1998 ice storm effects on the health and productivity of sugar bushes of eastern Ontario: Part 2

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Summary

In 1998, fifteen managed sugar bush blocks with 7% to 72% ice-induced crown damage were established in eastern Ontario. All blocks received dolomitic lime (calcium and magnesium) and phosphorous (P) and potassium (K) treatments in June 1999. Initial crown damage, fall root starch, sap production and sweetness were all measured. Syrup production was calculated. Trees with greater than 50% (severe) crown damage had reduced root starch content in 1998, 2000, 2001, but not in 1999 or 2003. Sap produced per tap and sap sweetness were reduced by damage, but not consistently in all years. Syrup production per tap was consistently reduced in damaged trees in all years in trees with moderate (26-50%) and/or severe damage. The lime and P and K treatments did not significantly affect syrup production. Results suggest that severe ice storm damage to crowns resulted in reduced fall root starch levels and less sap production, and/or sap sweetness, and therefore lowered the syrup producing capacity of sugar maple for six years after the storm.

Introduction

One of the worst weather disasters ever recorded in Canadian history (Milton and Bourque 1999), the ice storm of January 5-10, 1998 was unprecedented in its duration, severity, and area affected (Chapeskie 1999). At its peak the ice storm covered a large portion of eastern Ontario, southern Quebec, and into Atlantic Canada along with the adjacent areas of northeastern

United States. As a result of this storm, sugar maple trees suffered extensive crown damage throughout the ice storm damage region of eastern Ontario.

Critical research needs identified by Ontario maple syrup producers included the impact of crown damage on tree health as measured by fall root starch level and on the rate of recovery or mortality for damaged sugar bushes, and on tree productivity as measured by sap production and sweetness (Chapeskie and Nielsen 1998). To address those needs the objective of this project was to determine whether ice storm damage to the crowns of sugar maple trees in working sugar bushes affected their health and productivity (but not mortality). This was assessed by measuring the amount of starch stored in the roots, the volume and sweetness of the sap produced. In addition, this study examined the effect of lime and fertilizer treatments to accelerate the recovery process of sugar bush health and productivity. The results from the first three years of this study were published previously in the maple digest. To determine the longer term affects of the ice storm on sugar maple productivity this paper reports results from the second set of measurements performed in 2003 (root starch) and 2004 (sap production and sweetness). Although data from all years measured will be presented in this paper only the results from the part 2 measurements will be featured and discussed.

Methods

Plot Network

In 1998, 15 one-hectare blocks were established throughout the heavily ice-damaged area of eastern Ontario in privately owned sugar bushes. Each block was rated for ice damage by visually estimating the percentage of branches in each tree's crown that were removed by ice damage (Lautenschlager and Winters 2001). Each block was divided into four, 0.25-ha plots that were treated with either: i) 2 tonnes of dolomitic lime/ha; ii) 200 kgs of P and K/ha; iii) lime plus P and K, or iv) nothing (control) in June 1999. At the time of establishment, 6 focus trees per plot (24 per block) were chosen to represent the average damage in the block and were marked for use in the study. At establishment, the following parameters were measured: I) tree damage, II) focus tree diameter at breast height (DBH), III) basal area m^2 ha^{-1}, IV) and root diameter of two roots sampled per tree for starch.

The experiment classified each block into one of three damage levels:

i) Light (0 - 25%),

ii) Moderate (26%-50%), and

iii) Severe (51% +).

Root Starch and Sap Sampling

Root starch samples were collected in 1998, 1999, 2000, 2001, and 2003 by taking late fall (Nov. or early Dec.) (Wargo 1979) increment cores, 2-3 (0.75-1.25") cm long, from two surface roots per tree of three focus trees per treatment plot (12 trees per block). Trees were tapped using standard 11.1 mm (7/16") diameter spiles with a taphole 6.35 cm (2.5”) deep using conservative tapping guidelines: a maximum of two taps per tree (Chapeskie and Nielsen 1998). Sap was collected using a tube and bucket system. Sap collection was made from the same 3 focus trees per plot as root starch. Fifteen blocks had sap collections made in the spring of 1999, 2000, 2001, and 2004. Syrup production was calculated by multiplying seasonal sugar content average times total seasonal sap volume using the rule of 87 (Walters 1982). During the tapping season of 2004 HOBO temperature probes were installed in all 15 blocks to record air temperature at a height of 1 m every 30 minutes.

Starch Analysis

Extraction of starch used 1.5 ml of methanol: chloroform: water mixture (12:5:3 by volume) (Haissig and Dickson 1979) and was done 3 times on each 25 mg DM (freeze-dried mass) root tissue sample (ground with size 20 mesh). Root starch was analyzed using a Waters’ HPLC system as described in Noland et al. (1997).

Results

Root Starch

Ice storm damage definitely affected root starch levels in sugar maple trees (Figure 1). In 2001, a drought year, the root starch levels of the severely damaged trees were lower than the trees with less than 51% crown damage. However, by 2003 the root starch levels were the same at all three damage levels.

Sap Volume and Sweetness

Sap volume was reduced by ice storm damage but not consistently every year (Figure 2). In 2004 the sap production was not affected by crown damage levels although it was affected in earlier years.

The impact of ice storm damage on sap sweetness was also variable (Table 1). In 2004, both moderately and severely damaged trees had less sugar in their sap, showing the same pattern as found in 2000.

Syrup Production

Potential syrup production was reduced by ice storm damage in all years measured (Figure 3). Six years after the storm in 2004, moderately damaged trees were still producing less syrup than either lightly damaged or heavily damaged trees the same result found in 2001.

Dolomitic lime and fertilizer treatments did not have a significant affect on anything measured in this project (data not shown). However, the P and K fertilizer treatments did stimulate diameter growth of ice storm damaged maple trees (Lautenschlager *et al*. 2003; Timmer *et al*. 2003).

Discussion

The crown of a sugar maple tree is its photosynthetic factory for producing sugar. By removing a significant portion of this crown, the ice storm of 1998 reduced the capacity of the tree to produce energy (sugar) needed for growth and development. Storm damage was assessed as the percentage of live crown removed. Although this provides a rough assessment of the ice storm impact on the tree's ability to produce energy, it does not account for differences in initial crown size between trees and the differing ability with age (Kramer and Kozlowski 1979) and crown classification (Meating et al. 2000) to sprout new epicormic branches to replace lost ones. Therefore, the impact of 50% damage on one tree that initially had 50 tertiary branches may not have been as great as on a second tree that had 20 such branches before the storm. This led to the effort to quantify the number of live and epicormic branches on the focus trees used for this experiment (Lautenschlager and Winters 2001). In addition, the age of the tree and its condition prior to the storm (Proulx and Greene 2001) also will influence the degree to which it will be affected by ice storm damage. The combination of these factors and weather patterns in the eastern Ontario region during the growing seasons (Parker 2003) after the storm are likely reasons why response to the ice storm was variable from stand to stand; these factors have been considered when interpreting the results.

The severe level of damage (>50 %) reduced fall root starch in 3 of the 5 years it was measured including the drought year of 2001. Reductions in autumn root starch levels have been reported for sugar maple trees where crown dieback equaled or exceeded 50% (Renaud and Mauffette 1991). Death of sugar maple has been associated with shoot and root starch depletion in artificially defoliated trees (Gregory and Wargo 1986). Severe insect defoliation reduced fall root starch levels in sugar maple (Kolb et al. 1992). Other ice storm studies estimated that, for hardwoods, a 40-50% crown loss was the critical level above which tree death tended to increase rapidly with increased damage (Proulx and Greene 2001, Boulet et al. 2000). The 50% crown damage threshold for root starch depletion found in this study tends to support this critical crown damage threshold for mortality.

Root starch levels of severely damaged trees were not significantly affected by crown damage in 1999 or 2003. This suggests that variable growing conditions during the different years (Parker 2003) also may affect the fall root starch levels. Other factors correlated with and possibly influencing autumn root starch content appear to be of little or no importance.

Ice storm damage tended to reduce sap production, sap sweetness, and syrup production; but results varied with the year. Sap sugar content was significantly reduced by crown damage in three of the four years measured including 2004. However, damage effects on sap volume were more variable (only affected in 2 of 4 years) and that variability may have been because of the strong dependence of sap volume production on weather during the sap run and the inherent natural variability of weather from year to year. Syrup production was significantly reduced by damage in all four years, but only in moderately damaged trees in 2001 and 2004. In his review, Coons (1999) could not find any previous literature documenting the effect of ice storms on sugar maple sap and syrup production. This study and that of Campbell *et al*. (2001) are, to my knowledge, the first evidence that ice storm induced damage to sugar maple crowns reduces sap sweetness, sap volume, and syrup production. Insect defoliation has been shown to lower sap production and sweetness in Pennsylvania (Kolb et al. 1992). The higher sap sugar content in the severely damaged trees in 2001 is similar to Kolb et al.'s (1992) finding that the second year after insect defoliation, sap sweetness was highest in the heavily (60-90% foliage damage) damaged maples.

Lime and fertilizer treatments did not have a significant effect on anything measured in this study. The P and K treatments were found to enhance the recovery of sugar maple from crown damage by stimulating diameter growth (Lautenschlager et al. 2003; Timmer et al. 2003). It is possible that such treatments could be used in the future to speed recovery of trees from crown damage. However, sugar maple response to liming treatments is a long term process (Long et al. 1997) and it is too early to make any definitive conclusions on liming treatment effects.

In conclusion, ice storm damaged sugar maple trees tended to have less syrup productive capacity (20 to 33% less syrup) and lower root starch levels in moderately and/or severely damaged trees. The ice storm damage effect has proven to be significant for maple syrup producers since it has persisted for seven sap runs after the ice storm.

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TABLE

Table 1. Ice storm damage impact on seasonal average sap total sugar content in sugar maple trees in Eastern Ontario (mean). Any mean in a column followed by the same letter is not significantly different ($p \leq 0.05$).

Damage Level	1999 Sap Sugar Content (%)	2000 Sap Sugar Content (%)	2001 Sap Sugar Content (%)	2004 Sap Sugar Content (%)
Light	1.74 ab	2.25 a	1.73 b	2.76 a
Moderate	2.00 a	1.97 b	1.73 b	2.50 b
Severe	1.57 b	1.94 b	1.93 a	2.52 b

Figure Captions

Figure 1. Effect of ice storm damage on fall root starch levels in sugar maple trees from 15 tapped and 1 non-tapped maple stands in Eastern Ontario (Mean). Any group of columns within a year topped by different letters are significantly different ($p \leq 0.05$).

Figure 2. Ice storm damage impact on seasonal sap volume production in sugar maple trees from 15 tapped stands in Eastern Ontario (Mean). Any group of columns within a year topped by different letters are significantly different ($p \leq 0.05$).

Figure 3. Ice storm damage impact on calculated syrup production in sugar maple trees from 15 tapped stands in Eastern Ontario (Mean). Any group of columns within a year topped by different letters are significantly different ($p \leq 0.05$).

Figure 1

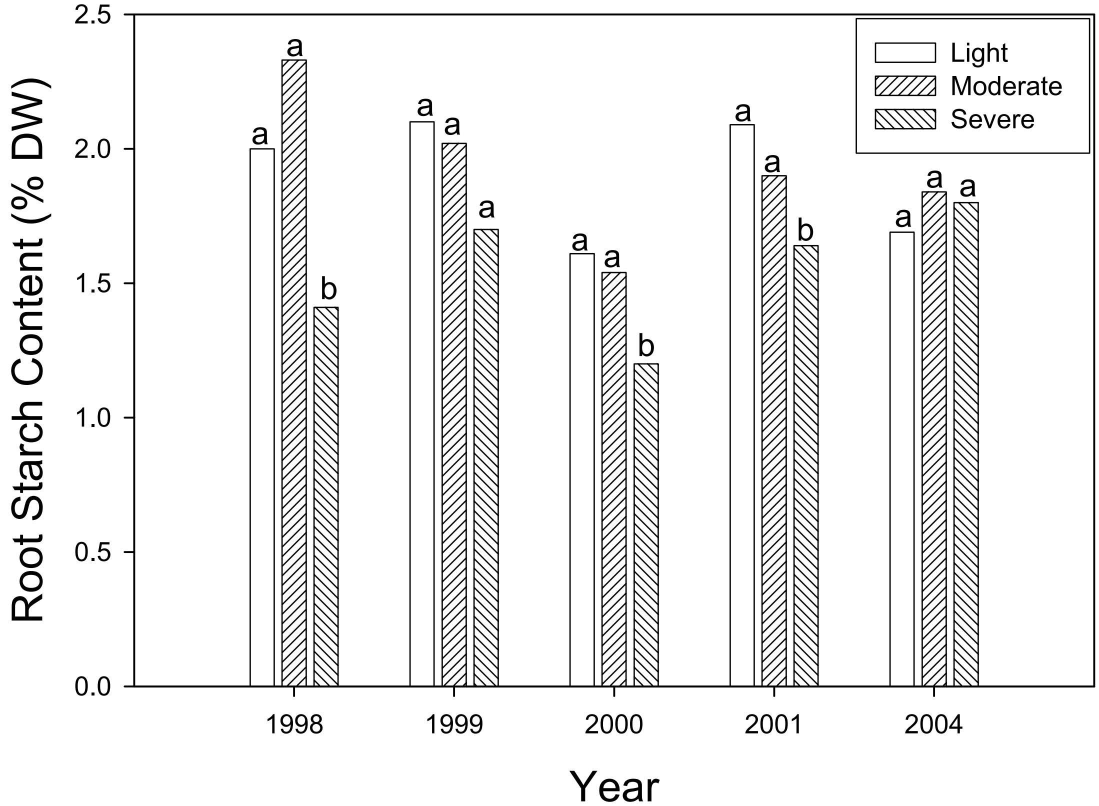

Root Starch Content (% DW)
2.5
2.0
1.5
1.0
0.5
0.0
Light
Moderate
Severe
a
a
b
a
a
a
a
a
b
a
a
b
a
a
a
1998
1999
2000
2001
2004
Year

Figure 2.

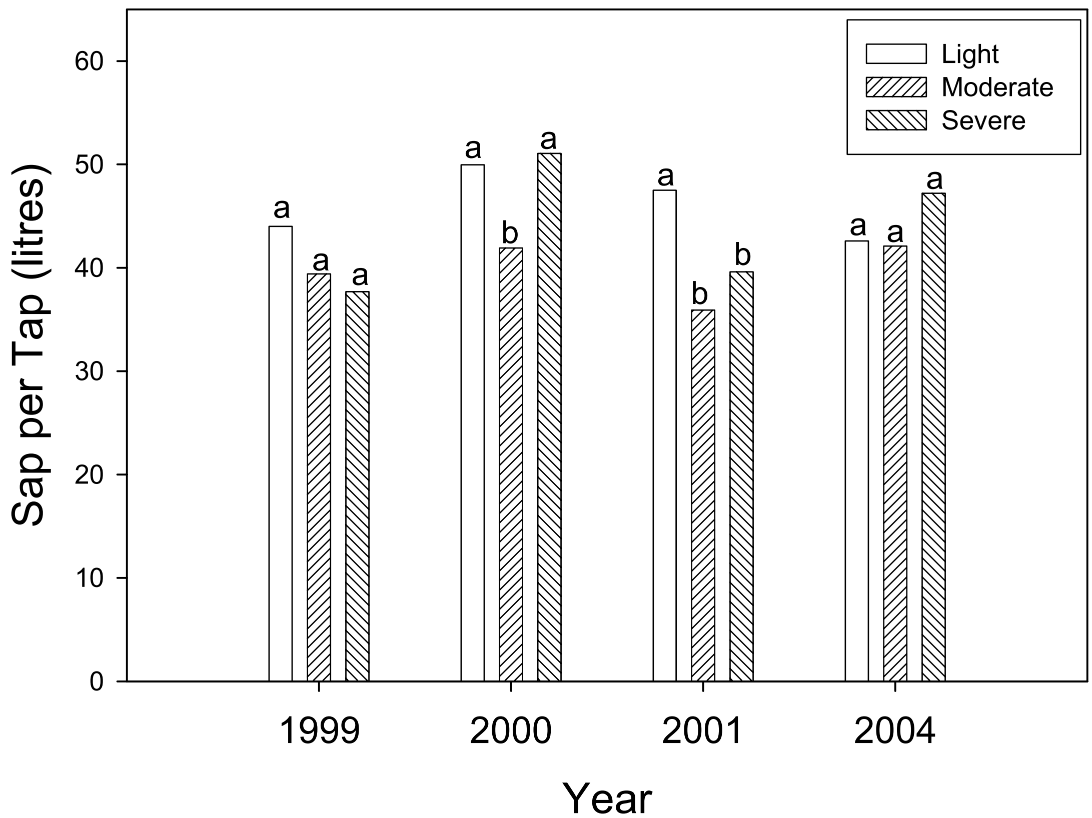
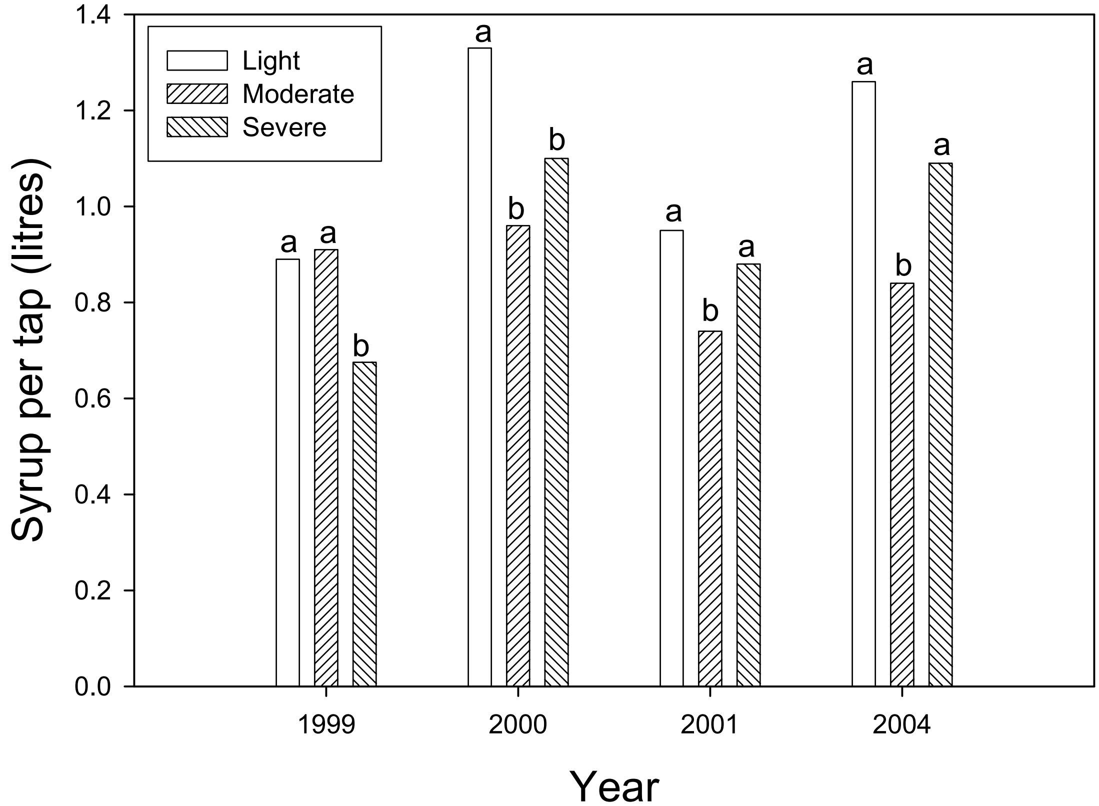

Light
Moderate
Severe
Sap per Tap (litres)
0
10
20
30
40
50
60
a
a
a
a
b
a
a
b
b
a
a
a
1999
2000
2001
2004
Year

Figure 3.



1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Syrup per tap (litres)
Light
Moderate
Severe
a
a
b
a
b
b
a
b
a
a
b
a
1999
2000
2001
2004
Year