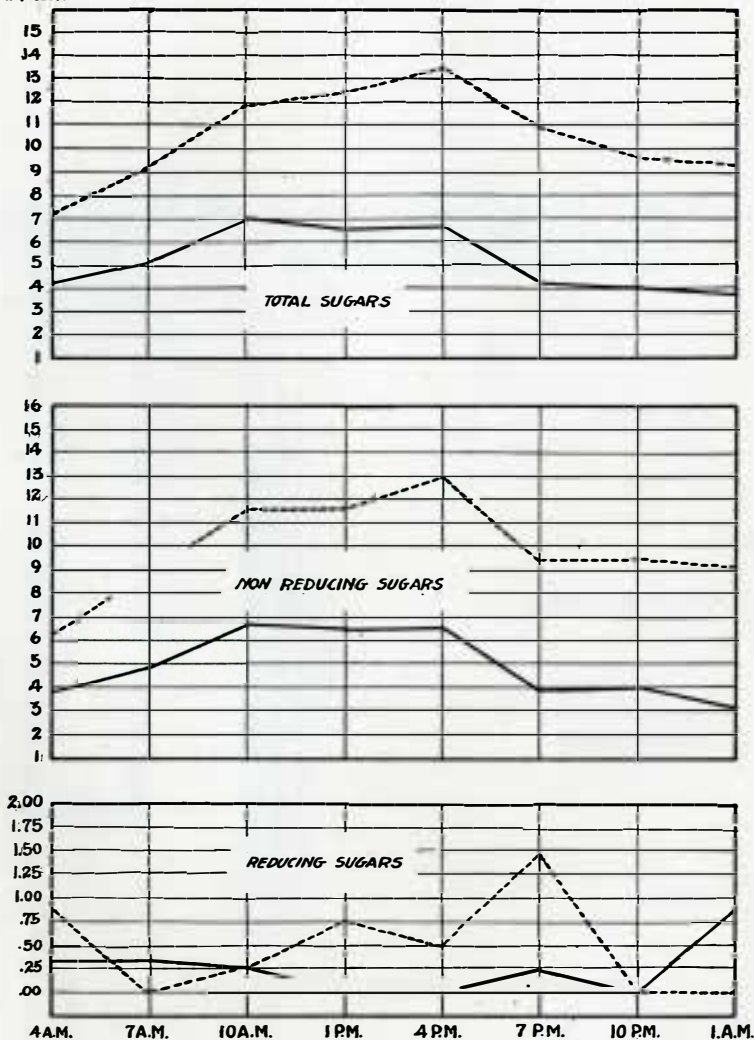
Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under greenhouse conditions. Sampled November 22, 1928. ——— Early; — — — — — Late.

TABLE 9.—PERCENTAGE OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER FIELD CONDITIONS. LEAF SAMPLES TAKEN AUGUST 6, 1929.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	4.12	7.06
	7 a. m.	5.15	9.12
	10 a. m.	6.93	11.66
	1 p. m.	6.40	12.32
	4 p. m.	6.50	13.37
	7 p. m.	4.16	10.79
	10 p. m.	3.95	9.41
	1 a. m.	3.76	9.11
Non-reducing Sugars	4 a. m.	3.78	6.18
	7 a. m.	4.81	9.12
	10 a. m.	6.67	11.40
	1 p. m.	6.40	11.55
	4 p. m.	6.50	12.88
	7 p. m.	3.92	9.36
	10 p. m.	3.95	9.41
	1 a. m.	3.11	9.11
Reducing Sugars	4 a. m.	.34	.88
	7 a. m.	.34	.—
	10 a. m.	.26	.26
	1 p. m.	.00	.77
	4 p. m.	.00	.49
	7 p. m.	.24	1.43
	10 p. m.	.00	.00
	1 a. m.	.75	.00
Starches			

CHART NINE

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 9.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn, under field conditions. Sampled August 6, 1929. — Early; — — — — Late.

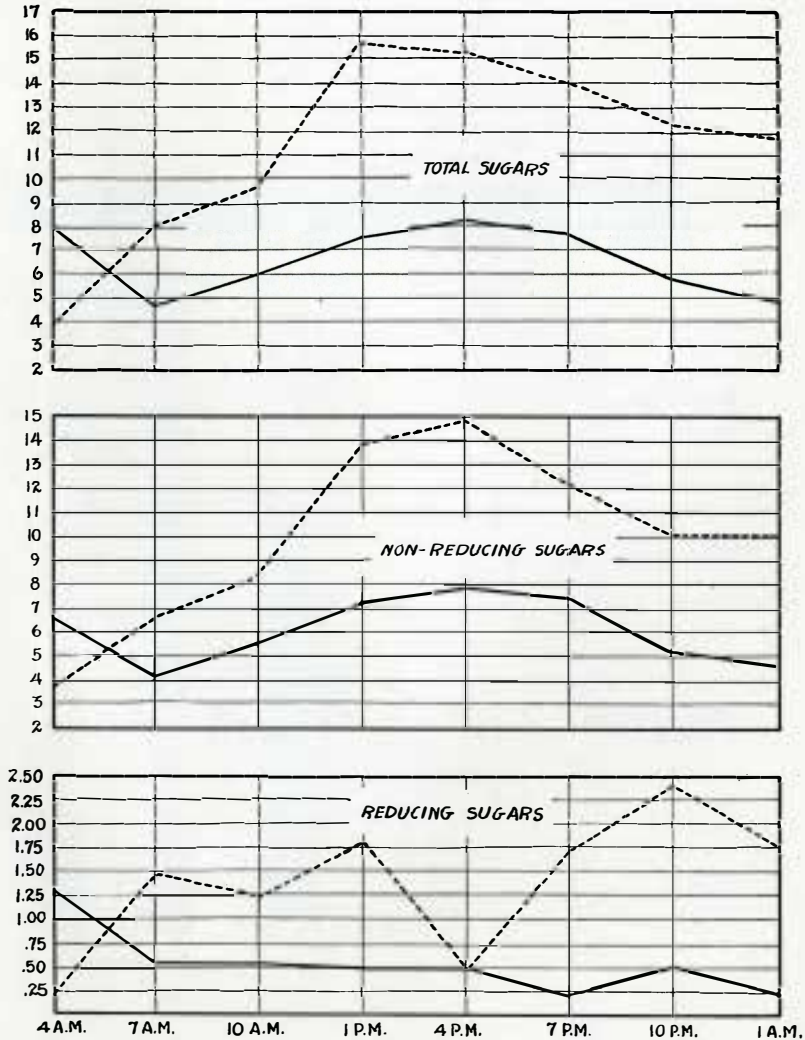
TABLE 10.—PERCENTAGE OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF A NEARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER FIELD CONDITIONS. LEAF SAMPLES TAKEN AUGUST 8, 1929.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	7.95	3.85
	7 a. m.	4.74	8.05
	10 a. m.	6.11	9.64
	1 p. m.	7.06	15.63
	4 p. m.	8.34	15.32
	7 p. m.	7.75	13.91
	10 p. m.	5.74	12.40
	1 a. m.	4.92	11.72
Non-reducing Sugars	4 a. m.	6.67	3.61
	7 a. m.	4.19	6.62
	10 a. m.	5.56	8.40
	1 p. m.	7.15	13.84
	4 p. m.	7.84	14.84
	7 p. m.	7.01	12.18
	10 p. m.	5.22	10.01
	1 a. m.	4.67	9.98
Reducing Sugars	4 a. m.	1.28	.24
	7 a. m.	.55	1.43
	10 a. m.	.55	1.24
	1 p. m.	.51	1.79
	4 p. m.	.50	.48
	7 p. m.	.24	1.73
	10 p. m.	.52	2.39
	1 a. m.	.25	1.74
	4 a. m.	No determinations available	
Starches	7 a. m.		
	10 a. m.		
	1 p. m.		
	4 p. m.		
	7 p. m.		
	10 p. m.		
	1 a. m.		



CHART TEN

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 10.

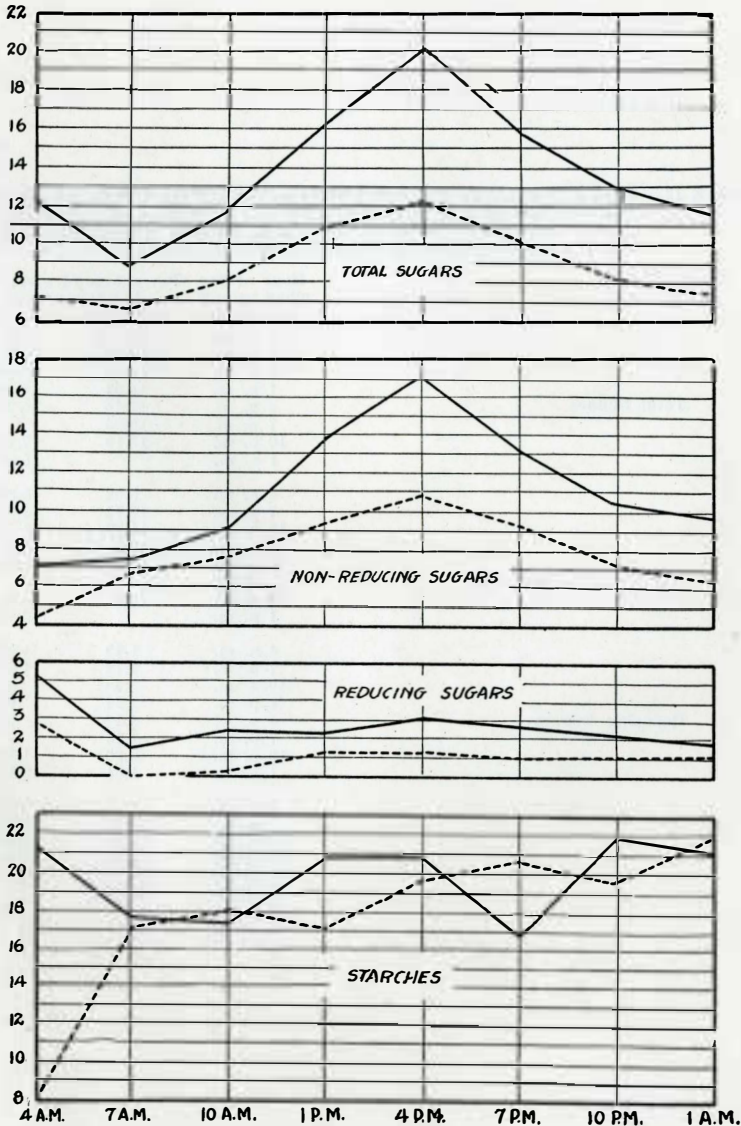
Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early maturing and a late maturing strain of corn, under field conditions. Sampled August 8, 1929. — Early; — — — — — Late.

TABLE 11.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER GREENHOUSE CONDITIONS. LEAF SAMPLES TAKEN APRIL 21, 1930.

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	12.15	7.13
	7 a. m.	8.84	6.62
	10 a. m.	11.70	8.11
	1 p. m.	16.14	10.87
	4 p. m.	20.17	12.32
	7 p. m.	15.84	10.30
	10 p. m.	12.91	8.21
	1 a. m.	11.67	7.50
Non-reducing Sugars	4 a. m.	7.01	4.39
	7 a. m.	7.37	6.62
	10 a. m.	9.27	7.47
	1 p. m.	13.84	9.32
	4 p. m.	17.10	10.78
	7 p. m.	13.20	9.27
	10 p. m.	10.61	7.12
	1 a. m.	9.81	6.43
Reducing Sugars	4 a. m.	5.14	2.74
	7 a. m.	1.47	.00
	10 a. m.	2.43	.54
	1 p. m.	2.30	1.55
	4 p. m.	3.07	1.54
	7 p. m.	2.64	1.03
	10 p. m.	2.30	1.09
	1 a. m.	1.86	1.07
Starches	4 a. m.	21.14	8.22
	7 a. m.	17.55	17.09
	10 a. m.	17.42	18.03
	1 p. m.	20.86	17.26
	4 p. m.	20.88	19.56
	7 p. m.	16.77	20.85
	10 p. m.	21.95	19.56
	1 a. m.	21.12	20.43

## CHART ELEVEN

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 11.

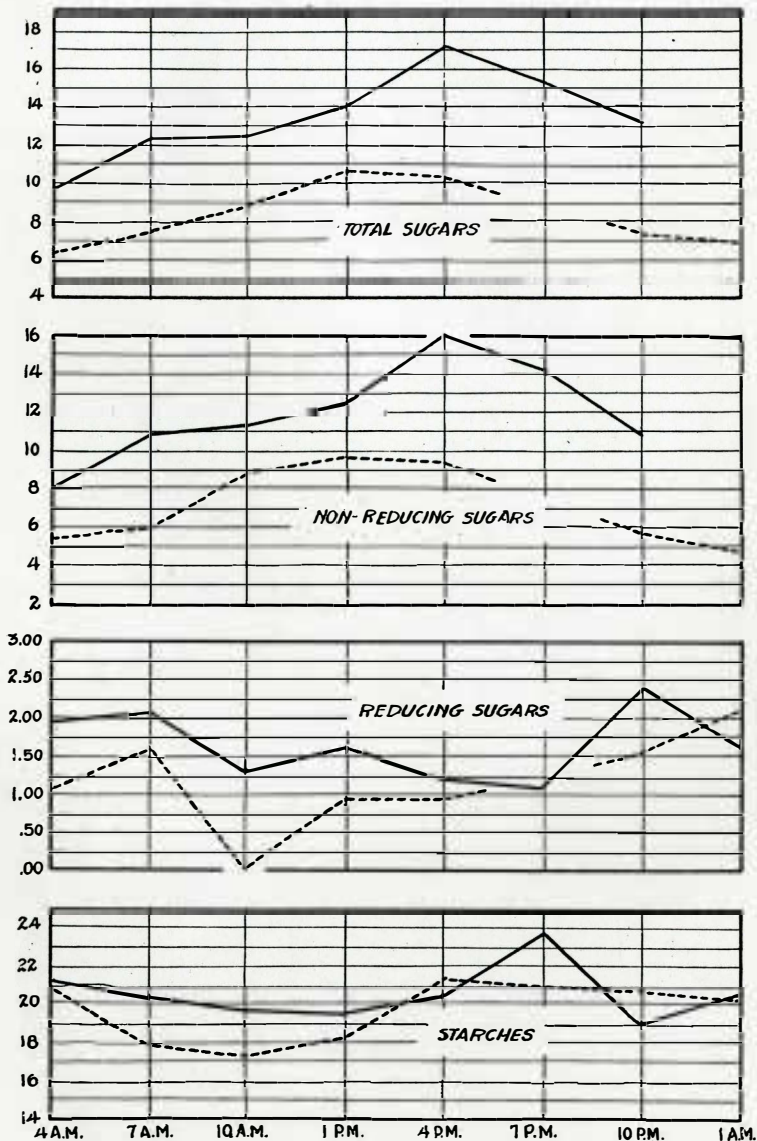
Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under greenhouse conditions. Sampled April 21, 1930. — Early; — — — — — Late.

**TABLE 12.—PERCENTAGES OF CARBOHYDRATES OF GIVEN KINDS AT SUCCESSIVE 3-HOUR PERIODS, IN LEAVES OF AN EARLY MATURING AND A LATE MATURING STRAIN OF CORN, UNDER GREENHOUSE CONDITIONS. LEAF SAMPLES TAKEN APRIL 24, 1930.**

	Hour of day when sample was taken	Percentage of given kind in given strain.	
		Early*	Late*
Total Sugars	4 a. m.	9.71	6.44
	7 a. m.	12.50	7.53
	10 a. m.	12.58	8.88
	1 p. m.	14.04	10.56
	4 p. m.	17.16	10.36
	7 p. m.	15.35	
	10 p. m.	13.19	7.14
	1 a. m.		6.89
Non-reducing Sugars	4 a. m.	8.02	5.37
	7 a. m.	10.72	5.92
	10 a. m.	11.28	8.88
	1 p. m.	12.48	9.60
	4 p. m.	15.99	9.42
	7 p. m.	14.20	
	10 p. m.	10.80	5.61
	1 a. m.		4.77
Reducing Sugars	4 a. m.	1.69	1.07
	7 a. m.	1.78	1.61
	10 a. m.	1.30	.00
	1 p. m.	1.56	.96
	4 p. m.	1.17	.94
	7 p. m.	1.15	
	10 p. m.	2.39	1.53
	1 a. m.	1.64	2.12
Starches	4 a. m.	21.12	20.74
	7 a. m.	20.19	17.93
	10 a. m.	19.62	17.44
	1 p. m.	19.50	18.26
	4 p. m.	20.43	21.31
	7 p. m.	23.76	
	10 p. m.	19.04	20.65
	1 a. m.	20.55	20.19

## CHART TWELVE

PER CENT



GRAPHIC PRESENTATION OF FOREGOING TABLE 12.

Percentages of carbohydrates of given kinds at successive 3-hour periods in leaves of an early and a late maturing strain of corn under greenhouse conditions. Sampled April 24, 1930. — Early; — — — — — Late.