# TIME AND RATE OF SYNTHESIS OF PHYTIN, INVERT SUGAR AND TOTAL SUGARS IN CORN GRAIN DURING THE REPRODUCTIVE PERIOD

BY

ERNEST BENTON EARLEY

B. S., Clemson College, 1928

M. S., Virginia Polytechnic Institute, 1929

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRONOMY
IN THE GRADUATE SCHOOL OF THE
UNIVERSITY OF ILLINOIS, 1941

URBANA, ILLINOIS

University of Illinois Library

Manuscript Theses

Unpublished theses submitted for the Master's and Doctor's degrees and deposited in the University of Illinois Library are open for inspection, but are to be used only with due regard to the rights of the authors. Bibliographical references may be noted, but passages may be copied only with permission of the authors, and proper credit must be given in subsequent written or published work. Extensive copying or publication of the thesis in whole or in part requires also the consent of the Dean of the Graduate School of the University of Illinois.

This thesis by Ernest Benton Carley has been used by the following persons, whose signatures attest their acceptance of the above restrictions.

A Library which borrows this thesis for use by its patrons is expected to secure the signature of each user.

| NAME AND ADDRESS | DATE |
|---|---|
| Thomas D. Fontaine, Southern Regional Research Lab., New Orleans, La. | 12/8/44 |
| Walter A. Ross Jr., Southern Regional Research Lab, New Orleans, La. | 12/18/44 |
| John D. Guthrie, Southern Reg. Research Lab, New Orleans, La | 12/22/44 |
| Carroll L. Hoffpauir Southern Regional Research Lab. New Orleans La | 12/26/44 |

# UNIVERSITY OF ILLINOIS

## THE GRADUATE SCHOOL

January 11, 1941

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Ernest Benton Earley

ENTITLED Time and Rate of Synthesis of Phytin, Invert Sugar and Total Sugars in Corn Grain During the Reproductive Period.

BE ACCEPTED* AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF Doctor of Philosophy

E. E. DeTurk
In Charge of Thesis

W. L. Burlison
Head of Department

Recommendation concurred in†

Committee on Final Examination†

*Subject to successful final examination in the case of the doctorate.
†Required for doctor's degree but not for master's.

1000—12-40—20306-S

ACKNOWLEDGMENT

The writer wishes to express his appreciation to all those who gave assistance in this investigation. He is particularly grateful to Dr. E. E. DeTurk for his helpful suggestions during the course of this work and for his aid in the preparation of the manuscript.

TABLE OF CONTENTS

# TIME AND RATE OF SYNTHESIS OF PHYTIN, INVERT SUGAR AND TOTAL SUGARS IN CORN GRAIN DURING THE REPRODUCTIVE PERIOD

## INTRODUCTION

There have been many investigations dealing with the chemical composition of the mature corn ovule. A few of these works ( 8, 15 ) were concerned primarily with the total percentage composition of the grain and its various parts, such as the hull, the horny gluten, the horny starch, the germ and so forth. The data usually consisted of percent protein, ash, oil and carbohydrates or nitrogen-free extract. In other experiments ( 16, 17, 18, ) the corn ovule has been subjected to total chemical analysis at several stages in its development. The purpose of these investigations was to determine at what stage of growth the yield and composition of the grain justified its use as feed. While these studies accomplished their purpose, and were desirable from several points of view, they contributed meager information on the metabolism of the chemical constituents of the developing ovule. This study therefore, was undertaken for the purpose of following the course of phytin, total phosphorus, reducing sugars, sucrose and starch in the corn ovule at frequent intervals from before pollination to advanced maturity.

## REVIEW OF LITERATURE

### Phosphorus

#### Phytin

Phytin is known to be the principal storage form of phosphorus in seeds. It is also known to be absent from vegetative tissue on which tests have been made, with the exception of a few grass species (14) grown at Ermelo, South Africa and wheat straw (19) produced in England. McCane and Widdowson (20)

reported that the tops of carrots, parsnips, potatoes, jerusalem artichokes, onions, swedes and turnips contained no phytin, whereas the under-ground portions of the first four contained phytin while the latter three did not. No explanation was given for the finding. Aside from this information, the rest of a rather large amount of data concerning phytin appears controversial. Even the exact chemical formula is not fully agreed upon, although the majority of investigators agree that phytic acid consists of one mole of inosite and six moles of phosphoric acid. Starkenstein ( 29) was of the opinion that phytic acid is a complex pyrophosphoric acid compound with inosite, whereas Anderson ( 3 ) believes it to be a hexa orthophosphoric acid ester of inosite. In support of the latter structure Anderson states: "We have been forced to the conclusion, therefore, that the assumption of Suzuki and collaborators, that phytic acid is inosite hexaphosphoric acid $C_6H_{18}O_{24}P_6$, is correct." Recently Young (31 ) prepared sodium phytate and from the analysis assigned to it the formula, $Na_{12}C_6H_6O_{24}P_6 \cdot 3H_2O + 35\ H_2O$. The naturally occurring calcium, magnesium and potassium salt of phytic acid is known as phytin.

Since the object of this investigation was quite different from that of previous work on the corn ovule, the literature on the subject is very limited. As a matter of fact the only published data touching directly on this problem appeared in 1933 by DeTurk, Holbert and Howk (11 ).

They reported the absence of phytin in the vegetative parts of the corn plant, including stalk, blades and forming tassels and ears, during the pre-pollination period. Two weeks after pollination, however, they found phytin in the fertilized ovules but failed to find it in any other part of the plant. This work represents the first recorded attempt to determine the initial synthesis of phytin in reproductive tissue.

From their work it appears that phytin is synthesized only in the fertilized ovule beginning during the first two weeks following pollination. In referring to the formation of phytin in the fertilized ovule DeTurk et. al.,

made the following comments: "The accepted reversibility of enzyme reactions ( 5) for instance, considered with the undisputed enzymatic cleavage of phytin by phytase ( 1, 2, 7, 23, ) leaves no doubt that phytin synthesis is an enzyme reaction. Furthermore, the fact that the beginning of this synthesis follows immediately after pollination and does not occur before pollination suggests an intimate association of activation of the zymogen with fertilization of the ovule. Inasmuch as extremely small quantities of an activator may be sufficient to set off a progressive enzyme reaction, it is not beyond the range of possibility that the pollen grain may serve as the carrier of this activator."

This hypothesis is based on the failure of the writers to find phytin in unpollinated ovules and on the data of Anderson and Kulp ( 4) who stated: "Judging by the very small difference between the total soluble and the inorganic phosphorus in pollen it appears rather doubtful if phytin or inosite hexaphosphoric acid is present in this material."

One might conclude from the data presented in the literature that the vegetative parts of the corn plant and the unpollinated ovules do not contain phytin. It seems to be questionable, however, as to whether or not corn pollen contains this compound.

Total Phosphorus

The review of the literature reveals no concrete evidence on the course of total phosphorus in the developing corn ovule. The problem has not been thoroughly investigated and the data presented in this study are perhaps the first showing the trend of total phosphorus throughout the complete development of the caryopsis.

Carbohydrates

The writer is unable to find in the literature any work dealing with the fractionation of the carbohydrate compounds throughout the growth of the corn ovule.

Weather Data.

The data in Table ( 1 ) represent some of the recorded weather information taken at this station during the 1939 growing season.

| Month | Total rain in inches | Max. Temp. °F | Min. Temp. °F | Mean Daily Temp. °F | Mean Max. Temp. °F | Mean Min. Temp °F | Total Hours Sunshine |
|---|---|---|---|---|---|---|---|
| March | 4.83 | 81 | 14 | 42.5 | 51.7 | 32.2 | 224.10 |
| April | 5.39 | 79 | 21 | 48.2 | 57.5 | 38.0 | 222.45 |
| May | 1.19 | 89 | 35 | 68.5 | 77.1 | 53.8 | 352.20 |
| June | 6.17 | 90 | 51 | 75.1 | 81.8 | 64.1 | 298.43 |
| July | 1.73 | 98 | 56 | 77.8 | 85.5 | 65.4 | 329.50 |
| Aug. | 6.38 | 91 | 54 | 75.1 | 83.6 | 61.7 | 334.14 |
| Sept. | 0.32 | 99 | 41 | 72.5 | 85.0 | 58.2 | 332.24 |
| Oct. | 2.54 | 89 | 28 | 57.4 | 69.0 | 43.3 | 250.27 |

## SAMPLES

### Collecting and Preserving

Station Reed's yellow dent corn was used for this investigation. Each day during the active shooting period shoot bags were put on a large number of normally developing ears on which no silks were visible. When the silks were ready to be pollinated the controlled pollination and sampling schedule was begun. The schedule is given in Table 1 .

The first sample consisted of 24 unpollinated ears selected at random from the bagged shoots at 10:00 A.M. July 20, 1939. At 8:00 A.M. the same day 48 ears were pollinated. These served for the second and third samples, representing intervals after pollination of 6 and 12 hours, respectively. From 5:00 to 7:30 P.M. July 20, all remaining bagged shoots were pollinated and marked. This large quantity of uniformly pollinated material supplied samples for the period from July 21 to August 3, during which time samples were taken daily except the last few days. From August 10 to September 28 weekly samples were selected at random from the naturally pollinated ears.

All samples, except the fully mature ones, were brought from the field to the laboratory in moist gunny sacks and preserved within three hours after being picked. Each field sample was divided into three laboratory samples and each of these three groups was husked separately and divided into shanks, silks, ovules and cob. The ovules were cut and then thoroughly scraped from the cobs into a clean, enameled pan. The material was mixed and about 50 grams placed into a tared 400 ml. beaker and covered with 300 ml. of boiling 95% alcohol without the addition of $CaCO_3$ ( 9). The alcohol-plant mixture was boiled about 15 minutes after which it was rapidly dried in a forced steam oven at 75°C. Upon being removed from the oven the sample was covered with 95% alcohol, a petri dish placed over the beaker and stored. The silks were preserved like the ovules while the cobs and shanks were dried in the steam oven. After the ovules were sufficiently mature to shell they were also rapidly dried in the steam oven at

Table 2 . Schedule of pollen and sample collection.

| Date pollinated | No. of ears per field sample[1] | Date Sampled. | Interval between Pollination and sampling |
|---|---|---|---|
| Not pollinated | 24 | 7-20-39--10 a.m. | 0 |
| 7-20-39, 8 a.m. | 24 | 7-20-39-- 2 p.m. | 6 hrs. |
| 7-20-39, 8 a.m. | 24 | 7-20-39-- 8 p.m. | 12 hrs. |
| 7-20-39, 5-7:30 p.m. | 21 | 7-21-39-- 7 p.m. | 1 day. |
| " " | 21 | 7-22-39-- " | 2 days. |
| " " | 18 | 7-23-39-- " | 3 days. |
| " " | 15 | 7-24-39-- " | 4 days. |
| " " | 12 | 7-25-39-- " | 5 days. |
| " " | 9 | 7-27-39-- " | 7 days. |
| " " | 9 | 7-30-39-- " | 10 days. |
| " " | 10 | 8-3-39-- " | 2 weeks. |
| Natural Pollination | 9 | 8-10-39 | 3 weeks. |
| " " | 9 | 8-17-39 | 4 weeks. |
| " " | 9 | 8-24-39 | 5 weeks. |
| " " | 9 | 8-31-39 | 6 weeks. |
| " " | 9 | 9-7-39 | 7 weeks. |
| " " | 9 | 9-14-39 | 8 weeks. |
| " " | 9 | 9-21-39 | 9 weeks. |
| " " | 12 | 9-28-39 | 10 weeks. |

[1]Each field sample was divided into three laboratory samples, taking one third of the number of ears indicated in this column for each.

73°C and stored in one-pint, glass jars with a few naphthalene balls.

Preparation of Samples for Analyses.

The samples preserved in alcohol were prepared for analysis by drying for 12 hours in the steam oven at 53°C. followed by 8 hours in a vacuum oven at 65°C. This treatment brought them to constant weight as shown in Table 3 .

After drying and weighing, the samples were ready for analysis. All materials not preserved in alcohol were ground in a Wiley mill and dried in the vacuum oven in preparation for analysis.

Table 3 . Rate of loss of moisture from alcohol preserved corn samples by drying in vacuum.

| Drying conditions | Sample No. 6 | 30 | 54 | 73 |
|---|---|---|---|---|
| 12 hrs. in steam oven at 53°C. | 145.970 | 116.169 | 126.975 | 145.193 |
| 1 hr. in vacuum oven at 65°C. | 145.956 | 116.159 | 126.970 | 145.134 |
| 2 hrs. in vacuum oven at 65°C | 145.938 | 116.144 | 126.957 | 145.104 |
| 3hrs. in vacuum oven at 65°C. | 145.928 | 116.138 | 126.954 | 145.106 |
| 4 hrs. in vacuum oven at 65°C | 145.925 | 116.138 | 126.955 | 145.127 |
| 5 hrs in vacuum oven at 65°C. | 145.918 | 116.129 | 126.950 | 145.114 |
| 6 hrs. in vacuum oven at 65°C. | 145.910 | 116.126 | 126.950 | 145.290 |
| 7 hrs. in vacuum oven at 65°C. | 145.903 | 116.119 | 126.945 | 145.099 |
| 8 hrs. in vacuum oven at 65°C. | 145.901 | 116.115 | 126.943 | 145.110 |

## METHODS OF ANALYSIS

### Phosphorus

#### Phytin

The sample was extracted 2 hours on a shaking machine with a solution of 1.2% HCl-10% anhydrous $Na_2SO_4$. The sample-solvent ratio may range from 1:10 to 1:20. It was then either filtered with suction through a gooch crucible with asbestos mat or centrifuged and filtered through a coarse filter paper. Fifty ml. of the extract were pipetted into a 250 ml. beaker and 50 ml. of distilled water added, giving an HCl concentration of 0.6%. An excess (usually 15 ml.) of about 0.2% ferric chloride solution in 0.6% HCl was added while the solution was slowly stirred. After the ferric phytate precipitate had stood 1 hour it was filtered onto a fine asbestos mat in a gooch crucible by means of suction. The precipitate was rinsed from the beaker with a few small quantities of 0.6% HCl-$Na_2SO_4$ solution, after which it was washed several times with the same solution to remove free phosphorus compounds. The gooch crucible was then ignited in the electric furnace for 3 hours at 1000°C.

After cooling the asbestos mat with the ignited precipitate it was transferred to a 250 ml. beaker and the precipitate dissolved in 10 ml. of concentrated HCl. Water was added and the solution filtered into a 200 ml. volumetric flask, made to volume and total phosphorus determined colorimetrically (12). This value expressed as percent of sample represents phytin phosphorus.

#### Time required for precipitation of ferric phytate.

Since, as previously stated, one of the major objects of this investigation was to ascertain the initial synthesis of phytin in the ovules, it was imperative to learn the smallest quantity of phytin phosphorus that this procedure could detect.

In order to do this about 1 liter of corn meal extract was prepared in the ratio of 5 grams of meal to 100 ml. of solvent and phytin phosphorus de-

termined. Different size aliquots of this solution were used. In each case the total volume was made up to 115 ml. and the total iron added, 28.5 mgms. The results of this test are shown in Table 4 .

Table 4 . Relationship of quantity of phytin phosphorus to rate of ferric phytate formation and precipitation.

| Vol. of Extract ml. | Phytin Phosphorus Present mgm. | Time Required for Cloudiness hrs. | Time Required for Complete Precip. hrs. |
|---|---|---|---|
| 0.5 | 0.066 | ---- | 96 - 4 days |
| 1.0 | 0.132 | 22.0 | 45 |
| 2.0 | 0.264 | 11.0 | 20 |
| 3.0 | 0.396 | 4.5 | 20 |
| 4.0 | 0.528 | 2.0 | 6 |
| 5.0 | 0.660 | 1.5 | 6 |
| 10.0 | 1.32 | 0.33 | 2 |
| 15.0 | 1.98 | 0.15 | 0.5 |
| 20.0 | 2.64 | immediately | 0.25 |
| 25.0 | 3.30 | " | 0.25 |
| 30.0 | 3.96 | " | 0.25 |
| 50.0 | ~~5.28~~ 6.6 | " | 0.25 |

These results show that as little as 0.066 mgm. of phytin phosphorus can be precipitated by this method if allowed to stand 96 hours.

Total Phosphorus.

Samples used for total phosphorus determination were oxidized by the nitric-perchloric acid method[1]. Following oxidation the residue was taken up in about 25 ml. of 5% $HNO_3$ and heated on the steam bath for a half hour to convert meta-phosphoric acid to orthophosphoric acid. Results at this station show that $HClO_4$ dehydrates a portion of the orthophosphoric to metaphosphoric acid during removal of excess $HClO_4$ on the hot plate. After the hydrolysis treatment phosphorus was determined colorimetrically. (14)

Carbohydrates.

Extraction of sugars.

The sample was extracted three times with 80 percent alcohol by

[1]Unpublished method.

digestion on the steam bath and decanting through an alundum crucible, after which the residue was transferred to the alundum crucible and the extraction continued for 15 hours in a soxhlet. The alcohol was removed by evaporation on the steam bath in the original 400 ml. beaker, water being added to prevent its going to dryness. Toluene was added and it was then made to volume in a 500 ml. volumetric flask, from which filtered aliquots were used without further treatment for reducing sugar determination ( 22 ). All samples not preserved in alcohol were weighed directly into alundum thimbles for extraction.

Determination of Reducing Sugars.

The Munson-Walker procedure was followed up to and including washing of the cuprous oxide with warm water. The crucible was then removed from the suction flask and the outside rinsed with water, after which the asbestos mat, containing the $Cu_2O$, was transferred to the original beaker and thoroughly disintegrated in about 25 ml. of warm water. The crucible was then placed in the beaker and about 25 ml. of ferric sulfate[1] added and stirred. The beaker was placed on the steam bath and heated approximately one half hour or until $Cu_2O$ had reacted completely with ferric sulfate. The beaker was removed from the steam bath, allowed to cool and distilled water added to a volume of about 200 ml. Two drops of ortho phenanthroline indicator were added and the ferrous ion titrated with approximately 0.05 N ceric sulfate solution previously standardized against pure dextrose. (See Table 5 Page 11 ).

Sucrose.

To a 250 ml. aliquot of the sugar solution was added 10 ml. of concentrated HCl and hydrolysis allowed to proceed for a minimum of 48 hours at about 30°C. The acid was then nearly neutralized with NaOH and made to 500 ml. with distilled water. After filtering, total sugar was determined on aliquots of this solution and sucrose calculated.

---

[1] 500 grams $Fe_2(SO_4)_3$ + 1000 ml. conc. $H_2SO_4$ + 5000 ml. distilled $H_2O$.

Table 5 . Standardization of ceric sulfate.

| mgms Dextrose | ml. $Ce(SO_4)_2$ | Ave. ml. $Ce(SO_4)_2$ minus blank | Ratio | $\frac{\text{mgm Dextrose}}{\text{ml. } Ce(SO_4)_2}$ |
|---|---|---|---|---|
| 10.408 | 6.90 | | | |
| | 6.80 | | | |
| | 6.90 | | | |
| | 6.90 | 6.635 | | 1.5686 |
| 20.816 | 14.00 | | | |
| | 13.80 | | | |
| | 13.70 | | | |
| | 14.00 | 13.640 | | 1.5261 |
| 31.224 | 20.20 | | | |
| | 20.20 | | | |
| | 20.30 | | | |
| | 20.20 | 20.00 | | 1.5616 |
| 41.632 | 27.45 | | | |
| | 27.35 | 27.16 | | 1.5328 |
| 52.040 | 33.50 | | | |
| | 33.70 | | | |
| | 33.79 | | | |
| | 33.50 | 33.36 | | 1.5600 |
| | | | Mean | 1.5497 |
| Blank | 0.26 | | | |
| | 0.30 | | | |
| | 0.20 | | | |
| | 0.20 | | | |

Starch.

The residue from sugar extractions was transferred to a 400 ml. beaker, 200 ml. of distilled water added, the beaker covered with a watch glass and boiled 25 minutes. The watch glass and sides of the beaker were rinsed and allowed to cool to 45°C. It was then placed in a 45°C. oven, undiluted taka-diastase was added in about a 1:1 ratio ( 10 ) with the starch and held at this temperature for three hours with occasional stirring. The beaker was heated on the steam bath, filtered into a 400 ml. beaker and washed until approximately 350 ml. were collected. Ten ml. of concentrated HCl were added and the solution evaporated to about 100 ml. ( 10 ) after which the HCl was nearly neutralized with NaOH. The solution was then made to 250 or 500 ml. depending on the quantity of starch. After filtering, its reducing value was determined and starch calculated. A blank ~~must be~~ was run with ~~this~~ each determination.

## RESULTS AND DISCUSSION OF DRY WEIGHT DATA

The values for dry weight of grain per ear of corn show a weekly rate of increase comparable to the autocatalytic reaction ( 26 ) of biological materials. This reaction is characterized by a slow rate of activity during the early part of its functioning, during which time the autocatalytic substances are accumulating. Following this priming period the reaction becomes accelerated and continues so until the organism reaches the peak of its first growth cycle. At this point the reaction subsides, probably because of exhaustion of food materials or on account of the inhibitory nature of the byproducts, and the rate of development of the organism becomes exceedingly slow. After a certain length of time, depending on the organism under investigation, the rate of the growth reaction increases for a second time until a maximum has been reached in a second growth cycle. Then follows the decline. A third or fourth cycle may occur.

Growth cycles have been described by Minot (21 ) for the guinea-pig and by Brody ( 6 ) in the fowl. Three successive periods of rapid growth alternating with periods of slow growth in the mouse have been described by Robertson (27 ). The growth rate of an annual plant (25 ) has also been shown to exhibit similar behavior.

The weekly rate growth of the developing corn ovule likewise proceeds in cycles and not at a uniform acceleration from pollination to maturity. Confirmation of this statement is obtained from a study of the weight data given in Table 6 and graphically shown in Figure 1 . It is observed (Fig. 2 ) that the rate of increase was rather slow for the first two weeks after pollination followed by a more rapid rate during the 3rd and 4th weeks. During the 5th and 6th weeks the rate of dry weight production decreased rather rapidly to zero, thereby completing the first cycle of the growth curve. Immediately thereafter growth was resumed, reaching the peak of a second cycle at the end of the 7th week. At the end of the 8th week the rate of growth had again fallen to zero, thus concluding the second and last cycle in the development of the corn ovule.

The loss of dry weight during the succeeding two weeks, 9th and 10th, may be accounted for as an experimental error resulting from the selection of ears from the same small plot from which all previous samples had been taken. The personal factor in this method of sampling may have resulted in leaving smaller ears for the two last periods, thereby showing a loss in weight of dry grain per ear. In this connection attention should be called to the work of Curtiss and Patrick ( 8 ) in which they reported a loss in weight of grain per acre from October 8 to October 15. They believed a slightly defective stand may have been partly responsible for the decrease but felt that this explanation alone was insufficient to account for the total loss. In both of these experiments respiration may have been responsible for at least a portion of the observed loss in weight of dry grain toward the end of the last cycle.

Table 6 . Dry weight data of corn samples.

| Interval after Pollination | No. of ears per field sample | Total dry weight of ovules gms. | Average dry wt. of ovules per ear gms. | Weekly gain of ovules per ear gms. |
|---|---|---|---|---|
| Unpollinated 7/20/39 | 24 | 26.40 | 1.10 | --- |
| 6 hours | 24 | 26.69 | 1.11 | --- |
| 12 hours | 24 | 23.95 | 1.00 | --- |
| 1 day | 21 | 27.95 | 1.33 | --- |
| 2 days | 21 | 33.21 | 1.58 | --- |
| 3 days | 18 | 53.71 | 2.98 | --- |
| 4 days | 15 | 41.03 | 2.74 | --- |
| 5 days | 12 | 65.59 | 5.47 | --- |
| 7 days 7/29/39 | 9 | 46.78 | 6.20 | 4.10 |
| 10 days | 9 | 79.05 | 8.78 | --- |
| 2 weeks 8/3/39 | 10 | 134.50 | 13.45 | 9.15 ~~4.67~~ |
| 3 weeks 8/10 | 9 | 626.70 | 58.52 | 45.07 |
| 4 weeks 8/17 | 9 | 974.29 | 108.25 | 49.73 |
| 5 weeks 8/24 | 9 | 1,157.15 | 128.57 | 20.32 |
| 6 weeks 8/31 | 9 | 1,143.28 | 127.03 | -1.54 |
| 7 weeks 9/7 | 9 | 1,551.00 | 172.33 | 45.30 |
| 8 weeks 9/14 | 9 | 1,561.26 | 173.47 | 1.14 |
| 9 weeks 9/21 | 9 | 1,461.35 | 162.37 | -11.10 |
| 10 weeks 9/28 | 12 | 1,797.06 | 149.76 | -12.61 |

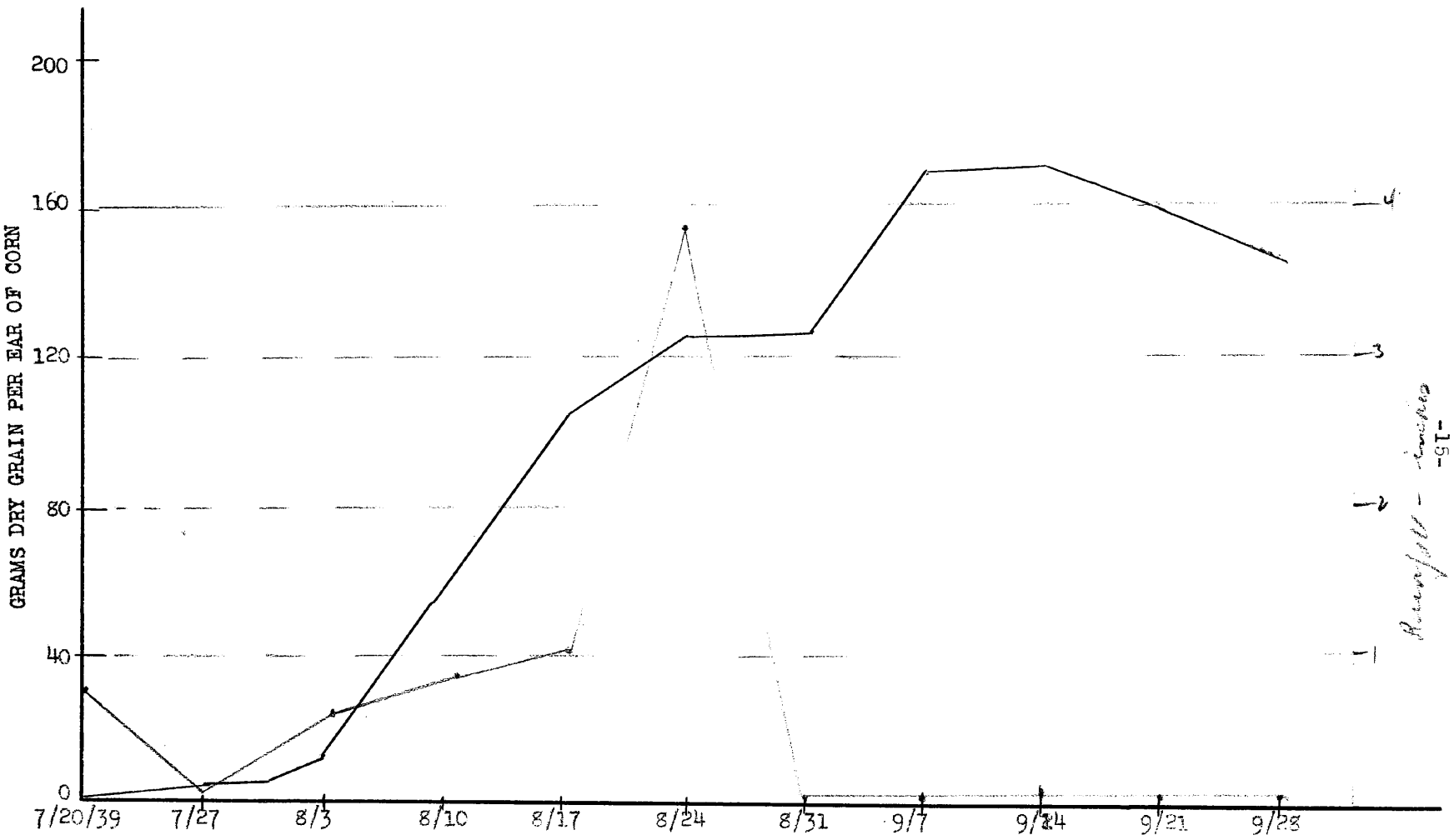
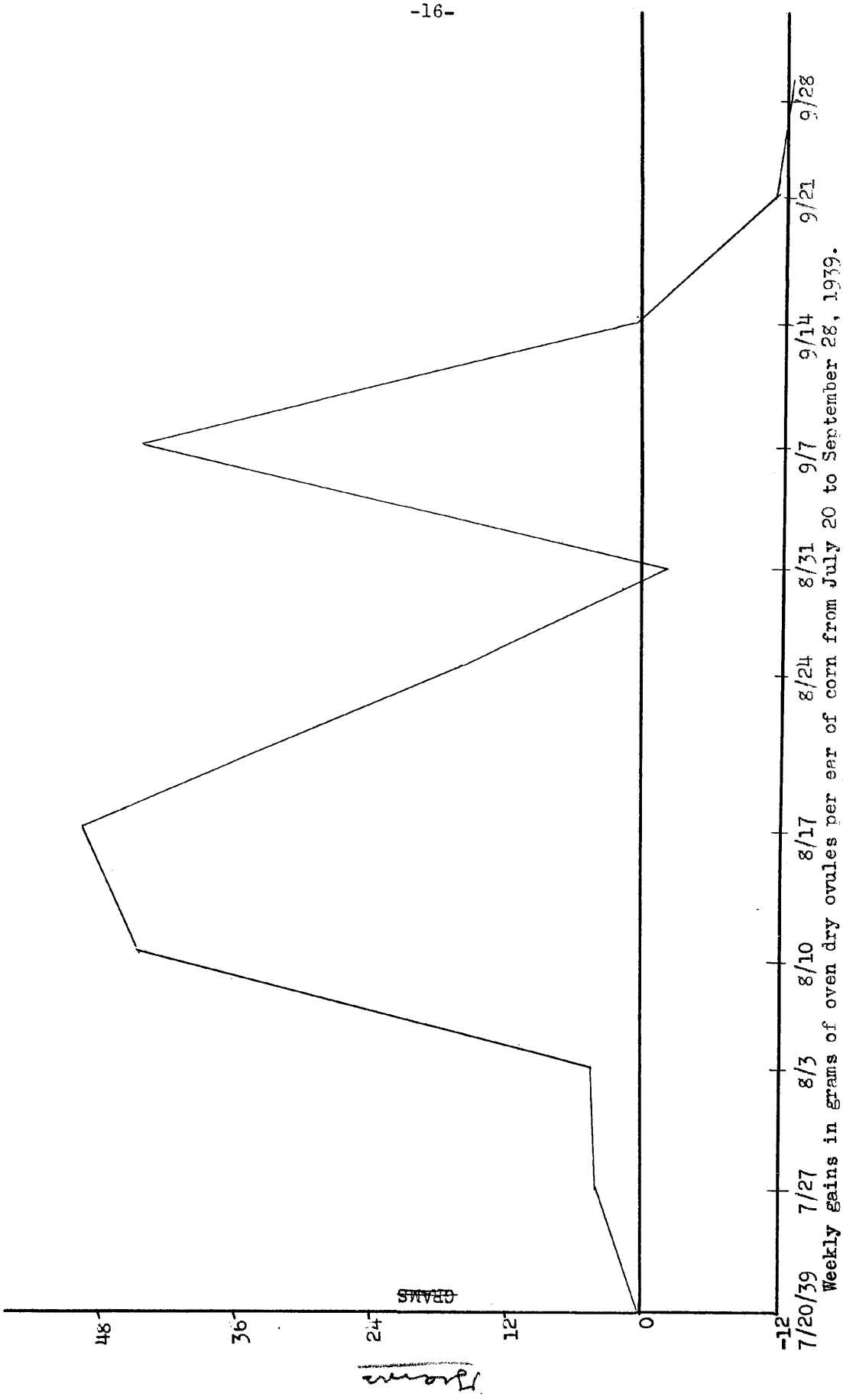



Fig.--1. Average dry weight of grain at different periods from pollination to maturity.




Weekly gains in grams of oven dry ovules per ear of corn from July 20 to September 28, 1939.
Fig. 2.

In 1889 Schweitzer ( 28 ) made weekly determinations of the average weight of grain per ear of corn from August 6 to September 17. This was done for the purpose of learning the time at which to harvest corn in order to secure the largest acre yield of grain. In doing this work he selected only four ears at each sampling date. The results are given in Table 7 . These data show a more rapid increase in dry weight per ear than that shown by the present work. However the varieties were different and this together with other variables would satisfactorily account for the observed differences in rate of growth of the ovules. Nevertheless in general, the growth curves and the weekly rate of increase in the two investigations agree quite well. The weekly rate of increase per ear for Schweitzer's work, like that of the writers' indicates cyclic rather than uniformly accelerated development.

Table 7 . Agronomic data of Schweitzer's work with St. Charles white variety of corn.

| Date Sampled | No. of ears per sample. | Dry weight of grain per sample. gms. | Weekly dry weight increase of ovules per ear gms. |
|---|---|---|---|
| August 6, 1889 | 4 | 25.5 | --- |
| " 13, | 4 | 56.4 | 30.9 |
| " 20, | 4 | 115.7 | 59.3 |
| " 27, | 4 | 191.8 | 76.1 |
| Sept. 3, | 4 | 181.2 | 10.6 |
| " 10, | 4 | 191.5 | 10.3 |
| " 17, | 4 | 236.6 | 45.1 |

## RESULTS AND DISCUSSION OF PHOSPHORUS DATA

The percentages of total and phytin phosphorus found in developing corn ovules are recorded in Table 8 and shown in Figure 3 . The unpollinated ovules contained 0.608 percent total phosphorus. Those ovules pollinated for 6 and 12 hour intervals showed only a slight decrease from the unpollinated sample. At the end of one day following pollination total phosphorus had decreased to 0.503 percent and remained close to this value for the 2nd, 3rd, 4th, 5th, 7th and 10th day after pollination. By the end of the 2nd week after pollination percentage total phosphorus started to decline and continued to do so until the completion of the 4th week. From this time to the end of the experiment percentage total phosphorus remained unchanged.

Observation of the phytin data shows the unpollinated ovules and those pollinated for a period up to 2 weeks to contain a very low percentage of phytin phosphorus. The average for this period was 0.0145 percent. The important fact in this connection, however, is the finding of phytin phosphorus in the unpollinated corn ovule. This is the first record so far as the author is aware of the detection of phytin phosphorus in the unfertilized ovule. Heretofore it has been found in ovules which had been pollinated for a period of about 2 weeks.

By the end of the third week after pollination rapid synthesis of phytin was under way and proceeded through the fifth week, at which time the percentage was 0.197. There was very little activity during the 6th week whereas by the end of the 7th week phytin phosphorus had increased to 0.257 percent where it remained practically unchanged to the 10th and final sampling period.

The above inverse relation of percentage of total and phytin phosphorus in the corn ovule has likewise been observed in the developing wheat kernel. Knowles and Watkins ( 19) found 0.941 percent total phosphorus and 0.079% phytin phosphorus in wheat ovules on June 18 whereas on August 6 total

Table 8 . Percentage of total and phytin phosphorus in developing corn ovules

| Interval after Pollination | Phosphorus Total % | Phosphorus Phytin % | Ave. percentage of Total P | Ave. percentage of Phytin P | Phytin phosphorus as Percentage of total phosphorus |
|---|---|---|---|---|---|
| Unpollinated | 0.615 1/<br>0.601 | 0.008<br>0.017 | 0.608 | 0.013 | 1.84 |
| 6 hours | 0.565<br>0.537 | 0.005<br>0.018 | 0.551 | 0.012 | 2.13 |
| 12 hours | 0.531<br>0.674 | 0.015<br>0.015 | 0.602 | 0.015 | 2.42 |
| 1 day | 0.495<br>0.512 | 0.013<br>0.013 | 0.503 | 0.013 | 2.60 |
| 2 days | 0.443<br>0.529 | 0.013<br>0.011 | 0.486 | 0.012 | 2.45 |
| 3 days | 0.460<br>0.496 | 0.007<br>0.018 | 0.478 | 0.013 | 2.62 |
| 4 days | 0.513<br>0.477 | 0.009<br>0.016 | 0.495 | 0.012 | 2.49 |
| 5 days | 0.484<br>0.483 | 0.002<br>0.066 | 0.484 | 0.064 | 7.02 |
| 7 days | 0.484<br>0.472 | 0.003<br>0.005 | 0.478 | 0.004 | 0.91 |
| 10 days | 0.518<br>0.466 | 0.012<br>0.006 | 0.492 | 0.009 | 1.86 |
| 2 weeks | 0.421<br>0.430 | 0.007<br>0.027 | 0.426 | 0.017 | 3.57 |
| 3 weeks | 0.343<br>0.304 | 0.107<br>0.121 | 0.323 | 0.114 | 35.15 |
| 4 weeks | 0.288<br>0.304 | 0.157<br>0.146 | 0.296 | 0.152 | 51.17 |
| 5 weeks | 0.324<br>0.302 | 0.205<br>0.188 | 0.313 | 0.197 | 62.84 |
| 6 weeks | 0.324<br>0.312 | 0.214<br>0.204 | 0.318 | 0.209 | 65.68 |
| 7 weeks | 0.312<br>0.281 | 0.273<br>0.241 | 0.297 | 0.257 | 86.67 |
| 8 weeks | 0.285<br>0.304 | 0.248<br>0.262 | 0.295 | 0.255 | 86.53 |

Table 8 Continued.

| Interval after Pollination | Phosphorus Total % | Phytin % | Ave. percentage of Total P | Phytin P | Phytin phosphorus as Percentage of total phosphorus | 5% non-phytin phos |
|---|---|---|---|---|---|---|
| 9 weeks | 0.312<br>0.299 | 0.270<br>0.272 | 0.305 | 0.271 | 88.79 | 0.034 |
| 10 weeks | 0.320<br>0.296 | 0.278<br>0.263 | 0.308 | 0.271 | 87.85 | 0.037 |

↓ These determinations are separate data from the preceding table and the difference between determinations includes natural variation in the plant material as well as experimental error of the phosphorus determination.

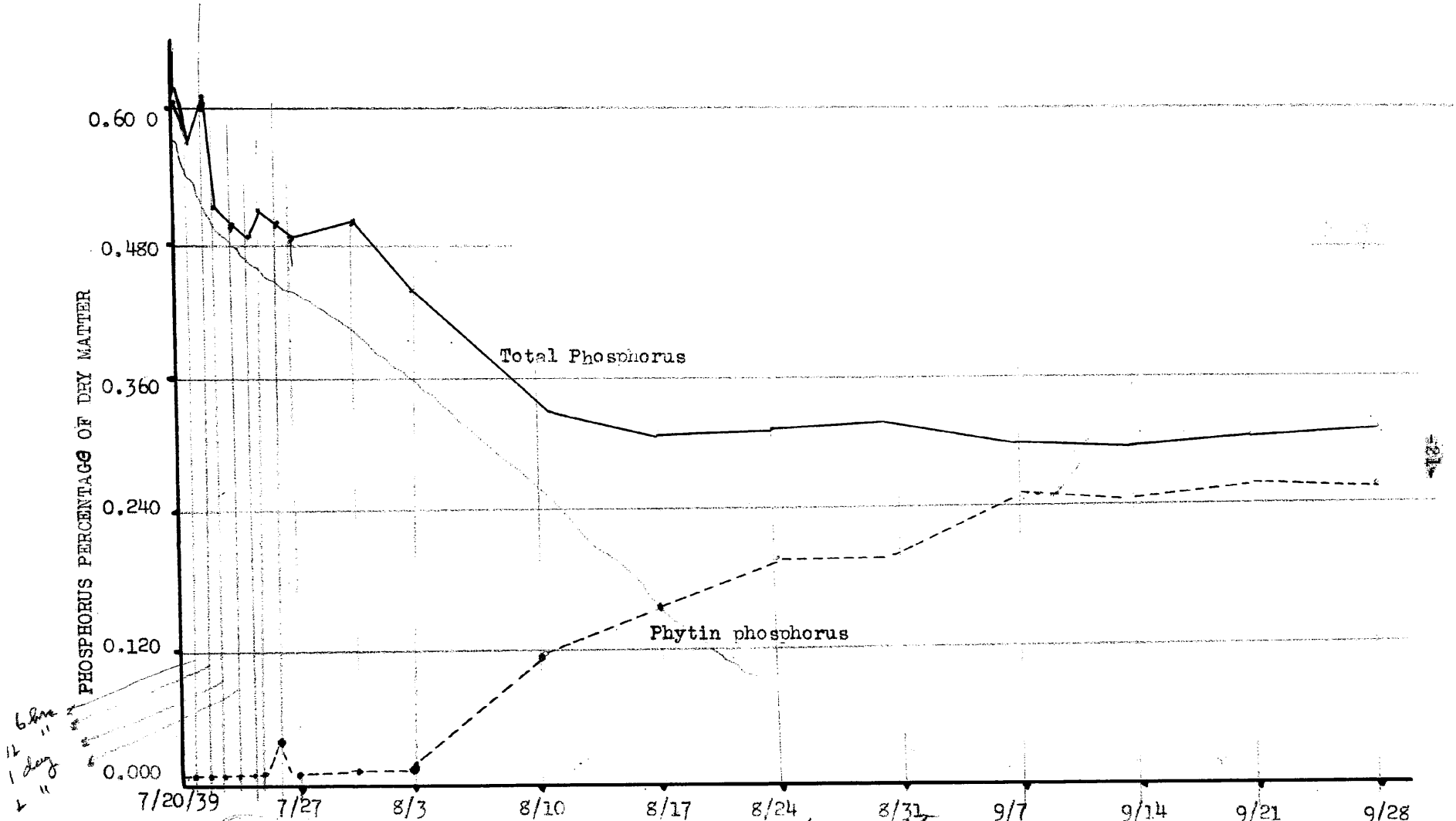



Fig. 1 Average percentage of total and phytin phosphorus in corn ovules from pollination to maturity.

phosphorus had diminished to 0.821% and phytin phosphorus had increased to 0.405 percent. This inverse relationship of percentages of total and phytin phosphorus for the first 4 weeks should not be construed as indicating conversion of the non-phytin phosphorus already in the ovule into phytin. (See Fig. 5 ).

The percentage of the total phosphorus which occurs as phytin (Table 8 and Fig. 4 ) indicates that the conversion of phosphorus into phytin took place very slowly during the first two weeks after pollination. At the end of this two week period phytin phosphorus constituted only 3.57% of the total phosphorus. From the second to the seventh week the formation of phytin phosphorus rapidly increased in proportion to the total phosphorus, finally constituting 88.67% of the latter. For the remaining three samples but little change was observed in the relationship of phytin and total phosphorus.

In the mature wheat kernel Knowles and Watkins ( 19) found phytin phosphorus to make up 49.3% of the total phosphorus. Rather (24 ) reported that phytin phosphorus represented 67 and 77 percent of the total phosphorus in two different samples of corn grain. According to Webster (30) phytin phosphorus amounted to 82.6% of the total in yellow dent and 76.5% of total phosphorus in white corn. Phytin values obtained by DeTurk et. al., ( 11) ranged about 83% of the total phosphorus in samples of yellow dent corn.

The average milligrams of total phosphorus, phytin phosphorus and non-phytin phosphorus in ovules per ear of corn throughout the development of the ear are given in Table 9 and shown graphically in Figure 5 .

In the first place these data show that the quantity of total and phytin phosphorus increased in the kernels per ear from July 20 to September 7 whereas the non-phytin phosphorus increased only to August 17. In the second place they show that the non-phytin phosphorus exceeds the phytin phosphorus during the first three weeks following pollination. Furthermore the fact that non-phytin phosphorus accumulation keeps pace with phytin during this period is proof that phosphorus intake from outside the ear is furnishing more phosphorus

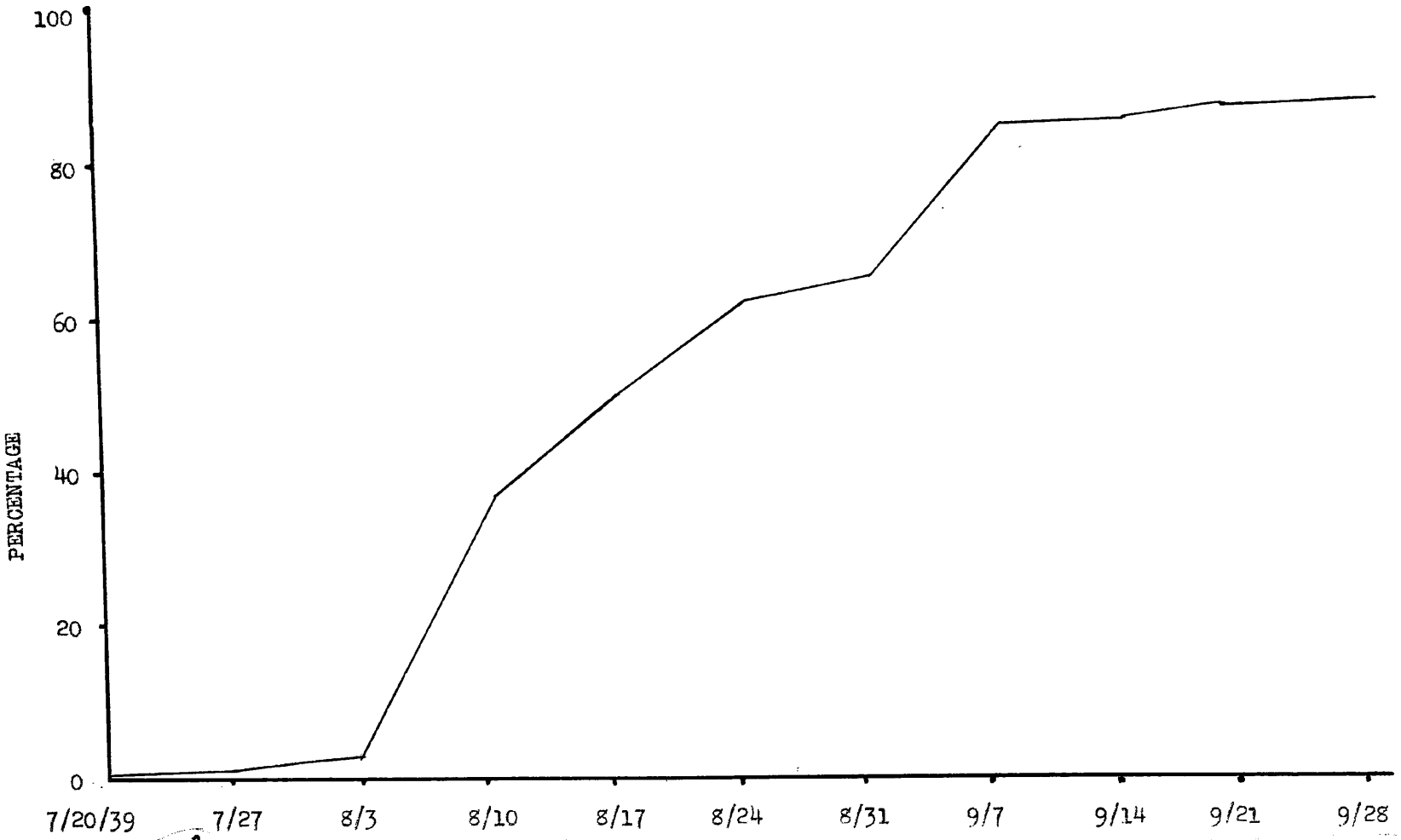



Fig. 2 4. Phytin phosphorus as percentage of total phosphorus in developing corn ovules at weekly intervals from pollination to maturity. The value at 7-20-39 represents the entire ovule only.

Table 9 . Milligrams of phosphorus in grain per ear during growth.

| Interval after Pollination | Phosphorus in ovules per ear | | | Weekly increases of Phosphorus in grain per ear | | |
|---|---|---|---|---|---|---|
| | Total mgm | Phytin mgm | non-Phytin mgm | Total mgm | Phytin mgm | non Phytin |
| Unpollinated | 6.60 | 0.12 | 6.48 | --- | --- | |
| 6 hours | 6.12 | 0.13 | 5.99 | --- | --- | |
| 12 hours | 6.01 | 0.15 | 5.86 | --- | --- | |
| 1 day | 6.70 | 0.17 | 6.53 | --- | --- | |
| 2 days | 7.69 | 0.19 | 7.50 | --- | --- | |
| 3 days | 14.27 | 0.37 | 13.90 | --- | --- | |
| 4 days | 13.53 | 0.34 | 13.19 | --- | --- | |
| 5 days | 26.43 | 1.86 | 24.57 | --- | --- | |
| 1 week | 24.85 | 0.23 | 24.62 | 18.25 | 0.10 | 18.14 |
| 10 days | 43.21 | 0.80 | 42.41 | --- | --- | |
| 2 weeks | 57.23 | 1.95 | 55.28 | 32.38 | 1.72 | 30.66 |
| 3 weeks | 189.25 | 66.51 | 122.74 | 132.02 | 64.56 | 67.46 |
| 4 weeks | 320.53 | 164.00 | 156.53 | 131.28 | 97.49 | 33.79 |
| 5 weeks | 402.04 | 252.64 | 149.40 | 81.51 | 88.64 | - 7.13 8.0% |
| 6 weeks | 404.21 | 265.49 | 138.72 | 2.17 | 12.85 | - 10.68 = 83.12 |
| 7 weeks | 510.96 | 442.89 | 68.07 | 106.75 | 177.40 | - 70.65 = 39% |
| 8 weeks | 511.22 | 442.35 | 68.87 | 0.26 | -0.54 | + 0.80 |
| 9 weeks | 495.55 | 440.02 | 55.53 | -15.67 | -2.33 | - 13.34 |
| 10 weeks | 461.11 | 405.10 | 56.01 | -34.44 | -34.96 | + 0.48 |

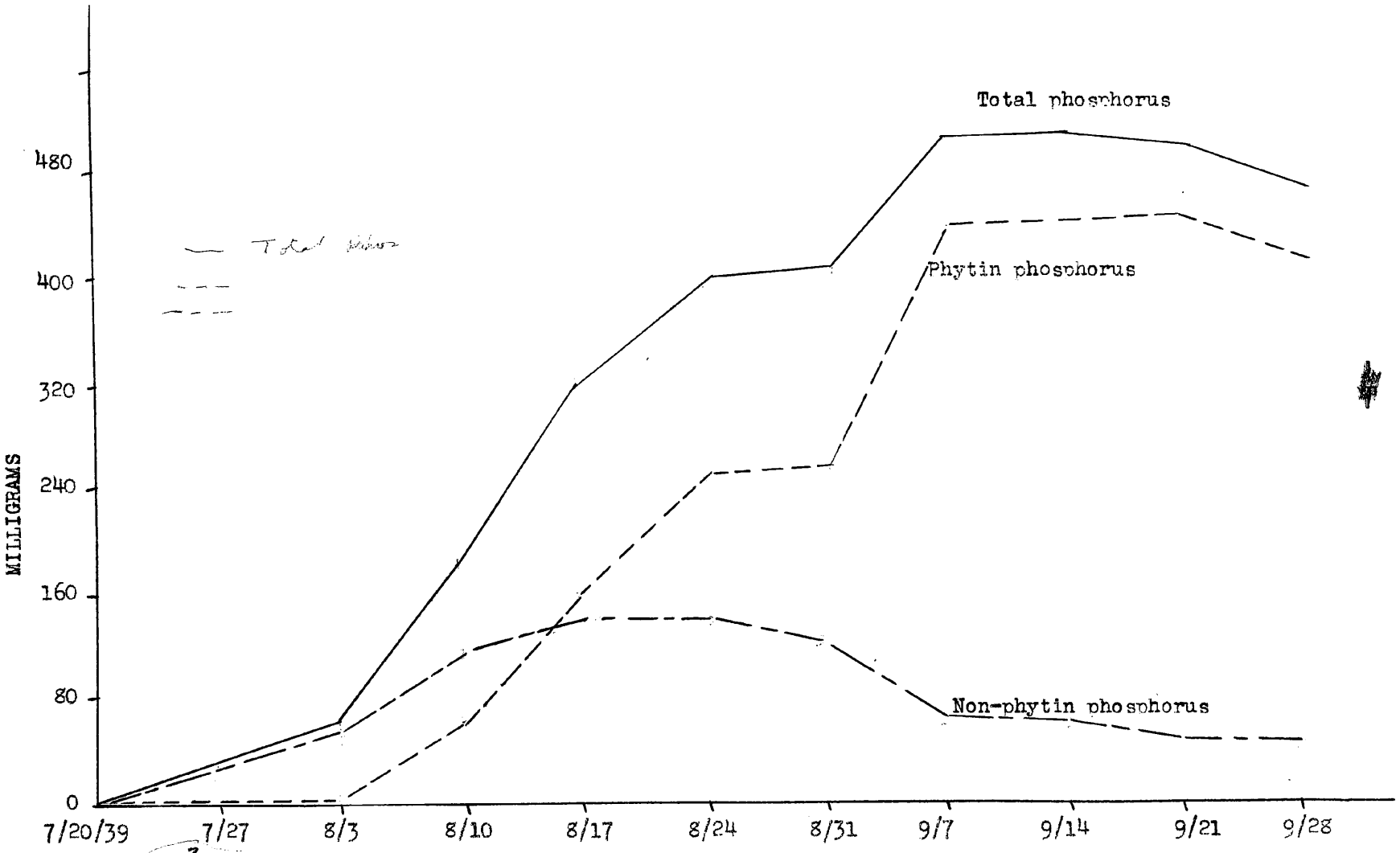



Fig. 3 Milligrams of total phosphorus, non-phytin phosphorus and phytin phosphorus in grain per ear at weekly intervals from pollination to maturity. Values at 7-20-39 are for the unpollinated ovules

than is needed for phytin synthesis. By the end of the 4th week, August 17, the rate of phytin synthesis had overtaken that of phosphorus intake, and from that time through the 7th week synthesis of phytin occurred partly at the expense of the other forms of phosphorus present in the ovules. At no time however, during the development of the ovules, was there a sufficient accumulation of phosphorus in the developing kernels to make them independent of a reserve external supply in the stalk and leaves or in the culture medium. Confirmation of this statement was found in another experiment in which corn plants were grown in sand culture. Complete removal of phosphorus from the culture solution just before shooting, resulted in the formation of only rudimentary shoots and in some plants no shoots were formed. As an example, during the 7 day period, August 31 to September 7, the non-phytin phosphorus decreased 71 milligrams in grain per ear while the phytin phosphorus increased 177 milligrams. The non-phytin phosphorus contributed, therefore, 40% of the phytin phosphorus leaving 60% to be supplied from a source external to the ovules.

The weekly gains of milligrams of total and phytin phosphorus in ovules per ear during growth are given in Table 9 and Figure 6 . These values show the rate of accumulation of total phosphorus to exceed that of phytin to the end of the 4th week following pollination. From the 5th through the 7th week phytin phosphorus accumulated at a faster rate than total phosphorus. The loss of total and phytin phosphorus for the 9th and 10th week is believed to be due to the decrease found in dry weight of grain per ear for these two periods. Had the dry weight of kernels per ear remained constant during this late maturation period no loss of either total or phytin phosphorus would have been observed. The curves in Figure 6 indicate that the weekly rate of phosphorus translocation into the ovules followed the weekly rate of dry ovule production or vice versa and therefore proceeded in accordance with an autocatalyzed reaction.

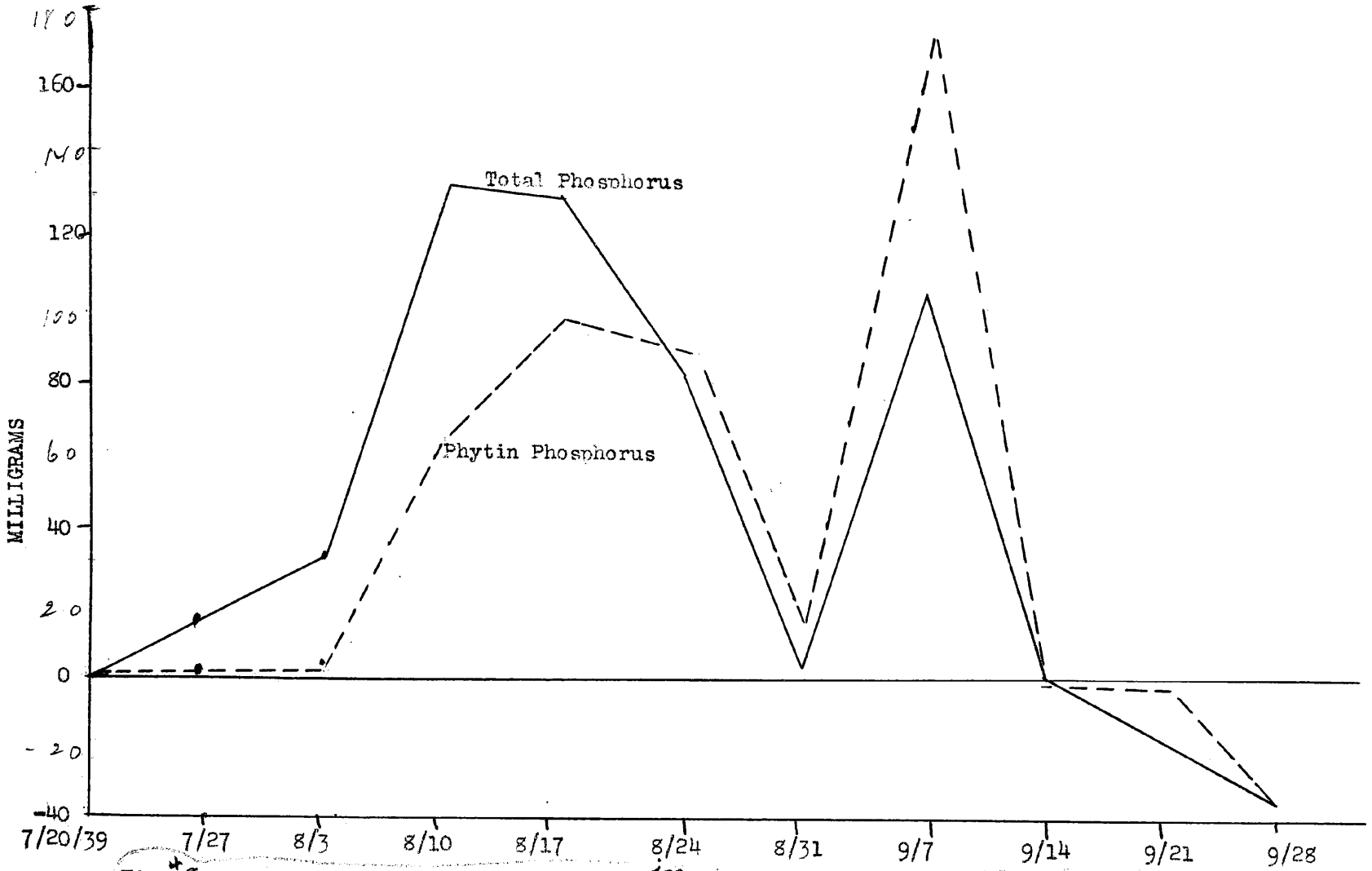



Fig. 4. Average weekly gain of phosphorus ~~by~~ in the ovules per ear of corn from pollination to maturity.

Phytin in corn silks

Samples of silks were collected from the ears harvested before pollination and those harvested 1, 3, 5, and 7 days after pollination for the purpose of learning if phytin were present in silk prior to or following pollination. The data are given in Table 10 .

Table 10 . Percentage phytin phosphorus present in corn silks.

| Interval after pollination | % phytin phosphorus | Average % Phytin Phosphorus. |
|---|---|---|
| Unpollinated | 0.018 | |
| | 0.016 | 0.017 |
| 1 day | 0.014 | |
| | 0.012 | 0.013 |
| 3 days | 0.010 | 0.011 |
| | 0.011 | |
| 5 " | 0.010 | |
| | 0.008 | 0.009 |
| 7 " | 0.014 | |
| | 0.005 | 0.010 |

It may be observed that each sample of silks analyzed contained phytin phosphorus, though the percentage was rather low. The data seem to suggest a decrease in percentage phytin phosphorus with increase in time after pollination.

Phytin in corn pollen

Several samples of pollen were collected from each of three varieties of corn and analyzed for phytin phosphorus. These data are given in Table 11 .

Table 11 . Phytin phosphorus analysis of pollen.

| Sample No. | Variety | Percent phytin phos. |
|---|---|---|
| 61 | Reed's Yellow Dent | 0.037 |
| 62 | " | 0.045 |
| 76 | Ohio 67 | 0.057 |
| 75 | " | 0.040 |
| 75 | " | 0.040 |

These results indicate that phytin phosphorus is present in pollen of the varieties tested. The percentage phytin phosphorus in pollen is considerably higher than that found in silks.

## RESULTS AND DISCUSSION OF CARBOHYDRATE DATA

### Reducing sugars and sucrose

The analyses of the various corn samples for reducing sugars, sucrose and total sugars are recorded in Table 12 and shown graphically in Figure 7 . It may be observed from these data that reducing sugars amounted to 25 percent of the dry material during the first 10 days after pollination whereas sucrose constituted only 10 percent during this period. The data show an increase for percentage reducing sugars during the first week following pollination with a corresponding decrease for percentage sucrose. However, as percentage reducing sugars decreased from the first to the second week percentage sucrose increased and exceeded percentage reducing sugars at the end of the two week period. Percentage reducing sugars continued to decrease at a rapid rate to the end of the third week after which they diminished slowly to the end of the experiment. After percentage sucrose reached its maximum concentration at the two week sampling period it too decreased rapidly to the third week, somewhat less rapidly to the fourth week and very slowly to the tenth and last sampling period.

In this connection it should be stated that on the third week after pollination the corn kernels were sufficiently mature to be shelled from the cob, although with difficulty.

Percentage total sugar shows the young ovules maintaining a relatively high concentration for the first 10 days following pollination after which the percentage rapidly decreased to the third week and slowly decreased to the end of the experiment.

Table 12 . Percentage sugar in developing ovules of Station Reed's yellow dent corn.

| Interval after Pollination | Percentage Sugars | | | Ave. Percentage Sugars | | |
|---|---|---|---|---|---|---|
| | Reducing as Dextrose | Sucrose | Total as Dextrose | Reducing as Dextrose | Sucrose | Total as Dextrose |
| Unpollinated | 22.50 | 10.69 | 33.75 | 23.98 | 9.98 | 34.49 |
| | 25.47 | 9.26 | 35.22 | | | |
| 6 hours | 25.37 | 10.05 | 35.95 | 25.37 | 10.05 | 35.95 |
| | ----- | ----- | | | | |
| 12 hours | 21.97 | 13.97 | 36.67 | 23.49 | 12.75 | 36.91 |
| | 25.00 | 11.53 | 37.14 | | | |
| 1 day | 21.96 | 9.83 | 32.29 | 22.92 | 11.21 | 34.71 |
| | 23.88 | 12.58 | 37.12 | | | |
| 2 days | 27.53 | 10.93 | 39.04 | 26.32 | 10.85 | 37.74 |
| | 25.11 | 10.76 | 36.44 | | | |
| 3 days | 28.67 | 8.86 | 38.00 | 28.67 | 8.86 | 38.00 |
| | ----- | ---- | | | | |
| 4 days | 29.17 | 8.54 | 38.15 | 26.82 | 8.44 | 35.70 |
| | 24.47 | 8.34 | 33.25 | | | |
| 5 days | 27.37 | 9.43 | 37.30 | 27.41 | 7.45 | 35.25 |
| | 27.44 | 5.46 | 33.19 | | | |
| 7 days | 25.77 | 9.87 | 36.16 | 25.88 | 9.94 | 36.40 |
| | 25.99 | 10.00 | 36.52 | | | |
| 10 days | 21.28 | 11.24 | 33.11 | 22.64 | 11.74 | 35.00 |
| | 23.99 | 12.24 | 36.88 | | | |
| 2 weeks | 9.68 | 14.62 | 25.07 | 12.10 | 14.96 | 27.85 |
| | 14.53 | 15.30 | 30.63 | | | |
| 3 weeks | 2.36 | 6.64 | 9.35 | 2.20 | 6.23 | 8.76 |
| | 2.04 | 5.81 | 8.16 | | | |
| 4 weeks | 1.87 | 4.10 | 6.19 | 1.93 | 4.19 | 6.34 |
| | 1.99 | 4.28 | 6.49 | | | |
| 5 weeks | 1.23 | 2.75 | 4.10 | 1.22 | 3.22 | 4.61 |
| | 1.21 | 3.71 | 5.11 | | | |
| 6 weeks | 1.15 | 2.60 | 3.87 | 1.15 | 2.81 | 4.11 |
| | 1.17 | 3.02 | 4.35 | | | |
| 7 weeks | 0.84 | 2.40 | 3.37 | 0.83 | 2.25 | 3.20 |
| | 0.82 | 2.09 | 3.02 | | | |
| 8 weeks | 0.49 | 1.93 | 2.52 | 0.39 | 1.73 | 2.21 |
| | 0.28 | 1.54 | 1.90 | | | |

Table 18 . Continued.

| Interval after Pollination | Percentage Sugars | | | Ave. Percentage Sugars | | |
|---|---|---|---|---|---|---|
| | Reducing as Dextrose | Sucrose | Total as Dextrose | Reducing as Dextrose | Sucrose | Total as Dextrose |
| 9 weeks | 0.99 | 0.82 | 1.85 | 0.59 | 1.11 | 1.76 |
| | 0.18 | 1.40 | 1.66 | | | |
| 10 weeks | 0.87 | 1.08 | 2.00 | 1.26 | 1.02 | 2.32 |
| | 1.64 | 0.95 | 2.64 | | | |

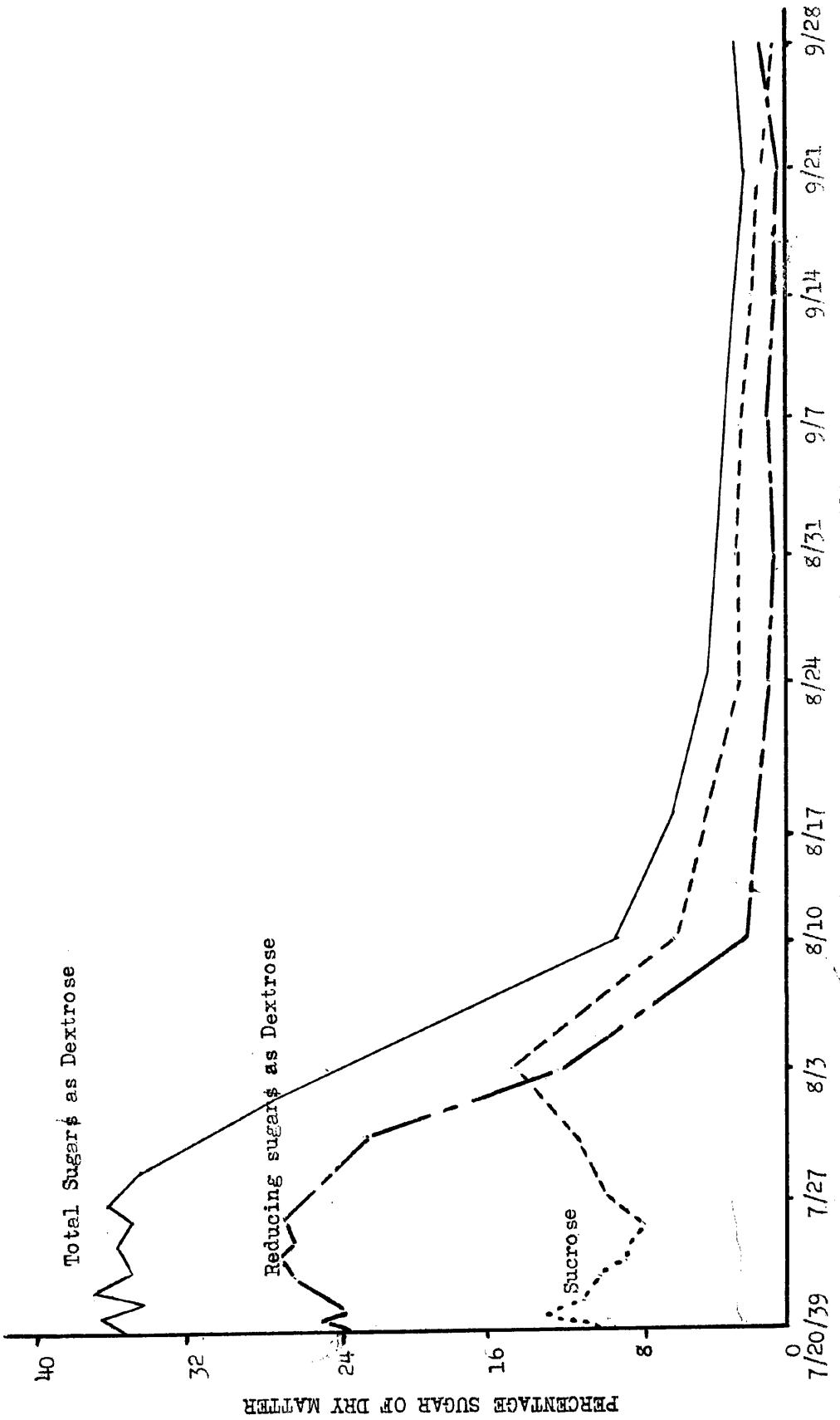



Fig. 7. Average percentage of sugars in corn ovules from pollination to maturity.

Starch

In analyzing the starch data, Table 13 and Figure 8 , it is interesting to note the rapid percentage increase of this compound in the ovules from the first to the third week after pollination despite a simultaneous increase in volume of ovule. From the third to the sixth week percentage starch remained fairly constant. By the seventh week there occurred a small increase which was maintained rather uniformly to the tenth week.

From a comparison of the curves in Figures 7 and 8 it may be seen that there is an inverse relation between percentage total sugar and percentage starch from the first to the third week after pollination. These curves appear to indicate that starch is being increased in the corn kernels at the expense of total sugar previously stored in the ovules. However, the data presented in Table 14 and Figure 9 , giving grams of sugar in ovules per ear, do not substantiate this inference, but instead show the two sets of data to be independent insofar as an increase in starch indicates a decrease in sugar. The fact is, that during the first four weeks following pollination the total sugar in the ovules, although decreasing in percentage, increased in grams per ear and therefore did not contribute to the rapidly increasing starch. Obviously this means that sugar was being translocated into the ovules at a rate such that total sugar, largely sucrose, and starch increased in absolute amount. The reason, therefore, for percentage reduction of total sugar appears to be a more rapid increase in volume of ovule than increase in quantity of sugar, thereby proving that the inverse relationship of percentage total sugar and percentage starch in developing corn ovules is basically unrelated though concommitant.

From the fourth to the tenth week following pollination there occurred a general decrease in grams of reducing sugars and sucrose per ear. This decrease may have resulted from a transformation of sugar into starch, however the quantity was too small to alter either the percentage or the grams of starch in the ovules per ear, Figure 10 .

Table 13 . Percentage and grams of starch in ovules per ear of corn.

| Interval after Pollination | Percent Starch | Average Percent Starch | Average grams of starch in grain per ear |
|---|---|---|---|
| Unpollinated | 7.64<br>12.03 | 9.83 | 0.11 |
| 3 days | 10.72<br>14.52 | 12.62 | 0.37 |
| 1 week | 4.00<br>4.51 | 4.25 | 0.22 |
| 2 weeks | 24.15<br>28.86 | 26.50 | 3.56 |
| 3 weeks | 53.72<br>55.92 | 54.82 | 32.08 |
| 4 weeks | 55.68<br>53.01 | 54.35 | 58.83 |
| 5 weeks | 53.40<br>54.08 | 53.74 | 69.09 |
| 6 weeks | 56.03<br>55.23 | 55.63 | 70.67 |
| 7 weeks | 63.24<br>55.46 | 59.35 | 102.11 |
| 8 weeks | 56.40<br>58.38 | 57.39 | 99.55 |
| 9 weeks | 58.45<br>60.00 | 59.27 | 96.24 |
| 10 weeks | 57.15<br>56.56 | 56.85 | 85.14 |

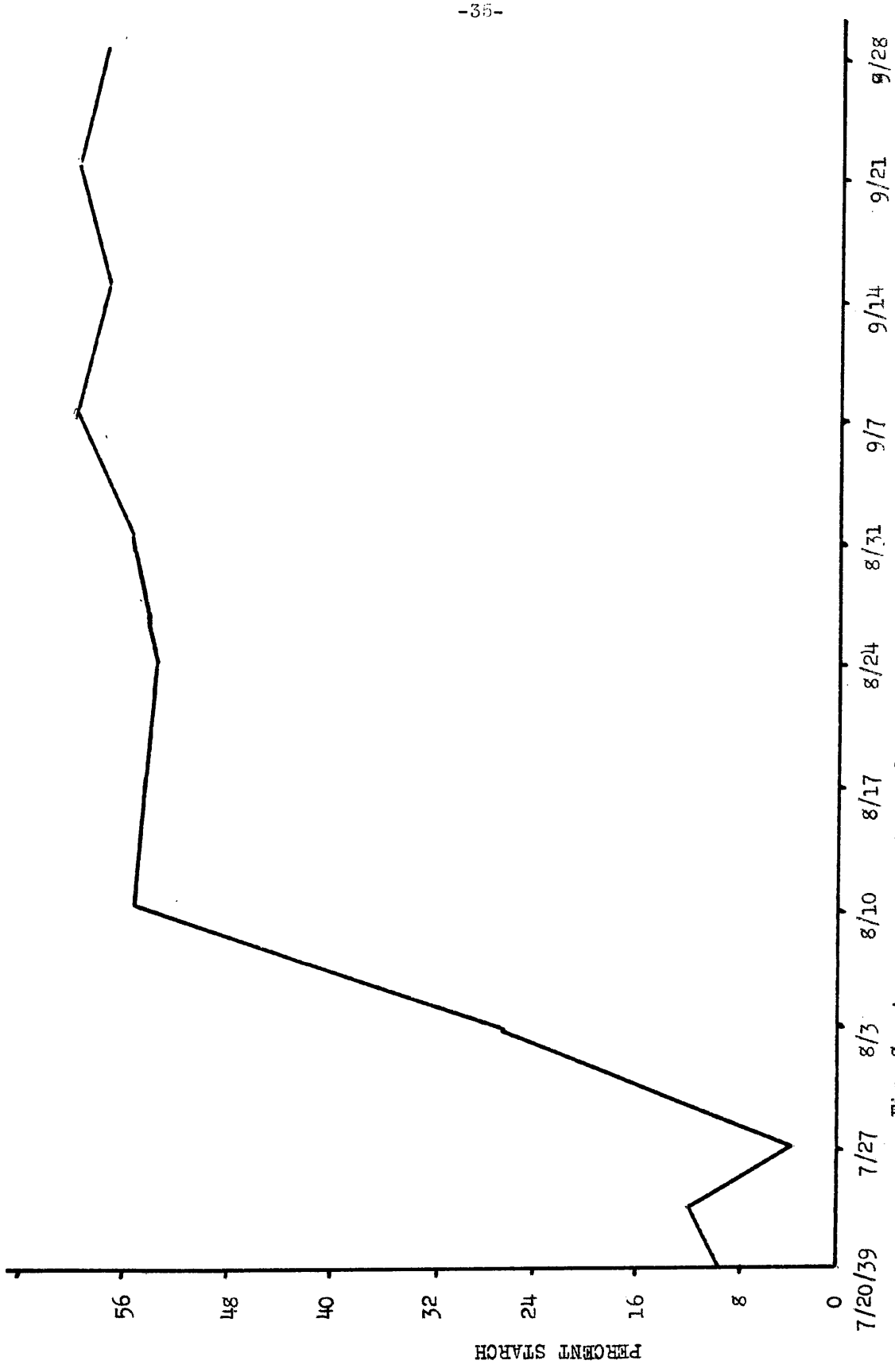



Fig. 8. Average percentage of starch in developing corn ovules.

Table 12 . Grams of sugar in ovules per ear of corn from July 20 to September 27, 1939.

| Interval after Pollination. | Sugar in ovules per ear | | |
|---|---|---|---|
| | Reducing sugar as Dextrose gms. | Sucrose gms. | Total Sugar as Dextrose gms. |
| Unpollinated | 0.26 | 0.11 | 0.38 |
| 6 hours | 0.28 | 0.10 | 0.40 |
| 12 hours | 0.23 | 0.13 | 0.37 |
| 1 day | 0.31 | 0.15 | 0.46 |
| 2 days | 0.42 | 0.17 | 0.60 |
| 3 days | 0.81 | 0.27 | 1.05 |
| 4 days | 0.73 | 0.24 | 0.98 |
| 5 days | 1.50 | 0.44 | 1.93 |
| 1 week | 1.35 | 0.52 | 1.89 |
| 10 days | 1.99 | 1.03 | 3.07 |
| 2 weeks | 1.57 | 1.89 | 3.50 |
| 3 weeks | 1.29 | 3.65 | 5.13 |
| 4 weeks | 2.09 | 4.54 | 6.86 |
| 5 weeks | 1.57 | 4.14 | 5.93 |
| 6 weeks | 1.46 | 3.57 | 5.22 |
| 7 weeks | 1.43 | 3.88 | 5.51 |
| 8 weeks | 0.67 | 3.00 | 3.83 |
| 9 weeks | 0.95 | 1.80 | 2.86 |
| 10 weeks | 1.88 | 1.52 | 3.47 |

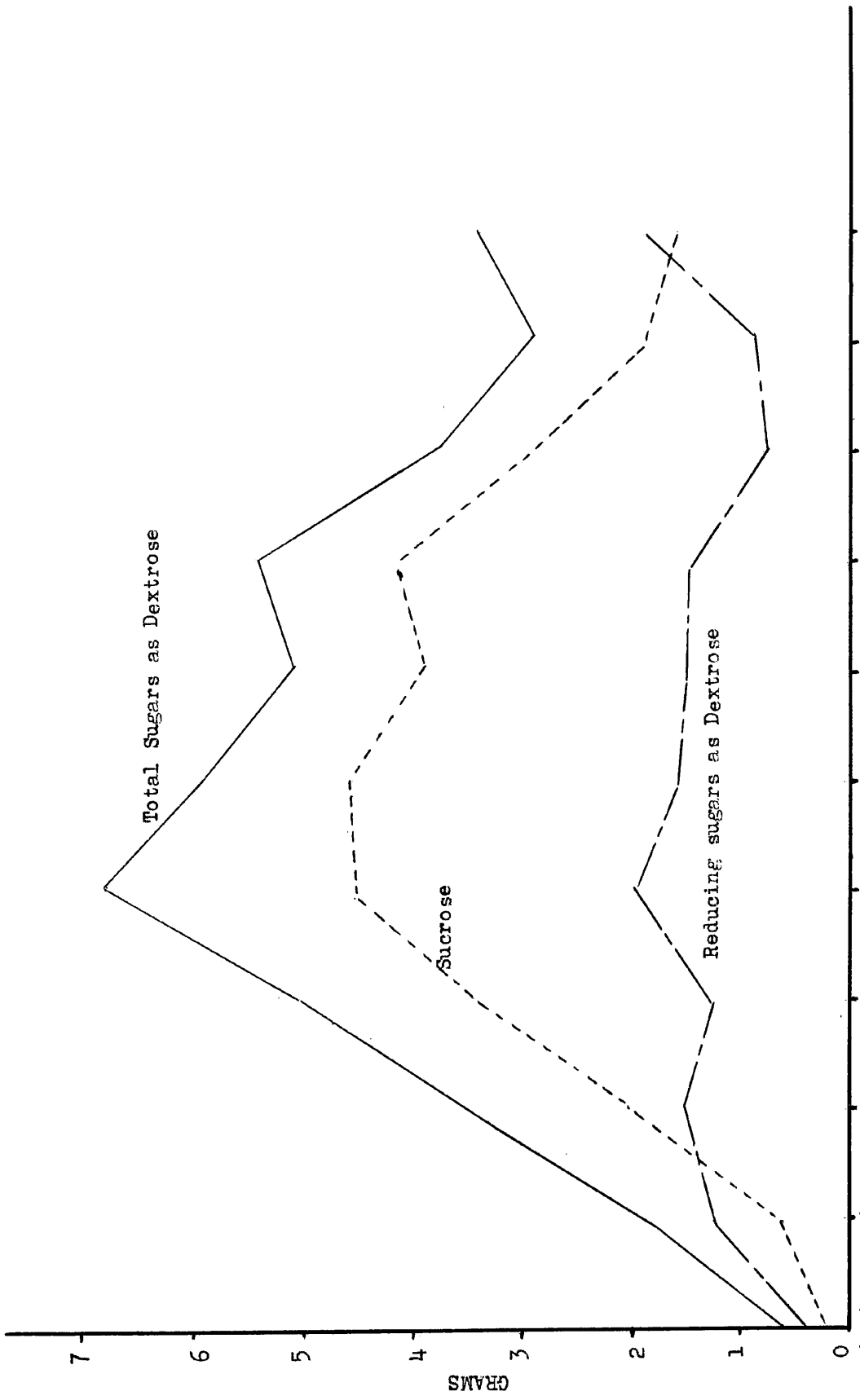



Fig. 9. Grams of sugar in ovules per ear of corn at weekly intervals from pollination to maturity.

The data given in Table 13 and Figure 10 show that there were weekly increases in grams of starch in the ovules per ear from July 20 to September 7 and at no time did the accumulated sugar in the grain suffice for these increases. They were made possible by continuous translocation of sugar into the ovules from a stored supply of sugar in the stalk and from a daily manufactured supply in the leaves. The latter source probably predominated in this respect (13).

The rate of translocation of sugar into the ovules cannot be determined very accurately from this work, yet a general idea is obtained as to the maximum rate which occurred from the 6th to the 7th week. During this period the analyses showed that 35.24 grams of sugar and starch, expressed as dextrose, were translocated into the ovules per ear of corn. This corresponds to a uniform translocation of 3.5 milligrams of dextrose per minute.

Of the 35.24 grams of dextrose the total sugar, as dextrose, represented only 0.29 gram, showing that the major reaction in the development of the corn grain is the synthesis of starch from sugar. This synthesis occurs immediately upon sugar entering the ovule and, in view of the small amount of sugar stored in the mature grain, may be considered to be a rather complete reaction.

Carbohydrate in corn silks

Percentage reducing and sucrose sugars in corn silks (Table 15 ) are in the same order as in the ovule. However,the difference between the two is greater, at least over the 1 week period tested. There is a definite tendency for percent reducing sugars to decrease by the fifth day after pollination with an increase in percent sucrose. On a percentage basis the increase in percent sucrose accounts for a little more than half the percent reduction in reducing sugars and in this case the percent reduction is believed to represent a milligram reduction as the weight of silks per ear probably increases

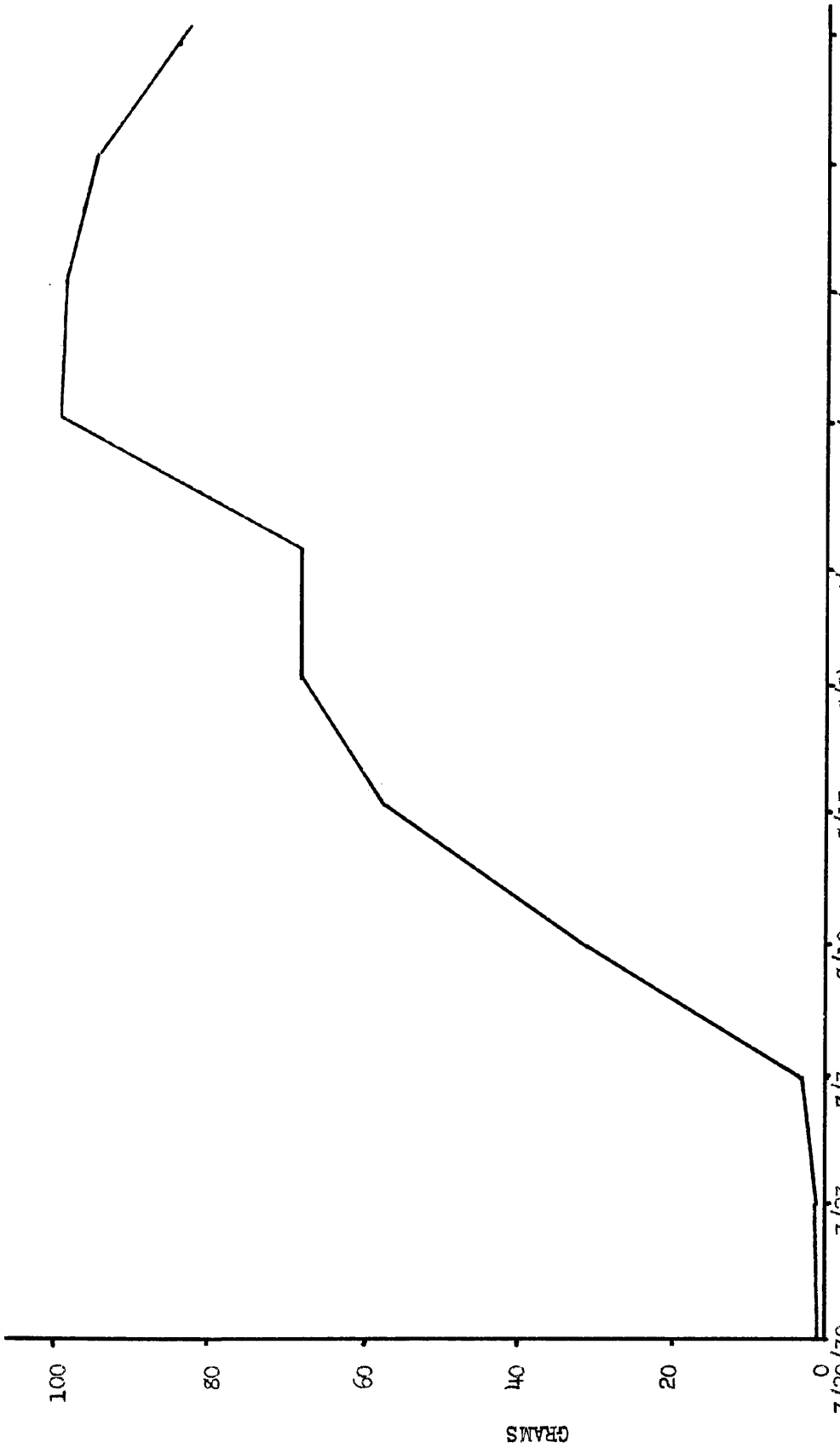



Fig. 10. Average grams of starch, in grain per ear of corn at weekly intervals from pollination to maturity.

very little if any after the 5th day following pollination. Although the chemical study of the carbohydrates of the silks was terminated on the 7th day after pollination, careful observation of the silks at weekly intervals thereafter would lead one to believe that a large part of the total sugars was transferred to the developing ovules. At what rate and order of transfer no suggestion would be offered.

It may be observed from Table 15 that during the first week following pollination the silks contain a higher percent of reducing sugars and a lower percent of sucrose than the developing ovules.

Table 15 . Percentage of sugars found in corn silks.

| Interval after Pollination. | % Reducing sugar | Average | % Sucrose | Average |
|---|---|---|---|---|
| Unpollinated | 36.44 | | 2.03 | |
| | 35.96 | 36.20 | 3.66 | 2.85 |
| 1 day | 37.29 | | 3.77 | |
| | 35.74 | 36.52 | 4.28 | 4.03 |
| 3 days | 36.34 | | 3.54 | |
| | 36.34 | 36.34 | 3.09 | 3.32 |
| 5 days | 31.98 | | 5.34 | |
| | 34.37 | 33.18 | 4.62 | 4.98 |
| 7 days | 33.73 | | 4.49 | |
| | 34.00 | 33.87 | 5.40 | 4.95 |

Carbohydrates in corn pollen

Observation of data in Table 16 shows percent reducing sugars and percent sucrose in pollen of Reed's yellow dent corn and variety 67[1] to be opposite that found in the silks. Whether high reducing sugars and low sucrose in the silks and low reducing sugars and high sucrose in pollen bears any significance is not known at this time, however it is believed this relationship has not been suggested heretofore. Anderson ( 4 ) in determining percentage

1 Ohio inbred line.

reducing sugars and sucrose in pollen of a yellow dent corn[1] found 3.50% for the former and 9.09% for the latter carbohydrate. These analyses are similar to those found by the writer.

The pollen was collected on July 22, two days after this work started and while the pollen was sheding freely.

Table 16 . Percentage sugars found in pollen.

| Variety | % Reducing sugar | Average | % Sucrose | Average |
|---|---|---|---|---|
| Reed's Yellow Dent | 1.37 | 1.37 | 9.82 | 9.82 |
| 67 [2] | 1.58 | | 14.36 | |
| 67 | 1.28 | | 14.58 | |
| 67 | 3.22 | | 9.37 | |
| | | 2.03 | | 12.77 |

[1] Improved Leaming.

[2] Ohio Inbred Line.

## SUMMARY

The developing corn ovule under investigation increased in weight per ear from July 20 to September 7, remained constant to September 14 and declined somewhat for the September 21 and 28 sampling periods. The weekly increases of grain per ear indicate that the development of the corn ovule takes place in cycles rather than at a uniform rate.

It is believed that both the staminate and pistillate parts of the corn plant contain phytin prior to the process of pollination. Following pollination phytin rapidly increases in the ovule and on September 21 constituted 88.79 percent of the total phosphorus.

During the first 10 days after pollination the young corn ovules contained about 35 percent total sugar expressed as dextrose. Of this amount 25 percent represented invert sugars and 10% represented sucrose. Percent invert sugars decreased rapidly from 10 days to two weeks whereas sucrose increased somewhat during this period. However from two weeks to the end of the experiment both invert sugars and sucrose decreased to approximately 1 percent each. Sucrose was maintained at a slightly higher concentration than invert sugars throughout this period.

Starch, on the other hand, made up about 8 percent of the dry ovules during the first week after pollination. At the end of the second week it had reached 20% and at the end of the third week it was 55%. Thereafter percentage starch in the developing corn grain remained fairly constant. Percentage starch however, did not increase at the expense of sugars stored in the ovules.

The relative proportion of invert sugars and sucrose in the pistillate and staminate inflorescence differ widely, in that the former contained approximately 36% invert sugars and about 3% sucrose while the latter contained about 1.8% invert sugars and approximately 12% sucrose.

## Literature References


1. Adler, L. Gewinnung von phytase aus maiz. Biochem. Ztschr. 75:319-338, 1916

2. Anderson, R.J. Concerning the organic phosphorus compound of wheat bran and the hydrolysis of phytin. New York Agr. Expt. Sta. Tech. Bul. 40, 1915.

3. Anderson, R. J. Concerning inosite phosphorus acids. New York Agr. Expt. Sta. Tech. Bul. No. 79. 1920.

4. Anderson, R.J. and Kulp, W. L. Studies with corn pollen. New York Agr. Expt. Sta. Tech. Bul. No. 92, 1923.

5. Bayliss, W.M. The nature of enzyme action. Ed. 5, 200 p. Illus. London, New York.

6. Brody, S. The rate of growth of the domestic fowl. Jour. Gen. Physiol. 3: 765, 1921.

7. Collatz, F.A. and Bailey, C. H. The activity of phytase as determined by the specific conductivity of phytin-phytase solutions. Jour. Ind. and Eng. Chem. 13: 317-318, 1921.

8. Curtiss, C. F. and Patrick, G. E. A study of ripening corn. Iowa Agri. Expt. Sta. Bul. 23: 874-880, 1893.

9. Denny, F.E. Eliminating the use of Calcium Carbonate in preparing plant tissue for analysis. Contrib. Boyce Thompson Inst. 5:103, 1933.

10. Denny, F.E. Improvements in methods of determining starch in plant tissues. Cont. Boyce Thompson Inst. 6:129-145. 1934.

11. DeTurk, E. E., Holbert, J.R. and Howk, B.W. Chemical transformations of phosphorus in the growing corn plant with results on two first-generation crosses. Jour. Agr. Res. 46:121-141, 1933.

12. Dickman, S.R. and Bray, R.H. Colorimetric determination of phosphate. Jour. Ind. and Eng. Chem. Anal. Ed. 12:665-668. 1940.

13. Dungan, G. H. Relation of blade injury to the yielding ability of corn plants. Jour. Amer. Soc. Agron. 22:164-170. 1930.

14. Henrici, M. Phosphormangel als Ursache von Störungen im Leben der Pflanze. Verhandl. Naturf. Gesell. Basel 38:316-326, 1927.

15. Hopkins, C.G., Smith, L.H. and East, E.M. The structure of the corn kernel and the composition of its different parts. Ill. Agr. Expt. Sta. Bul. No. 87, 1903.

16. Hopper, T. H. Composition and maturity of corn. North Dakota Agr. Expt. Sta. Bul. 192, 1925.

17. Jones, W.J., Jr., and Huston, H. A. Composition of maize at various stages of its growth. Ind. Agr. Expt. Sta. Bul. 175, 1914.

18. Kent, D.A. and Patrick, G. E. When to cut corn. Iowa Agr. Expt. Sta. Bul. 21:778-787, 1893.

19. Knowles, F. and Watkins, J.E. The amount and distribution of some phosphorus and nitrogen compounds in wheat during growth. Jour. Ag. Sci. 22:755-766. 1932.

20. McCane, R. A. and Widdowson, E.M. Phytin in Human nutrition. Biochem. Jour. 29:2694-2699. 1935.

21. Minot, C. S. Senescence and Rejuvenation. Jour. of Physiol. 12:97. 1891.

22. Morris, V.H. and Welton, F.A. The importance of clearing the hydrolyzed solutions in the determination of acid-hydrolyzable carbohydrates in green plant tissue. Jour. Agr. Res. 33:195-199. 1926.

23. Plimmer, R. H. H. The metabolism of organic phosphorus compounds. Their hydrolysis by enzymes. Biochem. Jour. 7:43-71. 1913.

24. Rather, J. B. The determination of phytin phosphorus in plant products. Jour Amer. Chem. Soc. 39:2506, 1917.

25. Reed, H. S. and Holland, R. H. The growth rate of an annual plant; Helianthus. Proc. Nat. Acad. of Sciences, Washington, 5:135. 1919.

26. Robertson, T. B. The chemical basis of growth and senescence. Text.

27. Robertson, T. B. Experimental studies on growth. II. The normal growth of the white mouse. Jour. Biol. Chem. 24:363, 1916.

28. Schweitzer, P. Study and life history of corn at its different periods of growth. Mo. Agr. Expt. Sta. Bul. No. 9, 1889.

29. Starkenstein, Emil. Die biologische Bedeutung der Inositphosphorsaure. Biochem. Zeitschr. 30:56. 1910.

30. Webster, J. E. Phosphorus distribution in grains. Jour. Ag. Res. 37: 123-125. 1928.

31. Young, L. The determination of phytic acid. Biochem. Jour. 30:252-257. 1936.

## VITA

The writer was born December 19, 1906 in Orangeburg County, South Carolina. He received his grade and High School education in the public schools of Orangeburg, S.C., graduating from the latter in June 1924. The following fall the writer enrolled in Clemson College, Clemson, South Carolina and was graduated from that institution in June 1928.

In September 1928 he entered the Graduate School of the Virginia Polytechnic Institute and received the Master of Science degree in Agronomy in June 1929. During this period he was employed by the Agronomy Department as part time Teaching fellow.

He is a member of Sigma Xi, Gamma Sigma Delta and Phi Sigma, honorary fraternities.