Effects of the January 1998 Ice Storm on Stem and Root Carbohydrate Reserves, Radial Growth and Tree Vigor in Two Vermont Sugarbushes

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Introduction

The ice storm of January 1998 damaged well over 17 million acres of forest in the northeast, including nearly 1 million acres of forests in Vermont (Figure 1, Miller-Weeks and Eagar 1999, Vermont Department of Forests, Parks & Recreation 2000). Many of the areas which experienced damage were active sugarbushes, with severe damage to tubing systems in affected zones.

It was expected that trees which suffered severe branch loss would produce less foliage in subsequent growing seasons, and thus would be unable to accumulate as much carbon as less-damaged individuals. Several studies have shown a relationship among crown dieback and carbohydrate reserves in sugar maple (Gregory and Wargo 1986, Renaud and Mauffette 1991), and carbohydrate depletion was proposed as a factor involved in dieback and decline of sugar maple (Gregory et al. 1986). Therefore, trees severely affected by the ice storm might also show reduced sap yield, growth and lower rates of survival. In an Ontario study, Noland (2003) found that, "…ice-storm-damaged sugar maple crowns tended to have less syrup productive capacity and lower root starch levels, especially in trees with more than 50% crown damage. The effect of the damage lasted up to three years after the ice storm." In New York, reduced radial growth was found in the season following the damage, but recovery was evident in subsequent years (Bevilacqua et al. 2021). Survival rates of even highly damaged sugar maple over the next four years tended to be high, although stem growth and wound closure rates were reduced in trees with higher levels of crown damage (Shortle et al. 2003).

We investigated the effects of the January 1998 ice storm on the levels of root and stem carbohydrates in trees across varying levels of damage in two sugarbushes in Vermont at the end of each growing seasons from 1998 through 2001. Basal area (radial growth) and vigor (crown regrowth) of trees were also assessed at the beginning and end of the study period.

Methods

Two ice storm damaged sites were

selected for study, one in the Champlain Valley (Guillemette, Shelburne, VT) and the other in southeast-central Vermont (Rose, Reading, VT, Figure 1). Both stands were heavily dominated by mature sugar maple and had been actively managed for maple production for several decades. Overall ice storm damage was moderate, although a range of damage to individual trees was present at both sites (Figure 2). The Guillemette site was located atop a calcium-rich ridge, whereas the Rose site is in the foothills of the Green Mountains with coarse, stony loam soil.

Five trees were selected at each site in each of the following five damage classes based upon a visual assessment of broken and missing branches:

0 = 0-10% crown loss,

1 = 11-25% crown loss,

2 = 26-50% crown loss,

3 = 51-75% crown loss, and

4 = greater than 75% crown loss.

This resulted in a total of 25 trees at each site.

In the summer of 1999, we revisited these sites to confirm that damage classes with regrowth with leaves present corresponded to damage classes with leaves missing. In November 1998, 1999, 2000, and 2001, approximately 1" cores were extracted from two different major roots and from the stem of each tree using a tree borer or increment hammer. Samples were immediately placed into plastic straws and transported to the lab in an ice-filled cooler, then stored in an ultra-low freezer (-80°C) prior to analysis.

Cores were homogenized in 80% ethanol and separated into soluble and insoluble carbohydrate fractions. The soluble fraction was analyzed using high pressure liquid chromatography (HPLC) for individual sugars and total sugar concentration. The insoluble wood pellet was then hydrolyzed with amyloglucosidase to break down the starches into sugars and assayed colorimetrically in a spectrophotometer for glucose. Starch concentrations were then calculated from those readings based upon standard curves.

Vigor of trees was visually evaluated in 2002 to compare with original 1999 assessments. Study trees were cored in May-June 2002, mounted into blocks and sanded smooth, and ring-widths measured to the nearest 0.01mm on an optical measuring bench. Basal area increment was calculated from ring-width and tree diameter, and the average post-ice storm basal area (1998-2001) compared with annual growth for the years immediately prior to the ice storm (1995-1997).

Results were analyzed for differences among crown damage levels within a site for each year using a one-way ANOVA. Rejection level for significant differences was set at alpha = 0.10.

Results & Discussion

Levels of root starch were significantly lower with increasing crown damage at both sites in the first year, with trees in the highest damage classes having 58% lower root starch than undamaged trees in 1998, and 36% lower in 1999 (Figures 3, Figure 4). There was a tendency for root starch to be lower with increasing levels of damage in subsequent years, however these did not often achieve significance. Stem starch was lower at the Guillemette site in 1998, but this did not persist beyond the first growing season. Conversely, stem starch at the Rose site was not significantly different in 1998, but was in 1999. Root total sugar was not significantly different among damage classes at either site in any year. Stem total sugar was not different for any damage class in any year at the Rose site, but was different for all years except 2000 at the Guillemette site, although these differences were marginal.

In general, there was a tendency towards higher levels of starch or sugar in less damaged trees. This was more the case for root starches than stem starches, and more the case for starches than sugars.

Interestingly, year-to-year variation in levels of starches and sugars tended to be considerably higher than differences related to crown damage. Accumulated root starch in 1999 and 2001 at both sites was much lower than the 1998 and 2000 levels (approximately about one-third as much) at both sites: stem starch in 1999 was lower than 1998 by nearly half **(Figures 3 and 4).** We suspect that the differences found in carbohydrates between the different years were highly influenced by the conditions prevalent during the growing season of each year. The growing season of 1998 was very good, with adequate rainfall and sunshine allowing for rapid crown regeneration. In contrast, June through August of 1999 were very dry. This likely limited photosynthesis during much of that growing season. The growing season of 2001 was similarly dry, with similar patterns in carbohydrate reserves. Large reductions in fall carbohydrate levels from sites in New York were noted when 1999 levels were compared to 1998 levels (K. Baggett, unpublished). It is interesting that these year-to-year differences are much larger in magnitude than the effects of ice storm damage on starch accumulation, which calls into question the physiological and ecological significance of the ice storm on long-term tree growth and survival on surviving trees. Had the growing season immediately after the January 1998 storm been less conducive to recovery, or other stresses been present at high levels, the impacts on carbohydrate levels, vigor, growth and survival might have been profoundly different.

Post-ice storm basal area growth of trees showed a decreasing trend with increasing levels of damage in both study sites (Figure 5), although due to high variability the effect was not significant. Basal area increment tended to be lower than in the years immediately preceding the ice storm at the Rose site with less fertile soils, but higher at the Guillemette site with calcium-rich soils.

Sugar maple is widely recognized as a calcium-demanding species (Wilmot 2000), so radial growth may have recovered faster at the Guillemette site because of higher levels of soil calcium

Tree vigor was significantly lower with increasing levels of crown damage in 1999 at both sites (Figure 6). When reassessed five years later (2002), vigor was still significantly lower with higher levels of crown damage at the Rose site, but not at the Guillemette site, again suggesting that recovery was mediated to some degree by soil nutrition.

There was no mortality of any of the study trees at either site up to five years following the ice storm.

Summary

•Carbohydrate storage, especially root starch, was reduced according to the level of crown loss following the first growing season after the ice storm.

•Root sugar, stem starch, and stem sugar tended to be less sensitive to the level of crown loss than root starch.

•The effects of the ice storm on root and stem carbohydrates largely disappeared by 2-4 years post-storm, perhaps reflecting a stimulatory effect caused by stand thinning allowing crowns of affected trees to expand into newly opened space.

•Large year-year changes in carbohydrate storage were evident, probably resulting from varying precipitation levels.

•There was no mortality of affected trees up to four years after the ice storm, regardless of the amount of crown damage.

•Radial growth rates after the ice storm were not significantly different than those before the ice storm, but tended to be somewhat lower in trees with increased levels of crown damage.

•Vigor of affected trees was lower in the second growing season following the ice storm at both sites, but on the more fertile site had recovered to match that of undamaged trees after five growing seasons, whereas on less fertile sites, the vigor of more highly crown damaged trees lagged behind those that had not been damaged or were less damaged.

These results suggest that sugar maple is rather resilient to even high levels of crown damage, but carbohydrate levels, vigor, and growth, and perhaps survival of affected sugar maple may be significantly modulated by stresses, growing season characteristics, and soil nutrition post-damage.

The lack of short-term mortality as well as the apparent strong recovery of growth and vigor in even highly-damaged trees suggest that maple producers and forest managers should not be overly hasty when considering a salvage cut in sugarbushes damaged by ice storms.

Acknowledgements

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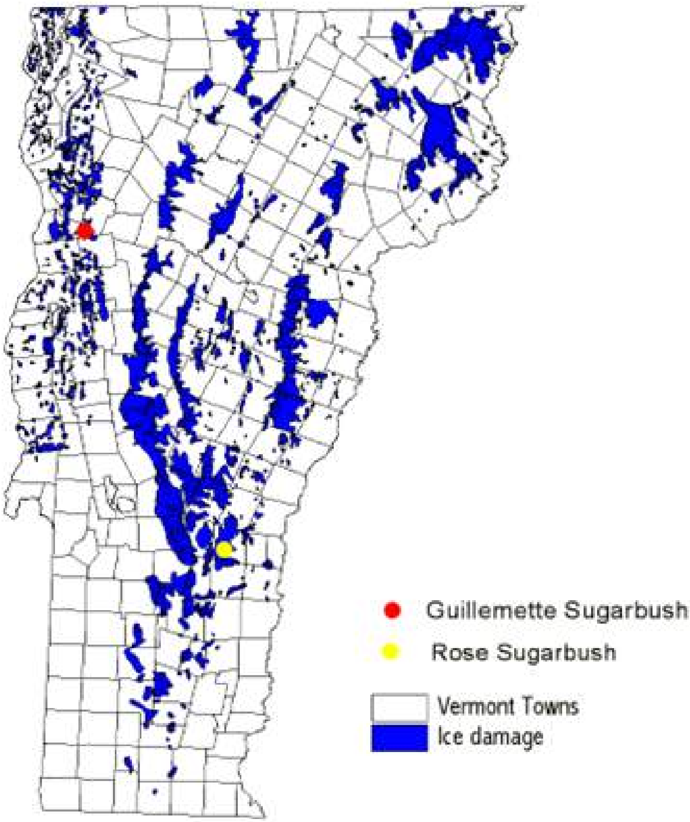


Figure 1. Vermont forestland damaged by the ice storm of January 1998 and location of two sugarbushes sampled for wood carbohydrate reserves in November 1998, 1999, 2000, and 2001 mapping of ice damage by Vermont Separtment of Forest, Parks & Recreation.

Figure 2. Damaged sugar maples at the Rose sugarbush in Reading, Vermont, on the morning of January 12, 1998. Photo credit: Sumner Williams, University of Vermont.

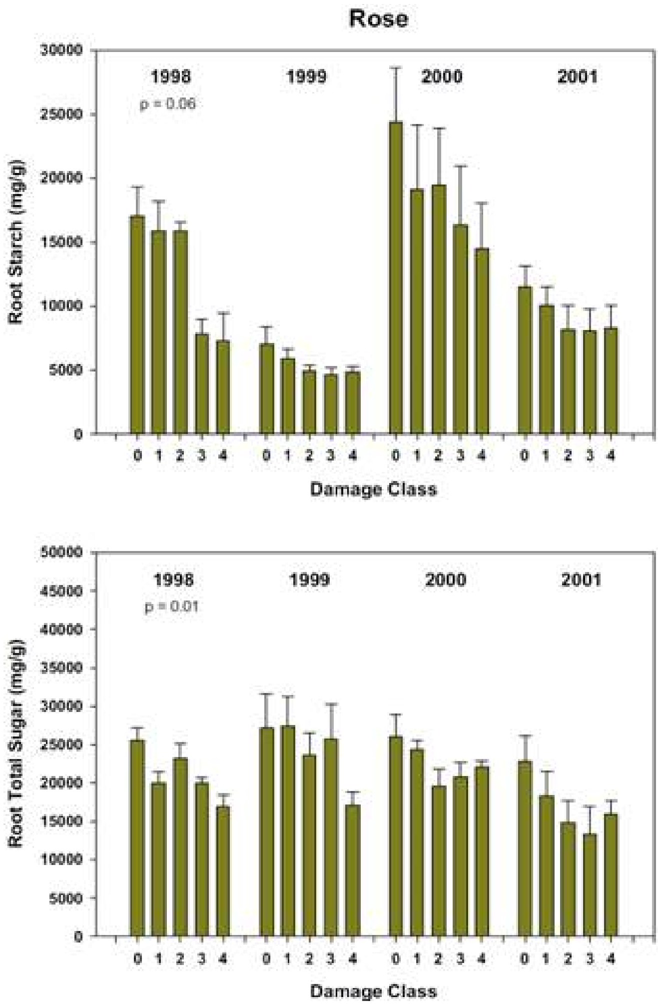
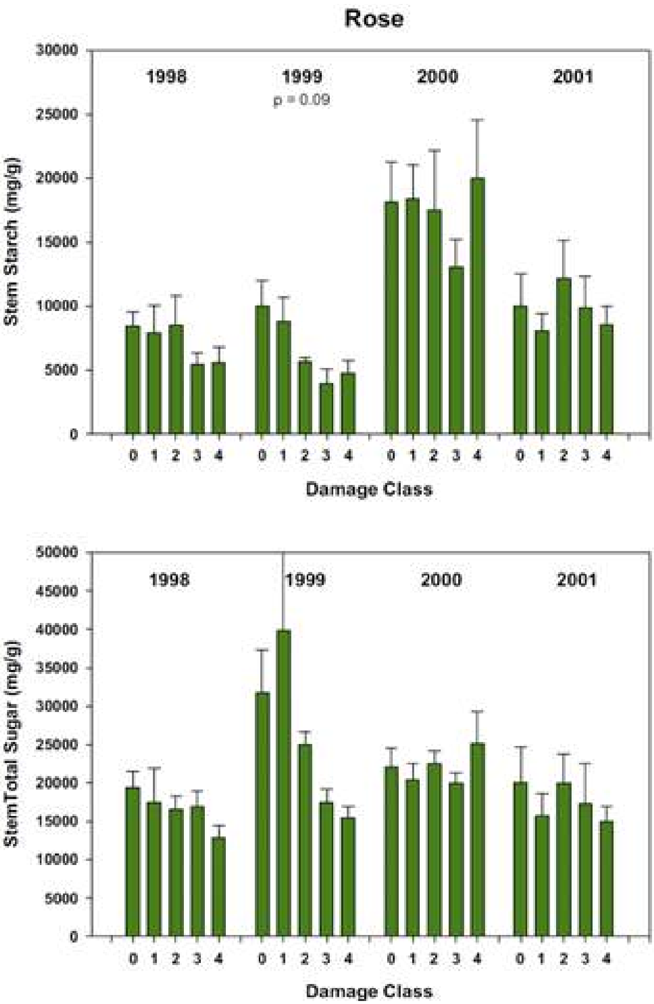
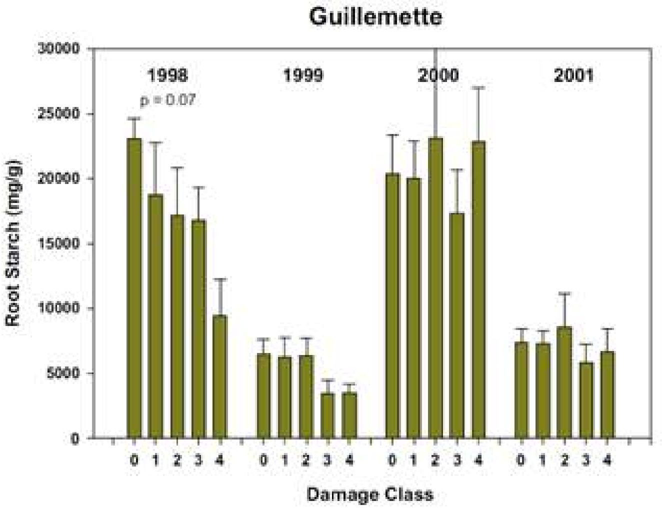


Figure 3. Carbohydrate (Root Starch, Stem Starch, Root Sugars, and Stem Sug
sugarbush. Significance values are shown for any variable comparison across



gars) by damage class in November 1998, 1999, 2000, and 2001, in the Rose
damage class achieving an alpha level < 0.10.



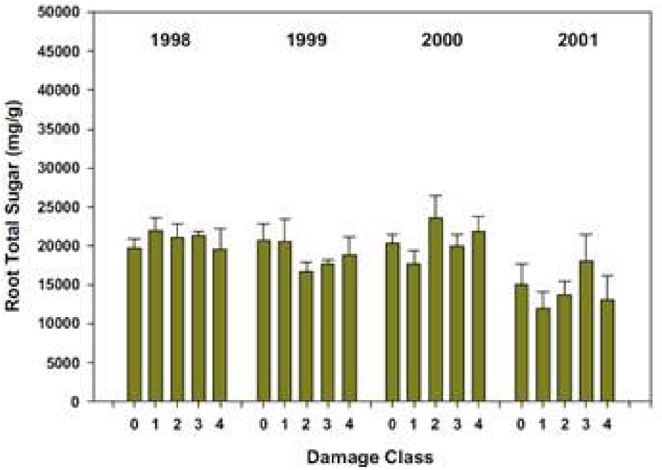
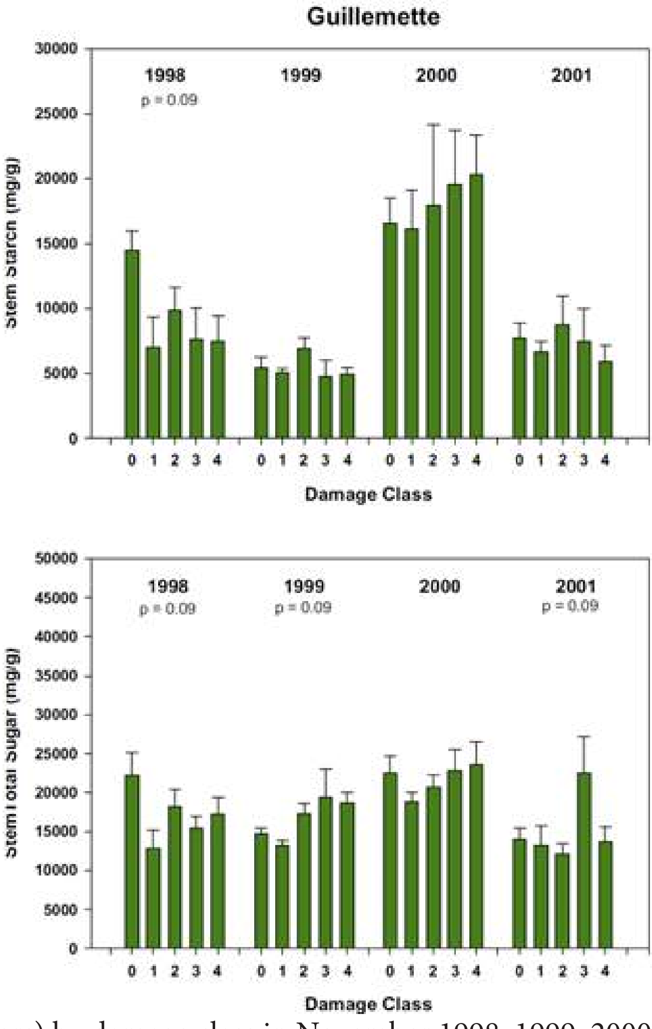


Figure 4. Carbohydrate (Root Starch, Stem Starch, Root Sugars, and Stem Sug
lemette sugarbush. Significance values are shown for any variable compariso



gars) by damage class in November 1998, 1999, 2000, and 2001, in the Guil-
n across damage class achieving an alpha level < 0.10.

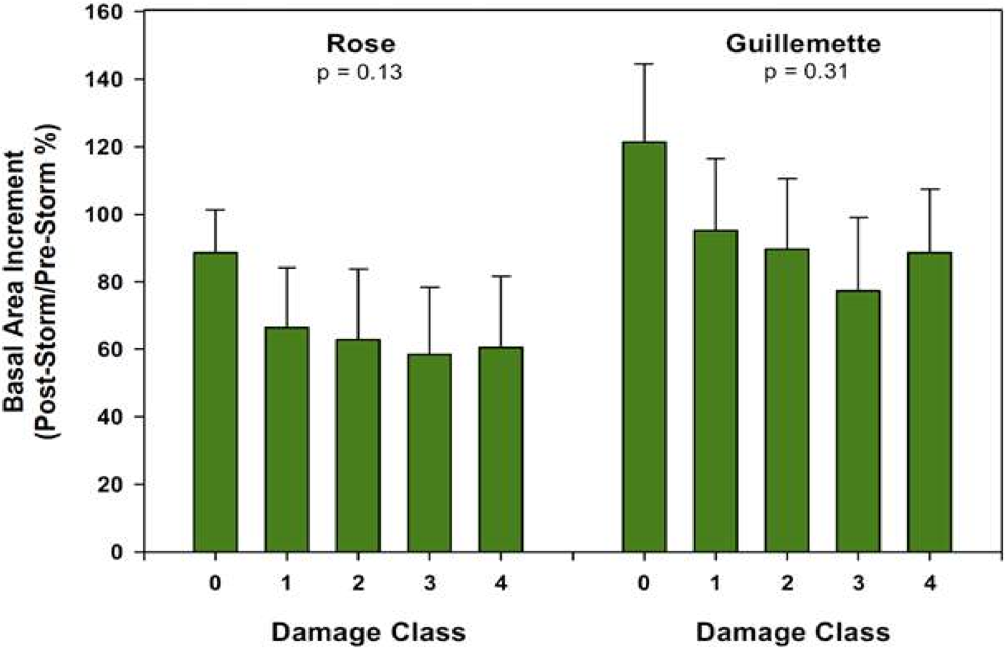
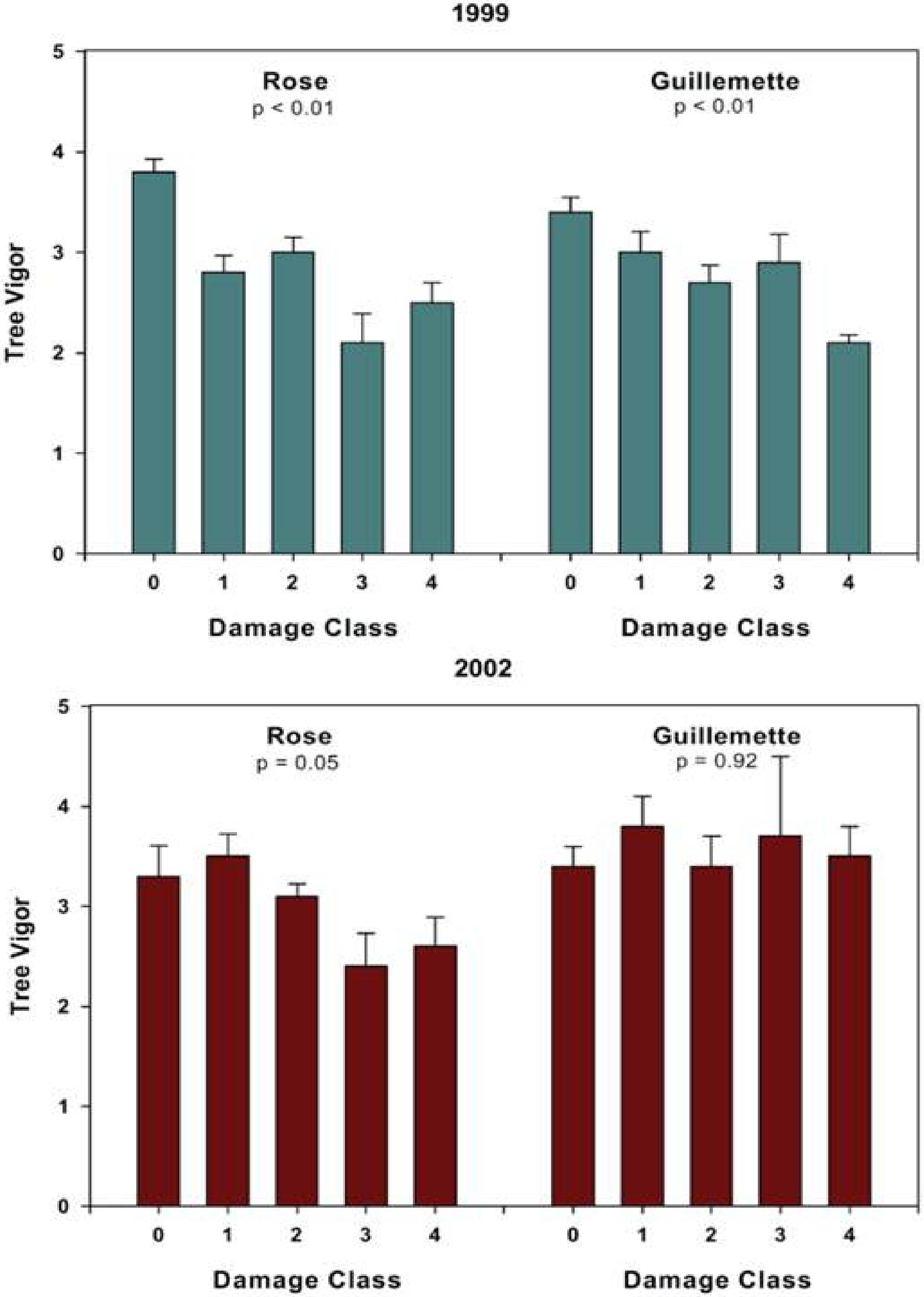


Figure 5. Radial stem growth expressed as post-ice storm basal area increment as a percentage of pre-ice storm basal area increment by damage class in two sugarbushes impacted by the January 1998 ice storm. Significance values are shown.

Figure 6. Vigor of trees by damage class in Vermont two sugarbushes two years (top) and five years (bottom) after the January 1998 ice storm. Significance values are shown. Figure 6. Vigor of trees by damage class in Vermont two sugarbushes two years (top) and five years (bottom) after the January 1998 ice storm. Significance values are shown. Figure 6. Vigor of trees by damage class in Vermont two sugarbushes two years (top) and five years (bottom) after the January 1998 ice storm. Significance values are shown. (page 35)


1999
Rose
p < 0.01
Guillemette
p < 0.01
Tree Vigor
5
4
3
2
1
0
0
1
2
3
4
Damage Class
0
1
2
3
4
Damage Class
2002
Rose
p = 0.05
Guillemette
p = 0.92
Tree Vigor
5
4
3
2
1
0
0
1
2
3
4
Damage Class
0
1
2
3
4
Damage Class