Impact of thinning and fertilization on tree resistance to bark beetles

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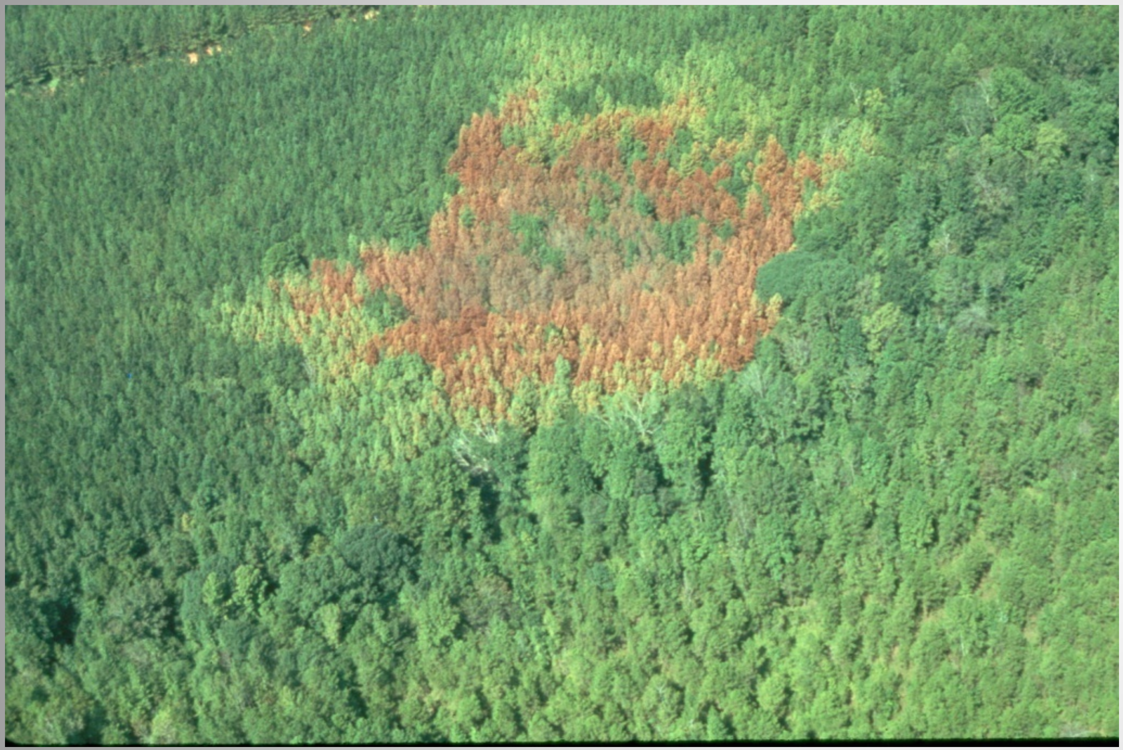
A ‘typical’ outbreak



Southern pine beetle infestation in monoculture loblolly pine.

Currently, the density and uniformity of many of our forest stands is conducive to prolonging infestations and enhancing bark beetle survival.

Currently in Idaho we have large outbreaks of mountain pine beetle and Douglas-fir beetle along with ‘minor’ outbreaks of western pine beetle and fir engraver.

Conifer Resistance to bole-invading insects: A quick review

First step of resistance:

Constitutive resin flow:

- Quantity is important – but –
- So is quality (viscosity and crystallization)

Second step of resistance:

Formation of an induced lesion:

- Increased monoterpenes
- Decreased soluble sugars

This resistance response is an energy intense process

It is important to keep in mind that the bark beetle-conifer relationship is usually a winner take all scenario (the winner lives – the loser dies).

After attack by bark beetles, conifers fade from green to yellow to red in a very short period of time.

The fading is related to the expenditure of energy from their reserves.

Remember – unlike deciduous trees that store starch primarily in their roots, conifers use their needles as a storage 'compartment' for starch.

Photo from: Terry Shaw, IFTNC

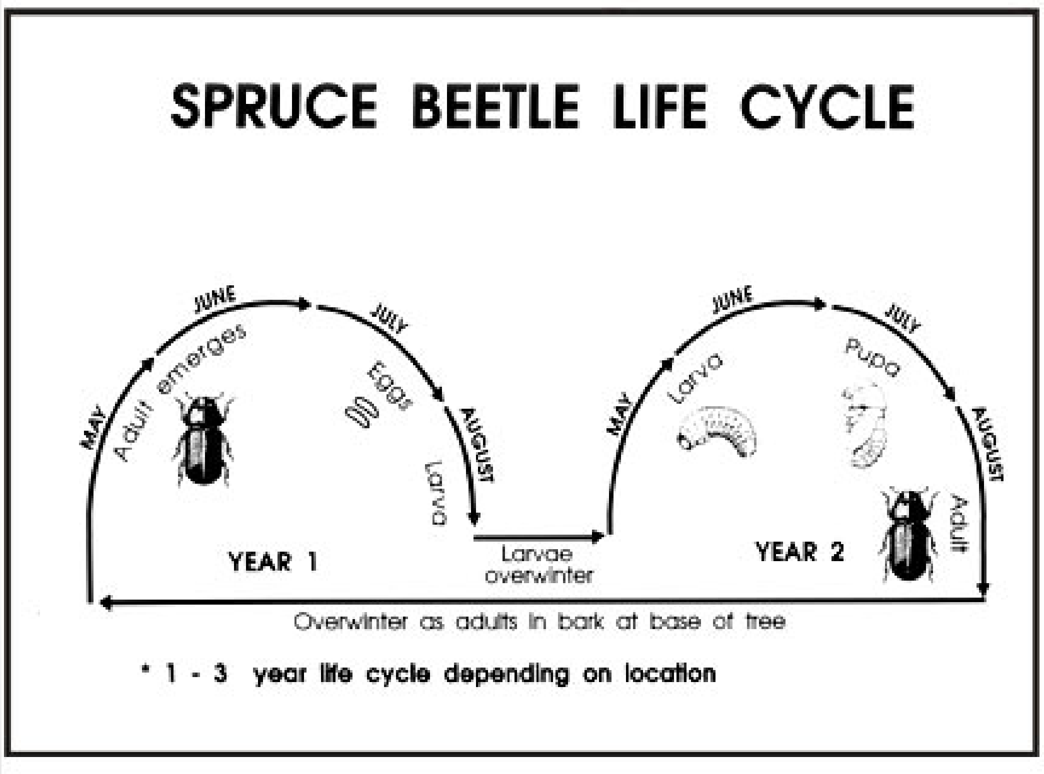
This resistance response governs much of the biology of tree-killing bark beetles

Mass attack is required to overcome tree resistance

Aggregation pheromones and host volatiles concentrate the attack process

Anti-aggregation pheromones shut down the process and push new beetles on to the next tree

Monoterpenes ⟶ Pheromones



From: Sustainable Resource Development, Alberta

Photo from: Ladd Livingston

Our first question was:
Can we modify the relationship between host trees and bark beetles 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?

Can we modify the relationship between host trees and bark beetles by altering some basic tree chemistry?

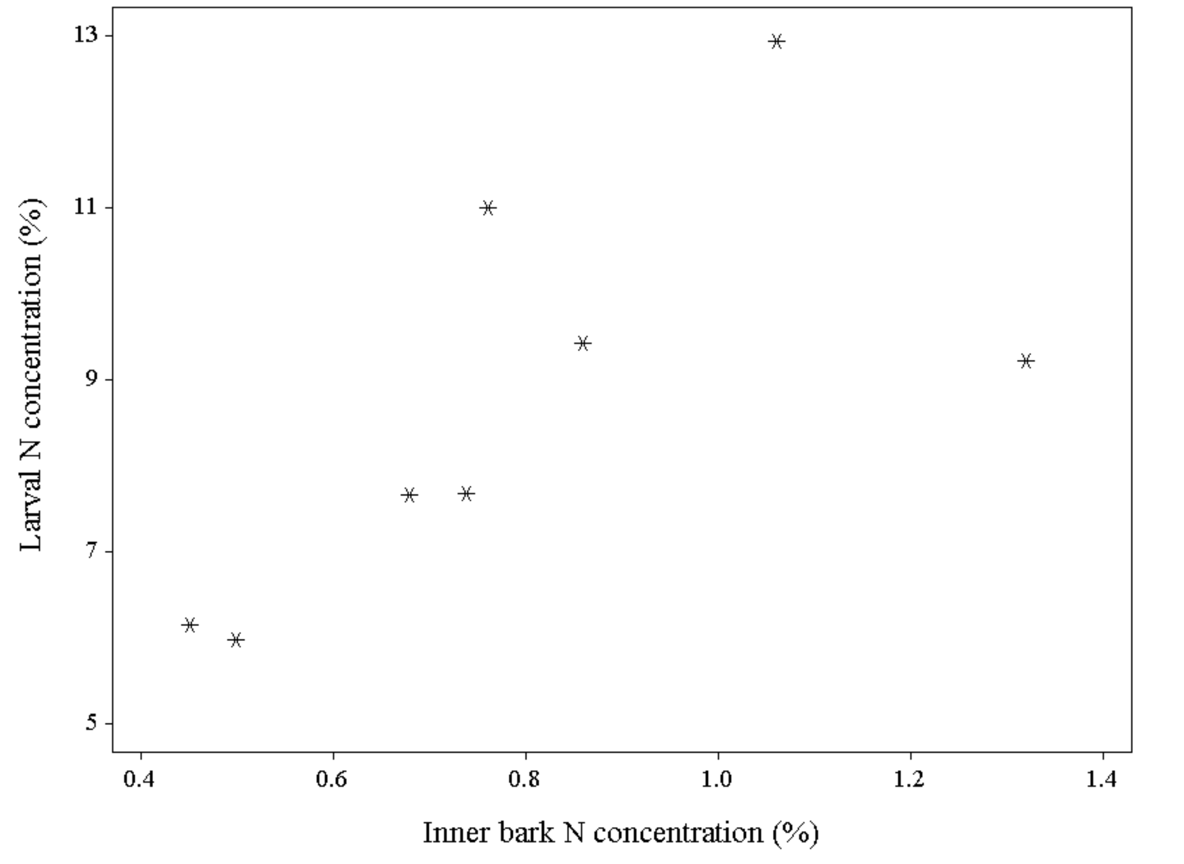
N treatment	% N Pre-fertilization	% N Post-fertilization	Difference
Control, 0 lbs/ac	0.50 ± 0.03 a	0.51 ± 0.02	0.04 ± 0.03 a
Low, 300 lbs/ac	0.52 ± 0.02 a	0.78 ± 0.07	0.31 ± 0.07 b
High, 600 lbs/ac	0.55 ± 0.03 a	0.75 ± 0.08	0.19 ± 0.11 a

From: Cook et al. 2010

We can modify tree chemistry relatively quickly.

A timeline such as this suggests that fertilization can be implemented adjacent to beetle infestations the same year that you are attempting to mitigate beetle-caused tree mortality.

Can we modify the relationship between host trees and bark beetles by altering some basic tree chemistry?



From: Cook et al 2010

There is a direct, positive relationship between the concentration of N in a tree and the concentration of N in a beetle.

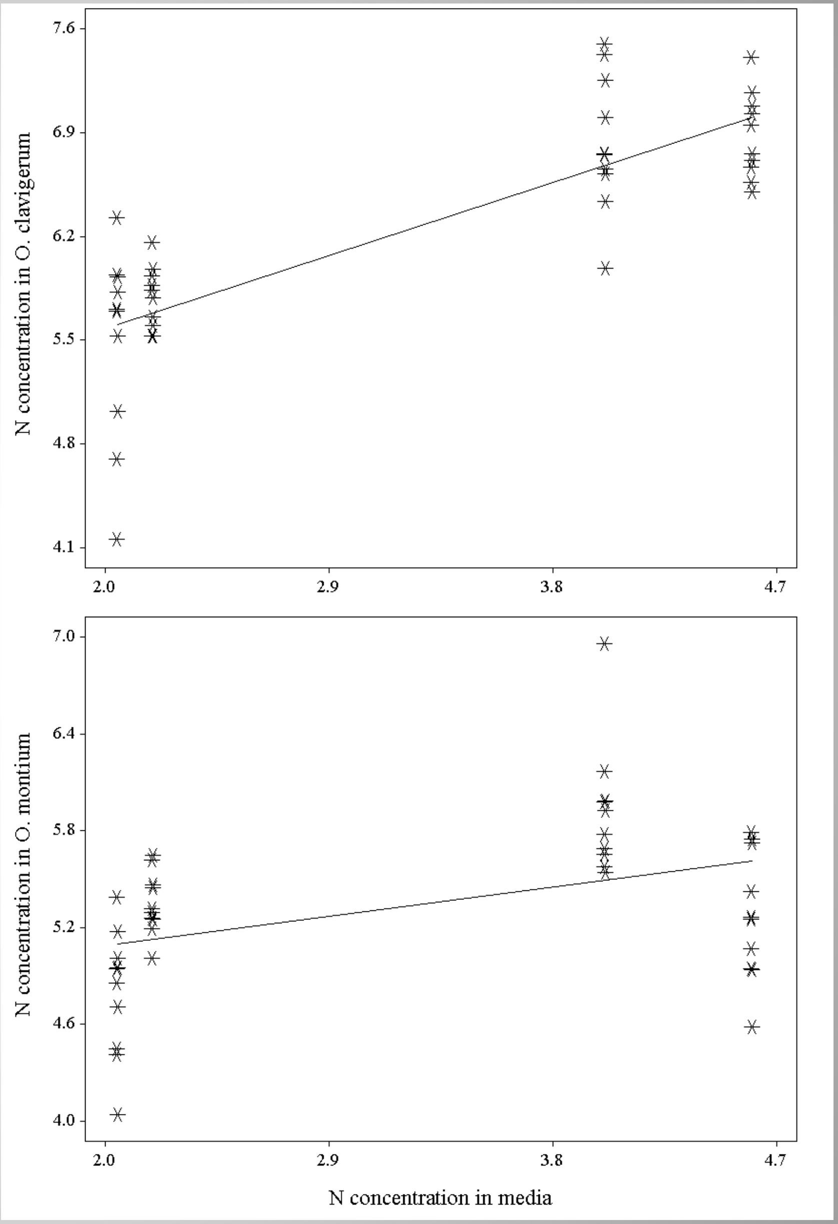
Size of adult beetles is also directly related to N concentration – and bigger beetles produce more offspring.

As with mountain pine beetle, there is a positive relationship between the N concentration in growth media and the subsequent concentration of N in the fungi.

This correlation is stronger with *O. clavigerum* than it is with *O. montium.*

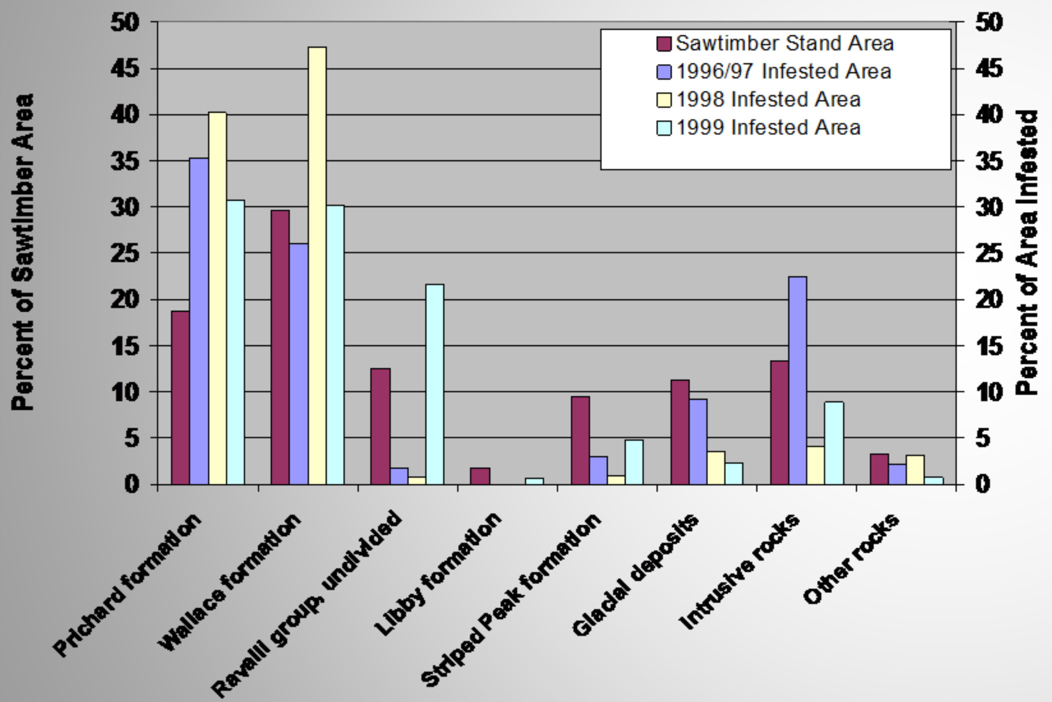
Both of these fungi may represent important sources of N to the developing beetles.

The fungi probably also act as a sterol source for the beetles.



From: Cook et al. 2010

Relationship between rock type and bark beetle refugia: Douglas-fir beetle in the intermountain west



From: Garrison-Johnson et al. 2003. Environmental Entomology

- Severe winter storm of 1996 resulted in top-kill of DF in restricted area
- DFB infestations followed the storm damage
- Reconstruction revealed that DFB was 'constantly' present in DF growing on certain rock types (primarily some medisentimentary rocks)
- Why – we have hypothesized a nutrient connection (N, S, B)

Tying this back into my interests in beetle-tree interactions: Examining the impact of fertilization on beetle resistance parameters

Natural pitch-out

Insert resin tube

48 hours later

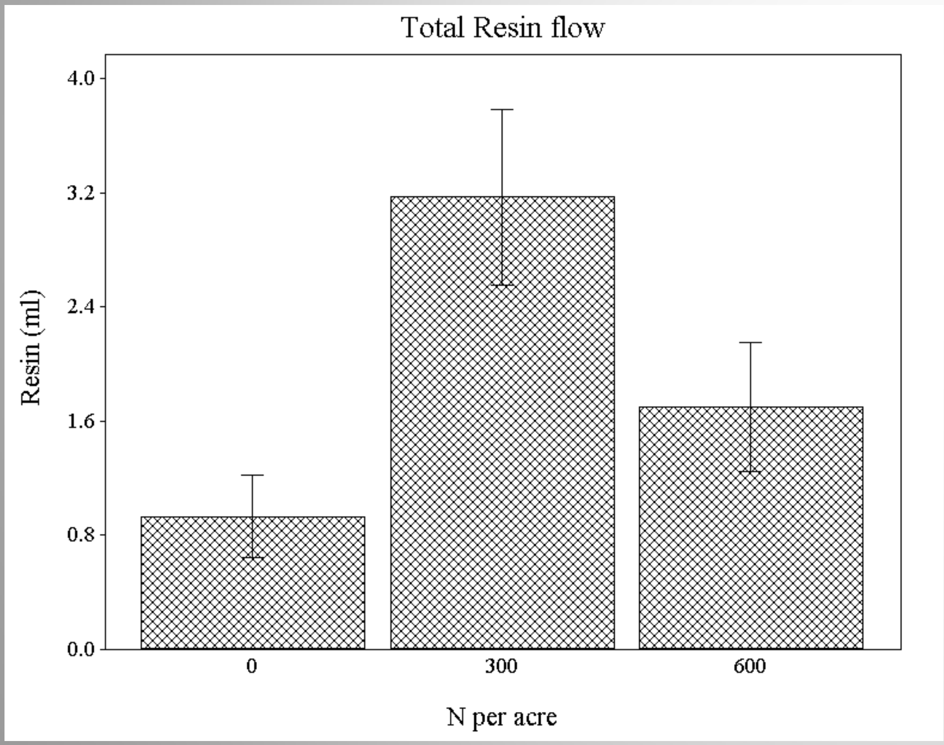
Inner bark sampling for monoterpene content

C.S. Osborne

Shaving the bark

Inner bark samples

First step in lodgepole resistance to MPB



From: Cook et al. submitted

We can significantly increase resin flow with the use of N fertilization.

When combined with stand thinning, we still see the same significant increase in resin flow and we have created spatial irregularity in the stand – a condition we hypothesize will limit the growth potential of infestations.

However, to date we have been working in areas without bark beetle pressure. The next step is to conduct work adjacent to ongoing outbreaks.

Conophthorus ponderosae: 2004 Toxicity trials of myrcene and a-pinene

Day	Terpene	LD_{50} (ppm)	95% C.I.
2	Control	no mortality	
	myrcene	52.6	43.3 – 67.0
	a-pinene	61.3	55.6 – 68.8
3	Control	no mortality	
	myrcene	45.1	37.3 – 56.1
	a-pinene	51.4	47.5 – 55.9

From: Shirley & Cook (2007)

Inner bark monoterpene concentrations in Douglas-firs that had received 1 of 4 fertilization trts

Treatment		**α–pinene**	**β–pinene**	**3-carene**	**limonene**	**γ–terpinene**
Control		0.28 ± 0.08	0.06 ± 0.02	0.01 ± 0.01	0.03 ± 0.01	0.00 ± 0.00
Low N		0.19 ± 0.09	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
High N		0.18 ± 0.02	0.03 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.00 ± 0.01
Complete		0.25 ± 0.13	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.00 ± 0.00

No significant differences among the 4 treatments

Proposed Project: Douglas-fir Beetle

Co-Investigators: Steve Cook, Mark Coleman and Terrie Jain

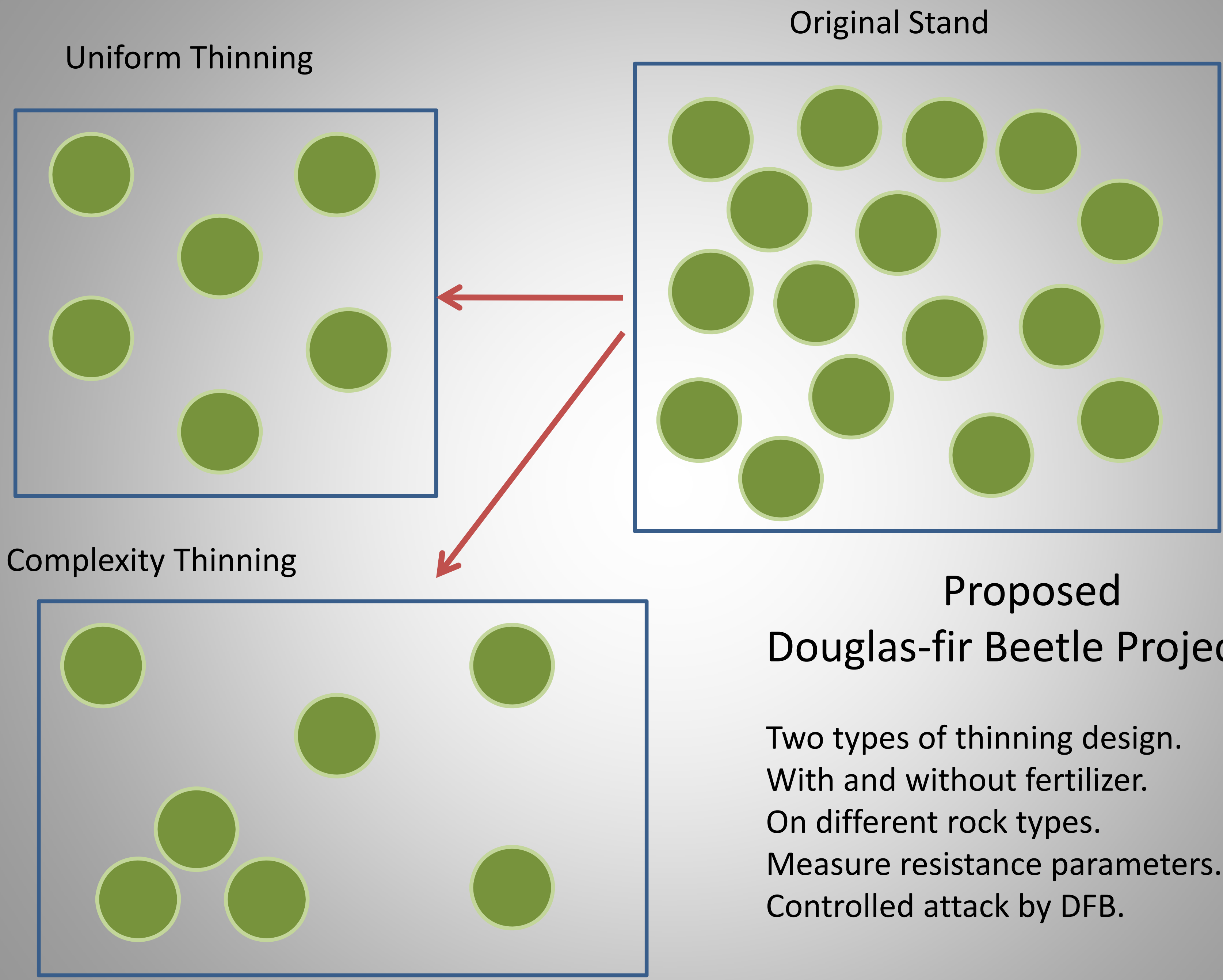
The primary objective of the study is to evaluate the impact of stand density management and fertilization on resistance of Douglas-fir to attack by the Douglas-fir beetle.

1. To describe interactions between tree biomass distributions of Douglas-fir stands and fertilization on inner bark and foliar nutrient content and growth of the residual trees.

2. To examine the impact of different thinning strategies (e.g. simple versus complex forest conditions) and/or fertilization on tree resistance mechanisms against bark beetle attack.

3. To determine the association among tree nutrient status, resistance parameters and overstory biomass distribution.

4. To describe changes in the community of ground beetles (Carabidae) following thinning and/or fertilization treatments.



Proposed
Douglas-fir Beetle Project:

Two types of thinning design.
With and without fertilizer.
On different rock types.
Measure resistance parameters.
Controlled attack by DFB.

Proposed Project: Douglas-fir Beetle

We will contain appropriate numbers of bark beetles using tree tents such as these that I previously used for work in the south.

Can test individual trees.

Need to be careful of edge effect – temperature.

Proposed Project: Douglas-fir Beetle

We will describe changes in the community of ground beetles (Carabidae) following thinning and/or fertilization treatments.

Can test for differences among density and fertilization treatments.

What we are after – the potential for using these common beetles as bio-indicators of change.