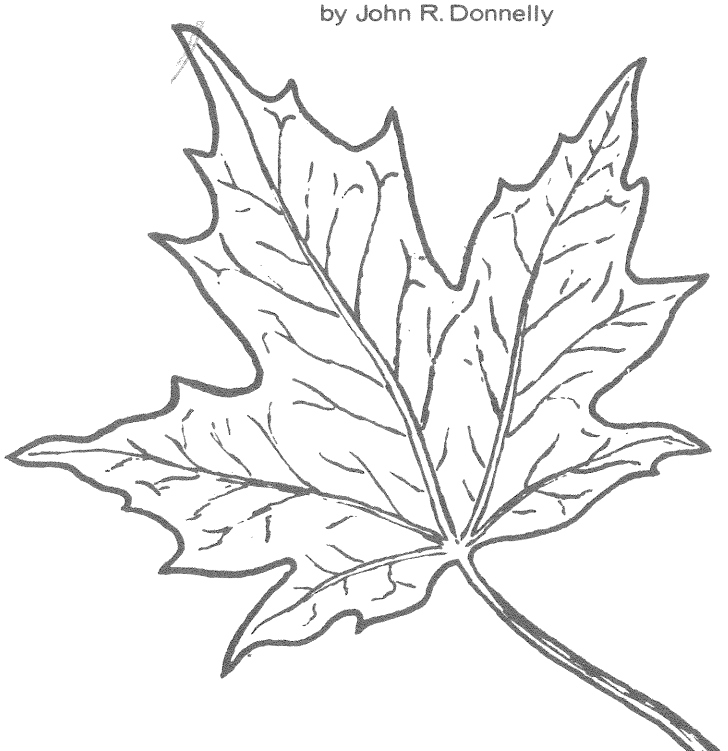
ODC 232.328.1 176.1 *Acer saccharum* Marsh.

Morphological and Physiological Factors Affecting Formation of Adventitious Roots on Sugar Maple Stem Cuttings

by John R. Donnelly



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Morphological and Physiological Factors Affecting Formation of Adventitious Roots on Sugar Maple Stem Cuttings

ABSTRACT

Sugar maple cuttings were collected twice a week throughout June from four mature trees. Some of the cuttings were analyzed for carbohydrate (starch and sugars) and nitrogen content; the others were stuck in rooting beds. Rooting response showed significant daily and clonal variations. Cuttings rooted best when their terminal leaves were mature, as judged by size and color. Daily changes in rooting response were only weakly correlated with sugar and nitrogen concentrations, but rooting response peaked soon after a marked rise in starch.

Keywords: Rooting, vegetative propagation

INTRODUCTION

SUGAR MAPLE (*Acer saccharum* Marsh.) is considered to be a difficult species to propagate vegetatively. Some cuttings root well, while many root poorly or not at all (*Donnelly 1974; Gabriel et al. 1961*). Response also varies with the time of year at which cuttings are collected (*Dunn and Townsend 1954; Enright 1958; Koelling 1968; Snow 1941*). Koelling collected cuttings at 2-week intervals from nine trees in Vermont during the period 3 February through 19 July, and found that no dormant cuttings rooted. Rooting improved as current-year shoots developed, was at its maximum in early June, and decreased through July. Apparently, sugar maple cuttings root best when collected in late spring, but the 2-week interval between collection periods in Koelling's study made it impossible to pinpoint the optimum time for collection.

In an attempt to refine the criteria for optimal selection of sugar maple cuttings, the rooting response of cuttings that had been collected twice a week throughout the month of June was monitored and compared with changes in physical appearance of the cuttings. Changes in carbohydrate and nitrogen content of the cuttings were also compared with rooting response.

METHODS

Twice a week during the period 2 June to 30 June 1967, 30 cuttings were collected from each of four mature sugar maple trees near Burlington, Vermont. Each cutting was an entire current-year shoot. Twenty of the cuttings from each tree were placed in rooting beds in a greenhouse. The 10 remaining cuttings from each tree were analyzed for starch, ethanol-soluble sugar, and nitrogen.

The cuttings to be rooted were placed in a 1:1 mixture of coarse Perlite[1] and shredded sphagnum moss. Minimum and maximum air temperatures in the 6 x 18-m plastic-covered greenhouse were about 16 and 32°C. Heating cables maintained the rooting medium at 27°C. Each cutting was wounded and dipped into undiluted Hormodin No. 3 before being inserted to a depth of 5 cm into the rooting medium. Cuttings were fertilized with a complete nutrient solution incorporated into the electronically controlled mist system (52.7 g of Rapid-Gro dissolved in 1000 ml of water; 7.5 ml of this solution was incorporated into each 1000 ml of water added through the mist system). Supplemental lighting (150-watt incandescent lamps placed about 1 m above the rooting beds) provided a 20-hour daylength. All cuttings were examined for root formation in mid-September, about 3-1/2 months after the first of them had been stuck in the rooting beds.

The cuttings for analysis were cut into small pieces that were mixed together; three 2-g samples were extracted with hot ethanol and analyzed for carbohydrates by procedures modified from Morris (*1948*), Hodge and Hofreiter *(1962)*, Horwitz *(1960)*, Ward and Johnston (*1962*) and Witherell (*1963*). Three additional 1-g samples were analyzed for total nitrogen by the University of Vermont, College of Agriculture. Regulatory Service.

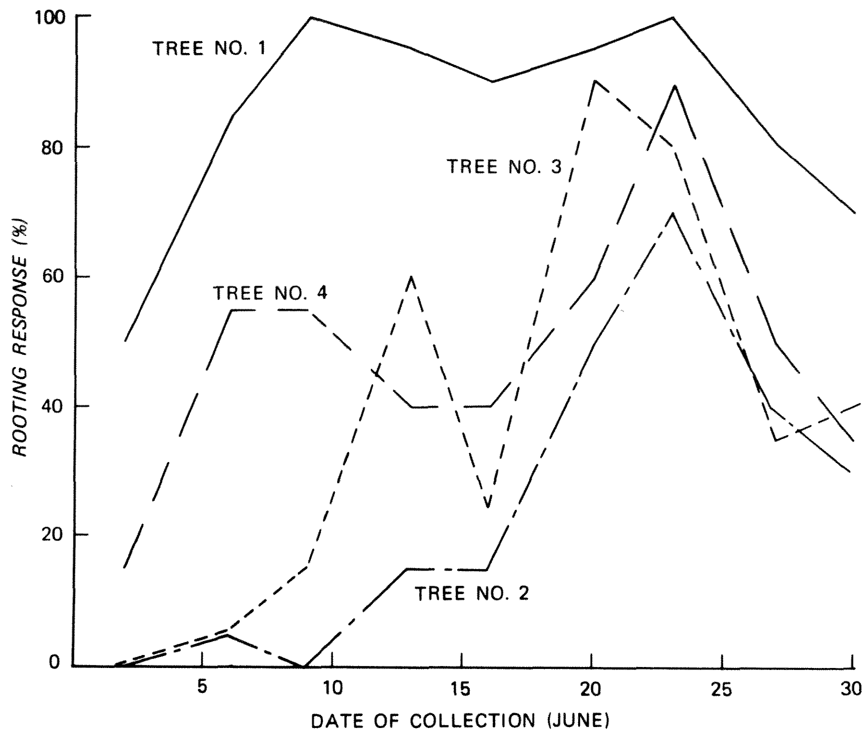
[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

RESULTS AND DISCUSSION

Morphological appearance.—The trees included in this study broke bud around the middle of May. On 22 May, individual leaves were distinguishable, and some shoots had grown to 5 cm. Shoots on two trees were further developed than those on the other two trees at this time, but, at later observation periods, all trees appeared to be at the same stage of development. By 2 June (the date of first collection), shoot stems were about 13 cm long and quite succulent, leaves were reddish-green, and the new terminal bud had not formed. By 6 June, stems were fully elongated and noticeably firmer. By 9 June, new terminal buds were visible. By 13 June, the terminal bud was enclosed within two dark-brown scales and, by 20 June, leaves appeared to be mature, as judged by size and color. No further changes in appearance were noted during later collections except that the stems of a few cuttings began to turn brown in late June.

Rooting response.—The average rooting response for all four trees increased from 16 per-

Figure 1.—Rooting response of sugar maple cuttings taken during June from four trees.



cent on 2 June to 85 percent on 23 June, then decreased to 44 percent by 30 June. There were clonal as well as daily variations in rooting response (Fig. 1). Tree No. 1 had consistently higher rooting responses than the other trees. Rooting trends in the last 2 weeks were similar for trees No. 2, 3, and 4. All trees rooted well during the third week of June.

Gabriel et al. (*1961*) studied clonal variations in the rooting response of cuttings from 46 mature sugar maple trees. Rooting response varied from 1.4 to 46.1 percent, but it is impossible to attribute this response solely to inherent clonal variation, because cuttings were collected in late June and early July, rather than all at the same time. As indicated in figure 1, rooting potential may drop off drastically during this period. Donnelly (*1974*) collected cuttings from three mature sugar maple trees in a study designed primarily to test the effect of shoot size on rooting. Even though all cuttings were collected at about the same time (mid-June), the average rooting response varied from 1 to 61 percent.

Chemical analyses.—It was difficult to detect any trend in the sugar concentration of the cuttings because of large tree-to-tree and day-to-day variations but, in general, the sugar concentration decreased slightly during the first half of June, then remained relatively constant through the remainder of the test period (fig. 2). The concentration of nitrogen decreased consistently in early June and then leveled off. The concentration of starch changed little during the first half of the month, rose sharply between 16 June and 20 June, then decreased slightly. The sharp rise in starch concentration in mid-June coincided with the apparent maturation of developing shoots.

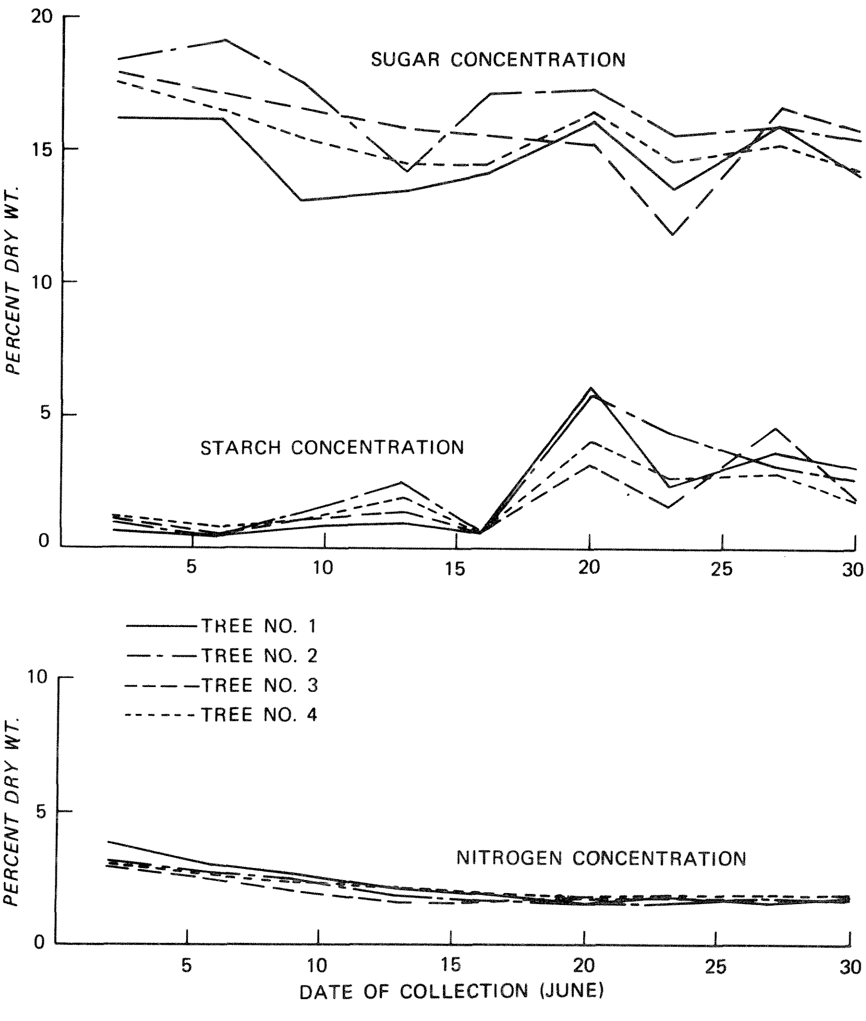
Factors correlated with rooting.—These cuttings collected between 20 June and 23 June rooted best. But Koelling (*1968*) found that cuttings from maple trees in the same general area rooted best when collected in early, rather than late, June. This difference is probably due to a difference in the timing of shoot development, and undoubtedly reflects variations in spring weather conditions. Perhaps the most important month to consider is May, when a new flush of growth can be expected. May 1965, when Koelling conducted his experiment, was warmer (approximately 6°C), drier (5.4 cm less rainfall), and sunnier than May 1967.[2] These disparities were presumably responsible for a difference between Koelling's work and ours in the rate of shoot maturation and, consequently, in the collection date of those cuttings that rooted best. Because of yearly variations in local weather conditions, date of collection is not a good criterion for pinpointing the optimal time when cuttings should be collected. Relative length of shoots was not a useful criterion either, because shoot elongation was no longer occurring in the cuttings that rooted well.

The morphological characteristic most noticeably associated with rooting potential was the color of terminal leaves. Cuttings rooted best when the tip (last formed) leaves were already mature, as judged by size and color. At that time, the shoot's stem was still green, and a new terminal bud had formed. The terminal bud was about 0.25 cm long and appeared to consist of two dark brown scales. This description of the optimum stage of development agrees with that given by Koelling (*1968*).

A high percentage of cuttings from all trees rooted when they were at this stage of develop-

[2] Source: U. S. Weather Bureau, Burlington, Vermont.

Figure 2.—Sugar, starch, and nitrogen concentrations in cuttings taken from four sugar maple trees during June.



ment. But cuttings from tree No. 1 rooted equally well when they were quite immature. In fact, immature cuttings from this tree rooted better than did cuttings from most other trees that were at the presumed optimum stage of development (fig. 1). Consequently, the value of morphological appearance as a criterion for selection seems limited. Appearance provides a general guideline for determining at what time cuttings should be selected, but it does not indicate how well these cuttings will root, nor does it explain why cuttings from certain trees root better than cuttings from others.

For several plant species, rooting of cuttings is promoted by high endogenous levels of carbohydrate and inhibited by high levels of nitrogen (reviewed by *Hartmann and Kester 1968*). To test whether such a relationship exists in sugar maples, daily changes in the rooting response of cuttings from individual trees were correlated with daily changes in carbohydrate and nitrogen levels in the cuttings (table 1). For each tree, the rooting response was negatively correlated with sugar and nitrogen concentrations and positively correlated with starch concentration and the carbohydrate:nitrogen ratio. Correlation coefficients were generally quite low. Linear regression showed that only 4 of the 20 correlations tested were significant at the 0.05 level. Three of the statistically significant correlations were for tree No. 2 and the other was for tree No. 3. The average correlation coefficient was 0.75 for tree No. 2 (the poorest rooter), but only 0.37 for tree No. 1 (the best rooter). These results are similar to the correlations between rooting response and morphological stage of development, i.e., the rooting response of cuttings from tree No. 2 was closely correlated with stage of development and relatively well correlated with carbohydrate and nitrogen content; in contrast, cuttings from tree No. 1 rooted well at various stages of development, and rooting response was not well correlated with carbohydrate or nitrogen level. The average correlation coefficients for trees No. 3 and 4 were 0.57 and 0.40 ,respectively. These trees were intermediate in terms of rooting response and degree of correlation between rooting and carbohydrate and nitrogen content.

Average correlation coefficients for all four trees ranged from 0.47 for starch to 0.61 for nitrogen (table 1). Although starch concentration was generally not well correlated with rooting response, the date of maximum response (23 June) coincided, approximately, with a marked increase in concentration of starch. Most current-year photosynthates are respired or assimilated into plant biomass while shoots are rapidly developing, but starch accumulates when developing leaves have matured and shoot elongation has ceased. At about that same time, shoots are at their maximum rooting potential. Although there may be no direct cause and effect relationship between rooting response and a sharp rise in concentration of starch, the two seem to be related. Molnar and LaCroix (*1972*) found that hydrangea cuttings with a high starch content rooted better than did those with a low starch content. In contrast, Nanda and Anand (*1970*) reported a negative correlation between rooting and starch content in *Populus nigra*. The authors equated rooting potential with the

Table 1.—Correlation coefficients between percent rooting and average concentrations of carbohydrates and nitrogen in cuttings taken semi-weekly during June.

Tree number	Independent variable			
	Percent sugar	Percent starch	Percent nitrogen	C/N ratio
1	-.53	.14	-.56	.24
2	-.46	.87**	-.77*	.89**
3	-.81**	.46	-.65	.37
4	-.26	.42	-.47	.46

*Significant at 0.05 level.
**Significant at 0.01 level.

presence of enzymes capable of mobilizing the food reserves. I did not analyze for enzymes in this study.

CONCLUSIONS

Softwood sugar maple cuttings rooted best when collected immediately after their leaves had matured. Rooting was not well correlated with concentrations of sugar or nitrogen, but peak rooting activity coincided approximately with a sharp rise in concentration of starch. If this apparent coincidence is meaningful, a rapid field method for determining starch content may be useful in deciding when to collect cuttings from high-yielding maple trees.

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