Seasonal Changes in CARBOHYDRATE LEVELS in roots of sugar maple

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U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-213
1971

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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MANUSCRIPT RECEIVED FOR PUBLICATION 6 APRIL 1971.

THE ONSET of some dieback and decline diseases has been associated with insect defoliation *(Giese et al. 1964, Staley 1965, Nichols 1968)*, but tree mortality in these diseases has been associated with the added effects of agents of secondary action *(Knull 1932, Houston and Kuntz 1964, Staley 1965, Nichols 1968)*.

Defoliation causes physiological changes in trees and may predispose trees to attack by pathogenic organisms *(Kozlowski 1969)*. Artificial defoliation of sugar maple trees causes significant changes in carbohydrate levels in the roots *(Parker and Houston 1970)*. These changes may be related to observed invasion and attack by the root pathogen *Armillaria mellea* (Vahl) Quel. of sugar maple trees weakened by defoliation *(Houston and Kuntz 1964)*.

These observations on carbohydrate changes in sugar maple roots were made near the end of the growing season, and it is not known whether carbohydrate changes caused by defoliation are different from those changes that occur naturally in the spring when food reserves are mobilized for use in initial shoot growth *(Keinholz 1941)*.

Jones and Bradlee *(1933)* obtained some information on seasonal changes in roots of sugar maple, but their observations were limited to one sample per month. They did not determine the concentrations of all individual carbohydrates.

This study was done to determine the normal complement of individual carbohydrates present in roots of sugar maples during

the year and to obtain, as a basis for future comparison, an estimate of the normal variation and range of concentrations of individual carbohydrates in the roots during the year.

MATERIALS AND METHODS

Dominant and codominant sugar maple trees, 5 to 12 cm. d.b.h. and 9 to 15 m. tall, growing in southern Connecticut, were used. Samples were harvested monthly from June 1969 until February 1970 and then bi-weekly until mid-May 1970. Three root lengths about 1 m. long were removed from each of five different trees on each harvest date.

Roots were excavated, cut into 15-cm. sections, put in polyethylene bags, and placed in insulated bags containing dry ice. They were transported to the laboratory and frozen at —30°C until they were analyzed.

Starch was extracted from whole root sections according to the procedure of Hassid and Neufeld *(1964)* and was measured by the method described by Siminovitch et al. *(1953)*. Standard starch solutions were prepared from starch extracted from sugar maple roots.

Only the outer wood—the tissue attacked by *A. mellea*—was analyzed for sugars. The bark was peeled from root sections, and the outermost wood was scraped off with a scalpel. Sugars were extracted with 80 percent ethanol *(Parker 1962)*. The tissue was placed with the alcohol in a cup surrounded by an icewater bath. It was comminuted twice for 4 minutes, with a "Virtis 23" homogenizer, using fresh ethanol each time. The extracted tissue was rinsed once with 80-percent ethanol. The combined extracts and rinse were filtered and evaporated to near dryness in a rotary evaporator at 39° $\pm$ 1°C and then spotted on No. 1 Whatman filter paper.

Sugars were separated on the paper with a butanol-acetic acid-water solution (4:1:5), detected with a benzidine-trichloroacetic acid-acetone spray reagent *(Linskens 1959)*, and quantified by densitometry.

RESULTS

Seasonal Trends

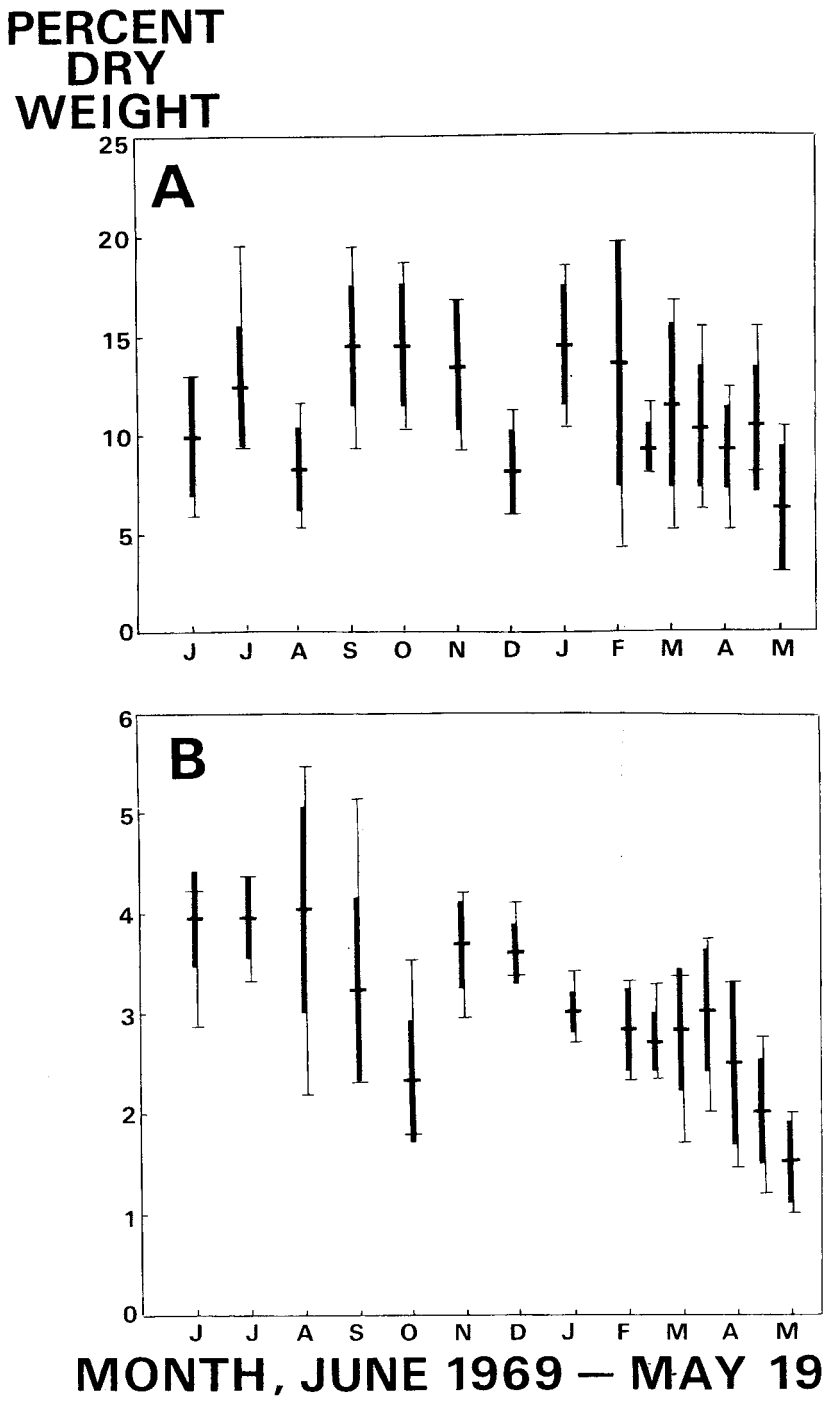
There was a definite seasonal trend in the starch content of sugar maple roots (fig. 1A). The starch level began to increase after budbreak; it increased to a maximum in late fall and began decreasing in late winter toward the spring minimum. The two low readings in August and December were probably the result of inherently low-starch trees included in the sample. These same groups of trees, in August and December 1970, had average starch contents of 9 percent though other groups of five trees sampled in August and December had average starch contents of 13 and 12 percent, respectively. The seasonal trend in sucrose concentration was generally similar to that observed for starch (fig. 1B). There appeared to be an autumn decrease in sucrose not apparent in starch. Glucose and fructose concentrations varied (figs. 1C and 1D). There was an indication of an autumn decrease in glucose and fructose similar to that observed in sucrose.

Stachyose, raffinose, and maltose, which first appeared in late summer, increased to a maximum by mid-winter and disappeared just after budbreak (figs. 2A, 2B, and 3). Stachyose concentrations remained high until mid-spring and then decreased rapidly. Raffinose and maltose slowly decreased from late winter on.

DISCUSSION

The seasonal pattern of carbohydrate changes in roots of sugar maple observed in this study is similar, in general, to that reported by Jones and Bradlee *(1933)*. The pronounced winter increase in hexoses reported in their study was not observed in this study. This difference possibly may be due to Jones and Bradlee's use of the reducing sugar reaction to detect hexoses. Maltose, although not a hexose, yields a reducing reaction; and the increase of this sugar in the winter months (fig. 3) would account for the winter "hexose increase" found by Jones and Bradlee.

Maltose is considered to be a common constituent of the carbohydrate complex of woody plants *(Kramer and Kozlowski 1960)*.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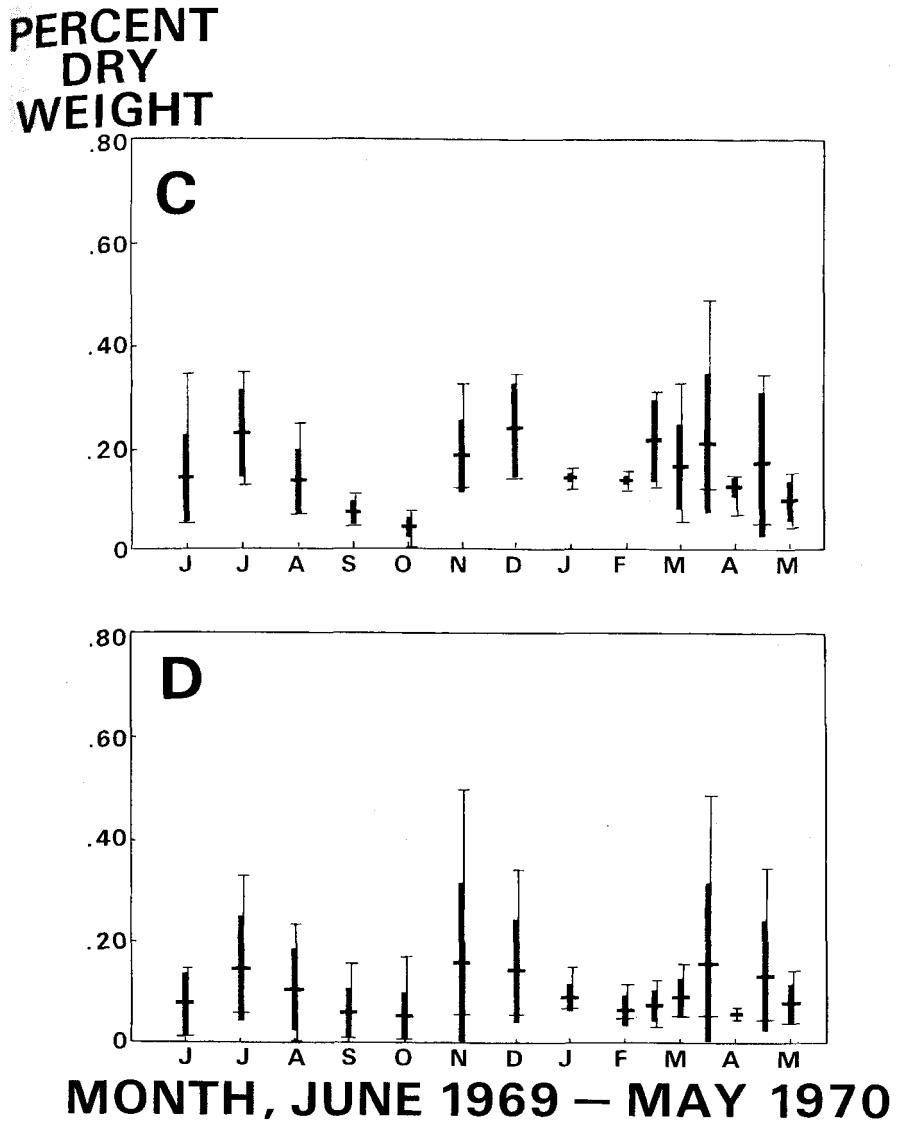
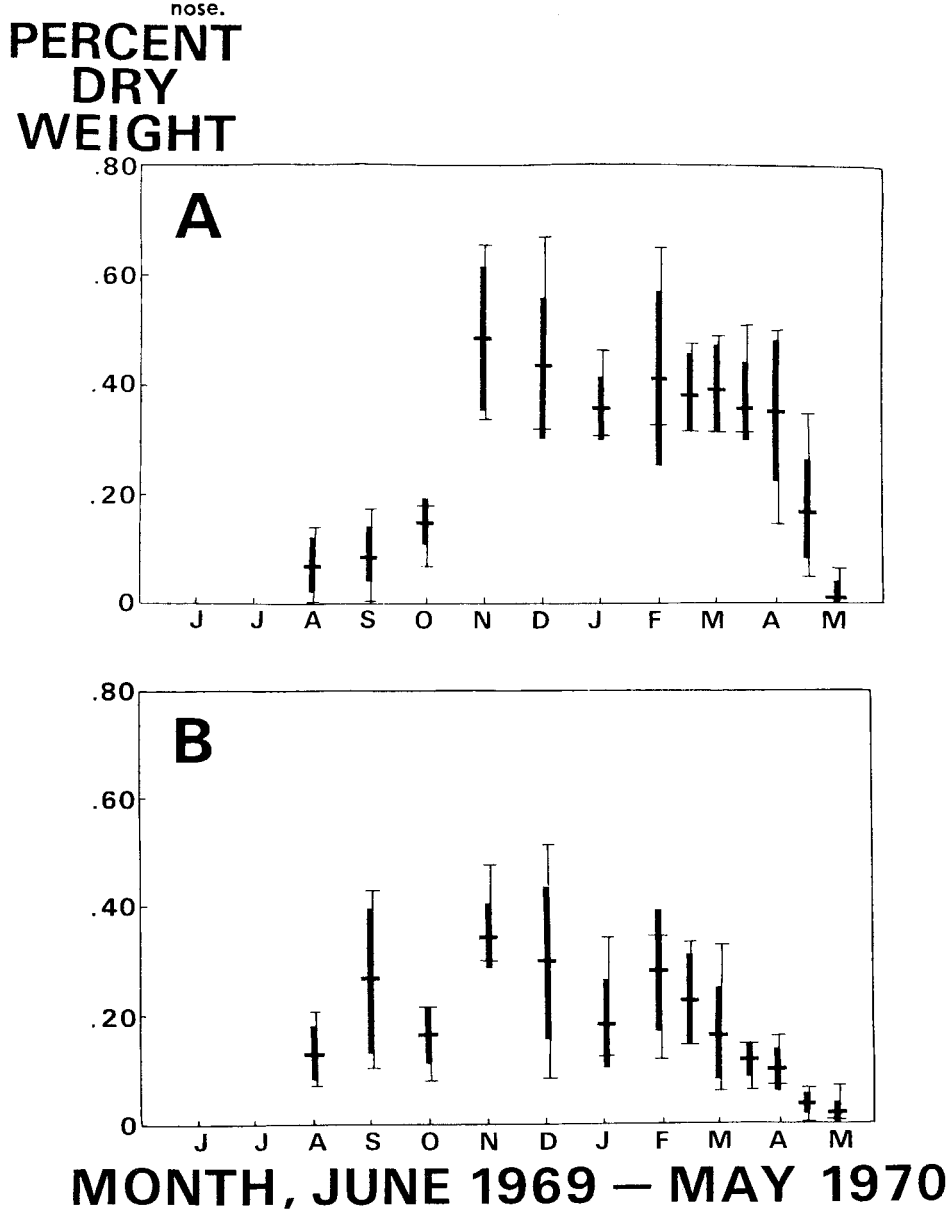


Figure 1. — Seasonal trends of carbohydrates in roots of sugar maple from June 1969 to May 1970. (A) Starch in whole roots; (B) Sucrose in outer wood; (C) Glucose in outer wood; (D) Fructose in outer wood. Range is shown by thin horizontal lines, average by heavy crossbar, and ± 2 standard errors by heavy vertical lines, for five trees each observation.

Figure 2. — Seasonal trends of carbohydrates in outer wood of roots of sugar maple. (A) Stachyose; (B) Raffinose.



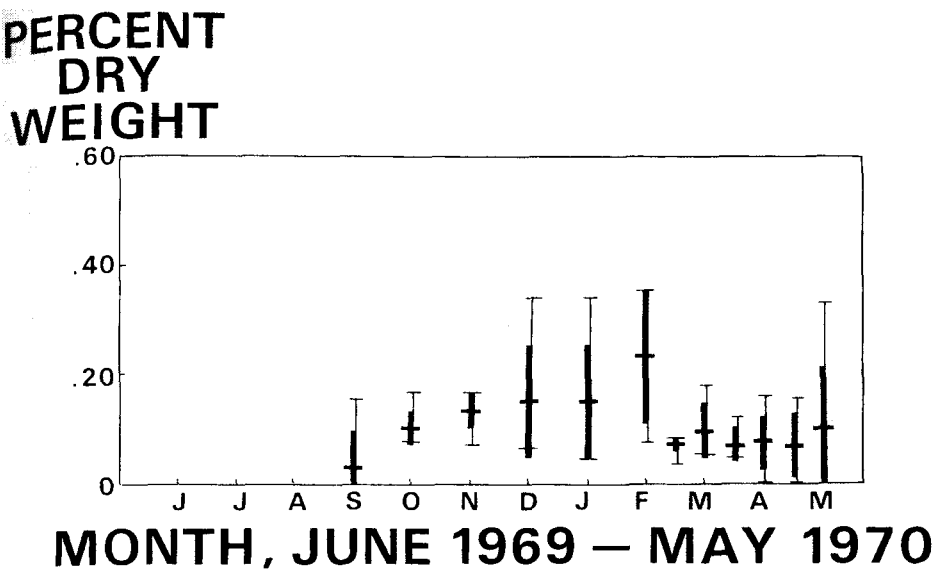


Figure 3. — Season trend of maltose in outer wood of roots of sugar maple.

However, there are no specific reports on the quantities present in woody plant tissues. Because most studies have examined reducing sugars as a group, maltose probably has been overlooked. The accumulation of maltose coincides with the winter decrease in starch content and may indicate an amylase-starch breakdown system. Amylases have been found in the sap of several maple species *(Meeuse 1952)*.

Stachyose and raffinose accumulated in sugar maple roots starting in late summer and then disappeared shortly after budbreak. This phenomenon apparently is related to the onset and termination of dormancy. Seasonal variation of these sugars in conifers has been related to cold hardiness *(Parker 1957, 1959)*.

The normal seasonal carbohydrate changes in sugar maple roots appear to follow a predictable pattern, and any physiological disturbance caused by defoliation or other stress factor that would alter the normal contents should be easily detected. With this seasonal data as a basis for comparison, studies to determine the effects of defoliation on tree physiology and susceptibility to pathogenic organisms can be started.

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