Assessing the Potential of Reduction Pruning in Mitigating the Risk of Branch Failure

By John W. Goodfellow and Andreas Detter

Abstract:

Branch reduction pruning reduces load-induced stress, thereby decreasing the likelihood of structural failure of a branch and reducing risk to targets below. Reduction pruning is a descriptive term that describes pruning intended to reduce the profile of a branch. Quantitative studies were performed that demonstrated that reduction pruning that is compliant with appropriate industry standards and best management practices can achieve approximately 50% reduction in stress in the critical fracture zone where the branch is most likely to fail. A qualitative assessment of branch reduction pruning demonstrates that it can be a cost-effective alternative to the removal of an entire branch.

Introduction

Arborists have become increasingly aware of the risks associated with hazard trees over the last several years. As a result, research has focused on the structural integrity of whole trees. More recently, the issue of branch failure within the crowns of trees has begun to receive attention. A gathering of some 200 practitioners in September 2012 at the Morton Arboretum[1] identified the failure of branches as a leading cause of damage and a significant concern shared by utility, commercial, and municipal arborists. Subsequently, a gathering of tree biomechanics researchers identified crown and branch reduction as the third highest research priority. The need for research into the efficacy of reduction pruning as a means of reducing risks scored closely behind the need to improve our understanding of tree growth response to stress, and to improve visual condition assessment techniques focused on the potential for structural failures.

Small- to medium-diameter (2-8 cm) branches adjacent to and above energized conductors in the upper crowns of trees present a substantial risk to electric system reliability. This is particularly true under ice and snow loading conditions. This point was clearly demonstrated in New England in late October 2011, when a Nor'easter brought significant accumulations of heavy wet snow across New England. As a result, millions lost power, some for over a week.

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[1] *Tree Risk Assessment Symposium: The Biomechanics of Stability, Strength, and Structure,* Morton Arboretum, September 24-25, 2012

Quantitative and qualitative assessments were performed to evaluate the efficacy of branch reduction pruning.

This article generally describes findings from a research project that considered the possibility that selective reduction of high-risk branches may be an effective means of reducing the likelihood of their structural failure, thereby reducing associated risks. The industry standard[2] defines reduction pruning as pruning to decrease height and/or spread of a branch. The current industry Best Management Practice[3] uses the term "subordination" as a synonym for reduction (e.g., *"leaders may be subordinated or reduced in length"*). The focus of this investigation was reduction pruning as a means of reducing branch size (length, width, depth, and mass).

Ice and snow loads on branches create relatively static unidirectional force (gravity), which may be considered as a pre-stressed cantilevered beam. The focus on snow and ice loading simplified the experimental design. In contrast, the force applied by wind loading is dynamic and more difficult to simulate.

There are several mechanisms at play when considering reduction pruning as a means of reducing risk. First, branch reduction effectively shortens the lever arm, thereby reducing leverage as a branch is loaded. Secondly, reduction pruning reduces the mass of the branch. Thirdly, the surface area available for accumulation of ice and snow is reduced, resulting in less loading. These first three points all act to reduce stress on the branch, and lower stress is expected to reduce the probability of branch failure. The reduction in the mass of a reduced branch diminishes the force of impact should the branch fail and fall into conductors. Finally, by reducing the size of the branch, its target area is also decreased making it less likely to adversely impact conductors should it fail.

A review of the literature related to branch reduction pruning was conducted as part of this project. A general observation is that there is a surprising lack of published research on the topic of reduction pruning, particularly as a means of reducing the risk of branch failure. In this study we were primarily interested in literature regarding the effect of reduction pruning on the degree of branch deflection and the likelihood of failure. Unfortunately, we found no experimental research on these topics.

The Experiment

The project involved loading a branch by simulating an accumulation of one-half inch of ice followed by progressive pruning to reduce its overall profile.

The field work was completed at the Davey Tree Company's research arboretum in Shalersville, Portage County, Ohio. This is the same site as was used in the previously-referenced branch

[2] ANSI A300 (Part 1) 2008 Pruning §4.34
[3] BMP: Utility Pruning of Trees

failure investigation. This site also hosted ISA Tree Biomechanics Week in August 2010, and will again in August 2013.

The trees selected for branch reduction pruning were located along the edge of the planting blocks. The individual branches selected for reduction were located in mid to upper crown positions, and ranged in orientation from near horizontal to an upright orientation. Thirty-two branches from four different species of trees were selected for testing.

The purpose of this investigation was to evaluate the efficacy of branch reduction pruning in reducing stress in the location branches would likely fail under static loading due to accumulation of ice or heavy wet snow. Because ice accretion was more easily simulated, it was selected as the loading condition. An accumulation of 1/2 inch (1.2 cm) was selected as a likely loading scenario. The volume of ice was calculated for each branch segment targeted for reduction.

The definition of pruning dose used was intentionally worded to be operationally practical and easily adopted by working line clearance crew personnel. A full pruning dose was defined as branch reduction to the full extent possible, while still maintaining compliance with industry standards and practices. In actual practice the amount of reduction in area achieved by the arboricultural technicians varied considerably. Branch allometry naturally varies, and pruning cuts were placed at appropriate nodes rather than at fixed distances. As a result, the amount of reduction achieved by experienced arboriculture technicians was variable.

Direct observations of the force being applied, branch deflection, and fiber strain were used to confirm the validity of the test protocol. The bending moment at the base of the branch in the Critical Fracture Zone (CFZ) where a branch is likely to fail was calculated for each pruning dose. Bending moment describes the force being created by loading the branch.

As expected, a correlation was identified between pruning dose and reduction in bending moment in the CFZ. Branch reduction pruning reduced the force (stress, defined as bending moment) exerted in the area where a branch is most likely to break. An average reduction in bending moment (stress) in the CFZ of 50% was achieved with the full reduction dose. The lighter reduction dose achieved an average 22% reduction in stress and may be an appropriate alternative for commercial and municipal arborists in applications where greater risks of branch failure can be tolerated. These results demonstrate that reduction pruning is an effective means of reducing stress in the CFZ and therefore the probability of branch failure.

Summary & Conclusions

This research project provides quantitative evidence that branch reduction pruning reduces load-induced stress, thereby the likelihood of structural failure. The recommended branch reduction pruning practices of interest to utility arborists will reduce stress on average by one half. A lighter reduction, while less effective, was shown to reduce stress by one quarter, and may be of interest to other arborists and applicable to situations with greater risk tolerances.

A qualitative assessment of branch reduction pruning demonstrates that it can be a cost-effective alternative to the removal of an entire branch.

The research was intended to be operationally relevant. A practical definition of reduction dose was selected, which in retrospect introduced variability. Ice loading was modeled and assumptions have made that stress imposed on a branch will be similar under snow loading. Tests were carried out on four species which are assumed to be representative of the utility forest.

Regardless of these limitations, the practical bias reflected in this project supported development of recommendation that should be easily incorporated into distribution vegetation maintenance specification.

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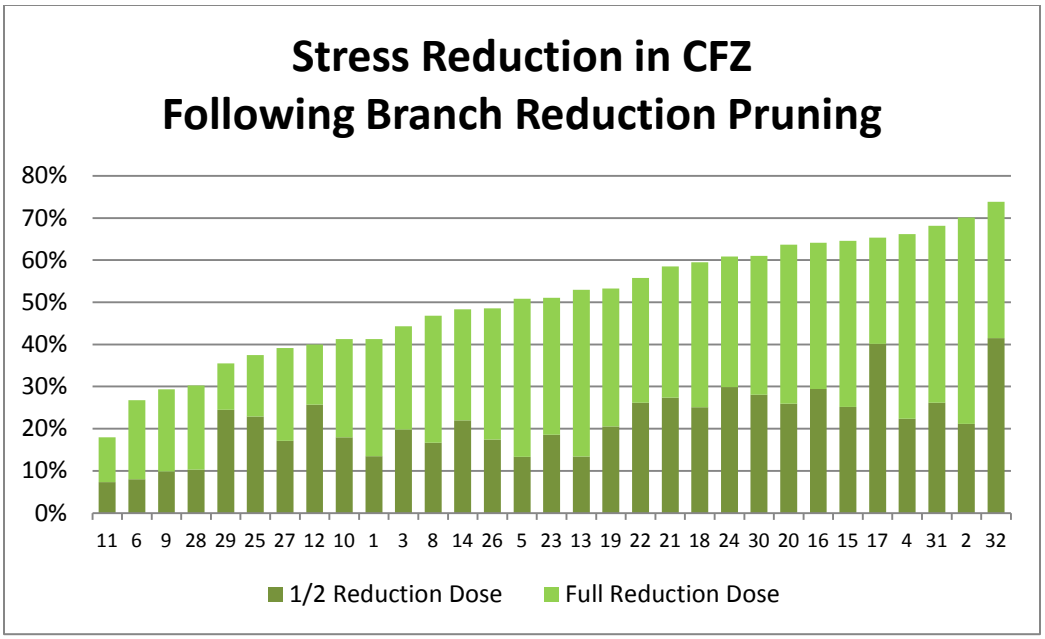
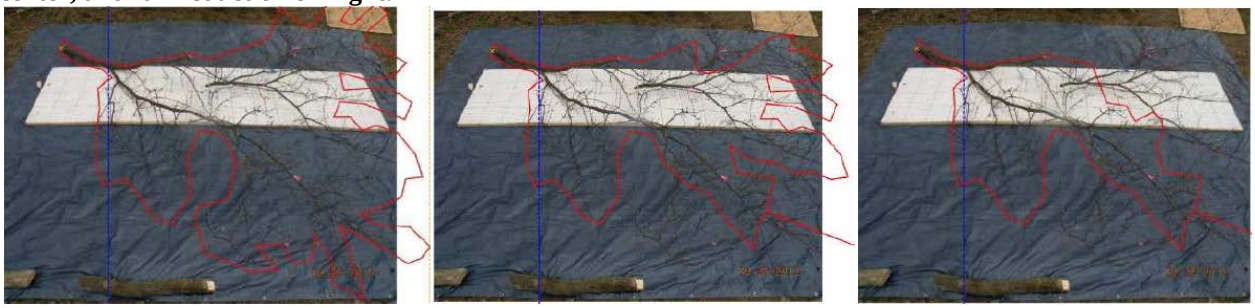


Reduction in bending moment following branch reduction pruning in the region where the branch is most likely to fail structurally.

An example of a series of progressive branch reductions. Full branch on left, first order reduction in center, and full reduction on right.



A branch subjected to load line tension and simulated weight of ice added to segments to be removed, prior to pruning.