Metabolic Index as a Diagnostic Tool in Tree Health Determination

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ABRIDGMENT

•PREVIOUS INVESTIGATIONS have established that levels of sodium and chloride in the leaves of sugar maples increase with the increasing exposure of the trees to road drainage (4, 6). Assessing the mechanism of toxicity of sodium or chloride to sugar maples is difficult because data on the normal and toxic concentrations of cations and anions in maple tissue are limited in the literature. In susceptible species, however, the toxic concentrations seem to be similar, and the mechanism of toxicity may be the same (1, 2). Chloride is reported to be lethal to peach trees at 1.0 percent of the dry weight of the leaf, with 0.5 percent producing serious leaf margin burn (3). Recent studies appear to establish similar toxic levels for sugar maples (4, 6). The 1966 Connecticut Study pointed out the possibility that trees obviously dying from the toxic effects of salt might fail to display alarming levels of Na or Cl in the leaf tissue because of the depressed metabolic rate and the reduced ability of the severely injured tree to take up moisture, nutrients, and salt from the soil (4). It was also stressed that a carry-over of accumulated chloride in woody tissue and the reduced rate of growth of older trees might be responsible for the more rapid accumulation of critical quantities of salt in the leaves of older trees, as mentioned by Bernstein (1, 2).

Although the manner in which the chloride ion is toxic to plants is not understood, certain hydrolytic functions by enzymes are suppressed and chlorophyll formation is depressed at high chloride concentrations. Visible symptoms on large trees may be delayed for several seasons after the appearance of high chloride levels in the leaves. The sodium ion is not readily or efficiently transported to the leaves until the latter stages of decline. In some cases in severely affected trees, nearly equal levels of sodium and potassium have been found, probably a lethal condition.

Data in the Connecticut Study indicated that sodium, through some mechanism, had suppressed the uptake of calcium, magnesium, and potassium. It is also possible that the significant presence of the negatively charged chloride ion in the cells depressed the natural production of negatively charged organic acids in the cell and thereby depressed the uptake, or negated the effect, of nutrient ions.

The Connecticut Study did suggest that high levels of Na and Cl had a depressing effect on the levels of Ca, Mg, P, and K found in the tissue. As a sequel to the previously published report (4), a method involving the relationship of the lethal Na and Cl ions to the essential Ca, Mg, P, and K ions found in the tissue has been devised (5).

To develop a tool to evaluate realistically the detrimental effect of exposure of a tree to chloride and sodium ions from de-icing materials, an intensive study of the levels of these ions as related to the levels of calcium, magnesium, phosphorus, and potassium ions also found in the plant tissue was initiated. The results of analyses of the tissue samples, obtained over a period of years from sugar maples at 3 locations, were assessed. The relationship of the ion levels to tree health is explored with 4 tree groups. The method of bringing the relationship of the harmful Cl and Na ions to the essential Ca, Mg, P, and K ions is brought into focus by employing the following ratio of all the ions found in the tissue.

$$\frac{Ca + Mg + P + K}{Cl + Na} = \text{index}$$

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The ions found are expressed as a percentage of dry weight of the tissue. Because leaf tissue responds more rapidly, and at a higher level than twig tissue from the same location on the same tree, the calculation is made for the leaf tissue and is called the leaf index. This index provides information on the effect, if any, of salt on the youngest cell tissue of the tree.

It has also been found that the harmful Cl and Na ions do gradually accumulate and persist in the woody tissue of trees that are continuously subjected to salt (4). The study of the levels of the harmful ions found in woody tissue over a long period of time does provide information on the gradual deterioration potentiality of the tree. It would appear that the same calculation should be employed by using the ions found in the twig tissue to derive a twig index.

It further appears that in some manner the two indexes, considered together, ought to present a simplified portrait of the metabolic condition of the tree. It is suggested that the following ratio of the 2 indexes can be used:

$$\frac{\text{leaf index} + \text{twig index}}{2} = \text{metabolic index}$$

The metabolic index appears to offer a realistic evaluation of the cumulative effect of exposure of roadside sugar maples to chloride and sodium ions polluting the root zone soil from seasonal applications of salts to the highway. It is proposed that other investigators explore this method of evaluation to assess the effect of salt on the general

TABLE 1

RELATIONSHIP OF METABOLIC INDEX TO OBSERVED TREE CONDITION

Metabolic Index		Tentative Health Category	Tree Condition
<5		a	Near death, recovery not possible
>5	<10	b	Severe defoliation, limb dieback, beyond recovery
>10	<25	c	Slight to serious leaf burn and limb dieback, depending on duration of exposure to detrimental factors
>25	<35	d	Very slight to no leaf burn, may show no signs of injury or decline if adverse conditions are eliminated
>35	<75	e	Good health
	>75	ee	Excellent health

TABLE 2

AVERAGE METABOLIC INDEX OF ALL TREE GROUPS

Group III Downslope[a]		Group II Upslope		Group IV Near Level	
Tree	Metabolic Index[b]	Tree	Metabolic Index[b]	Tree	Metabolic Index[b]
82-17-1	5 a	82-17-11	31 d	112-1	27 d
82-17-2	12 c	82-17-12	19 c	112-3	8 b
82-17-3	4 a	82-17-13	47 e	112-4	12 c
82-17-4	8 b	82-17-14	39 e	112-5	12 c
82-17-5	4 a	82-17-15	21 c	112-6	9 b
82-17-6	5 a	82-17-16	39 e	112-7	27 d
82-17-7	4 a	82-17-17	23 c		
82-17-8	7 b	82-17-18	28 d		
82-17-9	6 b	82-17-19	23 c		
82-17-10	3 a	82-17-20	23 c		

Note: Nonroadside control tree had an index of 81 ee.

[a]All downslope trees have been removed because they were either dead or hazardous.
[b]Refers to tentative health category in Table 1.

health of roadside sugar maples and other valuable tree species. It would appear that cellular biologists might also investigate the harmful reactions of Na and Cl ions that get into the plant cells and interfere with, or disrupt, vital life processes. The complete report (5) includes application of the metabolic index to sugar maples studied in Connecticut from 1964 through 1967.

Data given in Table 1 demonstrate the feasibility of employing the metabolic index in classifying the physiological condition of the tree as related to observed physical conditions. Table 2 gives the average metabolic indexes of the various groups of Connecticut sugar maples sampled and analyzed from 1964 through 1967. It must be pointed out that deriving the metabolic index from analyses obtained from one or two consecutive sampling dates proves of more value in assessing the effect, if any, of Na and Cl ions on the health of a tree at any given time during a growing season. The twig index might be also of value should a winter assessment be required.

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