Role of drought in mediating interactions between different host trees and the mountain pine beetle

Maya L. Evenden 1, Inka Lusebrink 1,2, Jared Sykes 1, Caroline Whitehouse 1, and Nadir Erbilgin 2

1 Department of Biological Sciences, University of Alberta, Edmonton, Canada
2 Department of Renewable Resources, University of Alberta, Edmonton, Canada
MPB success in B.C.

http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/maps.htm

Dezene Huber
MPB success

Having chewed through BC's pine forests, the mountain pine beetle turns to other anti-social activities:

Telemarketer

Parking Enforcement

Drunken Louts

Mr. Speaker, I'm pleased to announce we're giving ourselves another raise.

Liberal MLA

CAN I INTEREST YOU IN A SUBSCRIPTION TO BEETLE MAGAZINE?
Pine distribution in Canada

Let's move to Alberta
• MPB success in Alberta
• Colonization of hybrids
• Colonization of Jack Pine
- Implications of dry conditions on beetle-tree interaction
**Terpenes**

derived from five-carbon isoprene

<table>
<thead>
<tr>
<th>Terpenes</th>
<th>Isoprene Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoterpenes</td>
<td>2</td>
</tr>
<tr>
<td>Sesquiterpenes</td>
<td>3</td>
</tr>
<tr>
<td>Diterpenes</td>
<td>4</td>
</tr>
</tbody>
</table>

![Terpene Structure](image)

The structure of isoprene is shown above with the chemical formula $\text{C}_5\text{H}_{10}$. Each type of terpene is derived by combining isoprene units: monoterpenes from 2 units, sesquiterpenes from 3 units, and diterpenes from 4 units.
Examples from pine

acyclic

Myrcene

monocyclic

Limonene

β- Phellandrene

bicyclic

α- Pinene

β- Pinene

Camphene

3- Carene
Field experiment in hybrid zone
Objectives

1. To develop a chemical profile of volatile organic compounds (VOCs) and phloem and needle monoterpenes content from mature pine host trees.

2. To evaluate if VOC profiles vary with different environmental (water vs. water deficit).

3. To evaluate if VOC profiles vary with biological treatments (fungal inoculation with *Grosmania clavigera*).

4. To link the host chemical response to beetle fitness.
Field 2009

- field site 25 km NW of Whitecourt
- hybrid zone
- 40 trees selected
- DBH~24 cm
Environmental treatments

(n=20)

2, 160 L bladders filled every 2 wks  (n=20)
Watering
Soil water content

- Soil water content measured with time domain reflectometry
Soil water content

significant difference in soil water content between water treatments $p=0.008$
Biological treatments

- 5 wks after water treatment
- 5 trees in each water treatment
- 4 biological treatments
VOCs collection

- VOCs collected from boles
- measured before and after biological treatments
Chemical profile

Monoterpene emission (% ± SE)

alpha-Pinene: 32% ± SE
beta-Pinene: 6% ± SE
3-Carene: 35% ± SE
Myrcene: 5% ± SE
alpha-Terpinene: 18% ± SE
beta-Phellandrene: 57% ± SE
gamma-Terpinene: 15% ± SE
p-Cymene: 37% ± SE
Terpinolene: <1% ± SE
Total monoterpenes emission

- Water deficit vs well watered: $p = 0.029$
- Control vs fungus vs MPB mash wounding: $p < 0.001$
- Time post inoculation (0d, 4d, 2wk, 3wk, 5wk): $p < 0.001$
Individual monoterpane emission

- Redundancy Analysis
- Emission of α-Pinene, 3-carene, β-pinene and β-phellandrene correlated with fungal inoculation
- Volatile emission correlated with humidity and temperature
Beetle mash vs. fungal lesions

MPB mash caused shorter lesions $p<0.001$
Phloem monoterpenes

Two factor ANOVA:
Treatment
p=0.055
Phloem and needle monoterpenes

- Individual monoterpenes higher in beetle mash inoculated trees
- Higher concentration of total monoterpenes in needles from trees under water deficit
- PCA analysis of phloem chemistry shows hybrid trees clustering between jack and lodgepole pine
Treatment effect on N in phloem

Two factor ANOVA:

Treatment
$F(3,32)=5.600$, $p<0.005$

Water regime
$F(1,32)=3.957$, $p=0.055$
Beetle experiment

Bolts were inoculated with 4 pairs of MPB per bolt
Beetle condition

- Fresh weight
- Size
- Fat content
Treatment effect on fat content

Two factor ANOVA:

water regime

$F(1,23)=6.866$, $p<0.05$
Summary

1. The chemical profile of mature lodgepole x jack pine hybrids represents a mixture of both species’ bole VOCs profile.
2. Total monoterpenene emission higher in water deficit trees.
3. Fungal inoculation increases VOCs emission.
4. Important individual monoterpenes elevated after beetle mash inoculation.
5. Increased level of Nitrogen in phloem in fungal inoculated trees outside of the lesion.
6. Beetles that emerged from water deficit bolts had a higher fat content.
Beetle Dispersal

1. Determine flight capacity of MPB.

2. Evaluate the effect of beetle sex and age on flight capacity.

3. Quantify lipid content as a measure of energy use during flight.
1. Beetles reared from naturally infested lodgepole pine.

2. Three age groups tested:
   1. Young, 1-3 days old.
   2. Middle, 5-7 days old.
   3. Old, 9-11 days old.

3. Males and females flown for 24 h on different days.

4. Lipid content measured post flight.
Beetle Dispersal
**Beetle Dispersal**

**Table 1.** The effect of sex and age on flight performance of *Dendroctonus ponderosae*. Values are mean ± SE and sample size is stated in brackets.

<table>
<thead>
<tr>
<th></th>
<th>Proportion that flew</th>
<th>Total distance flown (km)</th>
<th>Longest single flight (km)</th>
<th>Longest single flight velocity (m/s⁻¹)</th>
<th>Pre-flight weight (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>0.66</td>
<td>3.34 ± 0.66 (59)</td>
<td>1.77 ± 0.46 (59)</td>
<td>0.50 ± 0.02 (39)</td>
<td>12.89 ± 0.31 (103)</td>
</tr>
<tr>
<td>Middle</td>
<td>0.72</td>
<td>3.56 ± 0.69 (54)</td>
<td>1.54 ± 0.35 (54)</td>
<td>0.51 ± 0.03 (39)</td>
<td>13.22 ± 0.34 (101)</td>
</tr>
<tr>
<td>Old</td>
<td>0.89</td>
<td>2.51 ± 0.68 (19)</td>
<td>0.96 ± 0.38 (19)</td>
<td>0.47 ± 0.05 (17)</td>
<td>12.58 ± 0.47 (43)</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>0.82</td>
<td>3.81 ± 0.72 (49)</td>
<td>2.09 ± 0.56 (49)</td>
<td>0.54 ± 0.03 (40)</td>
<td>9.59 ± 0.26 (94)</td>
</tr>
<tr>
<td>Middle</td>
<td>0.80</td>
<td>3.12 ± 0.52 (51)</td>
<td>1.18 ± 0.31 (51)</td>
<td>0.50 ± 0.04 (41)</td>
<td>9.72 ± 0.24 (93)</td>
</tr>
<tr>
<td>Old</td>
<td>0.81</td>
<td>1.24 ± 0.52 (31)</td>
<td>0.80 ± 0.43 (31)</td>
<td>0.54 ± 0.09 (25)</td>
<td>9.79 ± 0.24 (63)</td>
</tr>
</tbody>
</table>

Longest flying beetle= 24 km!
Beetle Dispersal

- Total distance flown was positively correlated with beetle pre-flight weight ($P<0.0001$)

- Age significantly affected total distance flown ($P<0.012$)

- Middle-aged beetles fly the farthest and old beetles fly the shortest distances
Beetle Dispersal

- Total flight duration increased with beetle pre-flight weight (P<0.0001)

- Significant interaction between sex and age affected flight duration

- Males spend more time in flight than females, except for old males
Beetle Dispersal

- Fat powers flight, unflown control beetles have more fat
- Females have more fat than males
Summary

1. Beetle weight dictates flight capacity by MPB.

2. Positive relationship between pre-flight weight and propensity to fly, flight distance, total time spent flying and flight velocity.

3. Propensity for flight, total flight distance and flight velocity were similar among male and female beetles.

4. Flight distance increased with beetle age until middle age and then decreased in old beetles.

5. Beetle sex and age affect time spent flying and body lipid content post flight.

6. Females have more fat and use more fat in flight than males.
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