SEASONAL CARBOHYDRATE LEVELS IN ROOTS OF APPALACHIAN HARDWOOD PLANTING STOCK

Root starch was the major carbohydrate. Most of the starch and sugar accumulated between mid-September and early November.

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In deciduous trees starch is a major storage carbohydrate. Its level is one indicator of physiological quality. Generally starch content has been found to increase during the summer, peak in late fall, and drop to depletion in spring to support shoot elongation. Reduced starch levels associated with such stress factors as defoliation and drought have been related to hardwood dieback decline diseases (*4, 7*). Some defoliation experiments with seedlings also suggest that lower starch content may be the cause of reduced root regeneration and growth (*2*). Starch content is, therefore, an important and easily measured characteristic which should be considered when evaluating physiological quality of hardwood planting stock.

In this study we monitored root starch and sugars in 1-0 stock of six Appalachian hardwood species. The treets were growing in a demonstration test incorporating several known cultural techniques essential to growing large, high-quality stock. Objectives were to compare the species' accumulation patterns and to determine carbohydrate levels which should be expected under good nursery conditions.

Methods

Nursery beds near Norris, Tennessee, were fall-seeded to yellow-poplar (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), chestnut oak (*Q. prinus* L.), and bear oak (*Q. ilicifolia* Wangenh). Seed from three to eight open-pollinated families from each species were planted in a randomized block design to allow comparison of growth among species. The bed area, which had supported a cover crop of ryegrass for one season prior to use, was prepared in September and treated with methyl bromide after incorporation of 300 pounds per acre of commercial (13:13:13) fertilizer. Two additional fertilizations with ammonium nitrate at a rate of one pound per hundred square feet were made in mid-May and July. After germination was completed, beds were thinned to five seedlings per square foot. They were irrigated twice weekly throughout the growing season.

Beginning in mid to late May, samples of each species except yellow-popular were harvested at four to five week intervals for growth analysis. The initial sample of yellow-poplar was taken in July since late germination was experienced with this species. Roots of seedlings were dried in a forced draft oven for 1 hour at 100°C followed by 23 hours at 70°C. After oven-dryweight determination, composite samples of whole root tissue from tap roots were made up of at least 8 to 10 randomly selected seedlings of each species. Tap roots were selected for analysis since they are the main repository of starch in seedlings. Roots were ground to 60 mesh in a Wiley mill and stored at—10°C until analysis. In November, 16 seedlings representing the range of size classes in the beds were harvested, and separate seedling root samples were prepared for analysis as above, but with xylem and phloem tissue prepared separately.

Starch was extracted from duplicate 100 mg. root samples by the method of Hassid and Neufeld (*1*) and estimated colorimetrically as the starch-iodine complex following Siminovitch et al. (*5*). After alcohol extraction, reducing sugar content was determined by the Shaefer-Somogeyi copper-iodometric titration method as outlined by Smith (*6*). Samples were then hydrolyzed with an ion exchange resin (*3*), and reducing sugar was again determined to obtain an estimate of sucrose content. For November samples, single starch determinations were made of individual seedling samples with enough duplicates to monitor accuracy, and sugar extracts were bulked to provide one sample per species.

Results

Yellow-poplar and black cherry exhibited continuous shoot elongation until early September and were substantially larger than oaks at the end of the growing season (table 1). All oaks made three to four flushes of shoot growth but leaf area increment was much higher for northern red oak and chestnut oak than for white oak and bear oak. This accounted for the major growth difference between the two oak groups.

There were major species differences in root starch content (percent oven-dry weight) across the growing season (table 1). Northern red oak and black cherry had 10 percent starch or less until autumn when a major increase began which resulted in levels of 40 to 50 percent. Yellow-poplar exhibited a more gradual increase over the growing season to 45 percent in November. White oak samples averaged around 15 percent during the growing season, then increased to 50 percent between mid-September and November. Roots of chestnut oak and bear oak, on the other hand, maintained a significantly higher starch content (25 to 30 percent) than other species through most of the growing season before accumulating around 50 percent starch by November.

Table 1. – *Carbohydrate content (percent oven-dry weight) of roots of six Appalachian hardwoods. Species means from May to September based on duplicate determinations of two to four composite samples containing 8 to 10 seedlings*

Sampling Time	Black Cherry	Yellow-Poplar	N. red Oak	White Oak	Chestnut Oak	Bear Oak
			Starch			
May-June	10	—	7	20	32	24
July-August	9	15	10	14	30	29
September	20	22	6	12	26	26
November						
xylem	40a[1]	46a	47a	50a	44a	53a
phloem	48b	49a	25b	45a	58b	29b
			Reducing Sugars			
May-June	1.7	—	3.2	2.0	2.8	0.7
July-August	2.2	7.8	2.1	1.1	2.0	1.2
September	1.4	1.6	0.7	1.6	1.4	1.1
November						
xylem	1.4	1.4	1.0	0.3	0.2	0.3
phloem	2.0	3.6	2.4	1.1	1.4	1.0
			Sucrose			
May-June	0.3	—	2.4	<0.1	0.9	0.3
July-August	<0.1	<0:1	1.4	0.4	0.1	<0.1
September	0.1	0.7	0.8	<0.1	0.2	<0.1
November						
xylem	0.4	3.4	4.0	1.7	2.7	4.4
phloem	1.1	4.5	2.4	1.4	2.9	5.1
			Mean September Oven-dry Weight per Plant			
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	135	76	27	11	28	11

[1]Xylem and phloem means accompanied by different letters as significantly different at the .05 level of probability.

The relatively low root starch in northern red oak, yellow-poplar, and black cherry is understandable, since major shoot and leaf development in these species continue throughout the season. Bear oak and white oak, on the other hand, exhibited conservative shoot development and low shoot/root ratios, conditions which might result in continuously high levels of storage carbohydrates. However, the relatively rapid shoot and leaf development and high root starch content of chestnut oak is not amenable to simple explanation. It is worth noting that both bear oak and chestnut are species occurring mostly on poorer sites where their continuously high starch levels during the growing season may have adaptive significance. The major observation, however, is that the bulk of the starch accumulation took place from mid-September to early November, after shoot extension had stopped but before leaves became disfunctional.

Individual seedling determinations in November of root xylem starch levels revealed no real differences among species. However, starch content was substantially higher in xylem than in phloem for the two red oaks. In the other species, starch levels were roughly equal, although significant differences were observed for black cherry and chestnut oak. There was no correlation between root starch content and seedling size in any of the species.

Total sugar content averaged 2 to 5 percent in May-June samples, was reduced to 1 to 2 percent during midsummer, then slightly elevated in the fall (table 1). Higher levels in midsummer for yellow-poplar may partly be due to its being a late starter. During the growing season, sucrose was a minor component of sugars in all species except northern red oak. In the fall, however, sucrose was the major sugar in most species. Phloem samples in the fall had slightly higher sugar content than xylem in most species. Northern red oak was an exception.

Conclusions

In all species examined, root starch was the major carbohydrate. Starch levels suggest that root systems are powerful physiological sinks in these plants grown at a low seed bed density, low moisture stress, and high nitrogen levels. Most of the starch and sugar accumulation took place between mid-September and early November. High starch content is assumed to be an important characteristic of seedling quality; therefore, culture efforts in the Southeast should: (1) concentrate on techniques essential to obtain large size and thus large root storage capacity during spring and early summer; and (2) stop shoot elongation by mid-September, as is usually prescribed to avoid frost damage, but maintain fall soil moisture adequate for good leaf retention until November.

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