Influence of Commercial Thinning on Resistance to and Recovery from Defoliation in Spruce-Fir Forests

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This study revealed that commercial thinning shifted carbohydrate allocation from storage reserves to growth in both red spruce and balsam fir. This change in allocation suggests that thinned stands will suffer greater mortality and slower post-defoliation recovery than unthinned stands in a spruce budworm outbreak.

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http://www.nsrcforest.org

Project Summary

Eastern spruce budworm has plagued spruce-fir ecosystems for centuries, causing widespread defoliation, loss of productivity and mortality. To manage this type of stress, trees have developed two strategies, tolerance and defense, and survival depends on the appropriate balance between these two strategies. A tree's capacity for recovery after consecutive years of defoliation typical of spruce budworm outbreak is linked to the pool of nonstructural carbohydrates (NSC) available to stimulate growth of latent buds and recover leaf area. While commercial thinning treatments have the potential to increase NSC pools, studies during past outbreaks have shown that thinning has a complicated effect on outbreak severity and duration. Secondary defensive compounds, such as soluble phenolics, may provide resistance to defoliation caused by the spruce budworm and other herbivores. This study evaluates the eco-physiological responses of red spruce and balsam fir to stand-level thinning and artificial defoliation treatments across three experimental locations throughout the state of Maine. In contrast to carbohydrate allocation theory, the results of this study suggest that stand level thinning treatments lower the NSC available to both species. This could leave trees within thinned stands vulnerable during an outbreak. The production of secondary defensive compounds was not found to be affected by the artificial defoliation treatment. Interestingly, balsam fir was found to maintain higher concentrations of nonstructural carbohydrates and tannic acid equivalence than red spruce. The results reported in this study should mean that balsam fir is better adapted to withstand defoliation caused by the spruce budworm; however, this is not the trend that has been reported historically when defoliation and mortality of the species are compared.

Background and Justification

- Previous studies have found an association between stand structure and composition and intensity of tree mortality and loss of productivity following spruce budworm outbreaks.
- At the stand-level, the detrimental effects of defoliation in spruce-fir stands is negatively correlated with percent balsam fir and lessens with spruce composition.
- Commercial thinning has been reported to have both negative and positive effects on budworm damage.
- However, the physiological basis for those phenomena are not understood.

Above: eastern spruce budworm
Below: damage during 1980s outbreak
(Maine Forest Service photos)

Background and Justification

- Host tree defenses include resistance to damage and resilience in recovery post-damage.
- Resistance stems from less palatable foliage, largely due to phenolic compounds such as tannins.
- Resilience post-defoliation stems from the availability of non-structural carbohydrate reserves that can be used for re-foliating.

Above: balsam fir foliage
Below: red spruce foliage
(M.E. Day photos)

Methods

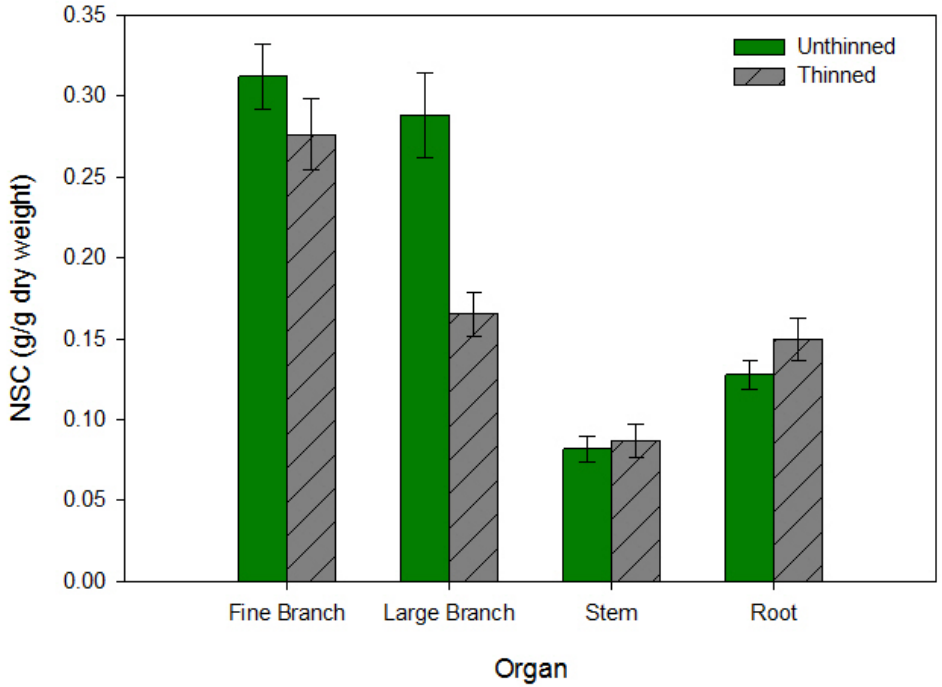
- Research sites were ‘piggy-backed’ on three Maine Cooperative Forest Research Unit’s Commercial Thinning Study sites.
- Non-structural carbohydrate concentrations were measured in branches, boles and roots of balsam fir trees in both unthinned and thinned plots.
- To ascertain biochemical response to defoliation, branches in the thinned plots were artificially defoliated by removing all no needles (control), all foliage or by clipping all needles in half.
- Needles produced the following growing season were tested for total phenolic content.

Above: applying defoliation treatments
Left: experimental sites

Results/Project Outcomes

- Both spruce and fir showed significant decreases in non-structural carbohydrate pools in thinned compared to unthinned control stands.

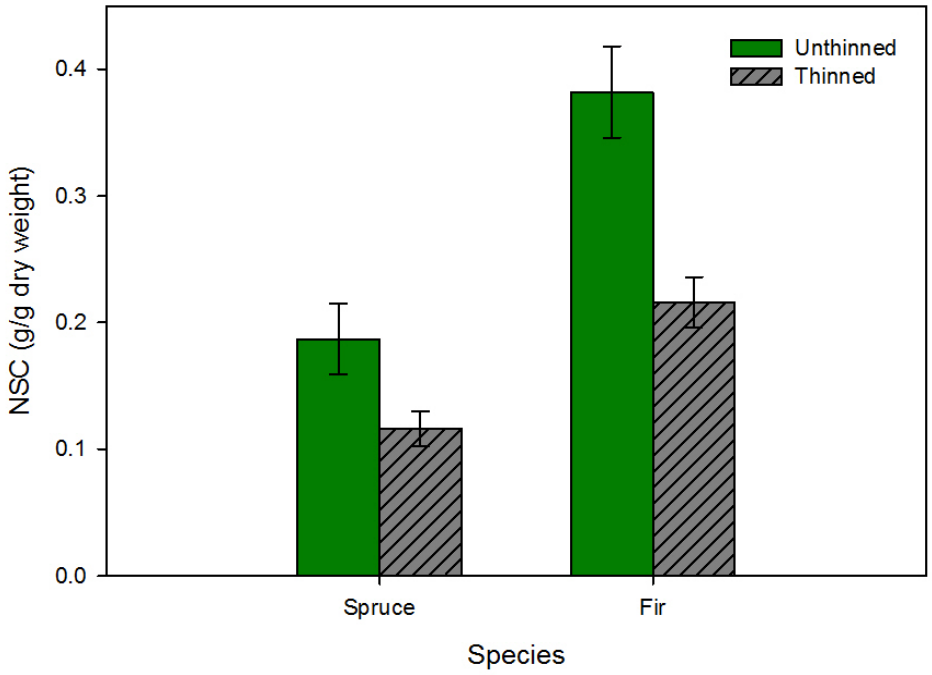
- The largest decreases were in the branches, those pools most accessible for supplying carbohydrates to developing foliage.



Non-structural carbohydrate concentrations in woody tissue of red spruce and balsam fir in thinned and unthinned stands. Bars indicate stand errors.

Results/Project Outcomes

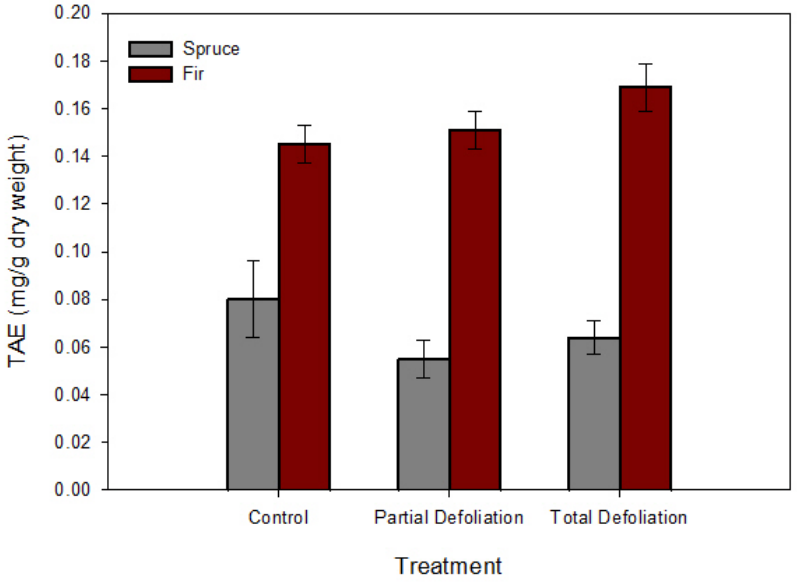
- In both thinned and non-thinned treatments and across sites, balsam fir had greater non-structural carbohydrate concentrations than red spruce, suggesting that carbon physiology may not be a principle factor explaining differential damage during budworm outbreaks.
- Artificial defoliation treatments did not stimulate production of defensive phenolics in either spruce or fir.



Non-structural carbohydrate concentrations in branches of red spruce and balsam fir in thinned and unthinned stands. Bars indicate stand errors.

Implications and applications in the Northern Forest region

- Commercial thinning shifts carbon allocation patterns from storage reserves to growth in both red spruce and balsam fir, decreasing their ability to produce new foliage and increasing their susceptibility to mortality and loss of productivity in spruce budworm outbreaks.
- Defoliation does not enhance resistance to defoliators by increasing phenolic content of needles in either species.



Phenolic concentrations in tannic acid equilivents following artificial defoliation treatments in red spruce and balsam fir. Bars indicate stand errors.

Future directions

- While this study suggests that commercial thinning increases the susceptibility to damage from spruce budworm in red spruce and balsam fir, the design and available sites did not permit evaluation of effects due to thinning intensity and time since treatment.
- Other possible herbivore defense mechanisms, both constitutive and induced, should be evaluated.

List of products

- Langley, C.J. Influence of Commercial Thinning on Resistance to and Recovery from Defoliation in Spruce-Fir Forests. Master of Science thesis. Expected completion December 2016.
- Langley, C.J., M.E. Day and B. Roth. Capacity for Recovery, Influence of Commercial Thinning and Resistance to Defoliation in Spruce-Fir Forests. Accepted oral presentation for the ECANUSA Forest Science Conference. Burligton, VT, September 30 to October 1, 2016.
- Langley, C.J., and M.E. Day. Capacity for recovery, influence of commercial thinning and resistance to defoliation in spruce-fir forests. Oral presentation. Annual Winter Meeting of the New England Society of American Foresters. Sturbridge , MA. March 2016.
- Day, M.E. and C.J. Langley. Influence of commercial thinning on recovery from defoliation in spruce-fir forests. Cooperative Forest Research Unit Fall Field Tour. Irving Woodlands T6R6 WELS, ME. October 2015.
- Langley, C.J. and M.E. Day. Capacity for recovery from defoliation in commercially thinned spruce-fir forests. Acadia Science Symposium. Schoodic Institute, Winter Harbor, ME. October 2015.