

# Relationship of Root Starch to Decline of Sugar Maple

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## ABSTRACT

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Starch content of roots of streetside sugar maples (*Acer saccharum*) was scored visually on the basis of intensity of staining of xylem sections treated with I<sub>2</sub>-KI. A significant relationship occurred between root starch content in autumn and decline symptoms; trees with declining crowns had the least starch. More trees with low or depleted starch supplies decline in crown condition than trees with moderate or high starch. This technique, used as an indicator of tree health, may be useful for detecting early stages of decline.

Decline of sugar maple (*Acer saccharum* Marsh.) occurs in forest, sugar bush, and urban environments and has been prevalent in the urban environment since the early 1900s (17,23). Factors most often associated with decline of urban sugar maples include road salt, drought, site disturbance, and nutrition (5-7,13,17). Other associated biotic factors include nematode injury (1) and reduced mycorrhizae (4,16). Collar rot and basal canker caused by *Phytophthora citricola* and *Fusarium* spp., respectively, were found associated with decline in Wisconsin (2).

Declining trees, even when treated for the predominant stress factor(s) associated with decline symptoms, often fail to recover (13,14). The key to successful treatment may be early detection of tree decline (14). Crown condition, often the only parameter used to determine stage of decline, is subject to error. Growth trends from increment cores (8) and twig increments (15) show strong correlation with symptom severity, but these measurements usually do not presage change in tree condition. Electrical resistance of the cambial zone has also been used to determine tree condition (22), but in urban sugar maple, these measurements were unreliable because they varied according to time of year, air temperature, tree diameter, bark blemish, callus tissue, decay, and measurement technique (8).

Root starch content has been suggested

as a more reliable measure of tree health (11,12,18-20). Root starch reserves in sugar maple were shown to decrease after defoliation (10,21) and/or drought (10), and the level of starch reflected the severity and frequency of stress (21). When compared with changes in crown condition, changes in root starch content were more sensitive for determining the response of trees to defoliation and for predicting changes in tree condition (20).

A simple procedure for determining relative amount of root starch has been used successfully for study of defoliated deciduous trees in the forest (18). The objectives of this research were to determine 1) if the procedure could be used successfully for trees in an urban environment, 2) if there was a relationship between root starch content and crown condition of declining streetside sugar maples, and 3) if starch content presaged changes in crown condition.

## MATERIALS AND METHODS

Ninety-three sugar maples were chosen for study: 77 in West Springfield and 16 in Amherst, MA. Trees ranged from 25 to 82 cm in diameter 1.4 m above the ground. The maples in West Springfield were in tree belts along residential streets and all had turf over their roots. The maples in Amherst were near streets, service access roads, and sidewalks of the campus of the University of Massachusetts and had turf or bare soil worn from pedestrian traffic over their roots.

**Root starch analysis.** During November and December 1979 and 1980, root samples were taken for analysis. Samples from buttress roots were taken at least 30 cm down the root from the soil surface using a 1.9-cm-diameter arch punch and hammer. Other samples were cut from roots 0.5-3 cm in diameter at least 8 cm below the soil surface that could be traced back to the test tree. The type of root sampled depended on availability and ease of taking the sample; some buttress roots were not large enough to sample with the arch punch because they bounced in the soil upon impact with the hammer or small roots were not readily found. Taking the sample below the soil line ensured sufficient ray tissue for starch observation and reduced the chances for temperature-induced, ephemeral changes in starch content (3). Three root samples were taken per tree and frozen at -15 C immediately on arrival at the laboratory.

Samples were thawed, debarked, and softened with distilled water. Cross sections 60 μm thick were cut on a sliding microtome and stained by Wargo's procedure (18) with a solution of 1.5 g potassium iodide and 0.3 g iodine in 100 ml distilled water. The stain was kept refrigerated in an opaque container and fresh stain was prepared every 30 days.

Four sections from each root were stained. Of these, two sections of similar thickness were mounted in glycerine on a microscope slide and the rest were discarded. A coverslip was placed on each slide and sections were examined over a white background within 24 hr of staining. Each section was scored visually for starch content as either high, medium, low, or depleted (18). The scores for three root samples were averaged for each tree. A numerical value of 1 (high) through 4 (depleted) was given to each tree.

**Crown condition and twig growth.** In June and August 1980 and 1981, the crown of each tree was classified as

**Table 1.** Crown condition ratings based on foliage symptoms, number and size of dead branches, and absence or presence of early autumn color

Crown condition	Foliage		Dead branches			Early fall color
	Density	Color	0.5-2 cm diameter	2-10 cm diameter	> 10 cm diameter	
I	Normal	Green	< 10	0	0	Absent
II	Subnormal	Green	10-20	1	0	Absent
III	Medium	Light green	20-35	2-3	1	Slight
IV	Sparse	Light green <sup>a</sup>	35-50	4-10	2-3	Present
V	Very sparse	Light green <sup>a</sup>	> 50	> 10	> 4	Conspicuous

<sup>a</sup> May be scorched and distorted.

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**Table 2.** Crown conditions of 1980 and 1981 and the corresponding mean root starch ratings of 1979 and 1980

Spring crown condition <sup>a</sup>	Autumn starch rating <sup>b</sup>	Trees sampled
<b>1980</b>		
I	2.3 ± 0.6	24
II	2.0 ± 0.5	33
III	2.2 ± 0.6	16
IV	3.1 ± 0.8	14
V	3.0 ± 1.0	6
<b>1981</b>		
I	2.4 ± 0.6	9
II	2.5 ± 0.6	36
III	3.0 ± 0.6	23
IV	3.4 ± 0.7	15
V	3.8 ± 0.4	10

<sup>a</sup>I = normal, and V = severe dieback (8).

<sup>b</sup>1 = high, 2 = medium, 3 = low, and 4 = depleted.

normal or assigned to one of four categories representing progressively more symptoms of decline (I = normal, V = severe dieback) (Table 1). Presence of large pruning wounds indicating substantial crown removal was considered when assigning trees to categories.

Four branches 1 m long were collected from the upper crown of each tree in August 1980; two were from the traffic side and two were from the nontraffic side. Annual twig growth, as distance between winter bud scars, was measured for 1976–1980 and averaged for the four branches per tree.

**Statistical analyses.** The data for root starch and crown condition were analyzed using two-way tables and the following statistics: Kendall's tau<sub>c</sub> and gamma (9). Kendall's tau<sub>c</sub> measures the association of pairs of data. If the association is positive, the statistic has a positive value. Gamma indicates the probability of correctly predicting one of a pair of variables once the order of the other variable is known. Relationships between 1979 root starch and 1980 crown condition, between 1980 crown condition and 1980 root starch, and between 1980 root starch and 1981 crown condition were thus studied.

Relationships between twig increments in 1976–1980 and the crown conditions in 1980 and 1981 and between twig increments and root starch contents in 1979 and 1980 were determined using linear-trend analysis of variance (9).

## RESULTS

**Root starch analysis and crown condition.** Root starch and crown condition were related. Mean starch content in 1979 and 1980 was higher in trees with normal or near-normal crowns than in trees conspicuously declining (Table 2). This relationship was clearest in 1980, when mean starch content was highest in trees with normal crowns and successively lower in trees with crown conditions II through V.

The relationship of 1979 root starch to

1980 crown condition was significant (tau<sub>c</sub> = 0.171,  $P = 0.017$ ) and there was a 27% probability (gamma = 0.272) of correctly predicting crown condition when root starch was known and vice versa. The association of 1980 crown condition with 1980 root starch was highly significant (tau<sub>c</sub> = 0.414,  $P < 0.0001$ ), and there was a 60% probability of correctly predicting one when the other was known (gamma = 0.599). The 1980 root starch and 1981 crown condition were also significantly related (tau<sub>c</sub> = 0.484,  $P < 0.0001$ ) and there was a 70% probability of correctly predicting crown condition when root starch content was known (gamma = 0.703).

Crown condition became worse from 1980 to 1981 in 35 of 93 trees. Twenty-eight of the 35 trees had low or depleted starch in 1979 and/or 1980 and none improved in crown condition. Root starch content ratings decreased from 1979 to 1980 in 48 trees, remained the same in 43 trees, and increased in 2 trees (both from low to medium). One of these two trees was in crown condition I both years; the other was in crown condition II both years. More trees changed categories in root starch content than in crown condition from year to year.

**Twig increments.** Trees with healthy appearing crowns had the most twig growth while those with extensive dieback had the least, and mean twig increment decreased with worsening crown condition categories. This trend was linear and significant ( $P < 0.05$ ) for crown condition in 1980 and 1981 related to growth in 1977 through 1980 but not 1976.

There was a significant positive relationship between starch content in 1980 and the twig increment in 1980 ( $P = 0.01$ ), 1979, and 1978 ( $P = 0.05$ ). The trend was linear ( $P = 0.05$ ) for 1979 root starch and 1980 twig increment, whereas for 1980 root starch, it was linear ( $P = 0.01$ ) with respect to twig increments of 1977 through 1980.

Of the thirty-five trees that declined in crown condition from 1980 to 1981, only five showed a decreasing trend in their twig increment measurements from 1976 to 1980.

## DISCUSSION

Wargo (20) suggested that starch content of roots of defoliated trees could be used as an indicator of physiological condition and effects of stress and as a predictor, to some extent, of a tree's ability to tolerate additional defoliation. Our results indicate that starch content in the roots of urban sugar maples may also be used to assess physiological condition and presage future crown deterioration. Although not all trees with low or depleted starch contents declined in crown condition from 1980 to 1981, 80% of those trees that did decline had low or

depleted starch contents in 1980. Most of the trees with low or depleted starch content that did not decline in crown condition were already in poor crown condition (classes III–V). Thus, starch content indicated some alteration in physiological condition that was subsequently expressed in a declining crown. Sampling from buttress roots rather than small roots seemed disadvantageous because fibers, which have no storage function, are more numerous in buttress roots than in small roots. This can lead to buttress roots being mistakenly given low starch ratings if these are based on the overall appearance of the root and not on ray tissues.

Twig increments augmented crown condition ratings as indicators of current tree condition but did not dependably indicate future change in crown condition.

Root starch content was a more sensitive indicator of physiological condition than either crown condition or twig increment and perhaps can be used to screen trees for treatment in areas where decline is prevalent. Healthy-appearing maples (crown conditions I and II) with low or depleted starch reserves may benefit from fertilization, watering, and pruning. Of trees in crown condition III, those with medium or high root starch content would hold the most promise of recovery through treatments, and the effectiveness of these treatments might be assessed by subsequent root starch analysis. When dieback has advanced, trees with low or depleted starch may be best considered for removal.

Results presented here are based on a relatively small sample of urban trees. Before the root starch technique is used as an arborist's tool on a large scale, it should be tested further with a larger tree population and a variety of urban settings.

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