Responses of forest pests to climate change: 
Tree resistance and herbivore damage along 
European elevational gradients

Ewelina Czwienckez, Lorenzo Marini*, Harvé Jactel, Marc Kenis, 
Massimo Faccoli, Alan Roques, Andrea Battisti

Tackling climate change: the contribution of forest scientific knowledge
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Climate change and insect damage

- Current spatio–temporal environmental changes are expected to alter interactions between plants and insect herbivores in forests.

- Among several contributory factors, temperature has been singled out as a major driver of plant–insect interactions and finally forest damages by herbivores.

Elevation gradients can be used as a proxy for temperature warming.
Plants and herbivores along elevation gradients

● Insect damage:
1. Slow growth rates in cold environments may extend developmental time and reduce survival and consumption rates

● Plant traits affecting herbivory:
2. Low temperatures and a shorter growing season would result in increased leaf nutrient concentrations (both N and P)
3. Slow-growing plants in cold environment should have better defenses against herbivore (e.g. higher toughness)
Plants and herbivores along elevation gradients

Complex direct and indirect temperature effects on herbivory

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Warmer temperatures → Host tree quality → Insect damage

Indirect effects on insects

Direct effects on insects
Aims

1. To test the effect of temperature on forest damage by different guilds of insect herbivores

2. To evaluate the relative importance of direct vs. indirect effect of temperature on herbivory via modified host tree quality

Predictions of temperature warming effect on the most important tree species of European forests
Methods: Sampling design

Main tree European species:
- Pinus sylvestris
- Picea abies
- Fagus sylvatica

Gradients across Europe

4-5 steps per gradient

Δ temperature ~4-5 °C

10 trees per step

~10 trees

Measures at the tree level
Methods: Measures at tree level

**TREE QUALITY**
1. Leaf toughness
2. C/N ratio

**INSECT DAMAGE**
Score (0-6) to estimate % of damaged plant tissues

Different guilds:
- Total herbivory
- Chewers
- Sap-feeders
- Gall makers
- Miners
- Cone insects
Data analysis: General linear mixed models

Random intercept models:

Toughness or C/N ~ Temperature, random= ~1|gradient/tree
Damage~ Temperature+Toughness, random= ~1|gradient/tree
Damage~ Temperature, random= ~1|gradient/tree

Unobserved causes (e.g. soil fertility, biotic interactions etc.)

We assume that all the relationships are linear in the chosen range
Temperature and leaf toughness

Toughness is lower at low, warmer sites for the three species

- Slow growing trees have more defences
- Higher radiation at high altitudes may increase leaf toughness
Temperature and leaf C/N ratio

C/N ratio varies in an unpredictable way with temperature for *Picea* and *Pinus*

C/N ratio tends to decline in *Fagus*

- Soil fertility was not controlled for: potential confounding effect of nutrient availability
General herbivory increases with temperature for *Picea* and *Pinus*: lowland forests are more damaged than high altitude forests but not for *Fagus*.
guild specific response to temperature

except for stem sap feeders, neutral or positive response to warmer temperatures
Neutral or positive response to warmer temperatures
Indirect effects on folivory (toughness)

- **73% of the cases**: (all other cases)
- **18% of the cases**: (Picea miners, Fagus leaf sap-feeders)
- **9% of the cases**: (Fagus chewers)

Dominant direct positive effect of temperature on damage
Indirect effects on folivory (C/N ratio)

Dominant direct positive effect of temperature on damage

All other cases

Pinus chewers
Conclusions

- Our findings anticipate dramatic changes in insect herbivory with temperature warming

- Little apparent effects of leaf toughness and C/N ratio on herbivory

- Dominant role of direct effect of temperature on insect damage: lowland forests are more damaged than high forests

BUT

Herbivore- and tree-specific response to temperature
Conclusions

- Spruce and pine forests seem to be more susceptible than beech to temperature warming.

- Herbivory will probably increase with temperature warming in European conifer forests.

![Graph showing the relationship between temperature and herbivory for different tree species.](image-url)
Thank you for your attention

BACCARA project information
www.baccara-project.eu/

Contact details:
E-mail: lorenzo.marini@unipd.it