SITE AND NUTRIENT FACTORS CAN INFLUENCE CONIFER RESISTANCE TO INSECT ATTACK

Stephen Cook
Department of Plant, Soil and Entomological Sciences
University of Idaho
Managing Insect ‘Pests’ = Stand Management

- Stand Density
- Stand Composition
- Stand Age

Douglas-fir tussock moth infestation

‘Typical’ bark beetle infestation
If you are an insect – there is a problem with using plants as food and two primary questions must be addressed:

• Nutritionally – what do plants (or various plant parts) offer insects?

• What do insects need for optimal growth and reproduction?
Plants can be thought of as a dilute nutrient soup (i.e. amino acids and sugars) in a matrix of structural compounds (such as cellulose and lignin) and allelochemicals (that can include quantitative/qualitative toxins, such as tannins or terpenes respectively).

**NITROGEN**

- Insects need all of the ‘normal’ nutrient requirements plus a source of sterols
- Nutrient ratios are not similar across species or plant parts

Xylem tissue is roughly 10X lower in N then is phloem tissue

Xylem tissue has roughly half the N as foliage

So – how does what an insect eats impact development?
Nitrogen

• N is essential to organic life on earth
  • It is a building block for proteins and proteins are the structural material for building insects
  • In insects, proteins > 50% of cuticular dry weight
  • Bulk of plant tissue is comprised of carbohydrates (cellulose, lignin, etc)

• Although it is a common chemical in the atmosphere – N is not very available in a usable form

• N is also frequently combined with other elements, making it more difficult for plants/insects to capture and utilize
Nitrogen

• Growth efficiency of insects if often correlated with protein content of their food

• N in plants varies by species, organ, season and environmental factors

• Plant amino acids differ from what is required for insect growth, development and reproduction
Nitrogen

• However, higher total N in plants may not coincide with usable N for insects because several classes of plant defensive chemistry have N as a building block (i.e. alkaloids and tannins)

• These compounds can/do reduce plant digestibility
Can nutrient measurements be used in predicting stand susceptibility?

- Why is rock type important?
  - Different nutrient concentrations.
- Metasedimentary rocks are poor nutrient producers.
  - Nitrogen, Potassium, Sulfur and Boron

Data from: Garriston-Johnson et al. 2003
Forest tree mortality from insect herbivores.
Represented by the red pixels.
From: USDA Forest Service
Same data – closer to home.
In other words, the obvious question became –

Why the bulls-eye on Idaho?
One Hypothesis
Based upon established plant-insect interaction theories.

• There is a continuum within plants of resource allocation between growth and differentiation

• One end of the continuum (in resource rich environments) has plants being selected based upon competition (growth characteristics)

• The other end of the continuum (in resource poor environments) suggests plants are selected based upon herbivore defense (differentiation characteristics)

• Thus – the dilemma faced by plants:
  Grow fast enough to compete with other plants while defending themselves against herbivores and pathogens
Competition and herbivory together will select for certain levels of defense allocation, if there is a cost to defense there is a tradeoff between these strategies.

![Graph showing the relationship between Herbivore pressure, Growth, Competition, and Defense Allocations.]
A plant has a finite amount of energy that is allocated among pools used for growth, reproduction and defense.

In this scenario – growth includes reproduction.

Energy is split between growth activities and ‘defense’ activities.
Where does the developing larva get its N?

How involved are the fungi with larval nutrition?

Does tree nutrition play a role?

Can we modify the relationship between the beetle, its host and its associated fungi by altering some basic tree chemistry?
Review of tree resistance mechanisms

Constitutive Defenses = Resin Flow
To some extent, always present

Induced Response = Hypersensitive Lesion
Occurs following attack (beetle or fungus)
Tree Resistance Mechanisms (continued – but new).

Vertical Resin Canal Comparison:

Lodgepole and Limber pines that resisted or succumbed to attack by MPB.

From: Ferrenberg et al. 2013. Oecolgia (online)
Two field sites:
  • Craig Mountain
  • University of Idaho Experimental Forest

Fertilizer applied to individual trees (fall or winter)
  • Measure inner bark N content
  • Measure resin flow
  • Measure inner bark monoterpane content (in progress)

Controlled laboratory studies focused on:
  • Grosmannia clavigera
  • Ophiostoma montium
What happens when you apply fertilizer:
Fertilizer applied in March, Measurements in July
Change in inner bark N content (dry weight)

<table>
<thead>
<tr>
<th>N treatment</th>
<th>Pre-fertilization</th>
<th>Post-fertilization</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control, 0 lbs/ac</td>
<td>0.50 ± 0.03 a</td>
<td>0.51 ± 0.02</td>
<td>0.04 ± 0.03 a</td>
</tr>
<tr>
<td>Low, 300 lbs/ac</td>
<td>0.52 ± 0.02 a</td>
<td>0.78 ± 0.07</td>
<td>0.31 ± 0.07 b</td>
</tr>
<tr>
<td>High, 600 lbs/ac</td>
<td>0.55 ± 0.03 a</td>
<td>0.75 ± 0.08</td>
<td>0.19 ± 0.11 a</td>
</tr>
</tbody>
</table>

From: Cook et al. 2010
Methods and Results

Correlation between tree inner bark and larval N contents

Pre-attack tree N
Larvae collected the following year

$r = 0.6727$

$P = 0.0675$

From: Cook et al. 2010
Beetle size is usually correlated with survival, dispersal and fecundity. Bigger is better for the beetle.

Tree N and size of SPB

From: Ayres et al. 2000 Ecology
Trophic movement of N:

There will be a different shift in isotopic N content depending on the source of the N acquired by the developing beetle.
Strong linear relationship between N concentration in the growth media and *G. clavigera*

R2 = 0.8116

Weaker relationship when we Examine the *O. montium*

R2 = 0.1801

From: Cook et al. 2010
Soil nitrogen five years after bark beetle infestation in lodgepole pine forests

From: Norton et al. 2015.
Soil Science Society of America Journal (online)
Nitrogen fertilization of individual Trees at 3 concentrations (0, 200 and 400 lbs/ac)

Fertilizer applied October 2007
Resin flow measured in July, 2008

One question to ask – how much is too much?

From: Cook et al. 2015.
Forests (online)
Lodgepole Pine:
Strong negative relationship between Growth and Resistance Mechanisms

From: Cook et al. 2015. Forests (online)
In many ways Mountain Pine Beetle infestations in Whitebark Pine provide a ‘slower-moving’ system in which to examine the interactions.
Stand Compositions are modified following infestations by Mountain Pine Beetle – but at most elevations: there are residual whitebark and lodgepole pines that remain.

Several factors are at play including: climate differences, blister rust intensity, competition, others.

We have initiated a project that also compares chemistry of the residual trees – University of Idaho collaboration with University of Wisconsin and University of Alberta.

Data from: Kendra Schotzko
Let’s look at tree mortality again.
Fertilization and Foliar Chemistry – Impact on Defoliators
Douglas-fir Tussock Moth

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total monoterpenes (mg/g foliar tissue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (0)</td>
<td>7.0 ± 0.9 a</td>
</tr>
<tr>
<td>Low (227 kg/ha)</td>
<td>8.6 ± 1.2 a</td>
</tr>
<tr>
<td>High (454 kg/ha)</td>
<td>6.9 ± 0.6 a</td>
</tr>
</tbody>
</table>

Data from: A. Carroll
Prior work indicates that there were significant differences in the concentration and/or percentage of some individual monoterpenes present in resistant versus susceptible Douglas-fir.

This prior work also showed a decrease in potential fitness of the insect as overall monoterpene concentrations increased.
There were also differences in the %age of N and Sugars between resistant and susceptible Douglas-fir foliage at two sample locations (Colorado and Arizona).
Fertilization and Foliar Chemistry – Impact on Defoliators
Douglas-fir Tussock Moth

<table>
<thead>
<tr>
<th>Treatment N applied</th>
<th>N</th>
<th>B</th>
<th>P</th>
<th>K</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control 0 kg/ha</td>
<td>1.2 ± 0.1</td>
<td>24.2±2.1</td>
<td>0.2±0.01</td>
<td>0.7±0.04</td>
<td>0.1±0.01</td>
</tr>
<tr>
<td>Low 227 kg/ha</td>
<td>1.4 ± 0.2</td>
<td>21.8±4.0</td>
<td>0.2±0.01</td>
<td>0.6±0.05</td>
<td>0.1±0.01</td>
</tr>
<tr>
<td>High 454 kg/ha</td>
<td>1.4 ± 0.1</td>
<td>23.3±3.7</td>
<td>0.2±0.01</td>
<td>0.7±0.04</td>
<td>0.1±0.01</td>
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</tbody>
</table>

- Other elements were also examined
- No change in foliar chemistry based upon fertilization (measured too early)
- Few correlations between individual monoterpenes and individual elements
- Need to refine tests
- Correlations between individual elements and Spruce Budworm performance have been reported

Data from: A. Carroll
Summary

• We can modify tree chemistry in such a way as to impact tree resistance and insect survival.

• By modifying tree chemistry, we can also impact the physical parameters of a tree that are important as resistance parameters.

• Individual treatments need to be assessed in relation to multiple factors including soil type, current pest status, management objectives, etc.

• There is still a lot of work to do and quite a few ‘new’ challenges.

Balsam Woolly Adelgid on Subalpine Fir
Acknowledgements

Funding for various projects from:
• National Science Foundation
• USDA-Forest Service
• USDA-AFRI
• USDA – McIntire-Stennis
• USDA – Hatch

Collaborations include:
• University of Idaho
  • University of Idaho Experimental Forest
  • Inland Empire Tree Nutrition Coop
  • Armando McDonald
  • Graduate students – Amy Carroll, Kendra Schotzko, Brian Shirley

• USDA-Forest Service
  • Multiple National Forests
  • Forest Health protection – Laura Lowery, Carl Jorgensen, Sandy Kegley, John Schwandt, Jim Hoffman

If I left any time – Questions anyone?
Or - If not -