A STUDY OF THE SEASONAL STARCH CONTENT OF CITRUS SHOOTS

by

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CHAPTER I

STATEMENT OF THE PROBLEM AND REVIEW OF THE LITERATURE

The problem

The present study was undertaken to investigate the seasonal starch content of citrus shoots, with a view of determining if changes in the amount of starch in the tree, or its parts, are correlated with fruiting performance or cultural treatments.

Review of the literature

Many investigators have studied the relationship of carbohydrate reserves to the fruiting habits of deciduous fruit and nut trees. As a result of their investigations much has been learned concerning the seasonal variations in carbohydrate reserves in the shoots and their role in the fruiting of the plant. Some of their findings will be pointed out in the paragraphs which follow.

Davis (5) working with trees of Sugar Prune, observed two maxima and two minima in the seasonal starch content; with a third maxima and minima occurring in the bearing trees due to utilization of carbohydrates at the time of sugar increase in the fruits. The chemical analyses indicated a consistently higher starch content in non-bearing than in bearing trees, suggestive of the importance of carbohydrate reserves in the phenomena of fruiting, as well as in the formation of fruit buds. Variations of starch content in both fruitful and non-fruitful trees showed a distinct seasonal trend. The carrying of fully ripened fruit on the tree appeared to exhaust the carbohydrate reserves.

Finch (6) investigated the relation of starch to nut-filling of pecans. He observed starch storage in the pith, xylem, ray parenchyma, cambium, phloem and cortical parenchyma. The storage of starch was more abundant during the winter. The presence of secondary thickenings of the cell wall occurred prior to starch storage. When relatively small amounts of starch were present storage took place in the pith, xylem, and ray parenchyma. Maximum accumulation of starch in fruiting shoots was reached in late July and early August. This was followed by a depletion during the period of nut-filling. The utilization of starch reserves was closely related to the synthesis of oils. The non-fruiting shoots showed a gradual increase of starch into the fall with no depletion during the period of nut-filling. The two sources of the carbohydrates used in nut-filling were: (1) stored carbohydrates translocated during the period of nut-filling and (2) those moved directly from the leaves to the nuts. The highest starch storage during the summer occurred in trees of moderately low-vegetativeness.

Potter and Phillips (10) in a study of fruit bud formation in non-bearing spurs of the Baldwin apple, found less carbohydrates in bearing than in non-bearing spurs. They also found that the production of a crop of apples tended to inhibit blossom formation.

Investigations by Roberts (11) indicated that the highest formation of blossom buds on apple trees was correlated with a condition of moderate growth and an intermediate carbohydrate-nitrogen ratio. Seasonal starch content was inversely proportional to the nitrogen content. The development of secondary thickenings of the cell wall was correlated with starch content and the cessation of terminal growth. The possibility of a relationship between the "June drop" and the nutritional set up of the tree was pointed out. Starch storage was found to be inhibited by fruit production. In a further paper Roberts (12) pointed out that differing environmental conditions failed to give uniform results in their effect on growth character and blossom bud formation, this lack of uniformity being primarily due to the internal character of the tree or branch.

Swarbrick (14) reported an abrupt and complete depletion of starch from the one- to three-year-old branches of apple. This marked change took place in one week (February 15-23). "It was observed that there was a close connection between the relative rates of starch disappearance and the development of cambial activity." Starch disappearance began in the phloem, originating in the apical regions and continuing basipetally. Depletion of starch was complete in younger branches and incomplete in the older ones. Starch disappearance lagged behind cambial activity in vegetative shoots and preceeded it in fruitful shoots. Later studies of Swarbrick (15) indicated that heavy starch accumulation in autumn was accompanied by a cessation of cambial activity and that the starch disappeared from the xylem prior to cambial development.

Thomas (16) observed the distribution of starch in the apple branches. He found starch in "the parenchymatous cells of the cortex, phloem, and medullary rays. The pith was packed with starch grains," although storage took place later in the pith than in other tissues.

The studies made of starch behavior in deciduous fruit trees suggested the possibility of related phenomena in the case of citrus trees. Investigations of the fruiting response of citrus trees and the factors influencing this response have been limited. There are many perplexing questions upon which similar studies of citrus trees might have a direct bearing. Does the date of harvest influence the fruit set of the following season? Will consistent late harvesting maintain an average yield equivalent to that of consistent early harvesting? Can the June drop be avoided by proper control of the nutritional conditions within the tree? Can nutritional conditions be modified to offset a lack of balance caused by variation of picking date? Do citrus trees react differently from deciduous trees in their utilization of food reserves? Does the tree respond as a unit or as an aggregate of local responses? Does local starch depletion take place following the summer and fall flushes of growth? Does the carrying of fruit after horticultural maturity has been reached cause further exhaustion of the carbohydrate reserves?

Answers to some of these questions are suggested by those investigators who have studied the metabolism of citrus trees. Cameron (1) on the basis of macro-chemical analyses of young Valencia orange trees states:

"Except in the root bark, fluctuations in starch content were not marked. A maximum in early spring was followed by a gradual decrease after growth had started to a minimum in late summer, after which there was a gradual accumulation during the fall and winter to the maximum in early spring."

The data gathered in the course of this study failed to agree with the above conclusion and will be discussed in Chapter III.

In a further paper Cameron (2) indicated clearly his conclusion that seasonal fluctuations in starch content in citrus trees are not comparable to those occurring in deciduous trees. He says:

"At no time was there a sudden appearance or disappearance of starch such a s occurs in deciduous species during the blossoming and leafing out period. The orange trees bloomed profusely in the spring and characteristically produced three cycles or flushes of growth during the growing season. However, except in the twigs and small branches the effect of this growth activity on starch content was slight."

Cameron and Appleman (3) came to the conclusion that the reduction of the nitrogen supply through blossoming and growth of the young fruit may be the limiting factor determining final fruit set.

Cameron, et al. (4) in a study of seasonal changes in nitrogen content of citrus fruit indicated a higher nitrogen content of fruit remaining on the tree after attaining horticultural maturity. They suggested the possibility that early picking influences the bearing behavior of the tree.

Halma (7) indicated the importance of food reserves for the initiation of sprout growth in citrus, part of which are utilized in the formation of growth-promoting substances.

Kinnison and Finch (9) reported definite effects in fruiting behavior following the use of different practices which caused changes in the nutritional balance of the trees.

A splendid discussion of the anatomy of citrus shoots was given by Webber and Fawcett (17) and should be consulted by those desiring a knowledge of the various tissues found in citrus shoots, particularly those which may be affected by nutritional changes. Further references to certain of these papers will be made in the presentation and discussion of the data obtained in this study.

CHAPTER II

MATERIALS AND METHODS

Source and character of material

All material used in this study came from the Yuma Mesa, near Yuma, Arizona. With the exception of shoots from a starved grove all material was obtained from the citrus plantings at the Yuma Mesa Citrus Experiment Station. The salient geographical and climatic factors of this region are pointed out in the study by Smith, et al. (13).

Both the grapefruit and oranges were upon sour orange (*Citrus aurantium*) stock. Variety, type, condition of fruitfulness, and treatment of trees is indicated in Table 1. With the exception of the young non-fruitful type all trees were of a fruiting age. The samples of the late pick fruiting and non-fruiting shoots were from the same tree. The types of trees used were chosen with a view to securing material most likely to show the widest extremes in starch content.

Shoots of the previous seasons growth i.e. from the 1936 growing season, were selected for examination. The dates of collection are indicated in Table 2.

Preservation and preparation of the material for study

Samples were collected in mid-afternoon. The leaves were removed at once, and the shoots placed in formalin-alcohol-acetic acid solution (100 cc. of 50 % alcohol,

Table 1.--Trees used as sources of material for this study

Designation	Type, Condition of fruitfulness, treatment
<u>Grapefruits</u> (Marsh Seedless)	
1. Early Pick 1936	Tree in production, age 15 years. Fruit picked Octover 1936. Guard row of fertilizer test plot, five ton manure per acre.
2. Late Pick Fruiting Shoots	Same age and cultural conditions as above. Fruit remained on tree during entire period of study.
3. Late Pick Non-Fruiting shoots	Same as preceeding except limited to non-fruiting shoots i.e. those not carrying fruit thru fall, winter and spring of 1936-37.
<u>Oranges</u> (Washington Navel)	
4. Navel Shaded	Tree 15 years of age, very unfruitful. Shaded by shelter of palm leaves since early spring of 1932. Fruit mammoth size, coarse; vegetative growth thin, dark green, willowy.
5. Navel Sun	Fruitful tree, vegetative condition normal. Other conditions equal to above.
<u>Grapefruits</u> (Marsh Seedless)	
6. Calcium nitrate	Productive tree, age 15 years. Calcium nitrate treatment past three years.
7. Starved tree	Approximate age eight years; crop moderate; orchard completely abandoned to weed growth. Tree of low vegetativeness.
8. Unfertilized	Age nine years, productive. Prior to fall of 1935 received three tons manure annually, since then all fertilizers suppressed.
9. Young tree	Vegetative and non-fruitful, approximately four years of age. Development retarded due to previous cover crop treatment.

2-3 cc. of acetic acid, and 7 cc. of 40 % formalin). Freehand transverse sections were later made in the laboratory, stained in Iodine in Potassium Iodide solution, and mounted in a glycerine solution of the same.

The procedure involving the use of microscopic observation of stained material was adopted for the following reasons: (1) This method indicates more effectively and accurately minor fluctuations in starch content. (2) It indicates the tissues serving in starch storage and the relative amounts of starch contained in them. (3) It provides a rapid means of following the behavior of individual trees thruout the season. (4) A means is provided for the study of different local responses within the same tree as in the case of the fruitful and non-fruitful shoots of the Late Pick tree. The advantages of the microscopic study as a means of determining starch content is indicated by Cameron (2). He states:

"So far as starch content is concerned the microscopic study which preceded the quantitative determinations furnished considerably more information as to what the actual situation in the plant was than did the quantitative data."

For the purpose of gaining a more accurate concept of the actual structure of the tissues a limited number of slides were prepared from transverse sections cut on the sliding microtome. Before sectioning the shoots were placed for twenty-four to forty-eight hours in a softening solution of five parts of 95 % alcohol in one part of glycerine. The sections were then stained by the use of safranin and analine blue and mounted in balsam. Only a limited number of such slides were prepared and will not be given further consideration in this study.

CHAPTER III

PRESENTATION AND DISCUSSION OF DATA

General character of starch storage in citrus shoots

Before presenting the data concerning the observations on the starch content of citrus shoots a brief presentation of the tissues where storage occurs would be in order. Beginning at the center of the shoot starch is stored in the pith cells, xylem rays, xylem parenchyma, phloem rays and parenchyma, and cortical parenchyma. The xylem parenchyma may be of two kinds, vasicentric i.e. found in the regions adjacent to the xylem vessels, and diffuse i.e. scattered about irregularly through the xylem.

Storage is first apparent in the rays of the xylem, then begins to take place in the pith followed by the xylem parenchyma and lastly those tissues in closest relationship with the cambium: phloem rays and parenchyma, and cortical parenchyma. In the older shoots the cortical parenchyma is limited to the large parenchymatous cells beneath the epidermal layer, however, in the shoots even those cells containing chloroplasts are sufficiently parenchymatous as to store starch.

The photomicrographs included at the close of this study illustrate these various tissues and some varying degrees of starch storage.

Seasonal starch content of Grapefruit shoots

The discussion of the seasonal starch content of the grapefruit shoots will be limited to pointing out the general situation found in the various samples from December 4, 1936 to April 16, 1937. Details of those samples collected on November 8, 1936 are to be found in Table 2. Furthermore, the discussion will be confined, in a large measure, to those three types which gave indications of wider variation in starch content, namely: Early Pick 1936, Late Pick Fruiting Shoots, and Late Pick Non-Fruiting Shoots. The general situation existing in the other types of grapefruit trees under observation will be presented very briefly.

December 4, 1936: Certain differences in the rate of starch storage between the Early Pick and Late Pick Fruiting shoots were apparent at this time. In the former there was an abundance of starch in the pith and in the xylem rays closest to the central pith. A small amount of starch was present in the phloem and cortical parenchyma. Storage was most noticeable toward the basal portion of the shoots. In the Late Pick Fruiting shoots starch was present largely in the outer cells of the central pith and in the xylem rays. Some of the central pith cells showed slight starch storage, but only where there was evident thickening of the cell walls. The regions outside the cambium were devoid of starch except for a limited amount in the cortex. Samples from trees representing differing cultural practices showed less variation and were similar in that they showed storage in the pith, xylem rays, and limited amounts in the phloem, and cortical parenchyma.

Table 2.--Starch storage and depletion in citrus shoots

Designation	November 8, 1936	December 4, 1936	December 31, 1936	January 28, 1937	February 24, 1937	March 3, 1937	March 10, 1937	March 17, 1937	March 24, 1937	April 3, 1937	April 16, 1937
Grapefruits											
No. 1 Early Pick	No samples	Starch very abundant in pith, abundant xylem rays, small amount phloem and cortex. Less storage at tip.	No appreciable change in pith, increased storage in phloem and cortex toward tip.	Starch very abundant at tip less so at base.	All tissues gorged. Maximum starch storage. Slight cambial activity.	Decrease of starch in phloem and cortex, remaining abundant other tissues. Increasing cambial activity.	Little appreciable change.	Very marked depletion of starch from pith, xylem, phloem and cortex.	Starch absent all tissues except trace in xylem. Loss of cell wall thickenings evident.	Depletion complete thru entire shoot.	Starch absent, save slight traces xylem at base only.
No. 2 Late Pick Non-Fruiting	No samples	Starch present outer pith and xylem rays, practically absent center pith. Less storage toward peduncle of fruit.	No increase of storage. Peduncle completely depleted.	Slight increase at base and center of shoot.	Slight increase in storage at base, but decrease in peduncle and center of shoot.	Increase to abundant outer pith, little in center pith preceeded by secondary thickenings of cell walls. Maximum storage. Absent peduncle, small amount phloem and cortex.	Depletion very marked, nearly absent pith, small amount xylem.	Depletion complete or nearly so. Absent peduncle of fruit.	Complete depletion of starch. Loss of cell wall thickenings very pronounced.	No change	No change
No. 3	No samples	No samples	No samples	No samples	Starch storage at maximum, tissues gorged. Slight cambial activity.	Starch very abundant except rapid utilization in phloem and cortex .	Shoots variable, decrease in phloem, cortex, and pith.	Depletion very marked, absent from all but xylem rays. At tip depletion complete.	Little appreciable change in starch. Loss of cell wall thickenings evident.	Depletion complete except traces in xylem.	No change
Navel Oranges											
No. 4 Navel Shaded	Starch abundant in pith, fair amount in xylem rays, absent in xylem parenchyma and phloem.	Little change	No examination	Little appreciable change in pith and xylem rays, small amount xylem parenchyma and phloem.	No examination	Maximum starch storage. Very abundant thruout tissues. Cambium active.	Little appreciable change.	Marked depletion.	Depletion very pronounced, starch much reduced.	Depletion nearly complete.	Starch absent all tissues.
No. 5 Navel Sun	Starch very abundant pith, fairly abundant xylem to cortex	Very abundant pith, slight decrease, xylem, phloem and cortex.	No examination	Slightly less than previous sample, decrease in pith and xylem.	No examination	Maximum storage, tissues gorged. Limited cambial activity.	Evident utilization from phloem and cortex.	Continued depletion but varying in different shoots.	Complete absence of starch except at tip.	Marked depletion, shoots variable.	Little appreciable change.

<u>December 31, 1936</u>: Although there was no appreciable change of starch in the pith of the Early Pick tree an increase of starch storage was apparent in the phloem and cortical parenchyma, particularly toward the tip. In the Late Pick Fruiting Shoots there was no evident increase in starch storage. Starch was completely absent from the peduncle of the fruit.

<u>January 28, 1937</u>: The samples collected on January 28 showed a lack of uniformity in the relative starch content of the different samples. There was a marked increase of starch in the Early Pick shoots, particularly toward the tip. The Late Pick Fruiting Shoots showed a slight increase at the base of the shoot. The increase was evident by the storage of small amounts of starch in the xylem parenchyma, phloem and cortex. An increase in the starch accumulation was also shown by the Calcium Nitrate type, particularly toward the tip and in the phloem. The three trees representing types of low-vegetativeness showed a decrease of starch, this depletion being especially noticeable in those tissues from the cambium outward. On January 9 and 10 the minimum temperature recorded at the Yuma station was 26° F. This was followed by temperatures of 19, 20 and 19° F. on January 22, 23 and 24 respectively. In view of the temperatures indicated this variation in starch content was of particular interest.

That the decrease of starch was a normal response to the low temperatures indicated above, appeared clear.

The effect of low temperatures on the starch-sugar ratio in living plant tissues has been pointed out by workers in the field of Plant Physiology. Many workers hold that as the temperature decreases starches are hydrolized to sugars. Hildreth (8) states: "Fischer has demonstrated that in woody plants starch is transformed into sugar on exposure to cold, and that with higher temperature starch is again formed." The increase in sugars aids in preventing the coagulation of some of the colloidal material within the cell sap and for this reason assists the plant in resisting low temperatures. That trees of low-vegetativeness showed this decrease was due, possibly, to a deficiency of sugars within the cell sap in comparison with the more vegetative types where all the sugars had not yet been converted into the form of starch for winter storage. The small increase in starch, indicated for the Early and Late Pick trees, probably more nearly represented the normal trend at this point in the season under normal conditions.

February 24, 1937: Maximum starch storage was indicateed by the Early Pick and by the Late Pick Non-Fruiting types. In both of these samples the tissues thruout the shoots were gorged with starch. There was also slight evidence of the beginning of cambial activity. The Late Pick Fruiting Shoots showed a slight increase over the previous sample so far as the base of the shoots were concerned. There was evidence of a decrease from the center of the shoot to the peduncle of the fruit. External evidence of vegetative activity at this time was limited to the initiation of growth from the buds and tip of the shoots.

March 3, 1937: These samples were characterized by a high starch content in all cases, however, there was evidence that in some cases the maximum had been passed. The Early Pick and Late Pick Non-Fruiting types agreed in their increase in cambial activity which was accompanied by a decrease of stored starch in the phloem. The Late Pick Fruiting type was at its approximate maximum of starch storage, however, this maximum represented a much lower degree of total storage of starch than was true of the maximum observed in the Early Pick and Late Pick Non-Fruiting shoots. This increase was particularly marked in the outer pith, xylem rays and xylem parenchyma. Limited amounts of starch were present in the phloem, and cortex. In the peduncle of the fruit there was evidence of further depletion of starch from all the tissues. There was but little storage of starch in the central pith, storage taking place only in those cells where the cell wall thickenings were present. All the other grapefruit samples gave evidence of high starch storage at this period and the cambium was active in all cases. There was an approximate doubling of the new growth from the time of the previous sample.

March 10, 1937: A uniformly rapid decrease in starch storage was occurring in all of the material examined. Although the Late Pick Fruiting shoots showed marked depletion from the pith and xylem but there appeared to be some deposition in the region of the cortex. Starch continued to be absent from the peduncle of the fruit. The least decrease of starch reserves was shown by the Early Pick and Calcium Nitrate types. Losses of starch from these types was most noticeable in the phloem, cortex and pith. At this time the new fruit buds were in evidence but no flowers had opened.

<u>March 17, 1937</u>: The shoots examined gave evidence of continued and in most cases marked depletion of starch in all tissues. The Early Pick suffered a heavy loss of starch from the pith and xylem and a complete loss from the cambium outward. Depletion was complete in the tip of the Late Pick Non-Fruiting type. There was a continued decline in the Late Pick Fruiting type. The other samples were also characterized by this general depletion of starch. The new terminal growth in the Early Pick and the Late P ick Non-Fruiting types had reached a length of from one and one-half inches to two and one-quarter inches.

<u>March 24, 1937</u>: On this date not only had the depletion of starch continued to the point of complete exhaustion in some cases, but was accompanied by a loss of the cell wall thickenings from a portion of the cells of the central pith. The depletion was complete and the utilization of the wall thickenings more evident in the Late Pick Fruiting type than in the others. Depletion in most cases was evident first at the tip of the shoot. The new shoot growth had continued to elongate and flowers were opening, however,

there were no flowers or new growth on the Late Pick Fruiting shoots. The maximum bloom of the grapefruit trees occurred on March 29, 1937.

April 3, 1937: The general depletion of starch continued. The Early Pick type now showed a complete utilization of the stored starch thru the entire shoot. Traces of starch remained in the Late Pick Non-Fruiting shoots but were absent in the Late Pick Fruiting shoots. The other grapefruit samples also gave evidence of continued depletion of starch. Shoot growth was abundant on the Early Pick and Late Pick Non-Fruiting types but there was little growth from the Late Pick Fruiting type.

April 16, 1937: In general these samples showed practically complete utilization of starch reserves, regardless of the previous condition of starch storage. New fruits to one-fourth inch in diameter were present on the new growth of both the Early Pick and Late Pick Non-Fruiting types. The Early Pick samples appeared more fruitful than those of the Late Pick Non-Fruiting shoots. The samples from the Late Pick Fruiting shoots had no new shoot growth.

The varying degrees of starch storage at four points during the period of the study are presented graphically in the Camera Lucida diagrams and the photomicrographs.

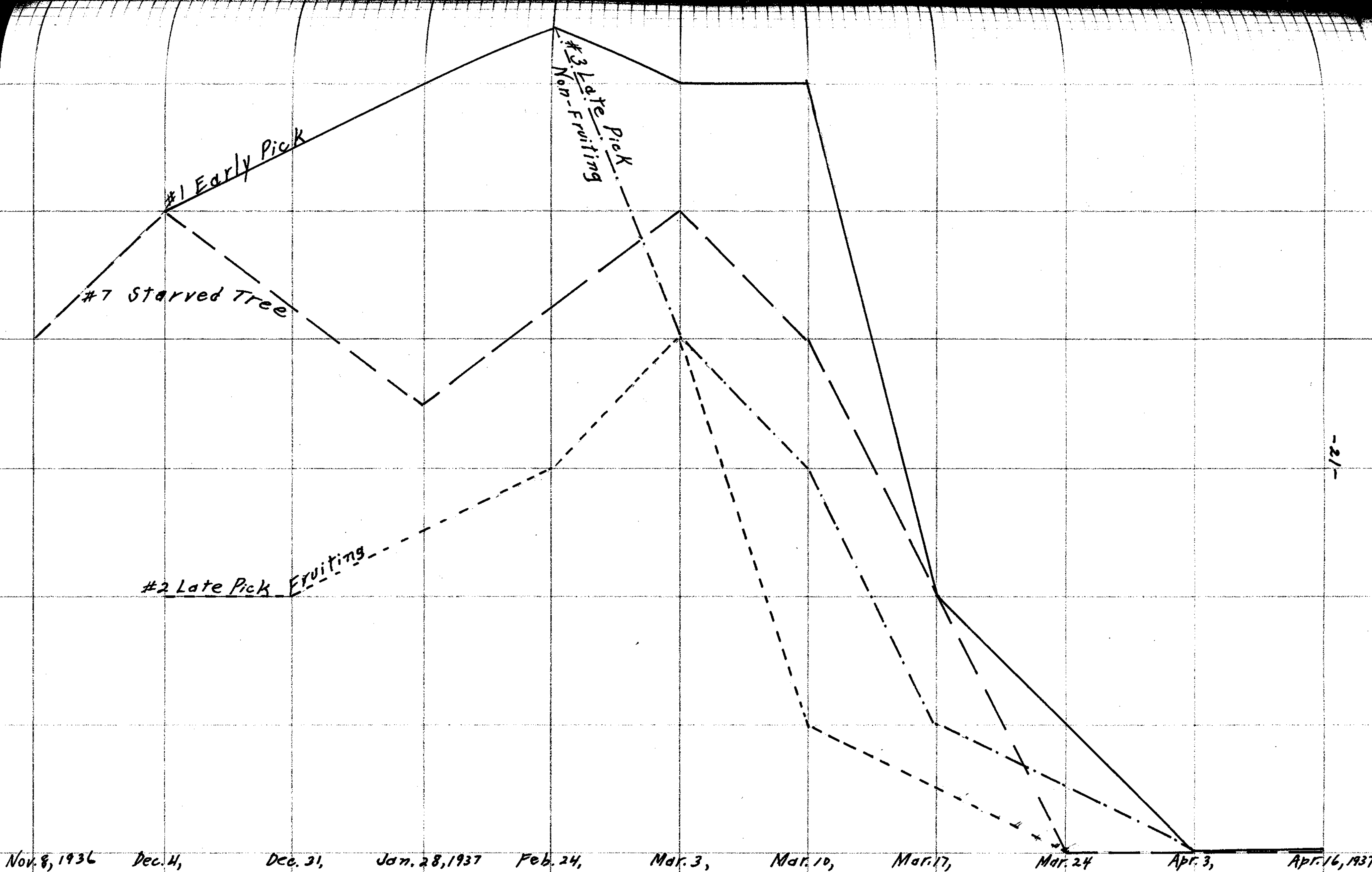
In general it may be said that the greatest variations in starch storage were present in those samples which represented a difference in fruiting habit (Early Pick vs. Late Pick Fruiting types), rather than those representing different cultural practices. Also, the Late Pick trees blossomed less profusely in 1937 than the Early Pick trees. This same condition was found by Kinnison and Finch (9): "Trees which were still carrying the 1932 crop at blossom time in 1933 produced fewer and smaller blossoms than check trees or than trees harvested early." The reduction in flowers indicated above has given further strength to the viewpoint expressed by Cameron, et al. (4). They stated: "That early removal of ripe fruit influences the bearing behavior."

The data gathered in this study appeared to indicate that there was an abrupt seasonal variation in the starch content of citrus shoots and that this variation can be correlated with the fruiting habits of the tree, as shown in the comparison of the Early and Late Pick types. These differences in starch storage appeared to be related to the growth of the tree as evidenced by the data given in Table 3. A further depletion of the starch reserves of the tree resulted from the practice of allowing the fruit to remain on the tree after horticultural maturity had been attained.

Cameron and Appleman (3) suggested nitrogen as the limiting factor in the set of citrus fruits under desert conditions. Evidence gathered in this study appeared to indicate that such is not the case as there was less influence on yield thru fertilizer practices where nitrogen was used than thru the different fruiting habits pointed out in the preceeding paragraphs. It has appeared more reason-

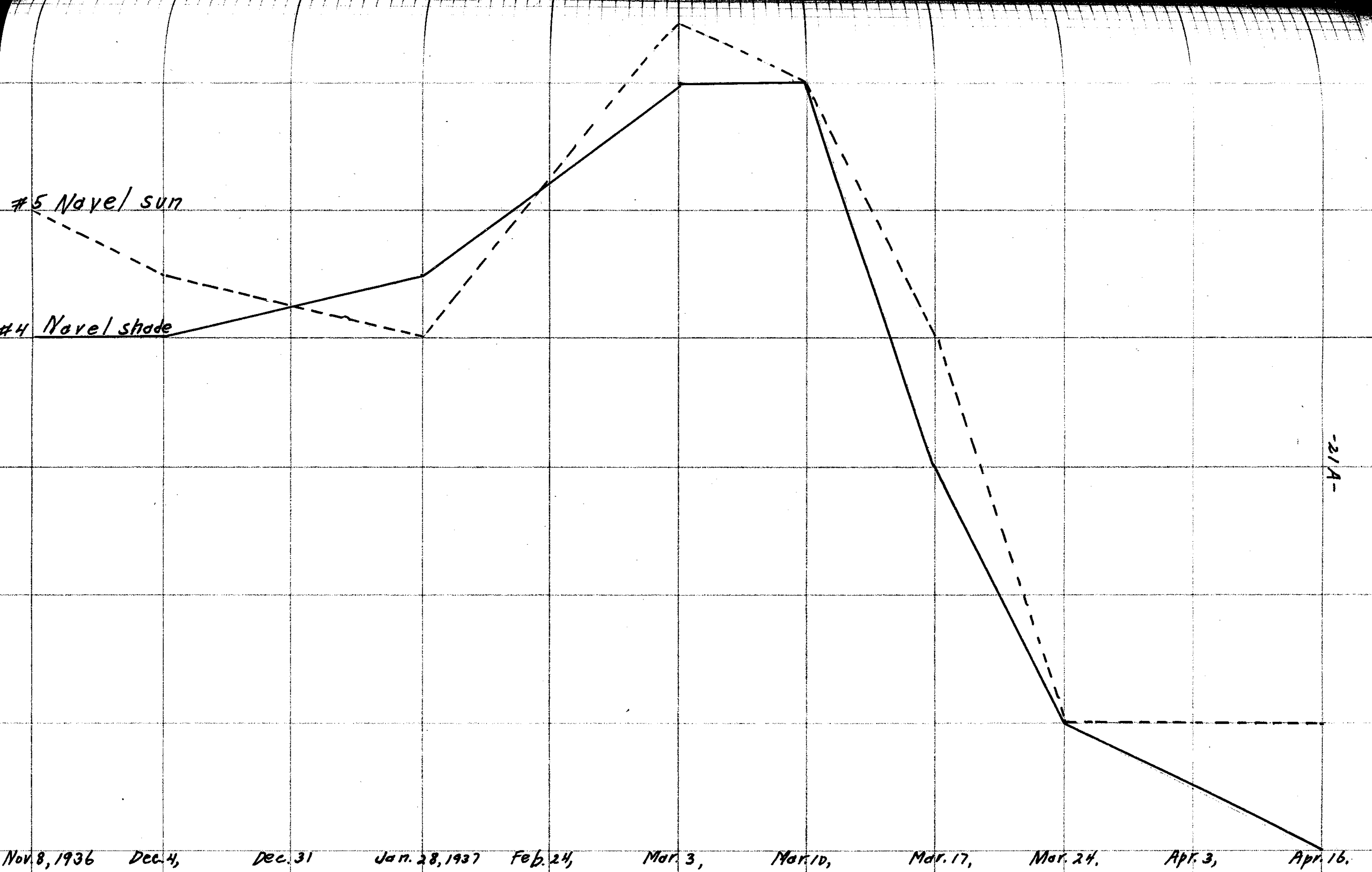
Table 3.--Vegetative condition of Grapefruit and Orange shoots

Key	Date	New growth	Flowering
__Grapefruits__			
No. 1 Early Pick	Mar.10	Less than one inch.	Numerous buds 2-3 mm. diam.
	Mar.17	One and one-half to two and one-half inches.	
	Mar.24	Vigorous growth.	Numerous flowers.
	Apr. 3	One and one-half inches.	Central flower petals fallen.
	Apr.16	Two inches.	Fruits one-fourth inch diameter.
No.2 Late Pick Fruiting Shoots	Mar.10	Three-quarters inch.	Little evidence of flowers.
	Mar.17	Growth scarce.	Few flowers.
	Mar.24	No new growth.	No flowers.
	Apr. 3	Little new growth.	
	Apr.16	Shoots short	Few fruits formed.
No.3 Late Pick Non-Fruiting	Mar. 10	Less than one and one-half inches.	Numerous flower buds.
	Mar.17	Vigorous.	No flowers.
	Mar.24	Abundant growth.	
	Apr. 3	Vigorous growth.	
	Apr.16	Shoots short	Few fruits.
__Navel Oranges__			
No.4 Navel Shaded	Mar.10	Less than one inch.	Few flower buds.
	Mar.17	Thin, willowy.	
	Mar.24	Little growth.	
	Apr. 3	No new growth	
	Apr.16	Growth thin.	Few fruits.
No.5 Navel Sun	Mar.10	Less than one inch.	
	Mar.17	One and one-half inches.	Many flower buds.
	Mar.24	Removed in taking sample.	
	Apr. 3	One and one-half in.	Flower petals fallen.
	Apr.16	Shoots short.	Fruits 3/16" diameter or less.



Degree and rate of starch storage and Utilization

Grapefruits



Degree and rate of starch storage and utilization

<u>Navel Orange</u>

able and in accord with the observations of this study to believe that the carbohydrate reserves also play an important role in determining the set of fruit. There is need for further work of this nature during the entire period of the June drop.

Seasonal starch content of Navel orange shoots

The variations in the seasonal starch content of Navel orange shoots were similar to those observed in the grapefruit shoots. The storage of starch continued during the fall and winter months reaching a maximum prior to flowering and followed by a rapid utilization of these reserves. Certain interesting data were obtained in the case of the two types under observation.

The shaded tree was characterized by those habits of growth usually associated with a high nitrogen and low carbohydrate relationship. The foliage was dark green, large and thin. The twigs were willowy, thin, dark green in color; and the shoots sectioned showed a narrower xylem than those from the unshaded tree.

Starch storage took place more slowly in the shaded tree as shown by the differences in the quantity of starch present in the pith and xylem at the time of the December 4, 1936 samples. The samples of January 28 also gave indication of the utilization of starch due to the effects of the low temperature which prevailed in that month. Both trees reached their approximate maximum of starch storage by March 3, 1937 and displayed an abundance of starch thruout the shoots. Utilization of starch was evident in the unshaded tree by March 10, 1937 but was not particularly noticeable in the case of the shaded tree until March 17. Flower buds were numerous in the case of the unshaded tree and reduced in number on the shaded tree.

Depletion of starch reserves was very pronounced by March 24, 1937, however, there were traces of starch in some of the shoots. The maximum of the Navel orange bloom occurred March 25, 1937. The same depleted condition existed on April 3, 1937 and April 16, 1937. Shading appeared to inhibit the rapid accumulation of starch reserves which are necessary for fruit formation and a normal development of the xylem tissues.

CHAPTER IV

SUMMARY

1. The accumulation of starch reserves was gradual and continued until prior to the initiation of cambial activity.
2. The depletion of starch reserves was very rapid following the initiation of growth.
3. Greater variation occurred between differing fruiting habits than between trees under differing cultural treatments. The Late Pick Fruiting shoots accumulated less starch and the maximum storage was reached later than was true of the Early Pick or the Late Pick Non-Fruiting types.
4. The carrying of a crop of fruit reduced the amount of starch accumulation and the amount of flowers produced. A similar inhibiting effect was caused by shading.
5. There appeared to be a distinct correlation between the accumulation of starch reserves and the fruiting character of the shoots.
6. Depletion was very marked by the time of maximum bloom.
7. Starch utilization in the shoots was nearly complete by March 24, 1937, regardless of previous cultural treatment or fruiting habit.

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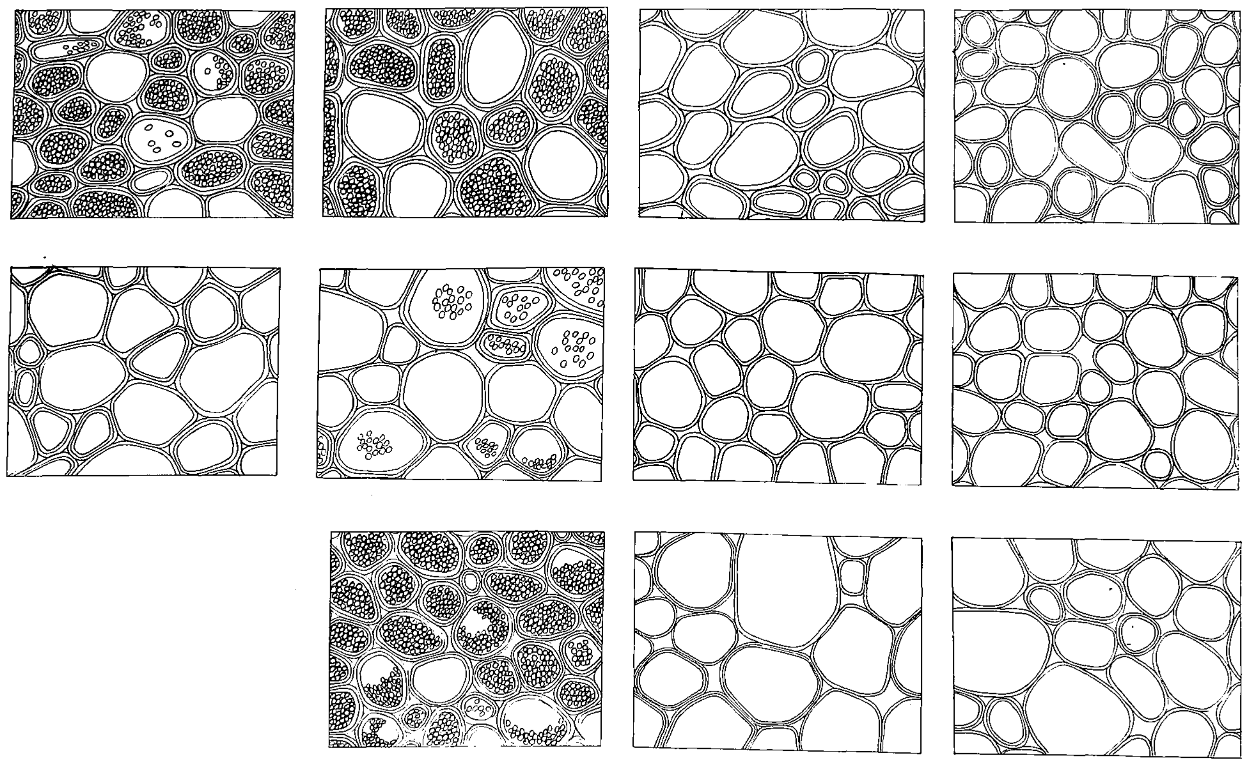
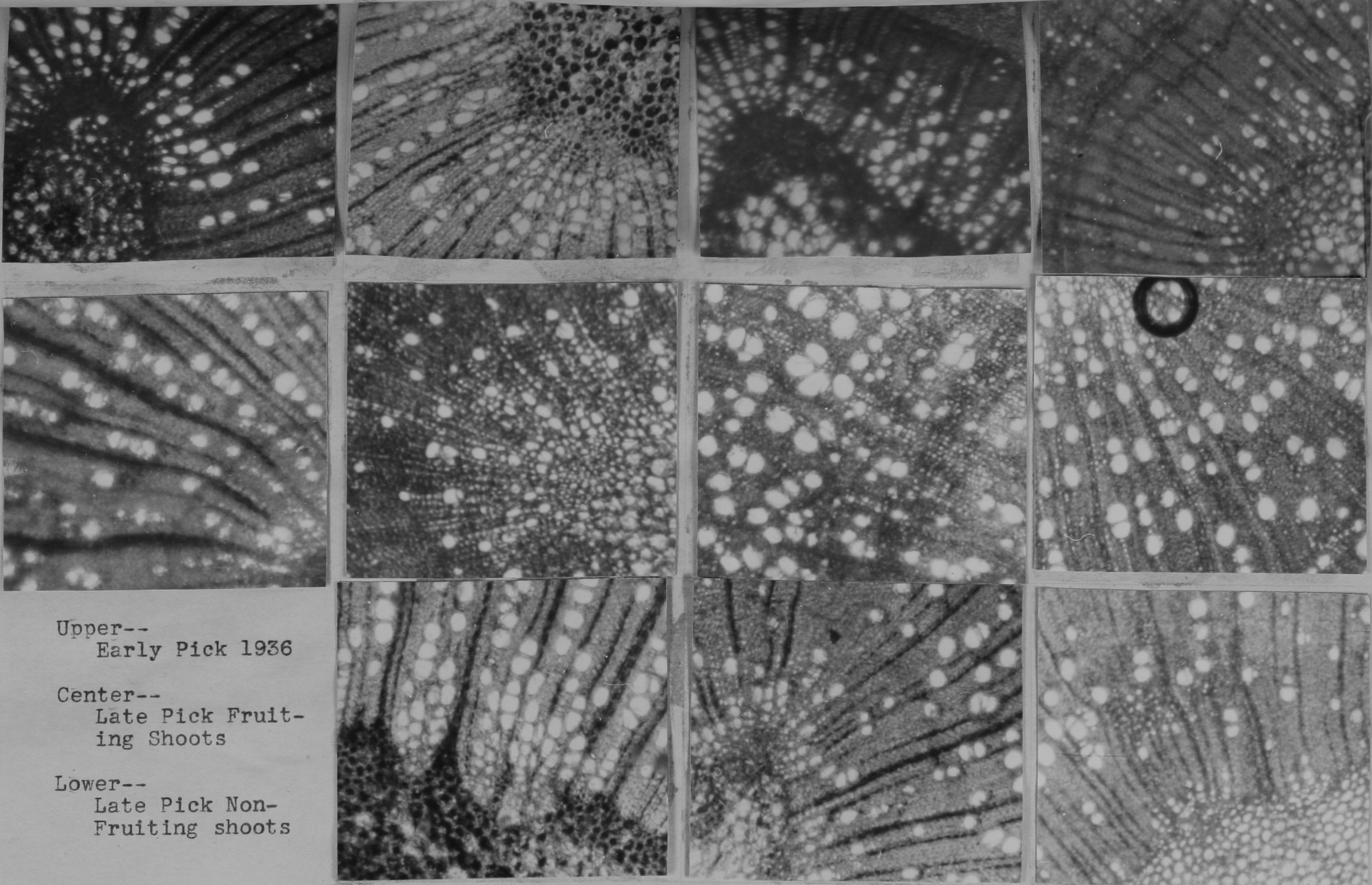


Grapefruit Shoots

PLATE I. Camera Lucida diagrams of starch content at intervals during 1936-1937 season.

Upper -- Early Pick 1936, Center-- Late Pick Fruiting
Lower--Late Pick Non-Fruiting.



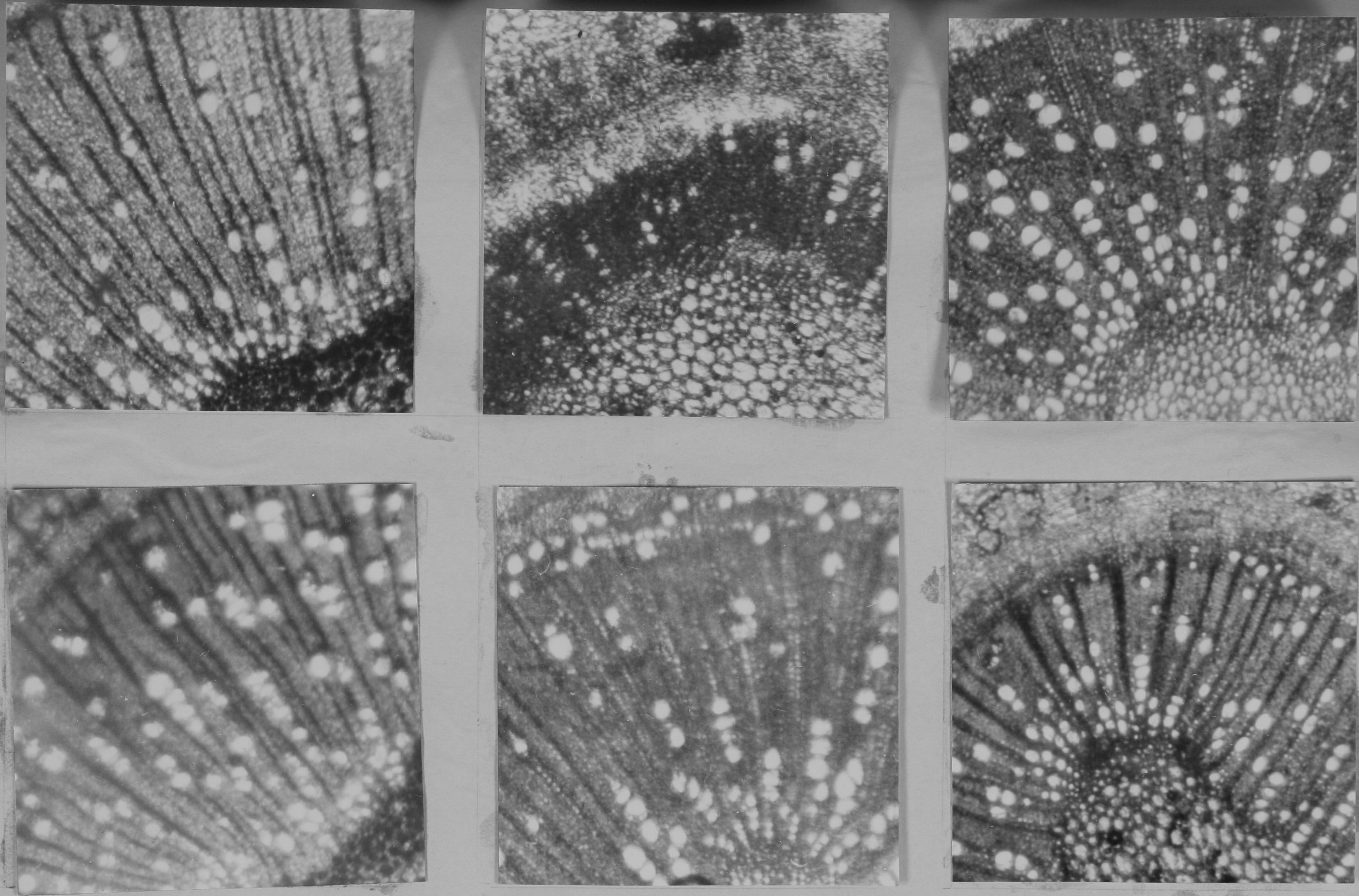
Upper--
Early Pick 1936

Center--
Late Pick Fruiting Shoots

Lower--
Late Pick Non-Fruiting shoots

December 4, 1936 | March 3, 1937 | March 24, 1937 | April 16, 1937

PLATE II. Photomicrographs of seasonal starch storage in Grapefruit shoots



March 3, 1936 March 24, 1937 April 16, 1937

PLATE III. Photomicrographs of seasonal starch storage in Navel Orange shoots.