# SITE AND NUTRIENT FACTORS CAN INFLUENCE CONIFER RESISTANCE TO INSECT ATTACK

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# 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

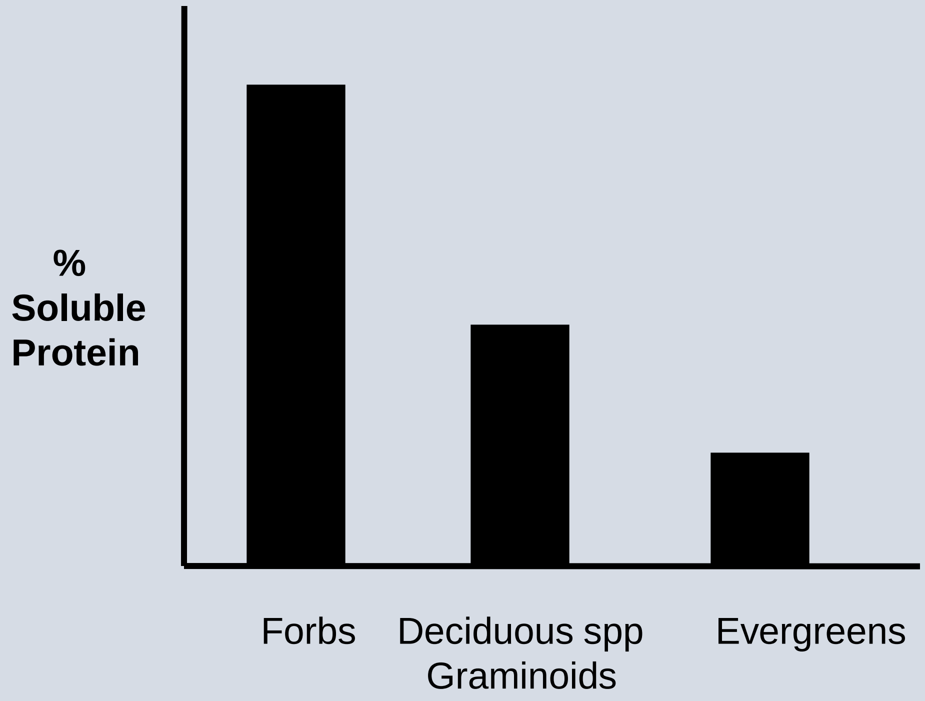
- N is essential to organic life on earth
  - It is a building block for proteins and proteins are the structural material for building insects
  - In insects, proteins > 50% of cuticular dry weight
  - Bulk of plant tissue is comprised of carbohydrates (cellulose, lignin, etc)
- Although it is a common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

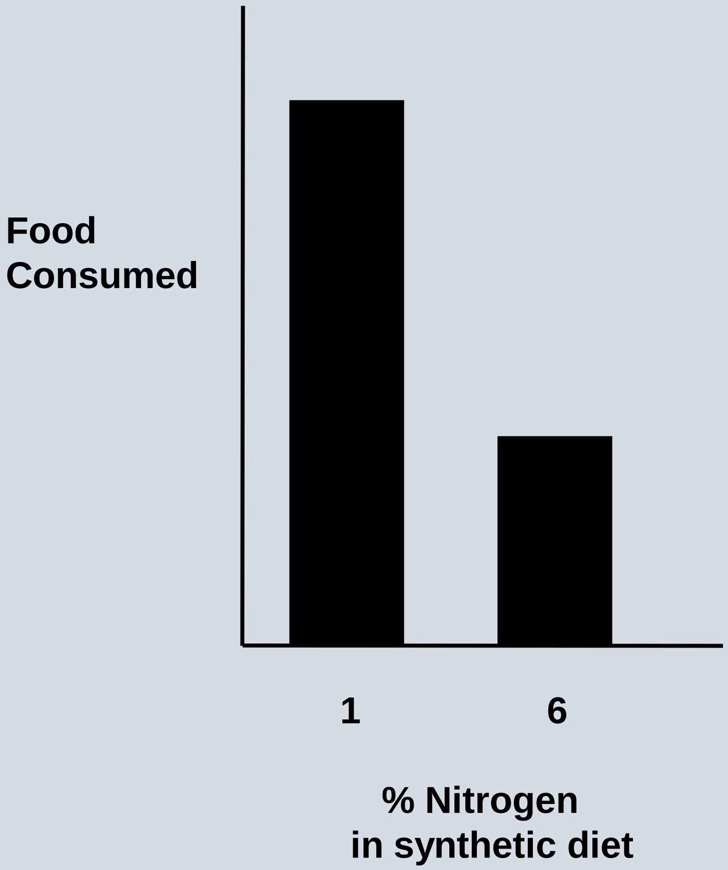
- Growth efficiency of insects if often correlated with protein content of their food

- 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



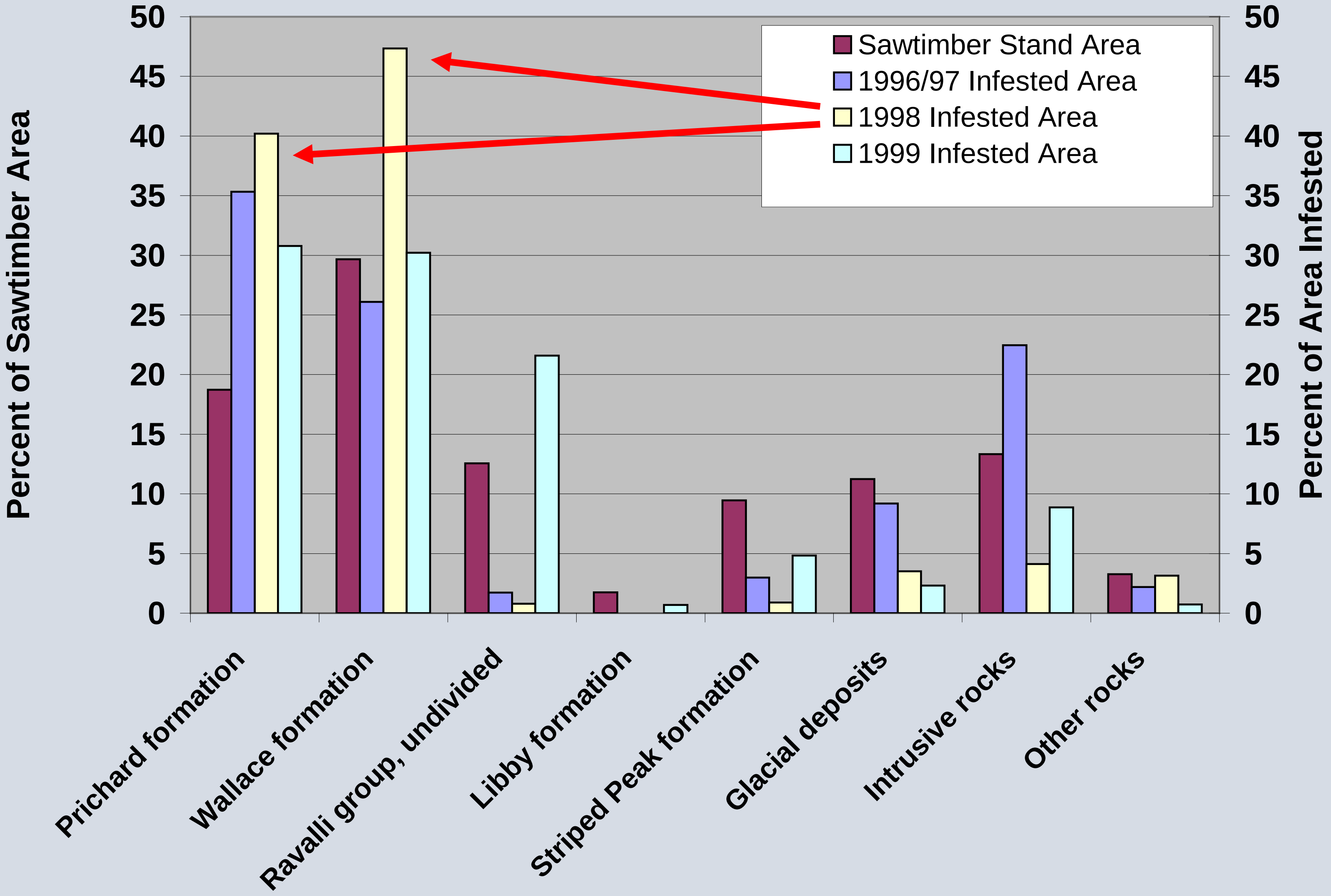
# Nitrogen




- 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

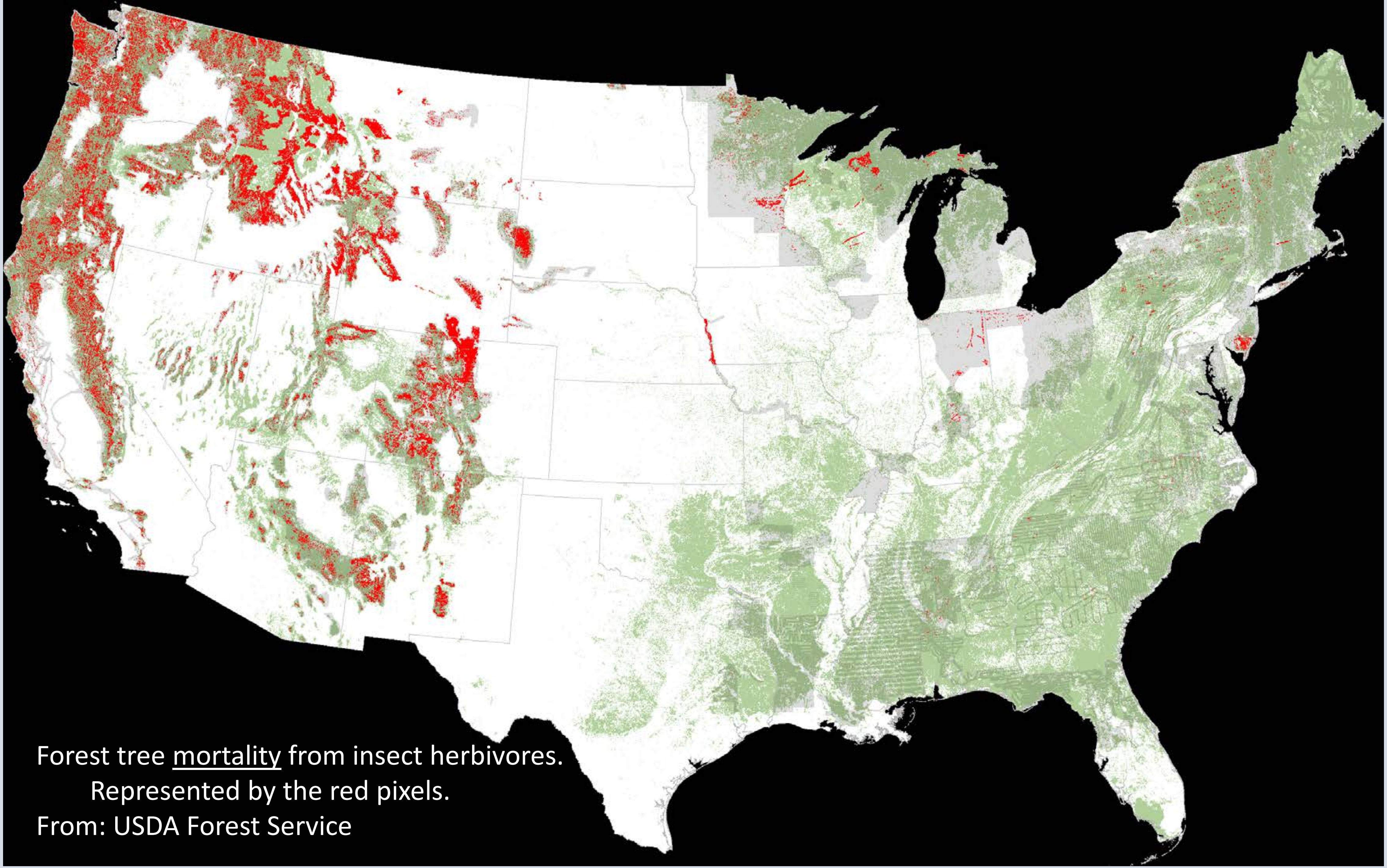
# Can nutrient measurements be used in predicting stand susceptibility?



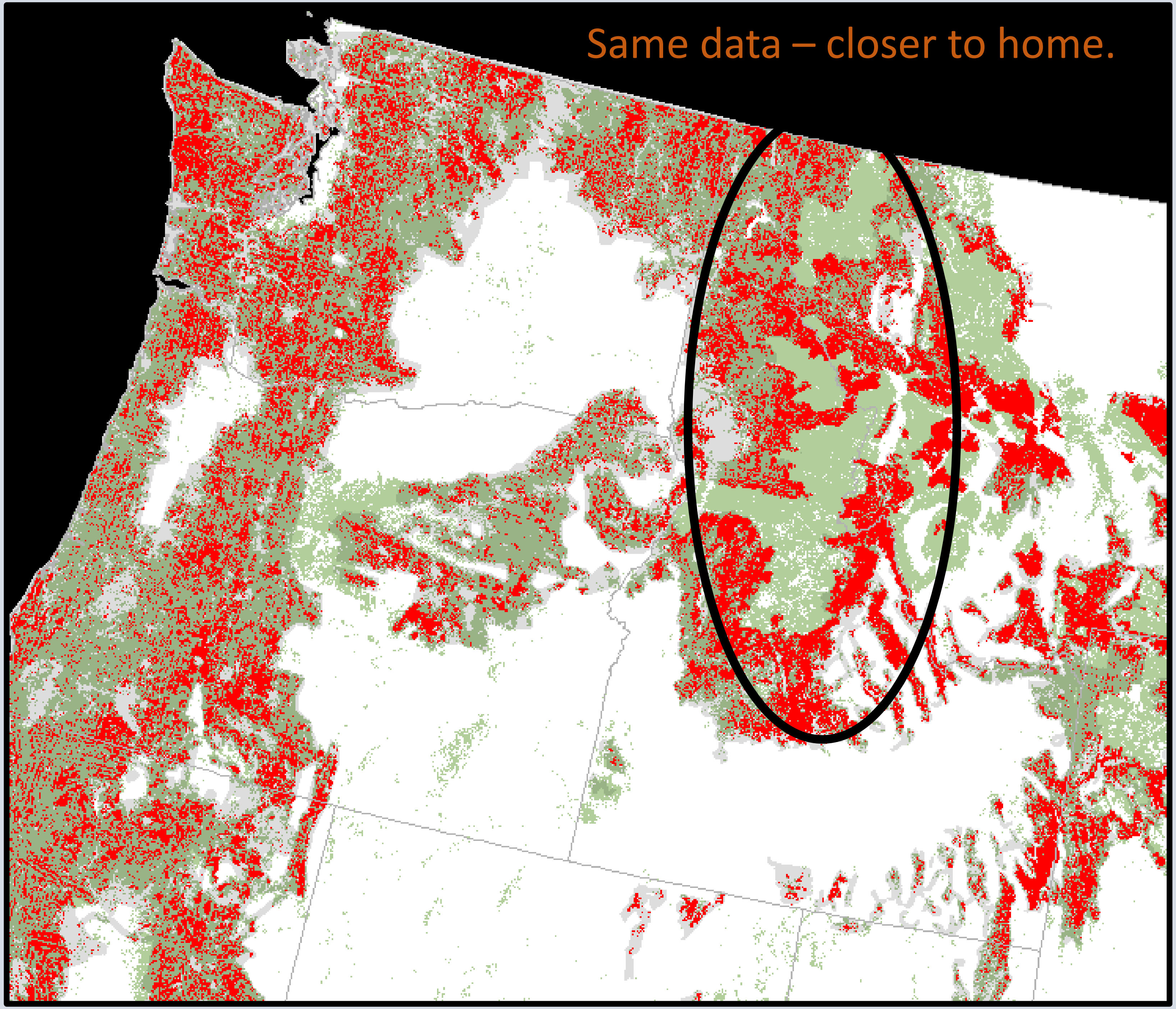

Good Rock – Bad Rock

- 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

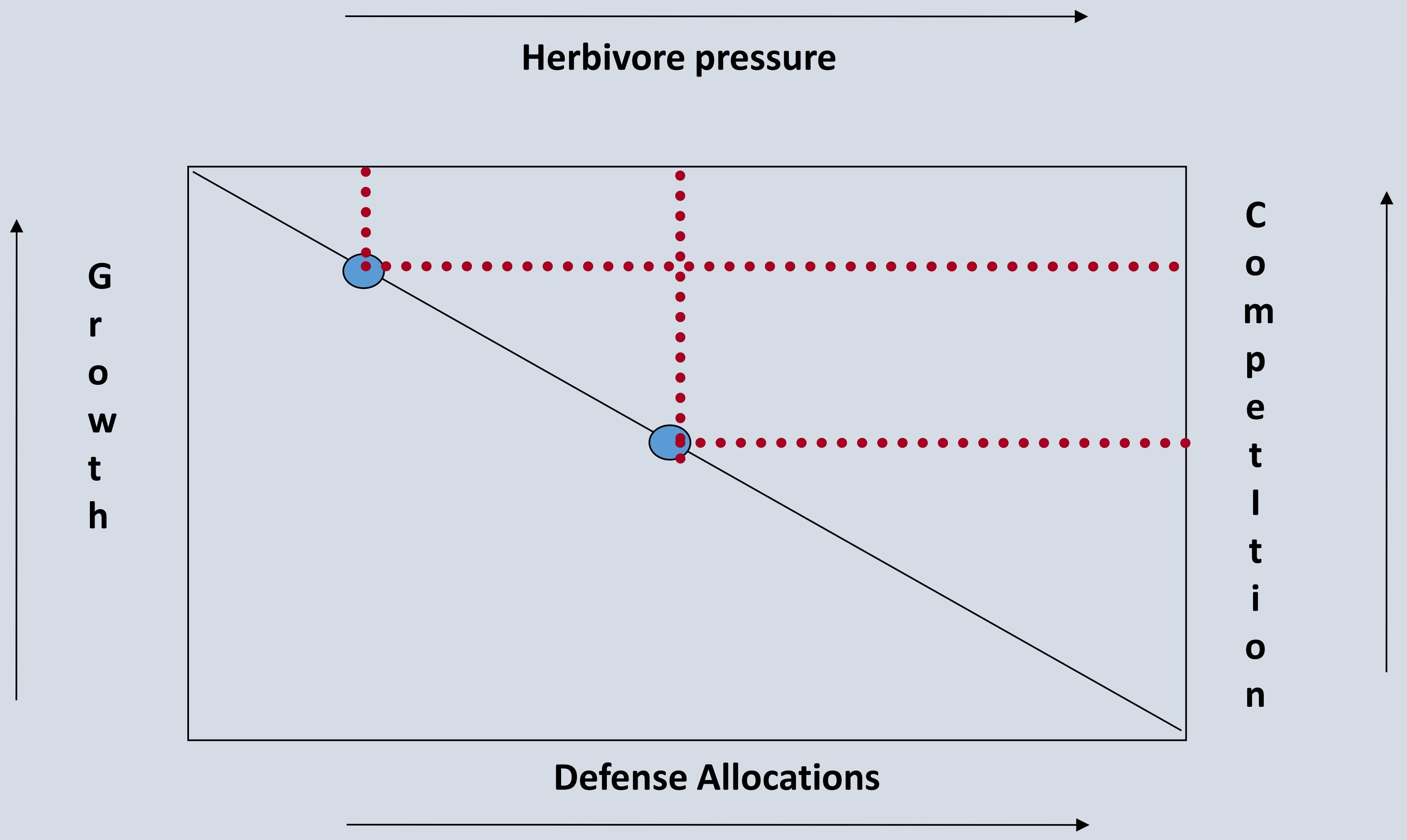
- One end of the continuum (<u>in resource rich environments</u>) has plants being selected based upon competition (growth characteristics)

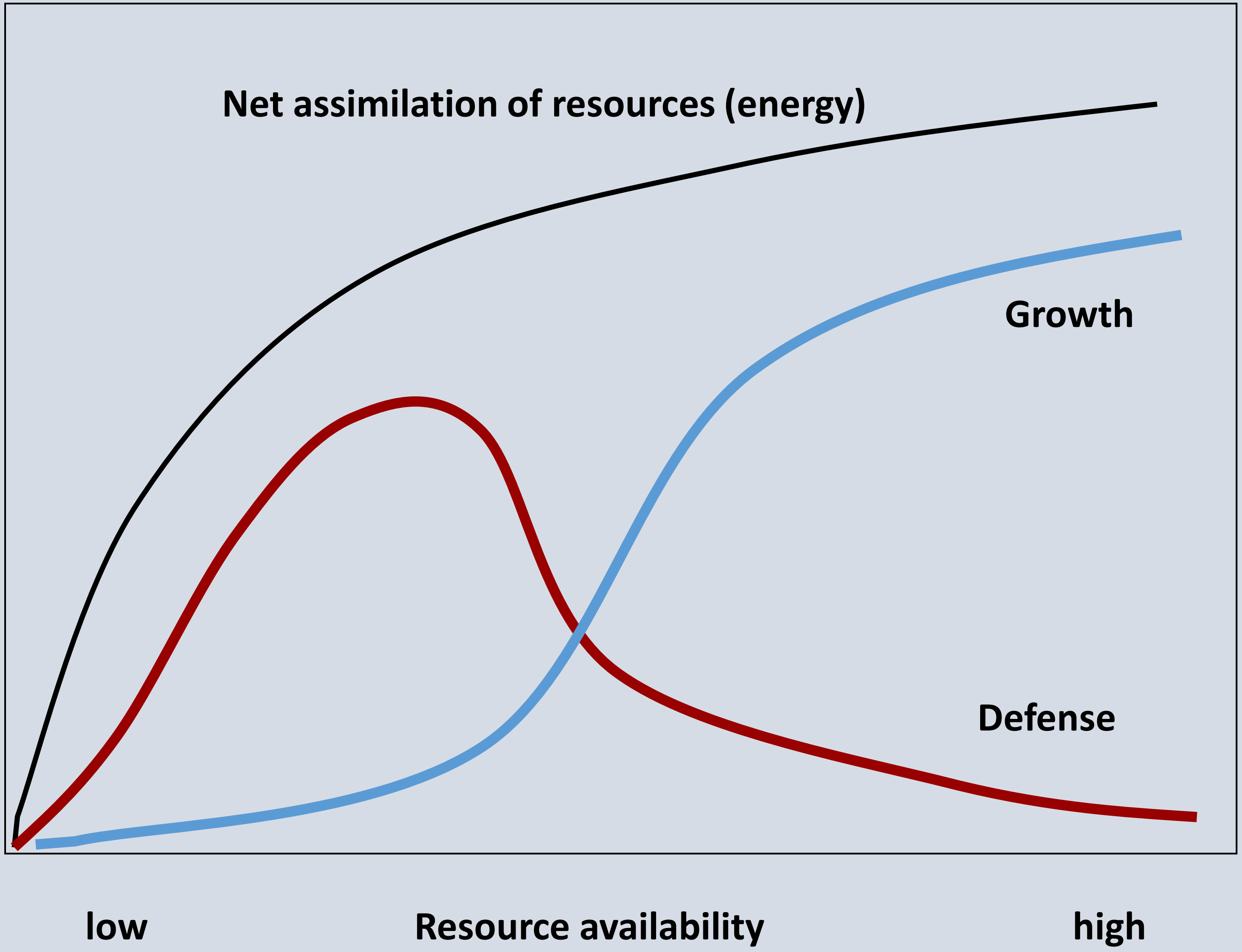
- The other end of the continuum (<u>in resource poor environments</u>) suggests plants are selected based upon herbivore defense (differentiation characteristics)

- 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






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.

Mountain Pine Beetle,
*Dendroctonus ponderosae*

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

Where does the developing larva get its N?

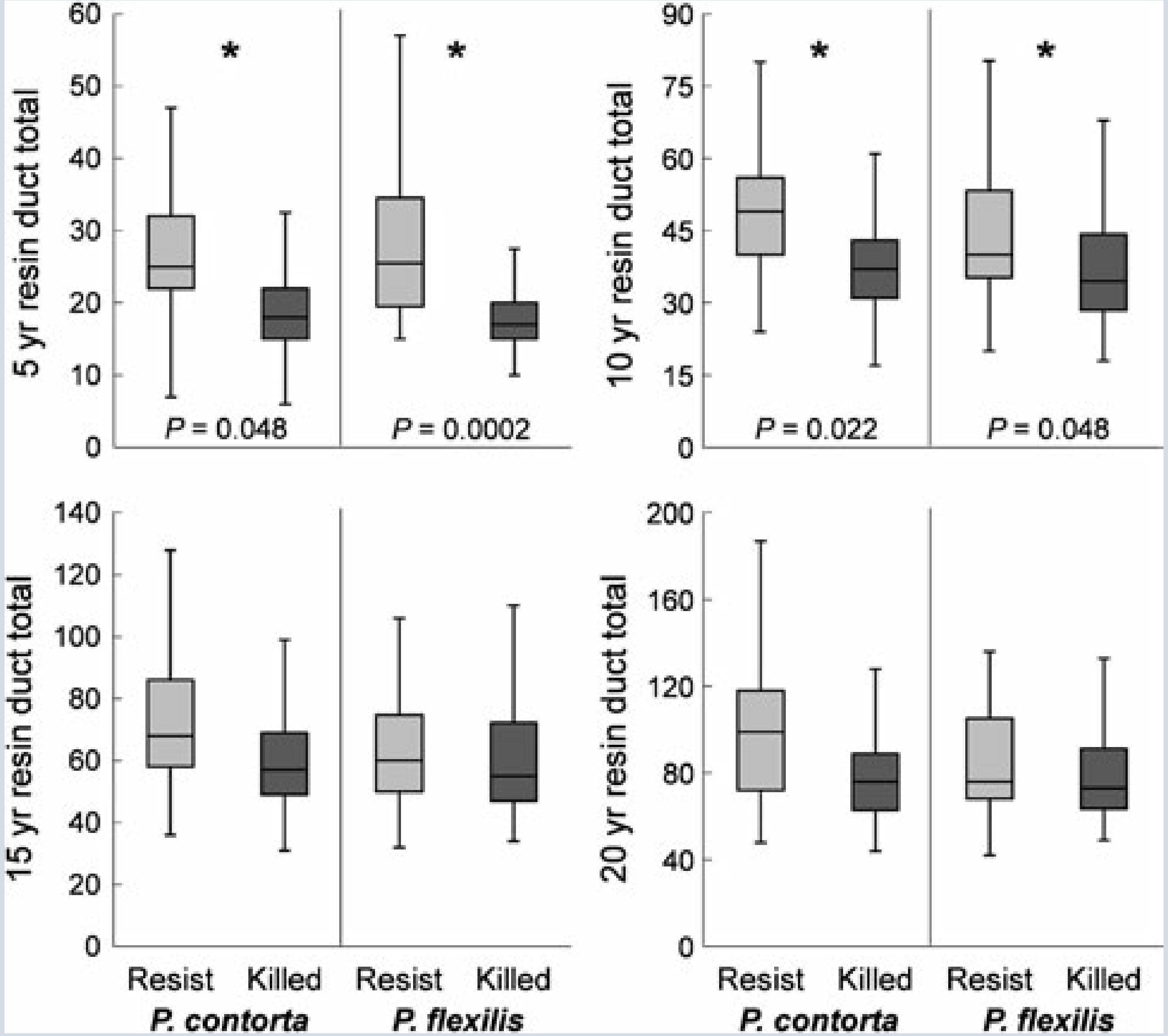
How involved are the fungi with larval nutrition?

Does tree nutrition play a role?

# 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)

# MPB-Lodgepole-Fungal Interactions

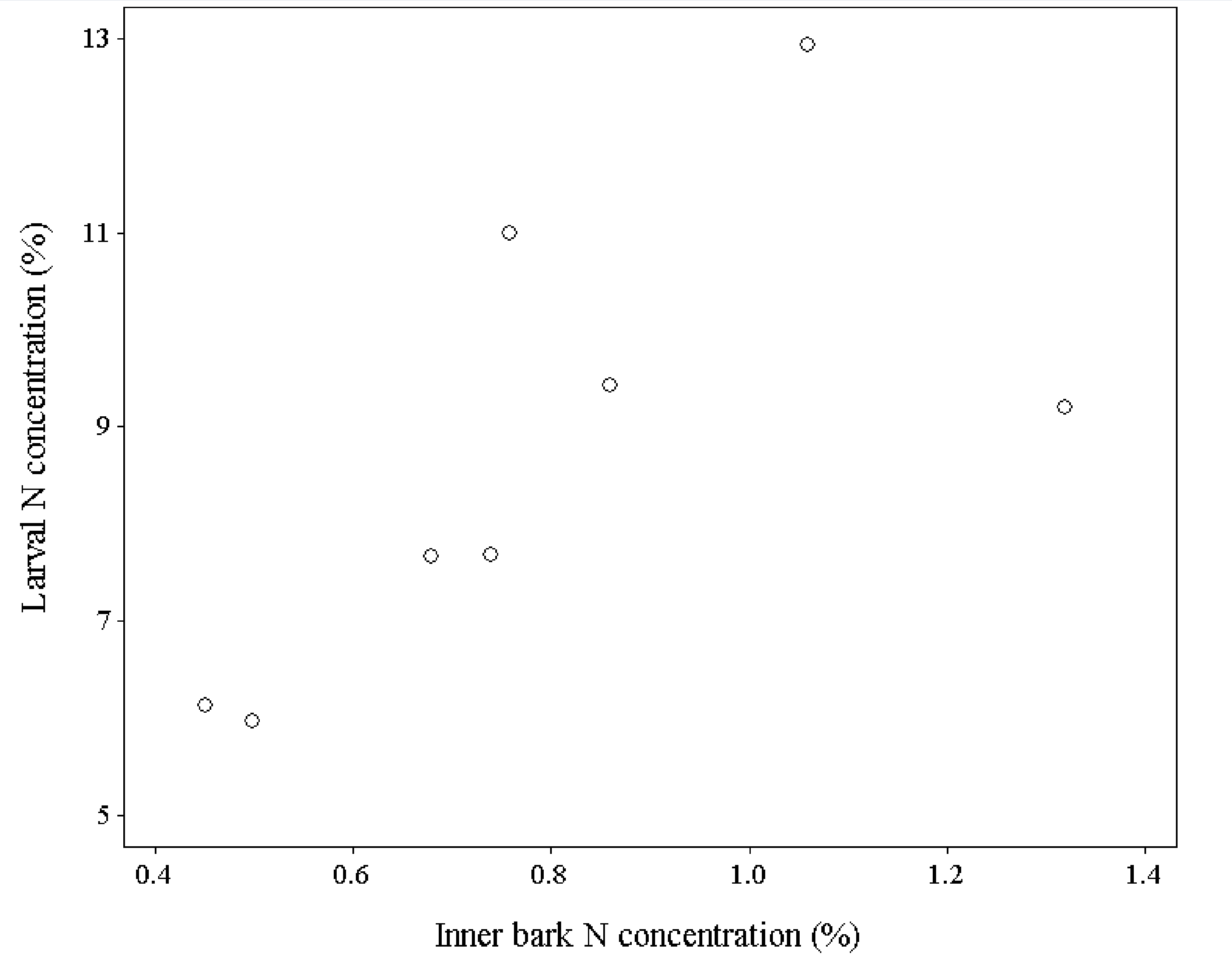
- Two field sites:
  - Craig Mountain
  - University of Idaho Experimental Forest
- Fertilizer applied to individual trees (fall or winter)
  - Measure inner bark N content
  - Measure resin flow
  - Measure inner bark monoterpene content (in progress)
- Controlled laboratory studies focused on:
  - *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)

| N treatment | Pre-fertilization | Post-fertilization | Difference |
|---|---|---|---|
| | | | |
| Control, 0 lbs/ac | 0.50 ± 0.03 a | 0.51 ± 0.02 | 0.04 ± 0.03 a |
| Low, 300 lbs/ac | 0.52 ± 0.02 a | 0.78 ± 0.07 | 0.31 ± 0.07 b |
| High, 600 lbs/ac | 0.55 ± 0.03 a | 0.75 ± 0.08 | 0.19 ± 0.11 a |

From: Cook et al. 2010

# Methods and Results
## Correlation between tree inner bark  and larval N contents

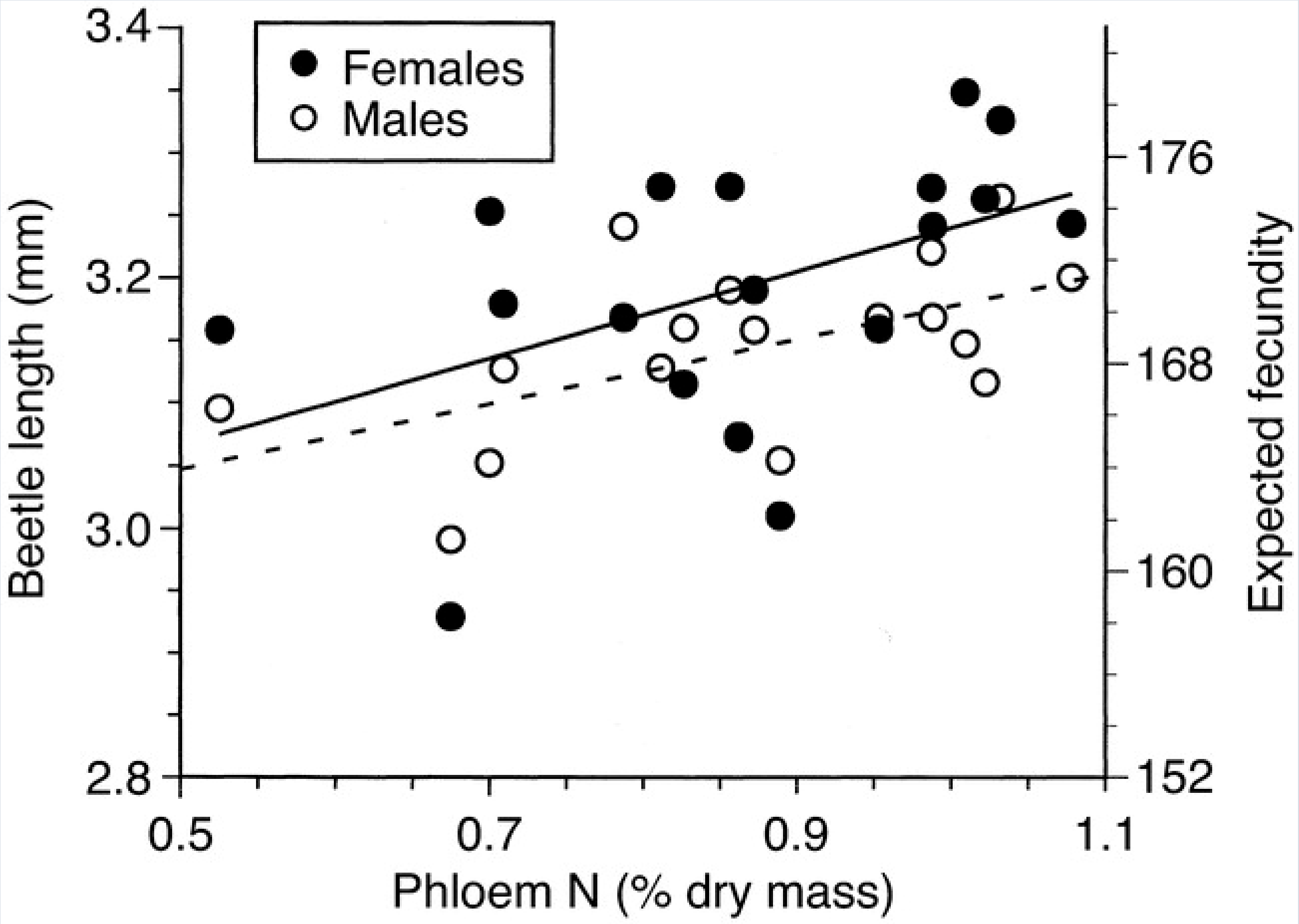



Pre-attack tree N
Larvae collected the following year

r = 0.6727

P = 0.0675

From: Cook et al. 2010



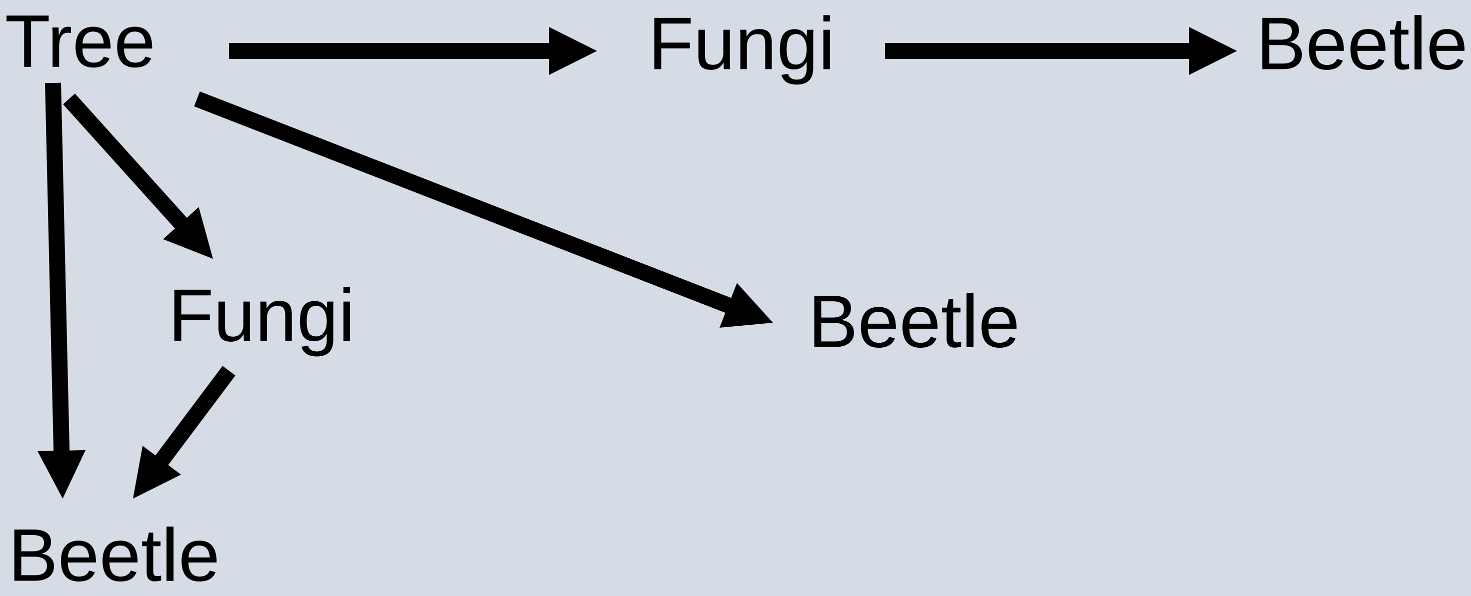

Tree N and size of SPB

From: Ayres et al. 2000 Ecology

Beetle size is usual correlated with survival, dispersal and fecundity

Bigger is better for the beetle

Trophic movement of N:



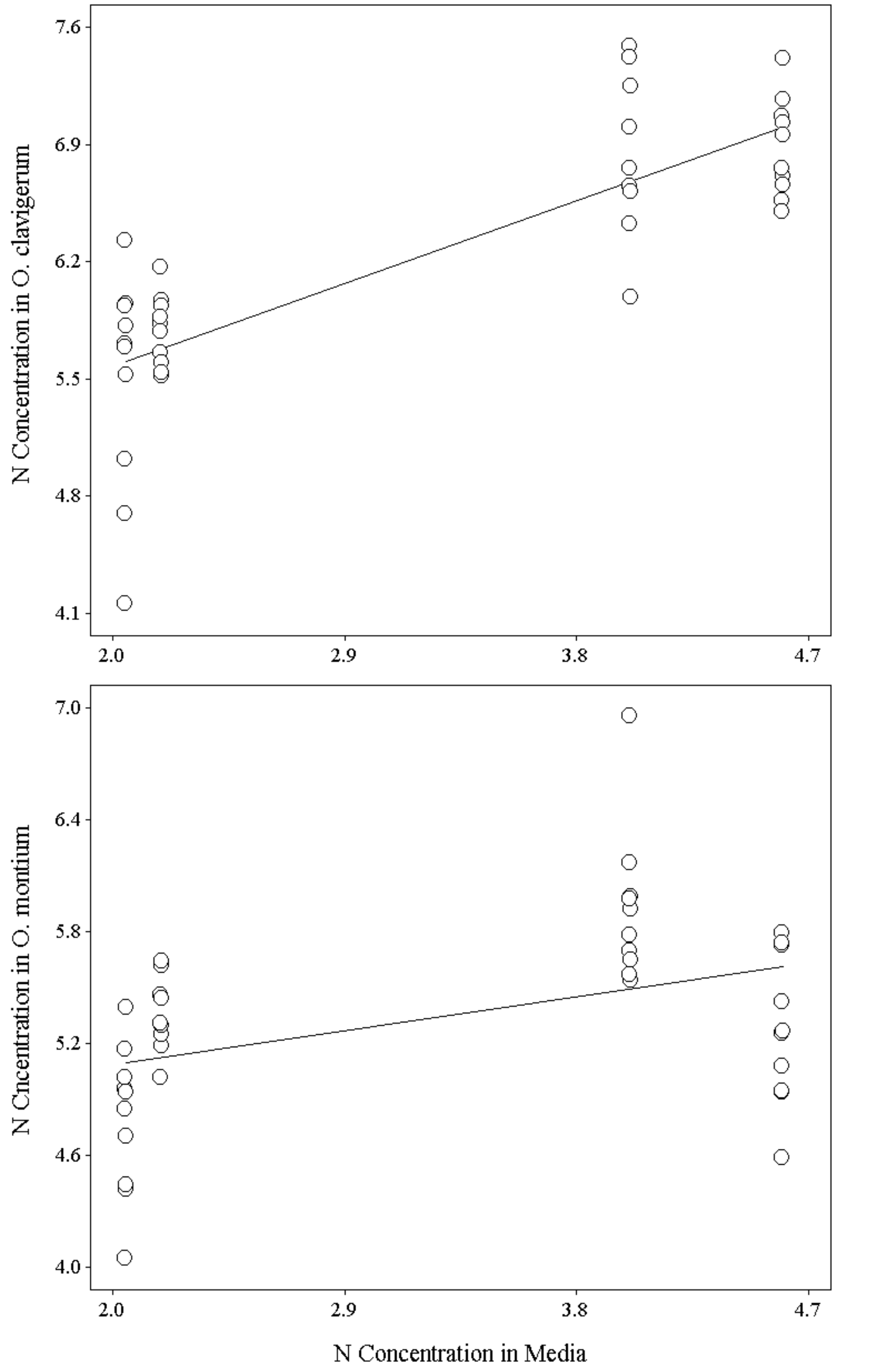

There will be a different shift in isotopic N content depending on the source of the N acquired by the developing beetle.

Strong linear relationship between N concentration in the growth media and *G. clavigera*

$R2 = 0.8116$

Weaker relationship when we Examine the *O. montium*

$R2 = 0.1801$

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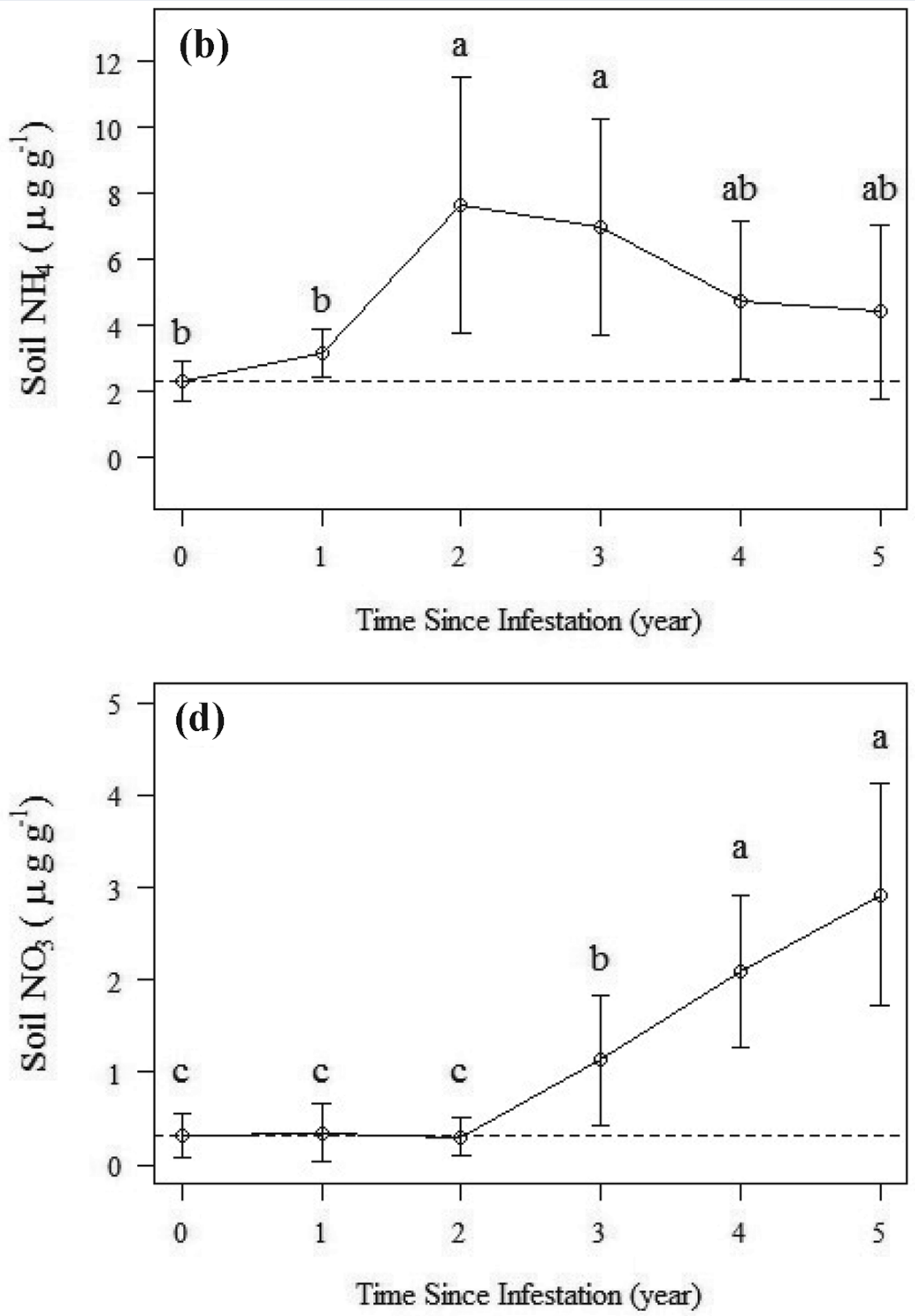
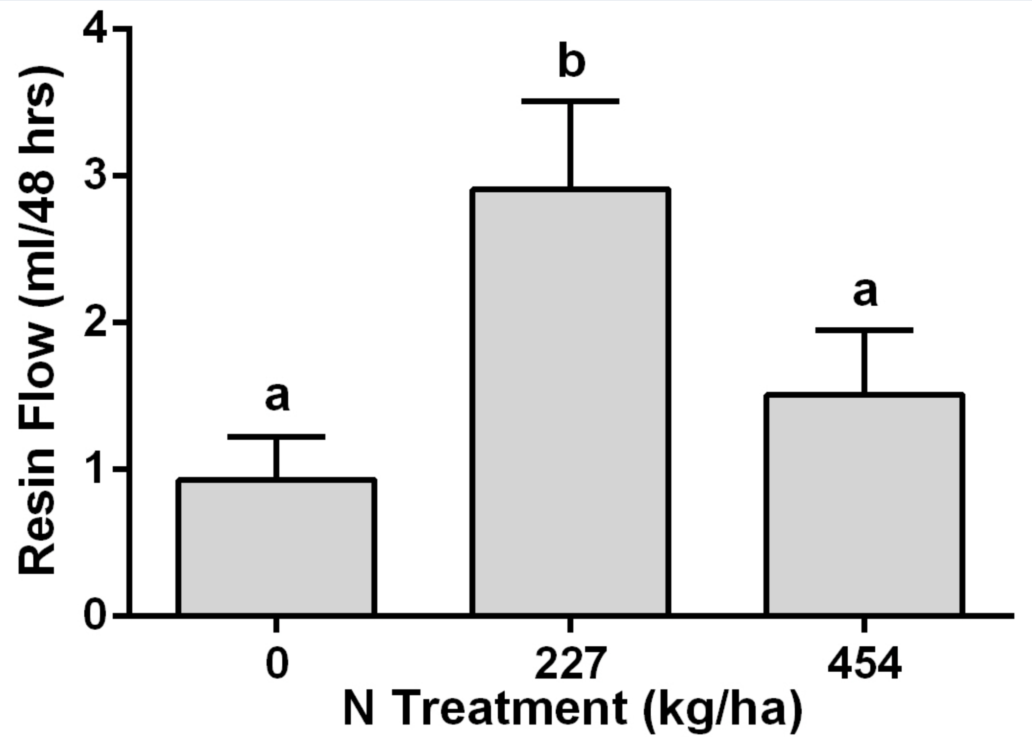



Soil nitrogen five years after bark beetle infestation in lodgepole pine forests

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)

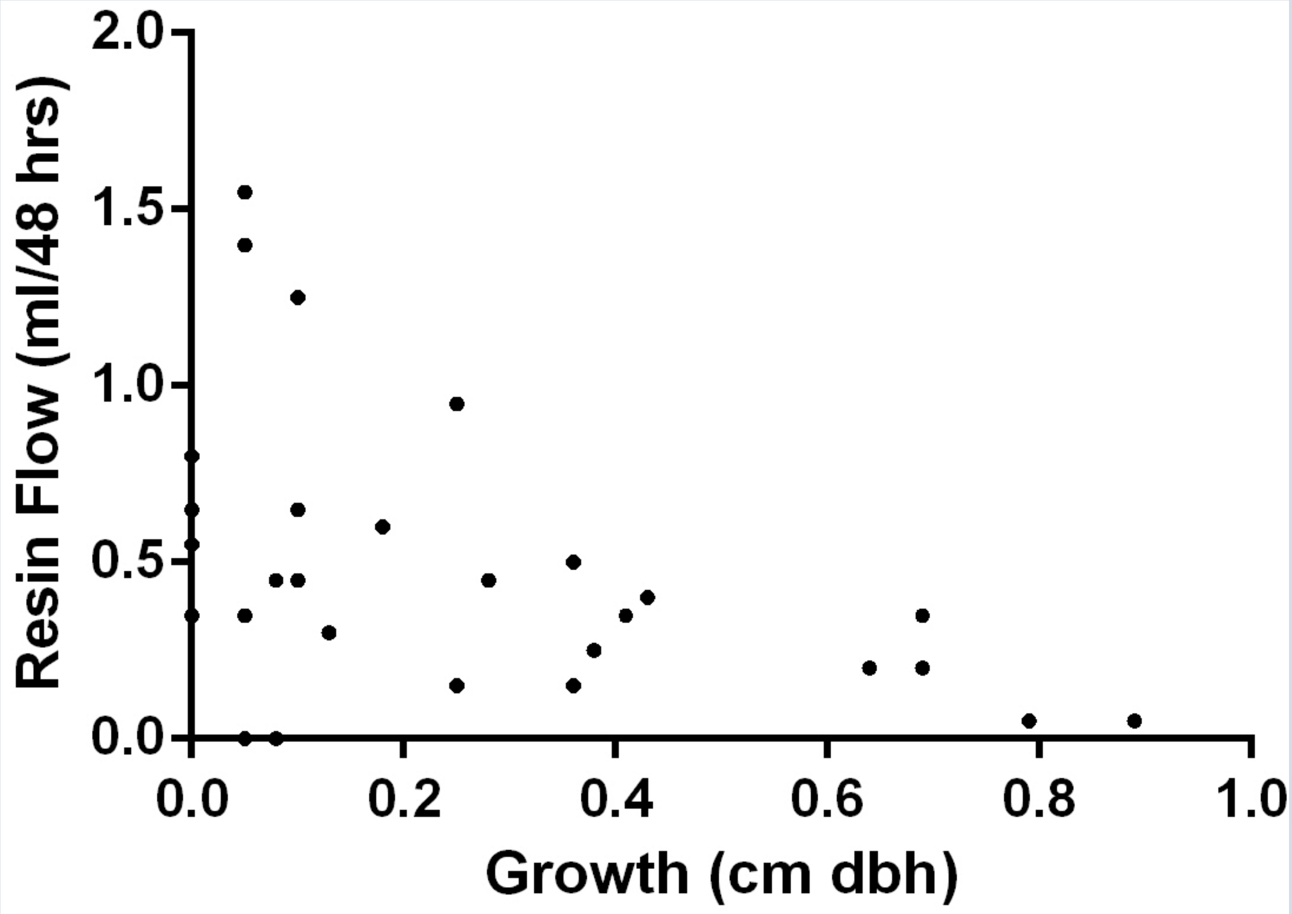
Fertilizer applied October 2007
Resin flow measured in July, 2008




One question to ask – how much is too much?

From: Cook et al. 2015.
Forests (online)

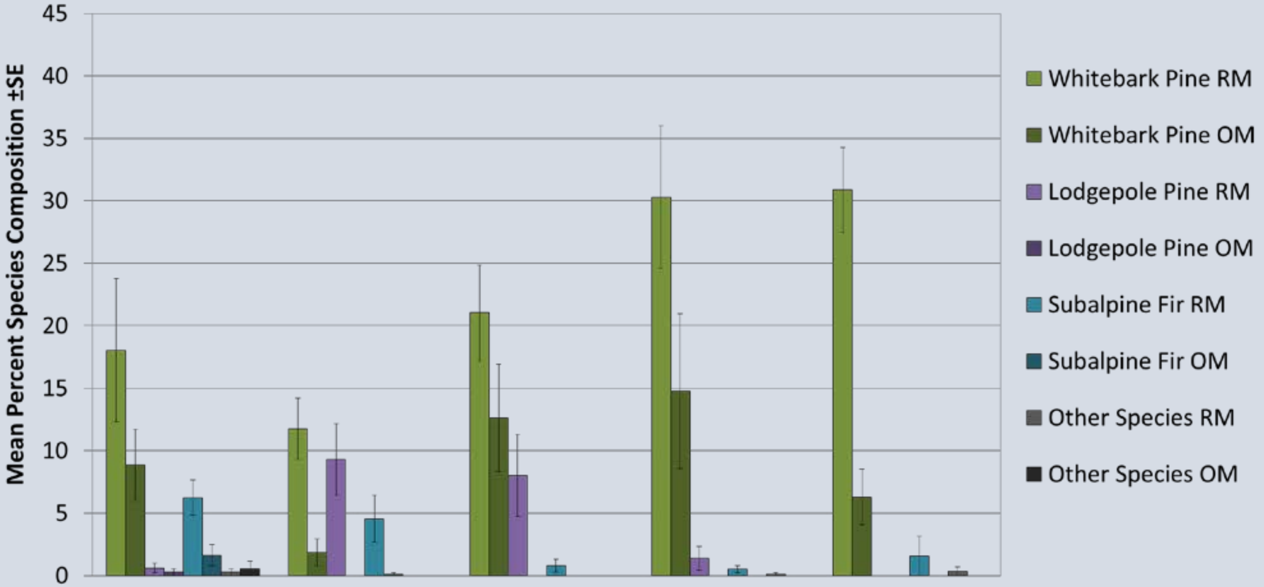
# Lodgepole Pine:
# Strong negative relationship between Growth and Resistance Mechanisms

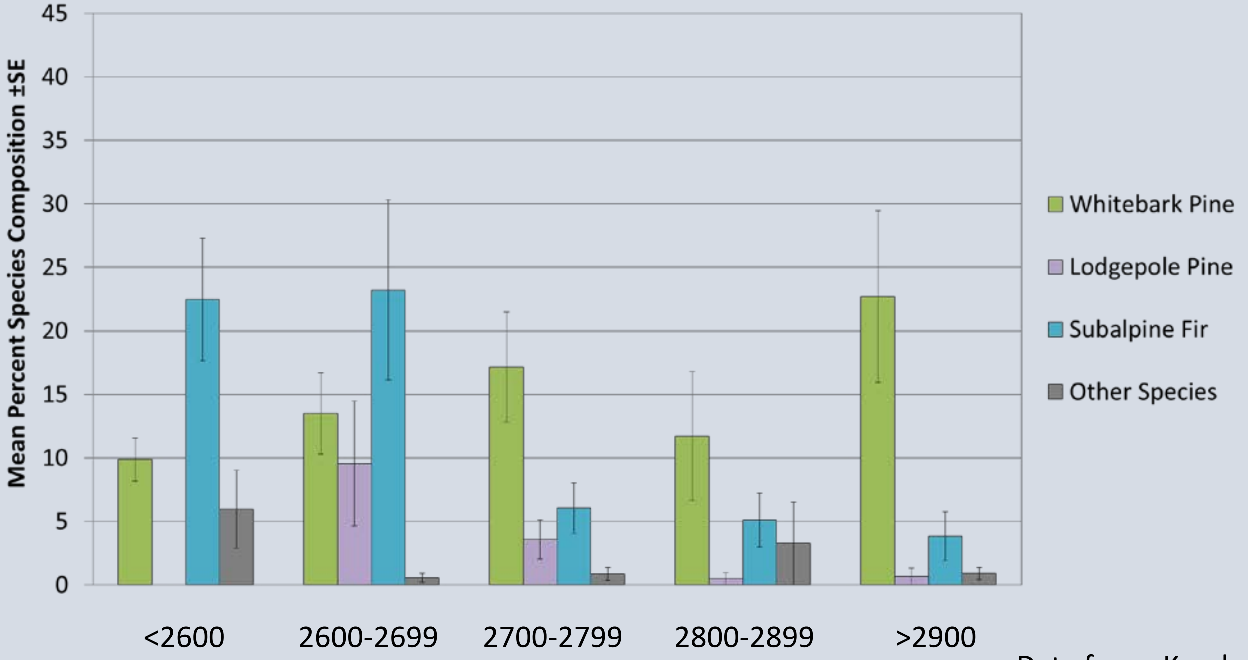



From: Cook et al. 2015. Forests (online)

In many ways Mountain Pine Beetle infestations in Whitebark Pine Provide a ‘slower-moving’ system in which to examine the interactions.

Photo from: Kendra Schotzko



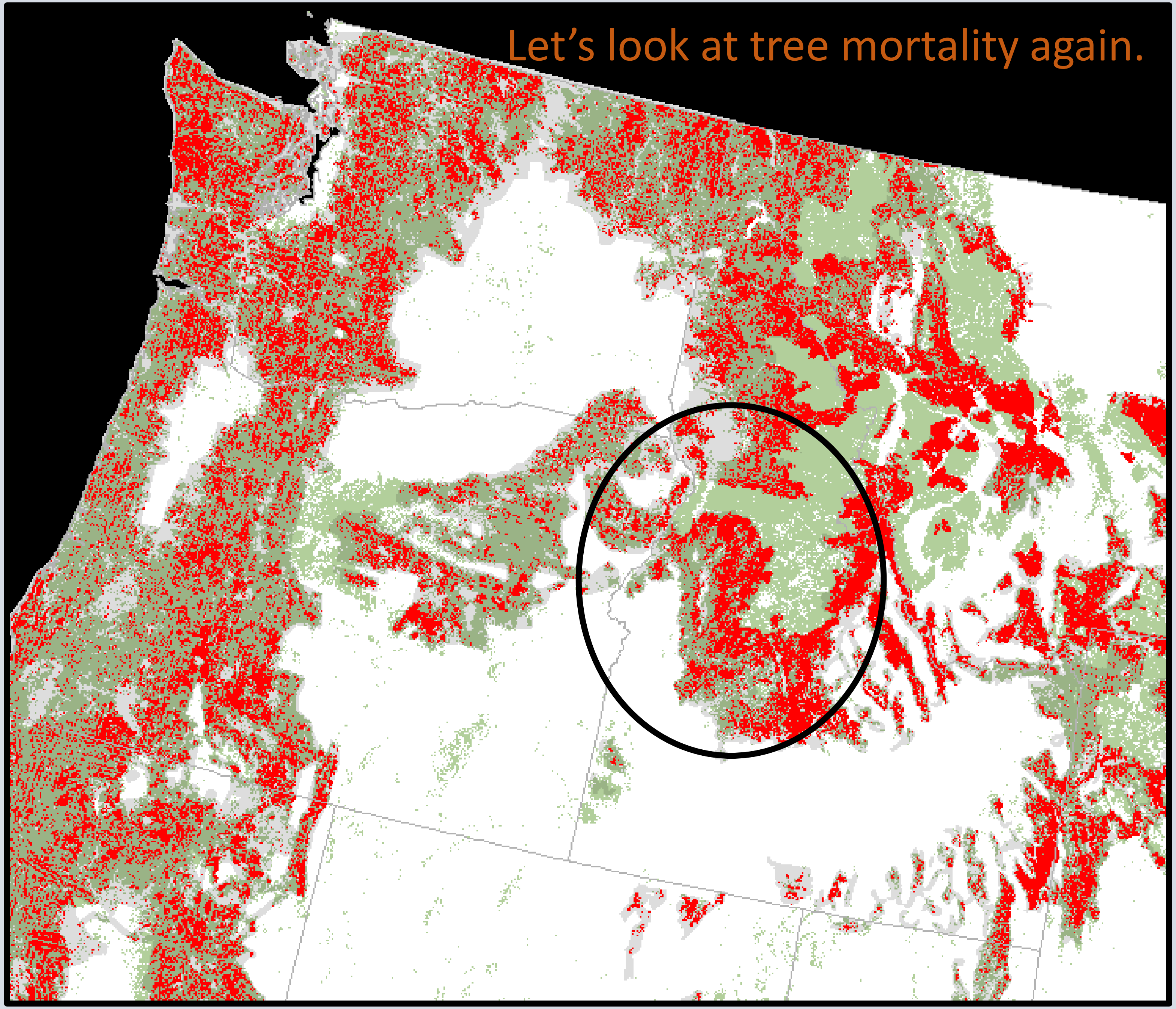




Data from: Kendra Schotzko

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.

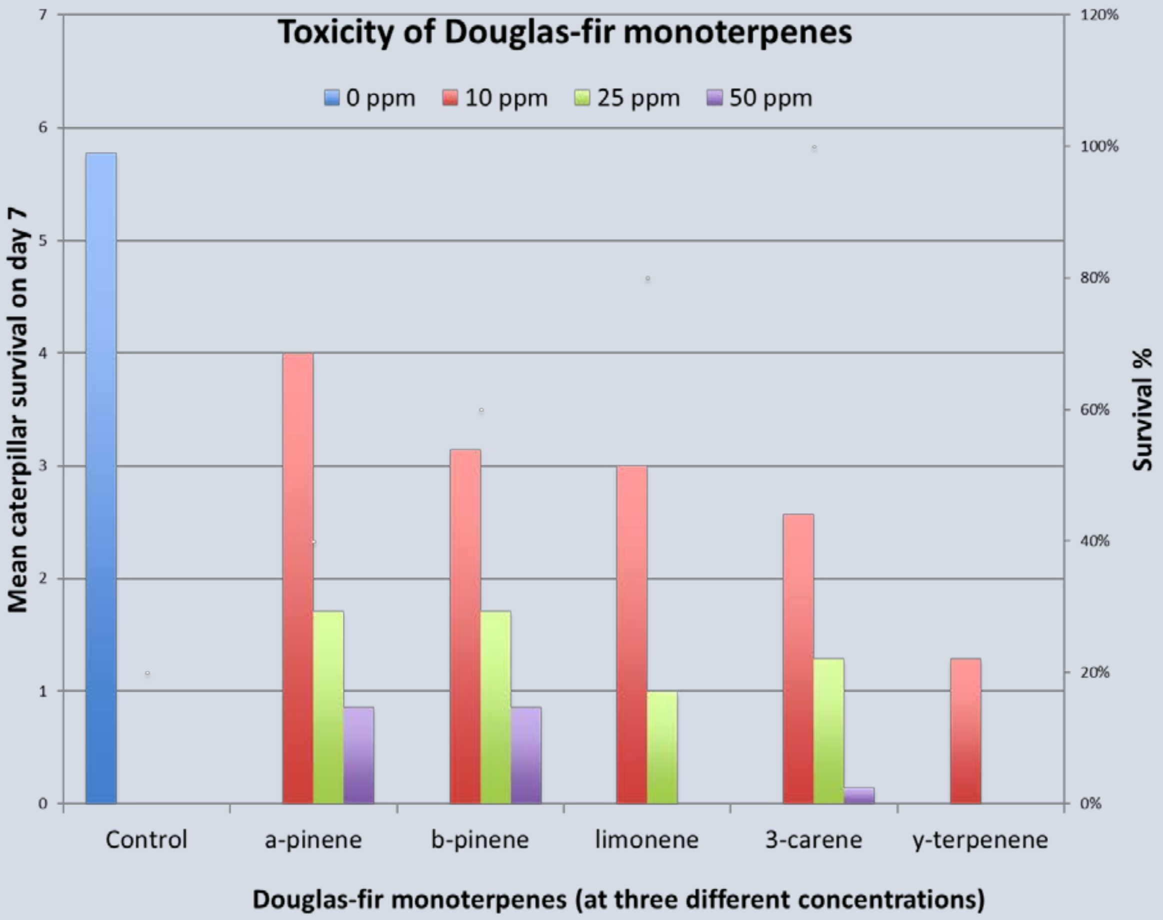
We have initiated a project that also compares chemistry of the residual trees – University of Idaho collaboration with University of Wisconsin and University of Alberta.



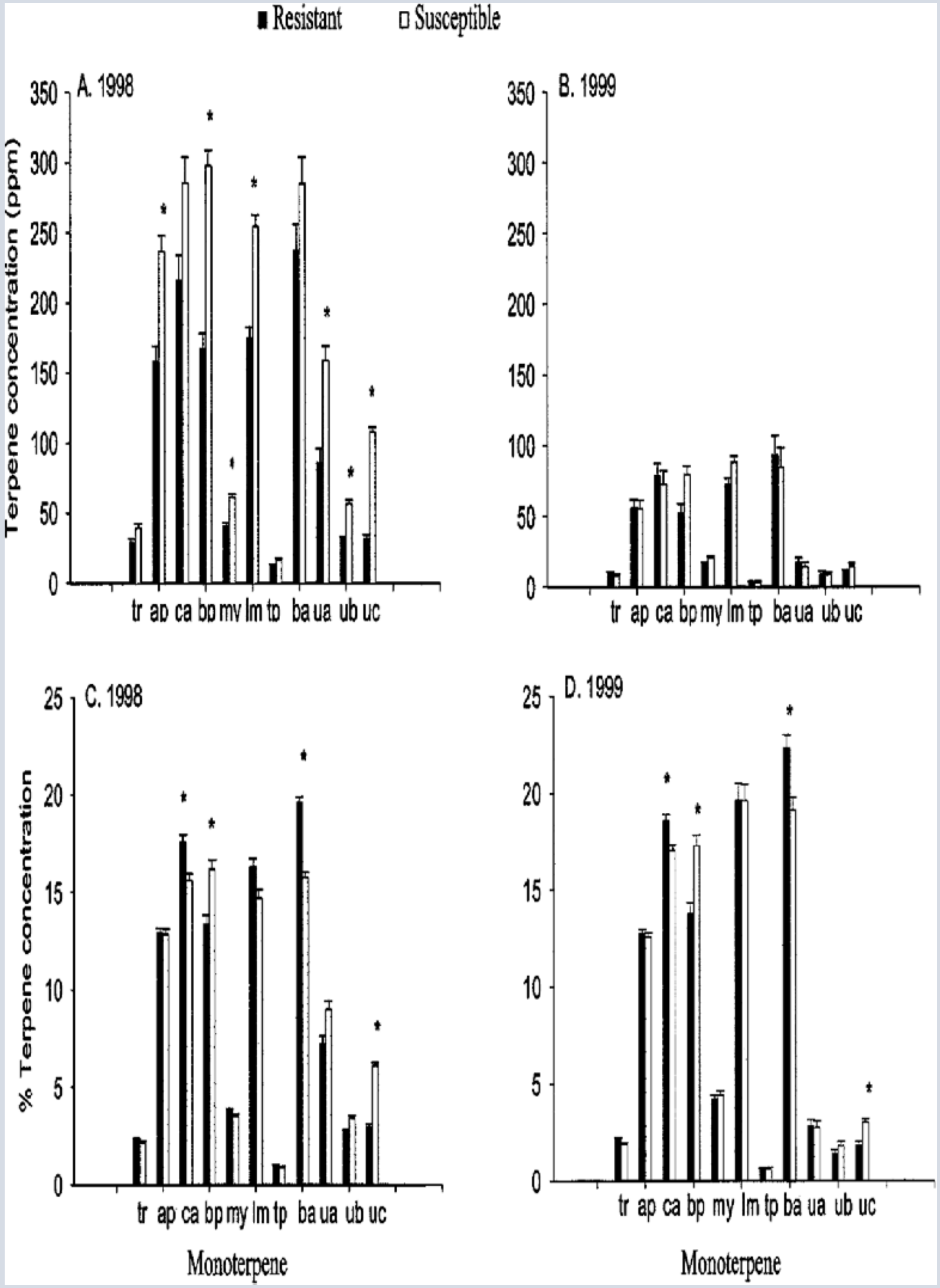

**Mountain Pine Beetle**
**Other Bark Beetles**
**Balsam Woolly Adelgid**
**Spruce Budworm**
**Douglas-fir Tussock Moth**
**Other Pests**

# Fertilization and Foliar Chemistry – Impact on Defoliators
# Douglas-fir Tussock Moth

| Treatment<br>N applied | Total monoterpenes (mg/g foliar tissue) |
|---|---|
| Control (0) | 7.0 ± 0.9 a |
| Low (227 kg/ha) | 8.6 ± 1.2 a |
| High (454 kg/ha) | 6.9 ± 0.6 a |
| | |




**Data from: A. Carroll**




**Western Spruce Budworm**

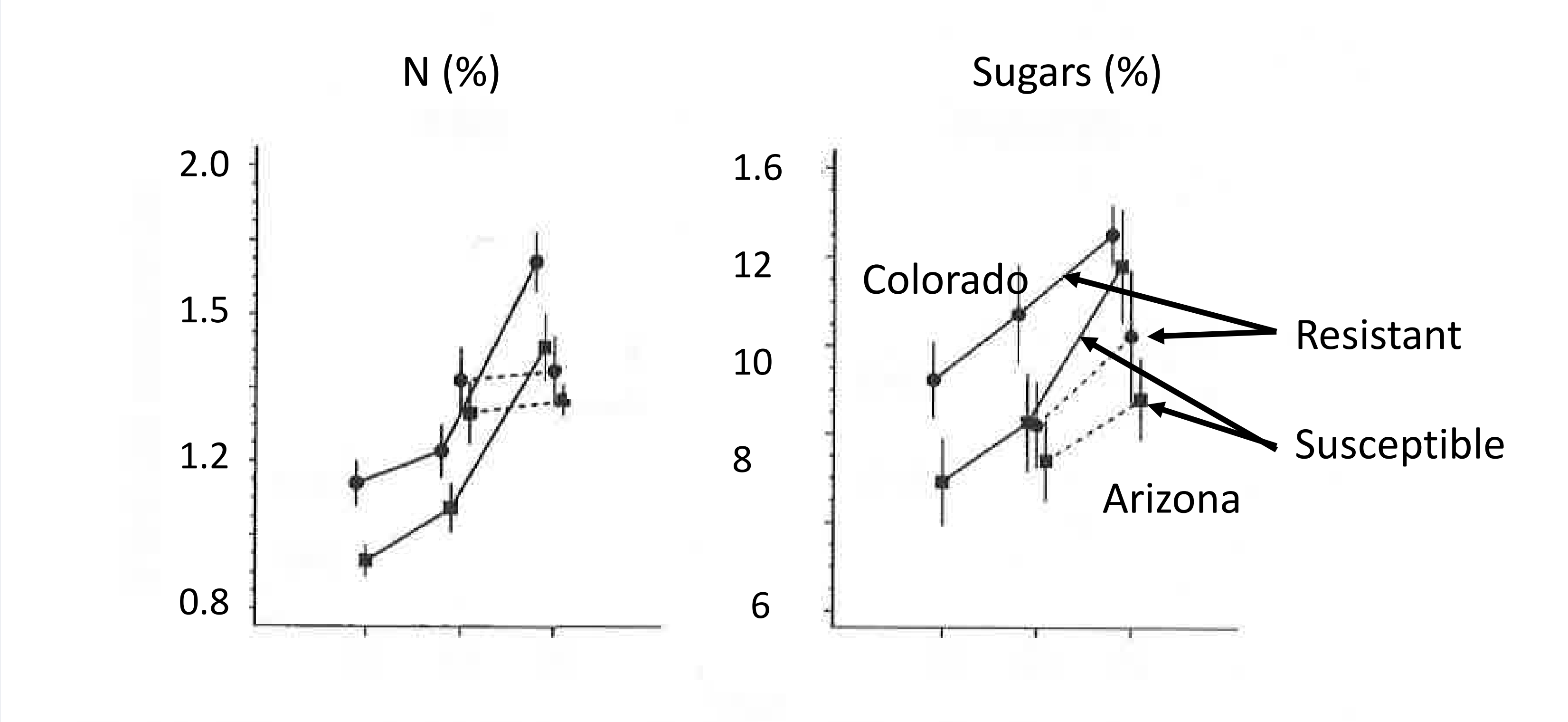
Prior work indicates that there were significant differences in the concentration and/or percentage of some individual monoterpenes present in resistant versus susceptible Douglas-fir.

This prior work also showed a decrease in potential fitness of the insect as overall monoterpene concentrations increased.

From: Chen et al. 2002

# Western Spruce Budworm

Data from: Clancy et al. 1993




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

| Treatment N applied | N | B | P | K | S |
|---|---|---|---|---|---|
| Control 0 kg/ha | 1.2 ± 0.1 | 24.2±2.1 | 0.2±0.01 | 0.7± 0.04 | 0.1±0.01 |
| Low 227 kg/ha | 1.4 ± 0.2 | 21.8±4.0 | 0.2±0.01 | 0.6±0.05 | 0.1±0.01 |
| High 454 kg/ha | 1.4 ± 0.1 | 23.3±3.7 | 0.2±0.01 | 0.7±0.04 | 0.1±0.01 |
| | | | | | |

**Data from: A. Carroll**

- **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**

# 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

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  - Armando McDonald
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- 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 -