Synchronous Pressure-Potential Changes in the Phloem of Fraxinus americana L.

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Abstract. Simultaneous measurement of the pressure potential of the phloem of F. americana made on two locations on the trunk over long periods of time showed synchronous oscillations of no fixed period during the day. The simultaneous changes in pressure in two different trees indicated environmental changes were responsible for the synchrony. The coincident changes of pressure 5 m apart on the same trunk implied that either transpiration had an immediate and direct effect upon the pressure potentials developed in the phloem because of the intimate relationship of the phloem water potential and the water potential of the adjacent transpiration stream, or factors affecting phloem loading resulted in pressure changes throughout the phloem.

Key words: Fraxinus – Phloem (pressure) – Pressure flow – Pressure potential (phloem) – Transpiration – Turgor pressure (phloem) – Water relations (phloem).

Introduction
Exudation from aphid styles or incisions into phloem tissue have demonstrated the existance of positive pressure potentials in the phloem. Exudates have been used to study the concentration and composition of the constituents of the translocation pathway for a number of species (for a recent review, see Zimmermann and Ziegler 1975). Exudation rates from severed aphid styles have been used to calculate the pressure potentials of sieve tubes (Mittler 1957; Weatherley et al. 1959; Barlow and Randolph 1978; Rogers and Peel 1975). Investigation of the pressure potential responsible for the exudation has, however, been limited. Using a manometric device, Hammel (1968) measured pressure potentials of Quercus rubra, a tree which produces only limited amounts of exudate, while Sheikholeslam and Currier (1977a, b) using a similar device, studied the pressure potentials of Echallium elaterium. Sovonick-Dunford et al. (1977) used a pressure-transducer device to measure turgor pressures in the phloem of Fraxinus americana, while, more recently Wright and Fisher (1980) have used aphid stylet exudation to measure pressure potentials manometrically from single sieve tubes.

With the exception of the recent work of Wright and Fisher (1980) all of the above experiments were conducted for only short periods of time. The design of the manometric device used by Wright and Fisher (1980) necessitated a long-term measurement to achieve equilibrium. In the work described in this report pressure-transducer devices with short response times were used over long time periods to monitor pressure potentials of the phloem of Fraxinus americana L.

Material and Methods
Phloem pressure potentials were measured with a device similar to that used by Hammel (1968) but the manometric portion was replaced with a pressure transducer. Two liquid-paraffin-filled Model 540-500 pressure transducers (MBIS, Akron, O., USA) each attached via an adaptor to a paraffin-filled modified hypodermic needle (Hammel, 1968) were used to measure the pressure potentials of ash trees at two points simultaneously. Power was supplied by a Micronta power supply at 10 volts (Radio Shack, Barrie, Ont., Canada). Data were recorded on a pair of Heath-Schlumberger (Mississauga, Ont.) model 504 recorders running at the same speed and adjusted to 2.0 MPa full-scale deflection, recorder and transducer forming a matched set.

The transducers were supported by tape about the multiconductor wire and the needle was inserted through the bark at a shallow angle, penetrating conducting phloem obliquely, so that the periderm acted as a seal about the needle. Penetration of the conducting phloem was indicated by an abrupt increase in the recorded pressure potential. The pair of holes in the tip of the modified hypodermic needle had to be aligned vertically at penetration in order to measure any pressures in the phloem. This concurs with the procedure and results of Hammel (1968). The size of the tip and position of the orifices of the needle meant that each
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pressure measurement was made upon 50–100 sieve elements at the one time.

The measurements of pressure potential were made at heights of 6.2 and 1.2 m or on opposite sides of the trunk 1.2–1.5 m above ground level during the months of July and August. The trees were in an even-aged stand approx. 15 m tall, unbranched to the 8-m level, with a breast height diameter of 30–47 cm, located in well drained soil on the north shore of the Kennebecasis River in New Brunswick, Canada.

**Results**

Tracings of coincident recorder outputs from 6.2 and 1.2 m are presented in Figs. 1 and 2. From these matched recordings it is evident that the pressure potential exhibits synchronous variation. The pressure changes have no set frequency, but the inflection points for increases and decreases are, with minor exceptions, simultaneous, although the amplitude of the coincidental fluctuations differ. It should be noted that Figs. 1–4 represent sample tracings selected from the set of recordings because the lines of the tracings do not cross or recross as in Fig. 5. Consistent separation without crossing or recrossing was the exception rather than the rule.

Figure 1 illustrates a tracing where the pressure potential at the top of the trunk was consistently greater than that at the bottom, while Fig. 2 shows the reverse situation throughout the illustrated time period. The amplitude of pressure oscillations was not consistently greater at either the top or bottom of the tree.

Synchronous pressure oscillations were also obtained from opposite sides of one tree at the same level, as illustrated in Fig. 3. This figure also illustrates that coincident oscillations could be recorded over long time periods. The zero point on the trace represents the pressures 56 and 57 min after insertion of the needles into the phloem for the upper and lower traces, respectively. The oscillations were recorded through the day for periods up to 6 h and synchrony was evident between approx. 09:00 and 18:00 o'clock Atlantic Daylight Time.

At night (Fig. 4), and during periods of continuous rain, pressures oscillated asynchronously with amplitudes generally less than 10³ Pa, usually in the range of 10⁴ to 5·10⁴ Pa. Pressure potentials also oscillated asynchronously from dawn until approx. 09:00 and after 18:00 ADT until sundown, but with