SEASONAL VARIATIONS IN THE CARBOHYDRATE AND NITROGEN CONTENT OF ROOTS OF BEARING PECAN TREES [1]

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INTRODUCTION

In the pecan (*Hicoria pecan* (Marsh.) Britton), as in other perennial plants, the early growth of the tree in spring is determined largely by the food reserves that have accumulated during the previous growing season and are made available in spring. These food reserves play a part in developing resistance to cold during winter and are utilized for new shoot and root growth, initiation of pistillate flowers, production of catkins and pollen, and the initial development of the nut.

Previous analyses of roots of top-worked pecan trees [3] indicated that there was considerable storage of food reserves in the roots and that a heavy nut crop materially affected the seasonal variation of the stored constituents. Since the pecan generally bears only in alternate years, and in view of the importance of food reserves in the growth, development, and fruiting performance of the tree, it seemed desirable to obtain some information on the proportionate seasonal accumulation of these food reserves in the roots of bearing pecan trees and the effect of a crop on their accumulation.

REVIEW OF LITERATURE

LeClerc du Sablon (*12, v. 16*)[4] analyzed the roots, stems, and leaves of various deciduous trees, including the chestnut, pear, and peach, for sucrose, starch, hemicellulose, and moisture. In general, he found that the total carbohydrate reserves in the roots pass through a maximum in autumn at the time of leaf fall, diminish a little in winter, and diminish greatly during growth in the spring. After growth has subsided and assimilation is at its height, reserve carbohydrates increase and attain their maximum again in autumn. The carbohydrate content of the roots was higher than that of the stems and showed more variation, indicating that the roots are more important storage organs than the stems. The extensive variation of hemicellulose indicated that it may be an important reserve. The variation of sucrose was relatively slight, and LeClerc du Sablon concludes that sucrose is a less important reserve material than the form in which other carbohydrates become mobile and assimilable.

Later LeClerc du Sablon (*12, v. 18*) worked with several evergreen trees. In all cases he found that the total carbohydrates in the roots

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[4] Italic numbers in parentheses refer to Literature Cited, p. 459.

decreased during leaf formation and new shoot development and increased after this growth was completed, although the growth periods occurred at different times of the year. He also analyzed the stems, roots, and leaves of the evergreen oak and Japanese spindle tree for nitrogen and found that in the roots it decreased in spring during new leaf formation, passed through a minimum in summer, and increased toward winter. He concluded that in spring nitrogen moves from the roots and stems to the newly formed leaves and, when growth ceases, continues to be absorbed and is stored, thereby increasing in late summer and toward winter.

Butler et al. (*2*) analyzed different parts of the apple tree and found that the reserves were stored chiefly as starch and sucrose, the roots and branches containing relatively more starch than the trunk. Davis (*6*) found that the roots and trunks of nonbearing Sugar prune trees contained much more starch than those of bearing trees, and that the starch concentration in the roots was much greater than in the trunks. He states that it is reasonable to suppose that root growth is suppressed when the demand for carbohydrates above ground becomes great, and suggests that fruit trees, which have a heavy annual crop that remains on the trees most of the summer, may experience a shortage of carbohydrates for the roots. He also noted that starch was the most variable of the carbohydrates. Cameron (*3*), working with young orange trees, noted a minimum of starch in the roots in August, then a gradual increase to a maximum in early spring, and a gradual decrease to a minimum again in August. An inverse relation between starch and moisture was indicated. For the greater part of the year, the starch content in the roots was higher than in the leaves, branches, or trunk, and the greatest starch fluctuation occurred in the root bark. Murneek (*16*), investigating the carbohydrate storage of bearing apple trees, noted the unusually high starch and sugar content of the roots in autumn. He concluded that the underground parts of the apple tree serve as storage organs for carbohydrates, primarily starch. His data indicate that there is an increase in total sugars and a slight decrease in hemicellulose, starch, and total carbohydrates in the roots from early November to late December.

The importance of hemicellulose as a reserve material has been stressed by a number of investigators working with parts of the tree other than the roots. Schellenberg (*18*), in a summary of such investigations, concludes that hemicellulose serves as a reserve material and its deposition enables the plant to survive the long rest periods (winter or dry period) into which it is forced at times. Tottingham et al. (*21*) and Murneek (*14, 15*), working with apple spurs, noted extreme fluctuations of hemicellulose and emphasized its significance as an available form of carbohydrate in the spur. Its accretion in the fruit reached a maximum in midsummer and then decreased rapidly, thus indicating that hemicellulose must be a source of sugars for the flesh of the apple. Hooker (*11*) found an extensive variation in hemicellulose in apple spurs, which seems to indicate that it functions as a reserve material. Murneek and Logan (*17*), investigating the autumnal migration of nitrogen and carbohydrates in the apple tree, concluded that with the onset of cold weather starch and possibly other more complex carbohydrates are hydrolyzed simultaneously into sugars in all peripheral regions of the tree. They state that modifications induced by weather often are of greater amplitude than possible seasonal trends.

Finch (*7*, *8*) concluded that for best filling of pecan nuts in Arizona the vegetative growth of trees must be checked during the early summer to provide conditions for carbohydrate storage during the summer months. He found that starch was formed in the current-season shoots in summer but disappeared completely during the nut-filling period. This emphasizes the importance of an abundant supply of carbohydrates for conversion to fats in nut filling.

Finch and Van Horn (*9*) found that starch storage in bearing pecan shoots reached a maximum shortly before nut filling began, and then decreased; whereas a comparable decrease did not occur in vegetative nonfruiting shoots. In the latter starch continued to accumulate, reaching a maximum in early fall. These authors conclude that the starch from the fruiting shoots is used in nut filling. Thor and Smith (*20*) have shown that most of the oil in pecan kernels is formed within a period of 4 to 6 weeks and that most of the carbohydrate material for its formation must be brought in from outside the nut during this period.

The maintenance of healthy foliage on the fruit tree has been emphasized by Heinicke and Hoffman (*10*) and other workers. Sitton (*19*) ringed bearing shoots of the pecan in early August after the shells of the nuts had begun to harden, but before any considerable filling had taken place, and noted that the best filling was obtained in nuts on shoots that bore the largest number of leaves per nut. Crane et al. (*5*) conclude that the almost universal tendency of pecan trees to bear more or less irregular crops from year to year cannot be called either biennial or alternate bearing and that without doubt the controlling factors are the nutritional condition and previous performance of the tree. Their data indicate that nut thinning may be expected to increase the annual yield per tree by maintaining a more nearly optimum nutritional condition in the tree at all times. Smith et al.,[5] in studies on top-working pecan trees, note the value of the leaf area in the functioning of the tree. Chemical analyses of the roots showed that with severe heading the balance of the carbohydrate reserves in the tree is disturbed to a greater degree than in trees with less severe topping. As the top is rebuilt the amount of these materials and their functions become more nearly like those of the normal tree. Crane and Hardy (*4*) have shown that cultural treatments, such as pruning or applications of nitrogen, which stimulate shoot growth with subsequent increase in leaf area, are of great importance in determining the ultimate size of pecan nuts and the degree to which they are filled.

MATERIALS AND METHODS

Since the pecan is frequently an alternate bearer, the progress of this investigation was facilitated by the use of trees in an alternate bearing condition during "off" and "on" years. During the first season of the experiment there was no nut crop; in the second season the crop was large; in the third season the crop was very small.

Seventy-five healthy seedling trees about 45 years old, growing in a cultivated river-bottom field about 15 miles from Austin, Tex.,

[5] SMITH, C. L., HAMILTON, J., THOR, C. J. B., and ROMBERG, L. D. See footnote 3

were selected and divided into 15 comparable groups of 5 trees each. The average diameter of the trees was about 25 inches. Composite root samples for chemical analysis were taken from these groups in rotation in time intervals ranging from 2 weeks to approximately 1 month. Owing to the death of the farm owner and subsequent litigation of ownership of the property, it was necessary to discontinue the investigations from October 1935 to August 1936. A summarized description of the condition of the trees during the course of the 3 years is given in the last column of table 1 (p. 457).

SAMPLING METHODS

Samples of lateral roots with diameters ranging from three-eighths to one-half inch were taken, brought immediately to the laboratory, chopped fine, and mixed thoroughly. Samples to be dried were killed by placing them in an oven at 100° C. for 1 to 2 hours and were then dried to constant weight in a vacuum oven. Two 50-g portions were transferred immediately to 500-ml Erlenmeyer flasks with sufficient boiling 95-percent alcohol to give a final alcohol concentration of 80 percent by weight. The flasks were then closed with short-stemmed funnels and heated 30 minutes on a water bath kept at 90° to 95°. The flasks were stoppered while still hot and stored in the dark until the samples were used for carbohydrate analyses.

ANALYTICAL METHODS

Whenever the nature of the material permitted, the official methods of the Association of Official Agricultural Chemists (*1*) were employed.

DRY MATTER

Samples that had been weighed into aluminum cans and placed in ovens at 100° C. for 1 to 2 hours were transferred to a vacuum oven and dried to constant weight at a temperature of 80° and a pressure of less than 1 mm of mercury. The resulting dry material was ground in a drug mill or food chopper and stored in glass bottles, and was redried under the same conditions before it was used in further analyses.

TOTAL ORGANIC NITROGEN

No analyses were made for nitrate or nitrite nitrogen since previous analyses had shown no appreciable amounts of these forms of nitrogen in pecan roots. The procedure for determination of total organic nitrogen followed closely the Kjeldahl-Gunning-Arnold method except for the use of copper wire as the digestion catalyst. In general 2-g portions of the dried material were used. The preliminary drying of the sample at 100° C. for 1 to 2 hours has been shown by Link and Schulz (*13*) to have little or no effect on the total nitrogen content of plant tissues.

SUGARS

The alcohol-preserved samples were transferred to large Soxhlet extractors with 80-percent alcohol and extracted for 22 to 24 hours on a water bath kept at 95° to 99° C. The alcohol extract was distilled almost to dryness in vacuo at temperatures not above 60°. The residue was taken up with water, treated with 25 cc of basic lead acetate to clear the solution, and made up to a volume of 250 ml. The lead acetate solution used for clearing was made up of 500 g of basic lead acetate in 1 liter of solution. The cleared filtrate was deleaded with anhydrous disodium phosphate.

The Munson-Walker method was used for the determination of sugars in aliquots of the lead-free filtrate. Reduced copper was determined by the volumetric permanganate method. For total sugars, inversion was accomplished by means of acid at room temperature as directed in official methods (*1, p. 187,* [*23c*]). Reducing-sugar values were calculated as invert sugar and nonreducing sugars as sucrose.

Starch by Diastase

The alcohol-insoluble residues were transferred to tared aluminum cans, dried in an air oven at 100° C., and weighed. After being ground in a drug mill the material was stored in aluminum cans in a desiccator until ready for analysis.

The official method for determination of starch in feeding stuffs by diastase with subsequent acid hydrolysis (*1, p. 120,* [*23*]) was used with the exception that a 0.5-percent solution of taka diastase was substituted for the malt extract. Preliminary extractions with cold water were eliminated since sugars had already been extracted with alcohol.

Starch by Direct Acid Hydrolysis

Alcohol-insoluble residues were used as in the diastase method. The official methods (*1, p. 119,* [*21*]) were used. As before, no preliminary extractions with cold water were necessary.

Those carbohydrates that are not hydrolyzed by the taka-diastase method for starch determination, but are hydrolyzed in the direct acid hydrolysis method, are designated as hemicelluloses. The hemicellulose values were obtained by subtracting the starch by taka-diastase values from the corresponding values for starch by direct acid hydrolysis.

EXPERIMENTAL DATA

Since no investigations were made on the variability of the constituents in comparable samples obtained at the same time, no particular emphasis can be attached to the analytical data for any individual sample, and the results must be viewed from the standpoint of trends. The analytical data are presented in figure 1.

DRY MATTER

The percentage of dry matter in the roots was higher in the summer and fall of 1934 than at any other time during the experiment. This was probably due to a deficiency of soil moisture during an extreme drought which lasted until November. After the drought was broken by rains the percentage of dry matter in the roots decreased rapidly until about January 1935. Between January and September there was only a slight decrease in dry matter, but from the middle of September to the latter part of October there was a considerable decrease. From August 1936 to February 1937 the dry matter fluctuated considerably between sampling dates, but showed no consistent increase or decrease.

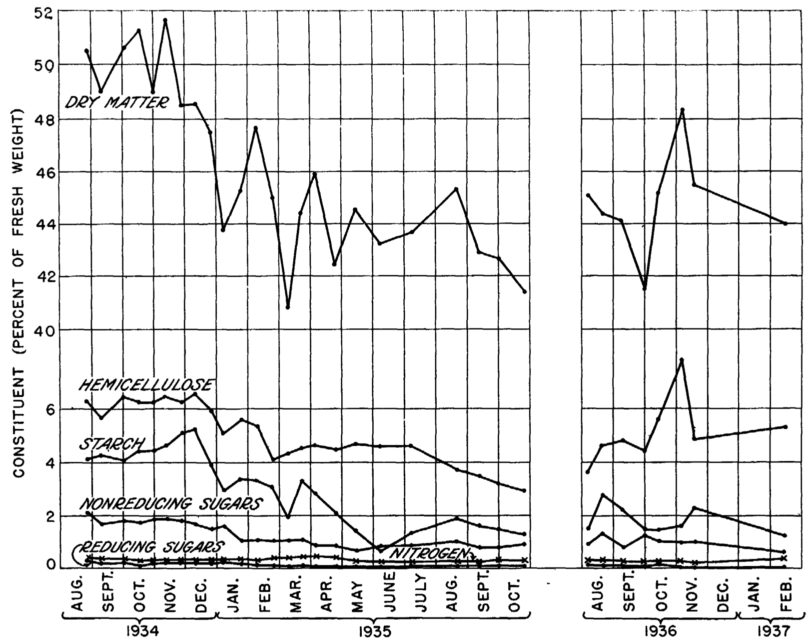

FIGURE 1.—Seasonal variation in dry matter, carbohydrates, and nitrogen in roots of pecan trees.

The following tabulation shows the monthly rainfall record at Austin, Tex., from January 1, 1934, to February 20, 1937, inclusive:

Year and month:	Rainfall (inches)
1934	
January	7.43
February	5.01
March	2.37
April	3.31
May	.90
June	.32
July	.39
August	.24
September	2.61
October	.32
November	3.40
December	4.59
1935	
January	.95
February	2.96
March	1.20
April	2.08
May	9.21
June	9.71
July	1.44

Year and month—Continued.	Rainfall (inches)
1935—Continued	
August	.24
September	8.79
October	1.65
November	.85
December	2.84
1936	
January	0.39
February	1.70
March	1.52
April	.66
May	8.15
June	3.30
July	9.25
August	2.90
September	5.22
October	2.63
November	2.30
December	1.88
1937	
January	2.43
February	.12

This record indicates that the roots had an abundant moisture supply throughout the experiment except in the summer and fall of 1934. The rainfall was low in July and August of 1935 but there was sufficient rain in June to carry the trees through this period without a moisture deficiency.

SUGARS

The concentration of reducing sugars was very low throughout the experiment and showed no consistent seasonal variations. The nonreducing sugars were present in appreciable quantities and fluctuated as starch did below but to a lesser extent. The highest concentration occurred in the late summer and fall of 1934. There was a decrease during the winter and spring, due in part to the decrease in dry matter. From May 13 to July 6 there was an appreciable increase in the nonreducing sugars, after which their concentration remained practically constant until October 25. On August 6, 1936, the concentration of these sugars was at the same level as in October 1935, but it increased considerably during August and then remained practically constant until November 18. Between the latter date and February 16, 1937, there was a material decrease similar to that in the winter of 1934–35.

STARCH

The concentration of starch increased slightly from August to December 1934, decreased rapidly to January 1935, and then decreased more slowly to June 7. There was no nut crop on the trees in 1934, and the increase in starch content of the roots was probably due to the photosynthetic activity of the leaves and translocation of carbohydrates to the roots where they were stored as starch. This seems to be further indicated by the comparatively high concentration of nonreducing sugars present in the roots during this period. From December 1934, after most of the leaves had fallen or had become inactive from frost, there was a rapid decrease in concentration of starch to January 1935. A decrease in carbohydrates in roots after leaf fall has been noted by other investigators (*12*, *16*) and indicates a translocation of these substances to the aerial portions of the tree. From January 7 to March 22 the starch showed only slight changes except for one low value on March 8. After March 22 the starch decreased rapidly, reaching a minimum on June 7. During the latter period the initiation of growth took place, shoots and leaves developed, the trees blossomed, and the development of the nuts was begun. All these processes create heavy demands upon the tree for carbohydrates. The leaves during most of this period are immature and small, and their total photosynthetic activity is very low and therefore inadequate to supply the necessary carbohydrates for the rapid growth and fruiting activities. It is interesting to note that the concentration of the hemicellulose remained practically constant during this period notwithstanding the fact that from December 10 to February 23 it decreased in about the same proportion as starch.

From June 7 to August 20, 1935, there was a considerable increase in the starch. During this period the shucks and shells of the nuts were being developed, but other vegetative growth was probably nearly completed for the season. The leaves were probably at their most efficient stage for photosynthesis and therefore were able to produce a greater amount of carbohydrates than was required for tree activities, some of the surplus being stored in the roots as starch.

From August 20 to October 25, 1935, the starch content of the roots decreased slightly. About September 1 the period of nut filling begins and the demand for carbohydrates during this period has been shown to be very great (*20*). This is especially true when the trees are carrying a large crop of nuts, as was the case here. Both starch and hemicellulose concentrations decreased during the nut-filling period from September 1 to the latter part of October. A part of this decrease was due to a decrease in the dry matter of the roots, but calculations show that both starch and hemicellulose decreased in greater proportion than the dry matter. Thus it seems probable that some of the hemicellulose as well as the starch was utilized in the nut-filling process. No doubt the photosynthetic activity of the leaves was high during the nut-filling period, but with a heavy crop of nuts on the trees the demand for carbohydrates for oil formation was greater than could be supplied by photosynthesis, and some of the reserves in the tree were used.

After the 9-month interval from October 25, 1935, to August 6, 1936, during which no samples were taken, the starch concentration showed a slight increase, which may be accounted for by the increase in the percentage of dry matter during this period. However, the starch concentration was still not so high in proportion to the dry matter as it was in 1934. The starch fluctuated considerably during the fall of 1936 but showed no consistent increase. On February 16, 1937, when the last samples were taken, the starch was low, amounting to 1.26 percent of the fresh weight. The nut crop was small in 1936 and therefore made much less demand for carbohydrates for nut filling than the large crop of 1935, but the starch content of the roots on the average was only slightly higher than for the corresponding period in 1935. Conditions were very favorable for vegetative growth in 1936, however, and the starch was probably utilized for this purpose.

HEMICELLULOSE

The percentage of hemicellulose was at its highest level in the summer and fall of 1934, when the dry matter was at its maximum. Its fluctuation was almost proportional to that of the dry matter from August 1934 to January 1935. From January to October, however, the percentage of hemicellulose shows a greater proportional decrease than the percentage of dry matter. This indicates that there was an actual decrease in the amount of hemicellulose in the roots and that only a part of the variation in its concentration was due to changes in the concentration of dry matter. The trees bloomed heavily in the spring of 1935 and matured a large crop of nuts. Therefore it is possible that some of the hemicellulose was utilized in the development and filling of the nuts. From October 1935 to August 1936 the percentage of hemicellulose had increased a little but not in proportion to the increase in dry matter. From the latter part of 1936 to February 1937 the hemicellulose increased gradually, but at the end of this period it was still somewhat lower in proportion to dry matter than in the fall of 1934.

NITROGEN

The percentage of total organic nitrogen decreased slightly from August 27, 1934, to January 7, 1935 (fig. 1 and table 1). This decrease may be accounted for by the decrease in the concentration of dry matter. There was a gradual increase in the nitrogen concentration from January 7 to April 5, probably because the roots absorbed more nitrogen than was translocated away. There was little growth activity in the tree during this period, while at the same time soil moisture and probably other factors were optimum for the absorption of nitrogen.

TABLE 1.—*Seasonal variation in total organic nitrogen in pecan roots and growth and fruiting condition of trees*

Sample No.	Sampling date	Total organic nitrogen	Growth and fruiting conditions
	1934	*Percent* [1]	
1	Aug. 27	0.38	Foliage on all trees apparently fully mature and in healthy condition. No apparent extension of shoot growth. No nut crop on trees.
2	Sept. 10	.39	
3	Oct. 2	.26	
4	Oct. 16	.31	
5	Oct. 30	.29	
6	Nov. 12	.34	About 3 percent of leaves have dropped.
7	Nov. 27	.30	Trees have lost about 40 percent of foliage and owing to frost leaves are turning yellow and dropping rapidly.
8	Dec. 10	.32	
9	Dec. 26	.33	Defoliation complete.
	1935		
10	Jan. 7	.32	Trees dormant.
11	Jan. 23	.39	
13	Feb. 8	.35	
15	Feb. 23	.40	
17	Mar. 8	.40	
19	Mar. 22	.45	Buds bursting into growth on a few trees.
21	Apr. 5	.52	Most trees well into growth and a few almost in full leaf. Heavy pistillate bloom.
22	Apr. 24	.42	Pollen shedding very active.
23	May 13	.34	Shoot growth well under way and active.
24	June 7	.35	Shoot growth nearly complete. Large crop of nuts set.
25	July 6	.27	Shoot growth complete and foliage mature.
27	Aug. 20	.32	Nuts in "watery" stage.
29	Sept. 12	.33	Nuts in "dough" stage.
31	Sept. 30	.37	Nuts beginning to ripen.
32	Oct. 25	.33	Nuts mature and dropping from trees. Foliage dropping rapidly.
	1936		
35	Aug. 6	.33	Foliage full grown and in good condition. Extension of shoot growth apparently continuing through most of this period. Nut crop very small.
36	Aug. 20	.31	
37	Sept. 9	.34	
38	Oct. 1	.34	
39	Oct. 13	.32	Nuts ripening.
40	Nov. 6	.37	Leaves beginning to fall. Nuts fully mature and dropped.
41	Nov. 18	.32	Trees almost completely defoliated.
	1937		
42	Feb. 16	.40	Trees dormant.

[1] Percentage based on fresh weight.

From April 15 to May 13, 1935, the nitrogen decreased to about its 1934 level, after which it remained practically constant for the remainder of the experiment, except that it had increased appreciably between November 18, 1936, and February 16, 1937.

The decrease in nitrogen in April and the first part of May may be ascribed to the intensive vegetative activity of the trees at this time. The initiation of shoot growth and the development of blossoms took place during this period and consequently created a heavy demand for nitrogen. Conditions were no doubt favorable for the absorption of nitrogen at this time, but the demand was probably greater than could be supplied by root absorption, and some of the reserve nitrogen from the tissues was used in the growth functions. After the intensive vegetative activity of the tree was over there was a large crop of nuts to be developed and filled; therefore the nitrogen did not increase again during that season. In the fall of 1936 the nut crop was light, but conditions for vegetative growth of the trees were more favorable than in 1935 and the growth extended later into the season, so that all the nitrogen absorbed was required in growth processes. After the growth season was over the nitrogen increased appreciably during the winter. In 1934 the low level of nitrogen in the roots may have been due to the extremely dry weather, which created unfavorable conditions for absorption of nitrogen by the roots.

DISCUSSION

Starch was the most variable constituent determined in the roots of pecan trees. The data indicate that it increases from early summer to a maximum in late fall and decreases to the summer minimum, but the levels of the maxima and minima seem to be determined by the growth and fruiting conditions during the time. Both growth and fruiting in the pecan are exhaustive processes, as has been found in other trees by Murneek (*14*), Davis (*6*), and other investigators. The starch in pecan roots was built up to a high maximum concentration in the fall of 1934, when there was no nut crop, and the vegetative growth was at a standstill owing to a severe drought. With the intensive spring growth and blossoming of the trees in 1935 the starch decreased to a very low level and did not increase during the summer and fall because of the great demand for carbohydrates in filling the large crop of nuts. There was also a decrease in the hemicellulose content of the roots during the nut-filling period. This indicates that both starch and hemicellulose may function as carbohydrate reserves and are used in the filling of the nuts or in other processes when the demand is sufficiently great.

It is not known how low a level the starch concentration reached in the fall of 1935, since no samples could be taken after October 25 until August 6 of the following year. However, on the latter date the starch concentration was still relatively low and did not increase materially during the autumn notwithstanding the fact that the nut crop was very small. Conditions were very favorable for vegetative growth throughout the season, and the failure of the starch to increase in the autumn can be explained only on the assumption that tree growth continued throughout the fall, thereby utilizing the carbohydrates, in this process and in the filling of the small crop of nuts, as fast as they were synthesized.

In the spring of 1936 and in the spring of 1937 the bloom was light and the starch in the autumn preceding each of these seasons was at a low concentration, whereas in the fall of 1934 the starch reached a high concentration which was followed by a very heavy bloom in the spring of 1935. Whether the lack of reserve carbohydrates, as indicated by starch, was the cause of the small bloom in the 2 later years is not known, but this same condition has been found in other trees (*6, 11*) and seems to be either directly or indirectly concerned with fruiting. The fact that the pecan seldom, if ever, bears two large crops in successive years and that fruiting is a very exhaustive process indicates that the amount of storage carbohydrates, especially starch, is a very important factor in fruiting whether the effect be direct or indirect. Davis (*6*) found that the starch content of roots of nonbearing Sugar prune trees was much higher than that of roots of bearing trees, and concludes that storage carbohydrates may be essential for fruit-bud differentiation or that other factors may cause fruit-bud differentiation because of their relationships to the storage carbohydrates.

The nonreducing sugars were present in appreciable quantities and fluctuated with the starch, although to a lesser extent. The wide variations in concentration of these sugars may indicate that they function as storage reserves. However, the fact that they fluctuated so nearly with the starch may indicate that they are labile forms and that their concentration is largely dependent upon that of the starch.

Although the concentration of nitrogen was relatively low throughout the experiment, the data indicate that the amount of nitrogen in pecan roots is governed partly by conditions favorable to absorption and partly by the nitrogen requirements for tree growth and fruiting. In the latter part of 1934 the nitrogen concentration was low, but it increased from January to April in 1935. The summer and fall of 1934 were extremely dry and the soil moisture was doubtless a limiting factor in the absorption of nitrogen. From January until April 1935, however, soil moisture was adequate for absorption, and the trees were dormant and therefore required very little nitrogen. With the initiation of spring growth and blossom development the demand for nitrogen was great and probably could not be met by root absorption; hence the nitrogen decreased in the roots. The heavy nut crop of 1935 made a considerable demand for nitrogen in nut filling, and the nitrogen did not increase during that time. However, from November 1936 to February 1937, when the trees were dormant, the nitrogen again increased materially as in the first part of 1935.

SUMMARY

Composite samples of lateral roots of pecan trees of bearing age were collected at intervals during an "off" and an "on" year and analyzed for the principal carbohydrates and total organic nitrogen.

The starch concentration tended to reach a maximum in late fall, after which there was a winter decrease and then a further decrease in spring to a minimum in early summer. The amount of starch in the roots for any period was apparently dependent upon the relative growth rate of the tree, age and condition of foliage, and the size and stage of development of the nut crop.

Starch was the most variable of the constituents determined, and its concentration appeared to have a marked influence on fruiting.

The rapid disappearance of starch during the spring growth and blossoming period and the decrease of starch and hemicellulose during the nut-filling period show that both growth and fruiting in the pecan are exhaustive processes.

Reducing sugars were low and showed no consistent seasonal variations, thus indicating they are labile forms of carbohydrates. The nonreducing sugars, however, were present in appreciable quantities and varied with the starch although to a lesser extent. These may serve as storage carbohydrates or may be labile forms whose concentration depends largely on that of starch.

The total nitrogen content in the roots was low at all times, but it decreased during rapid spring growth and increased during winter when the trees were dormant and soil conditions were favorable for nitrogen absorption. Nitrogen concentration was largely independent of dry-matter content.

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