



Restoration and regeneration of *Acacia koa* in Hawai'i

Kyle M. Earnshaw

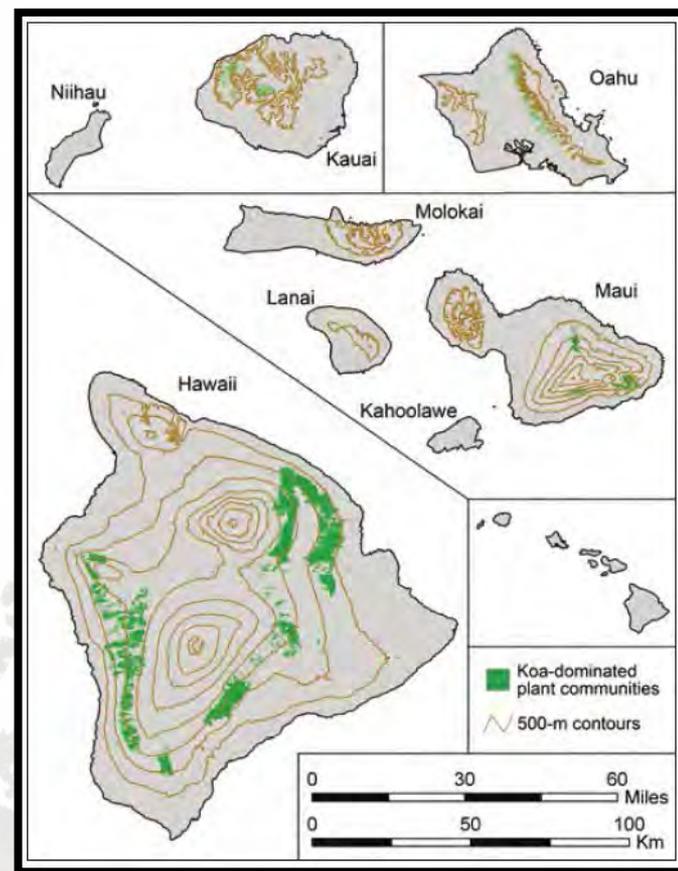
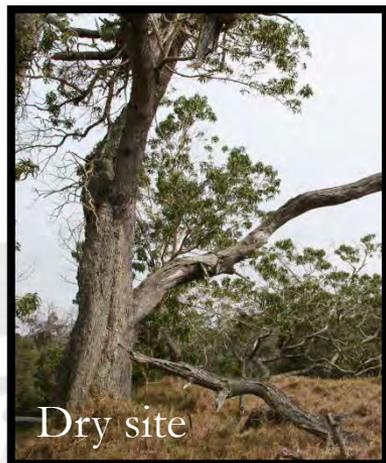


Acacia koa

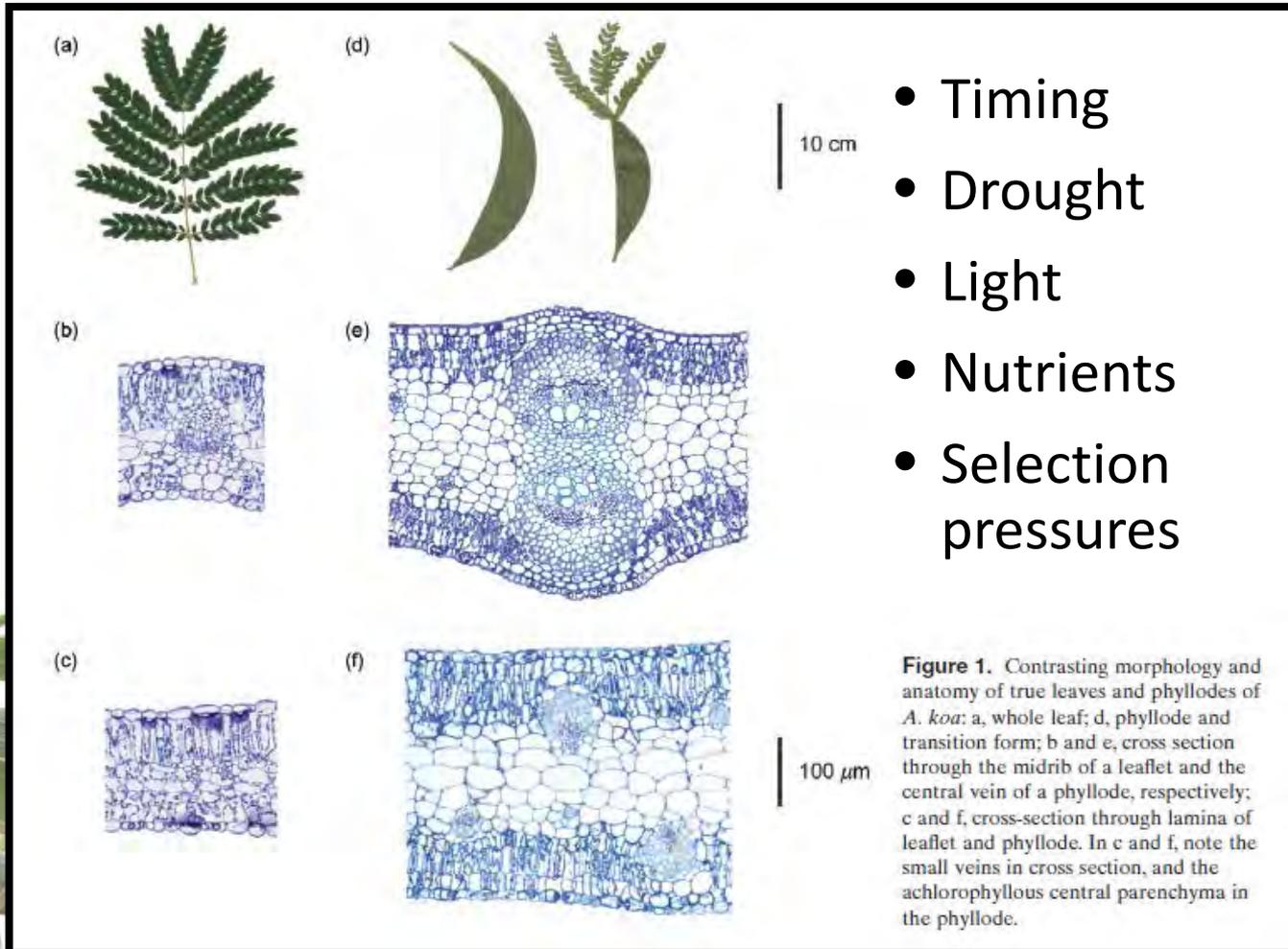


Acacia koa: distribution

- From sea level to more than 2100 masl
- On the Big Island:
 - Windward and leeward
 - Precipitation: <1000 mm/year to 4000 mm/year



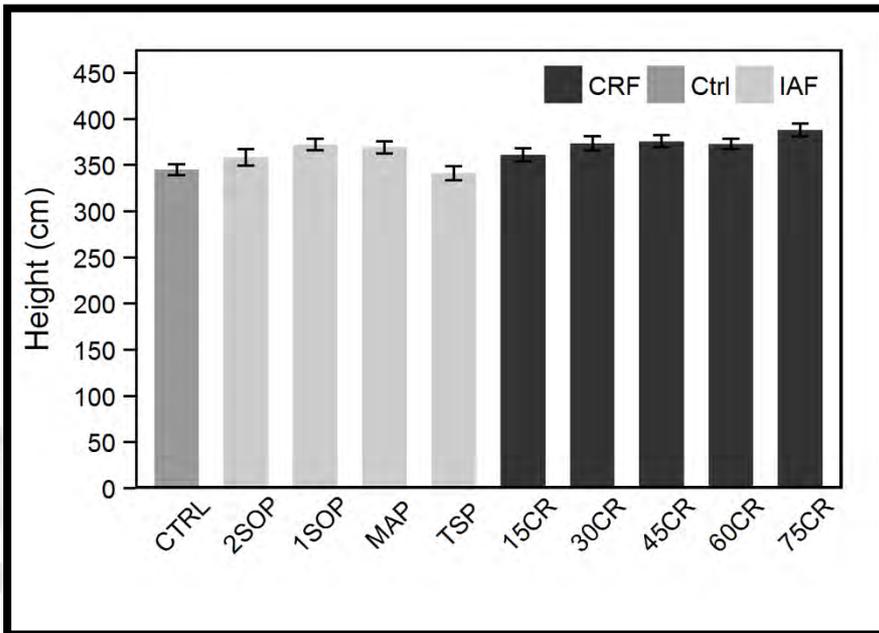
Koa heteroblasy



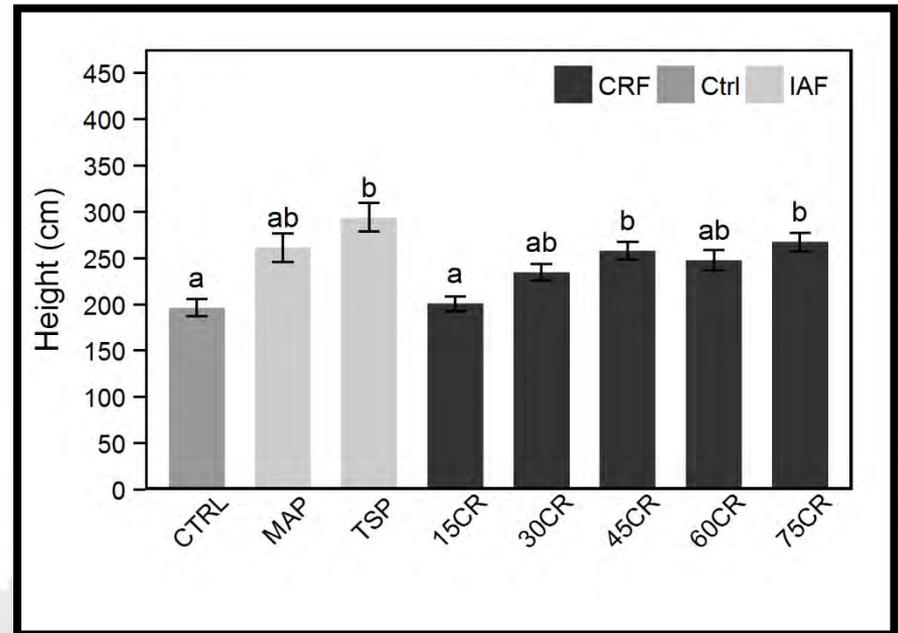
Overview of projects

- How will the use of immediately-available vs. controlled-release fertilizers on contrasting sites affect performance and survival?

Pahala

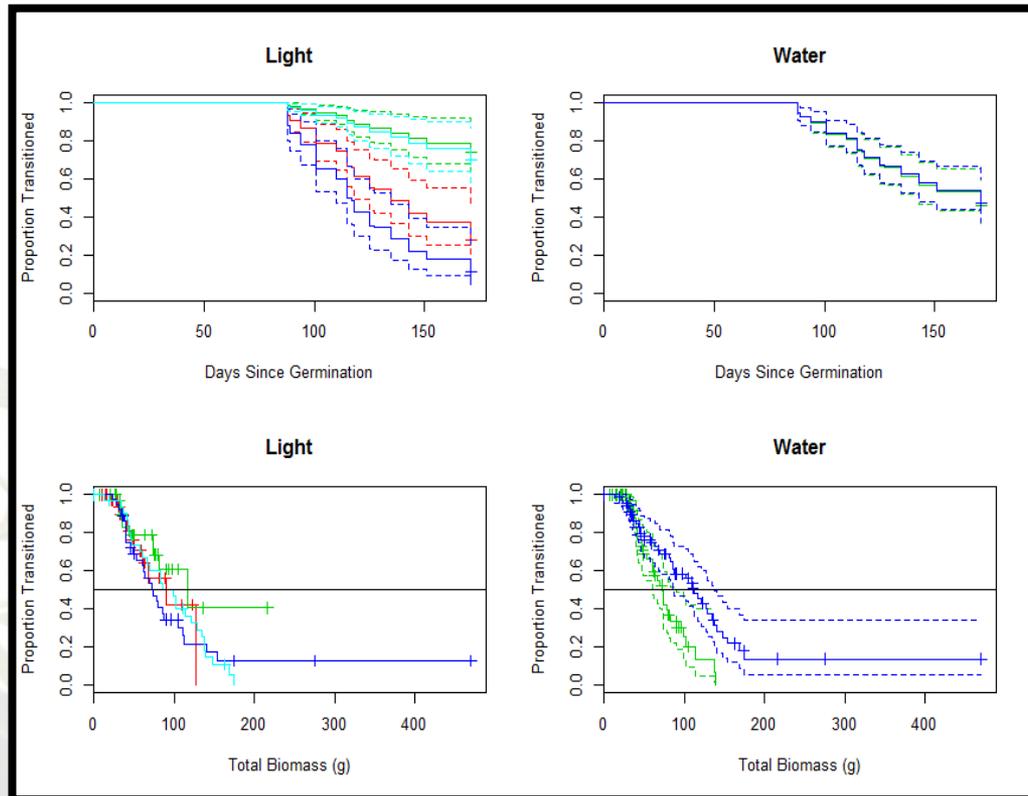


Volcano



Overview of projects

- How do light intensity, light quality, and drought affect the timing of transition from one leaf form to the next?



Overview of projects

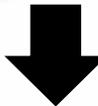
- How will the use of immediately-available vs. controlled-release fertilizers on contrasting sites affect performance and survival?
- How do light intensity, light quality, and drought affect the timing of transition from one leaf form to the next?
- How do contrasting populations differ in their development, performance, and survival on a drought-prone site? How does developmental plasticity affect these?



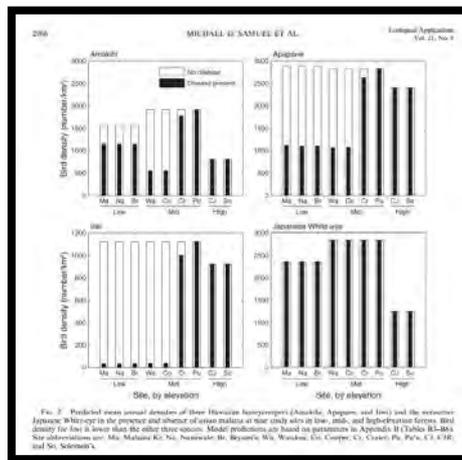
The use of a non-native conifer, *Cryptomeria japonica*, for the restoration of *Acacia koa* forests in frost-prone areas of Hawai'i

Kyle Earnshaw, Juan Oliet-Pala, Faith Inman-Narahari,
James B. Friday, Michael Mickelbart, and Douglass F. Jacobs





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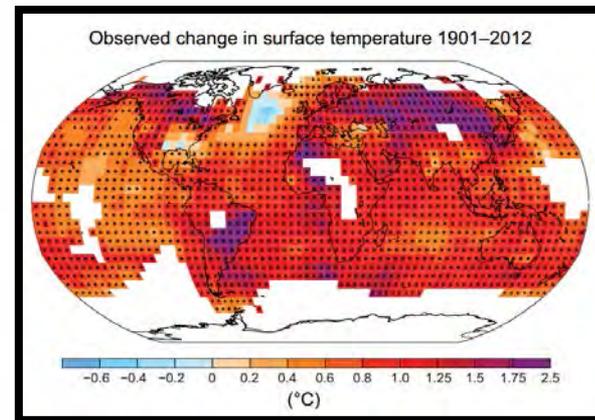


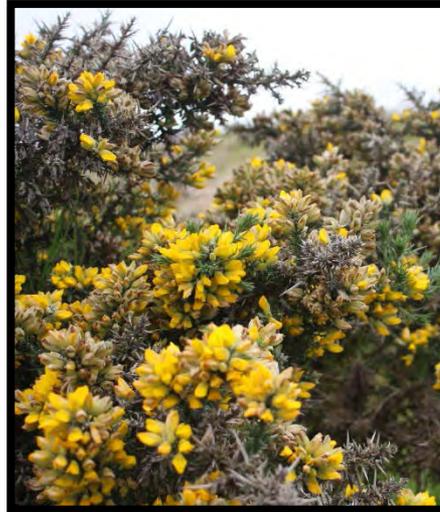
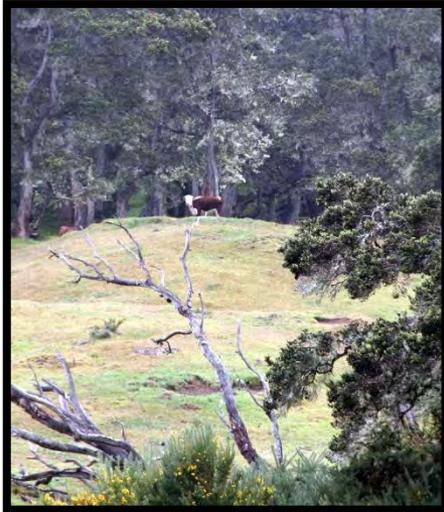
Table 1. Total forest area in hectares for each zone under current (before) and after 2°C warming scenario for each island refuge

Zones	Hanawi (3,166 hectares)		Hakalau (12,999 hectares)		Alakai region (15,326 hectares)	
	Before	After	Before	After	Before	After
Above 17°C	1,266	1,995	650	5,200	0	12,937
Between 17 and 13°C	1,235	886	9,229	7,669	15,236	2,299
Below 13°C	665	285	3,120	130	0	0

Total refuge area is shown in parentheses; values are rounded to the nearest whole number.

Limitations to reforestation on high elevation sites

Problem



Solution?



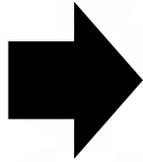
Methods against frost damage

- Avoidance: height growth
- Tolerance: soluble sugars, anti-freeze proteins
- Development? Leaf types?

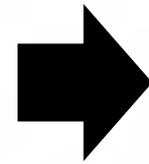
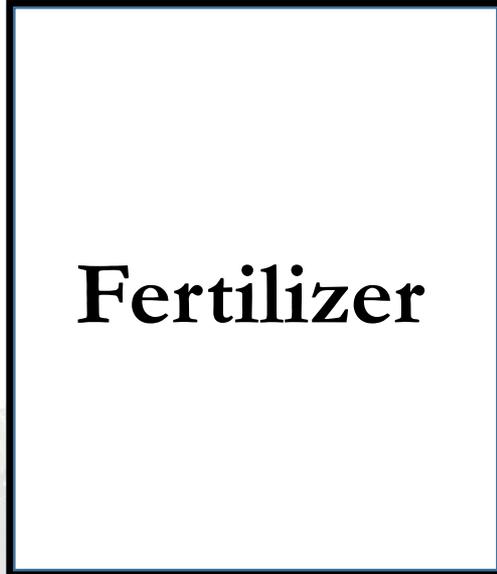




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Study Questions

1. Can nurse tree systems (with sugi pine, *Cryptomeria japonica*, for example) function with koa, a “shade-intolerant” species, to provide frost protection without limiting growth?
2. How will fertilization and shade interact to affect survival and early growth of koa on frost prone sites?
3. Does koa acclimate to cold temperatures? How will fertilization affect this process, if so?
4. How will interactions between abiotic stressors, such as shade and nutrient stress, which can speed up or slow down development, and cold temperatures affect early growth and survival?

Design



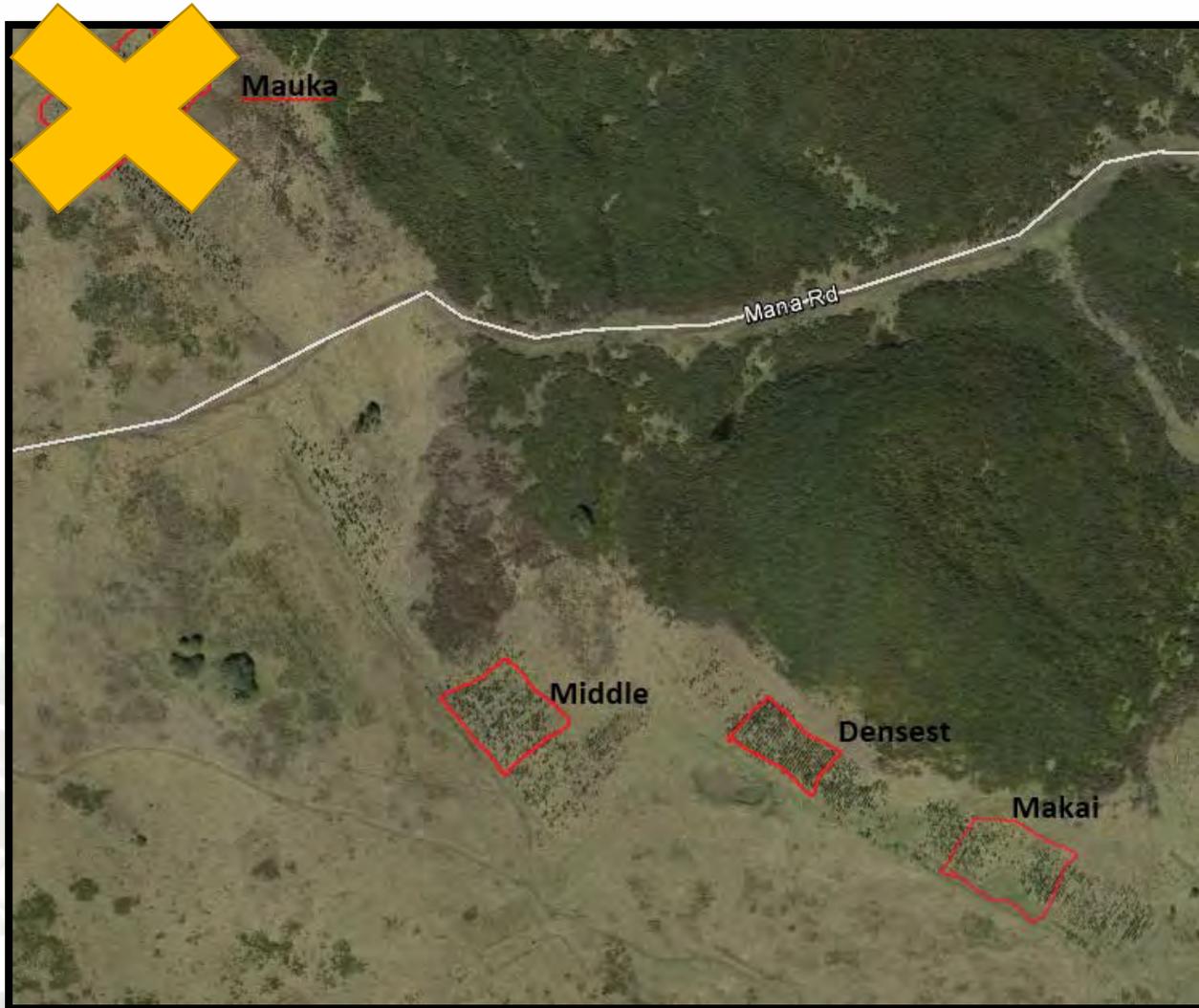
Design



Design



Design



Design



Methods

- Measurements:
 - Growth, morphology, and survival after 1, 16, 35, and 54 weeks
 - F_v/F_m , soluble carbohydrates, and leaf nitrogen content in leaves before, during, and after winter
 - Temperature: 32 thermocouples at 50 cm
 - Precipitation

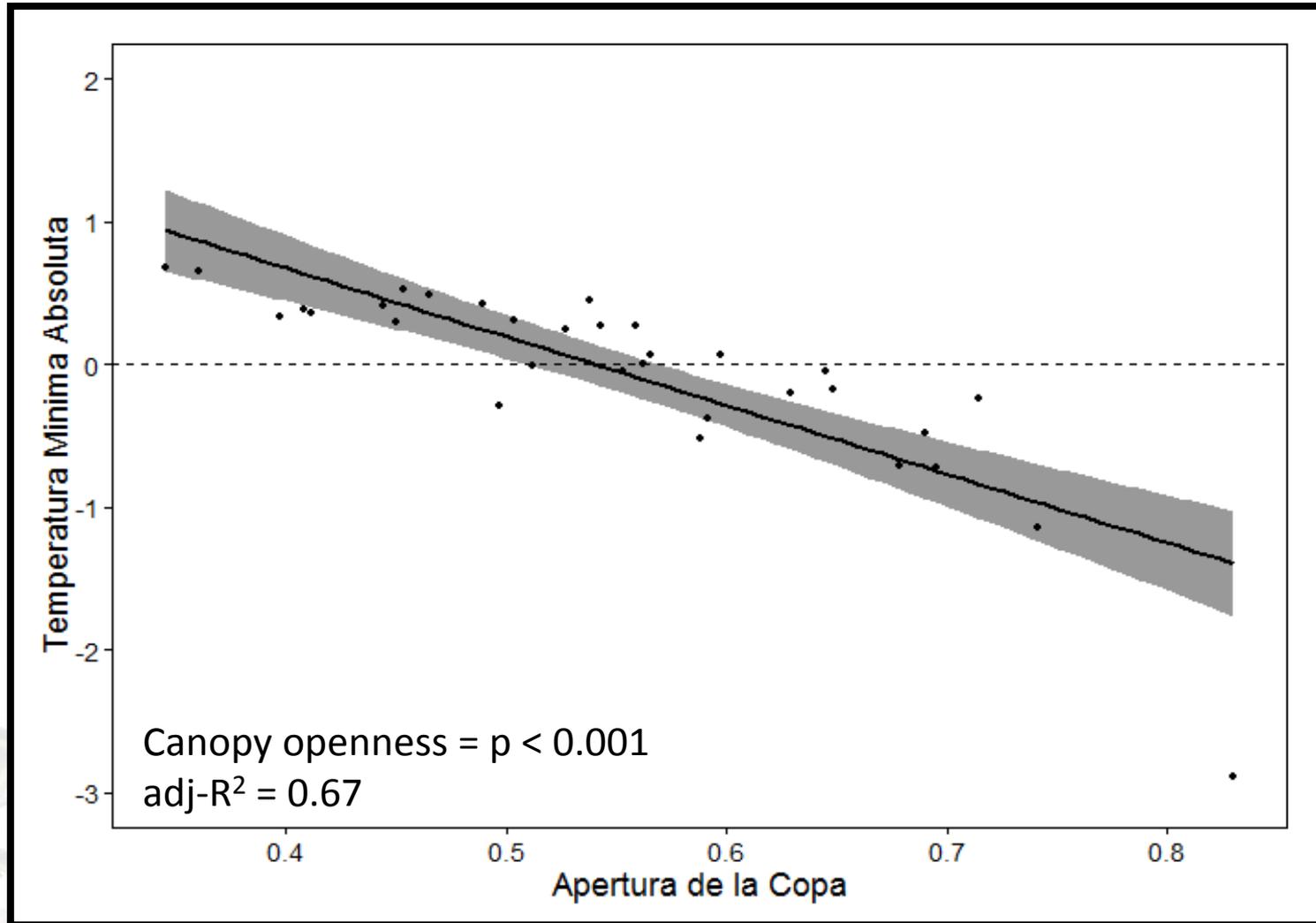


Methods

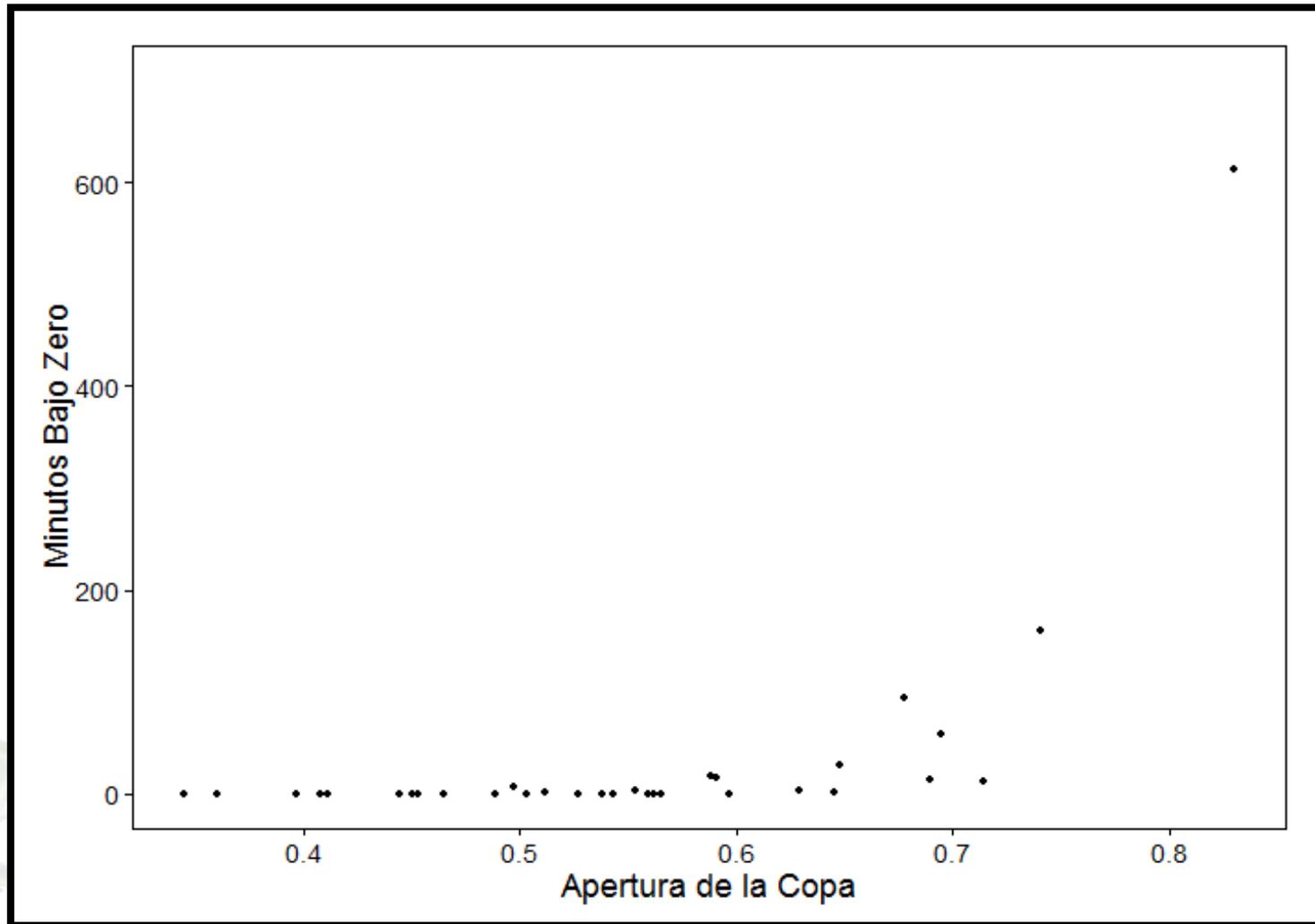
- Canopy openness: hemispherical photography and CIMES
- Statistics:
 - Linear regression: temperature
 - Mixed models (lmer in R): growth and morphology
 - Multinomial regression: frost damage



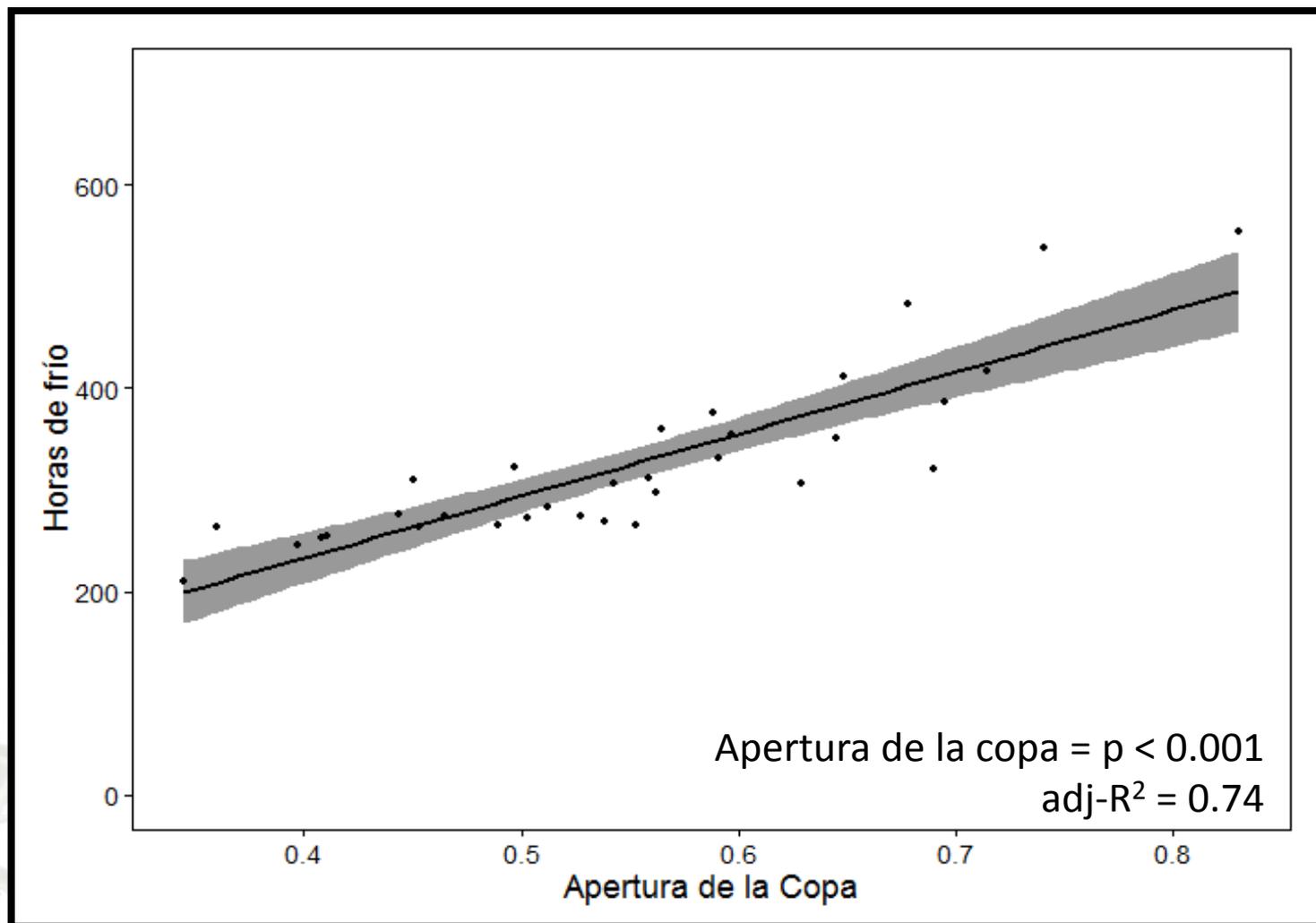
Results: absolute minimum temperature



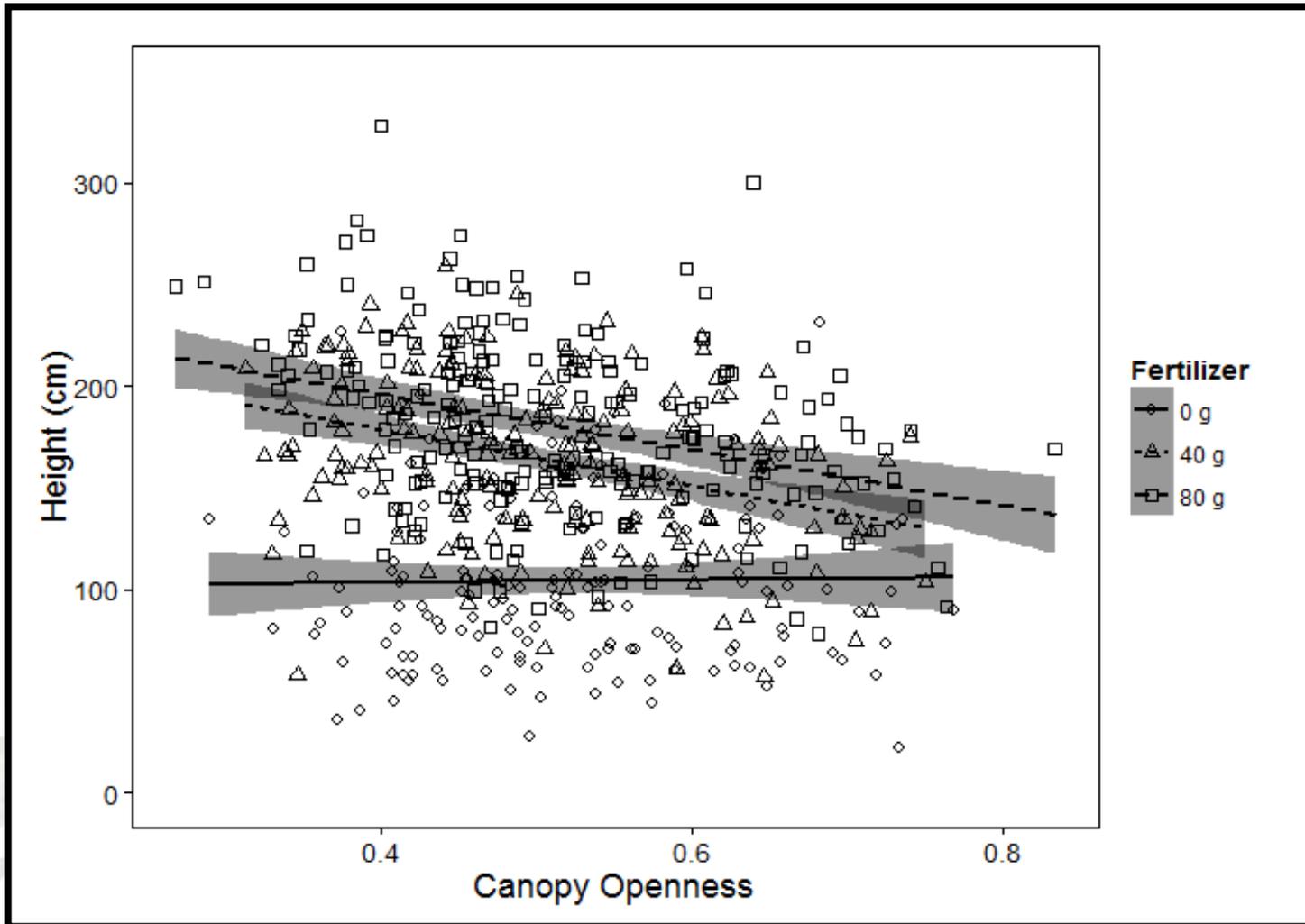
Results: minutes below zero (C)



Results: chilling (0-5°C)



Results: height

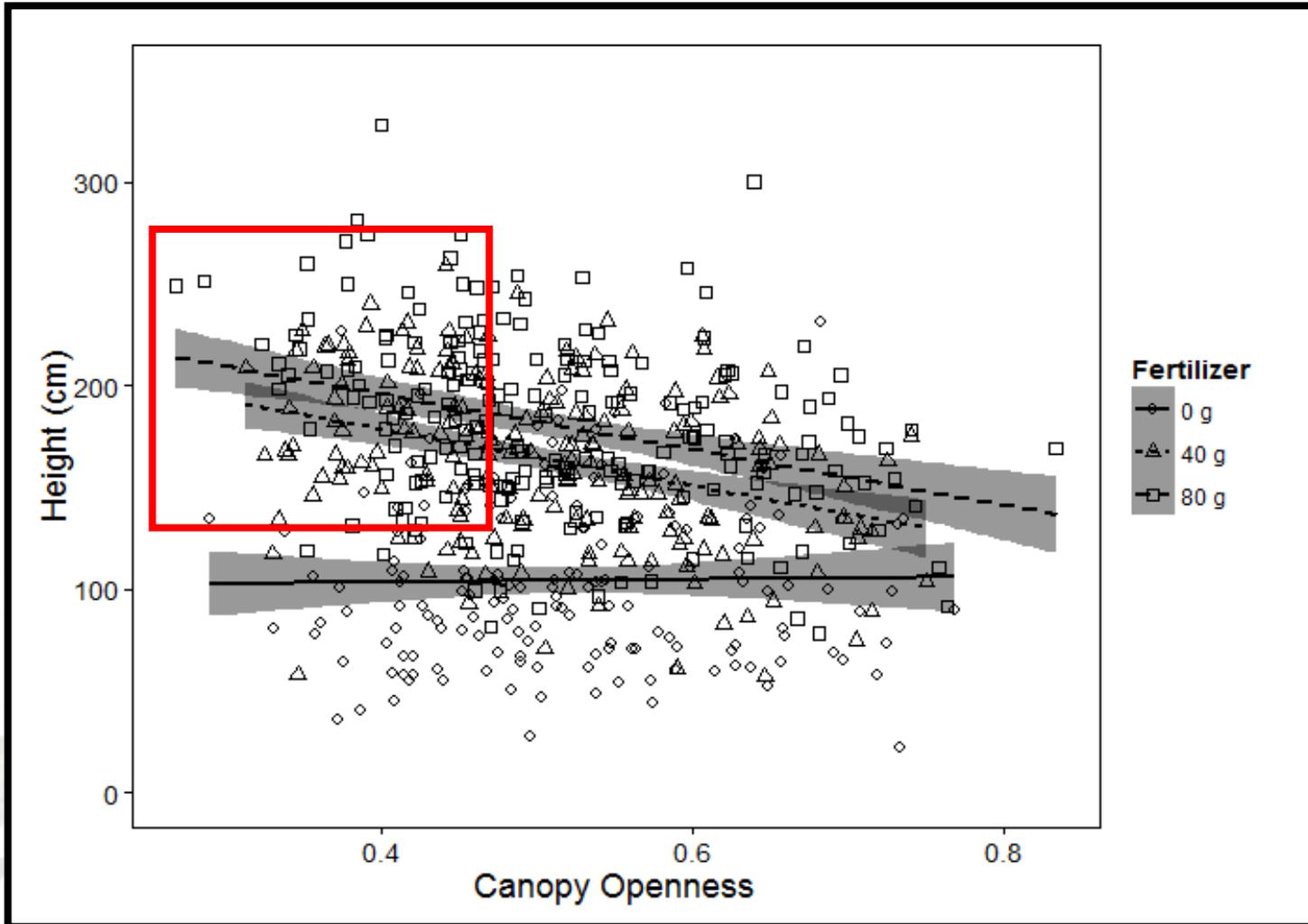


Canopy: $p < 0.001$

Fert: $p < 0.001$

Can:Fert: $p < 0.001$

Results: height

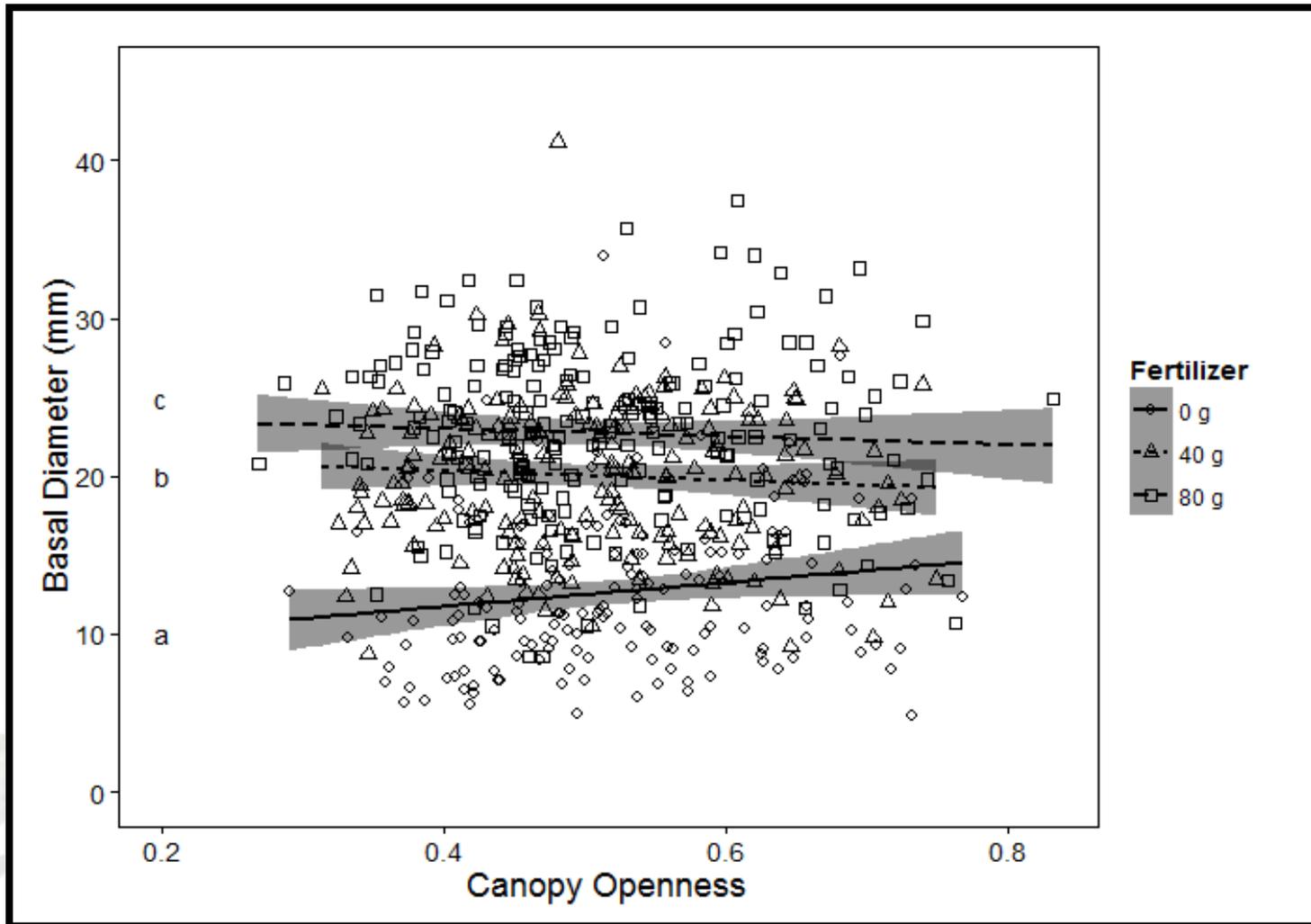


Canopy: $p < 0.001$

Fert: $p < 0.001$

Can:Fert: $p < 0.001$

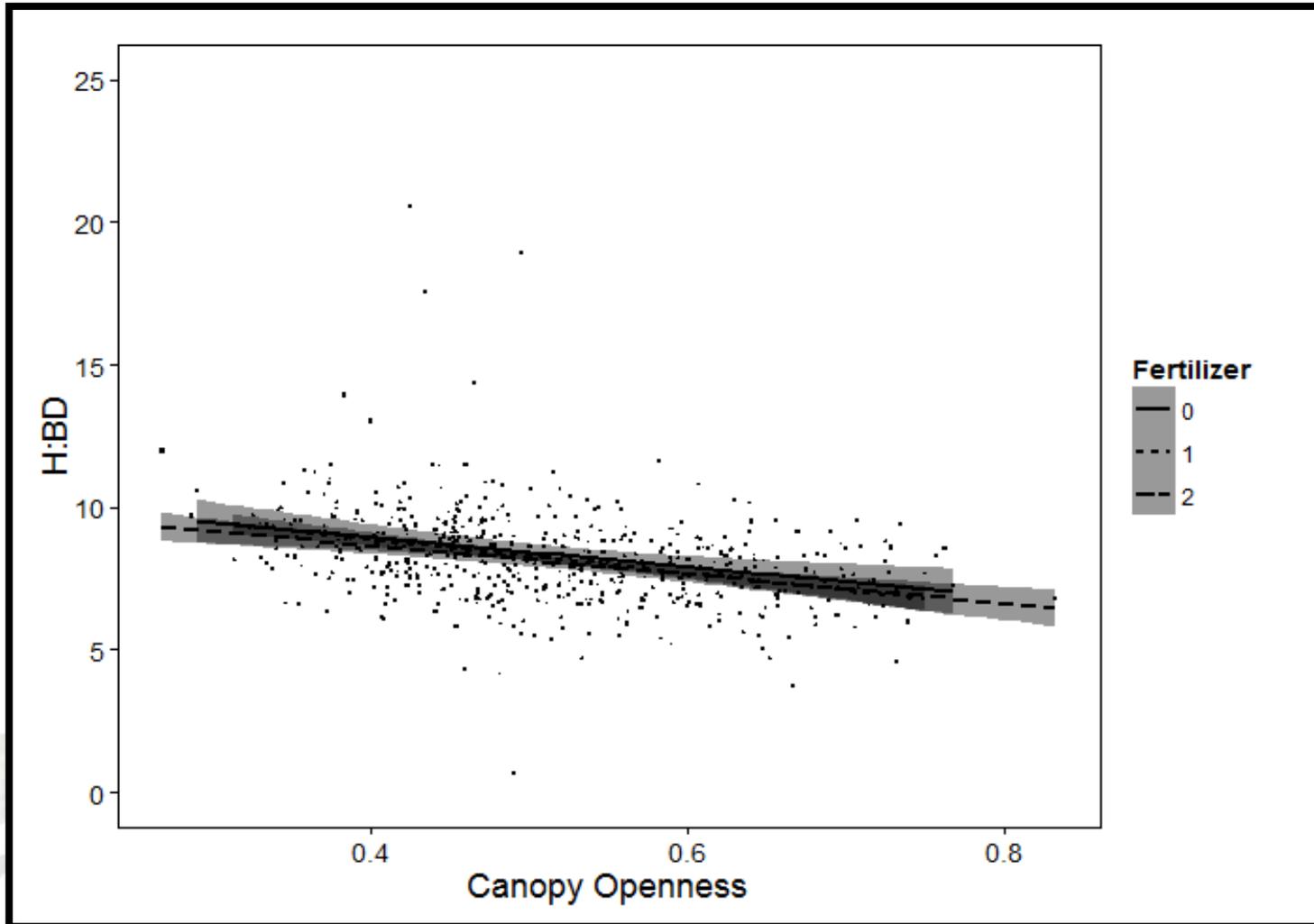
Results: basal diameter



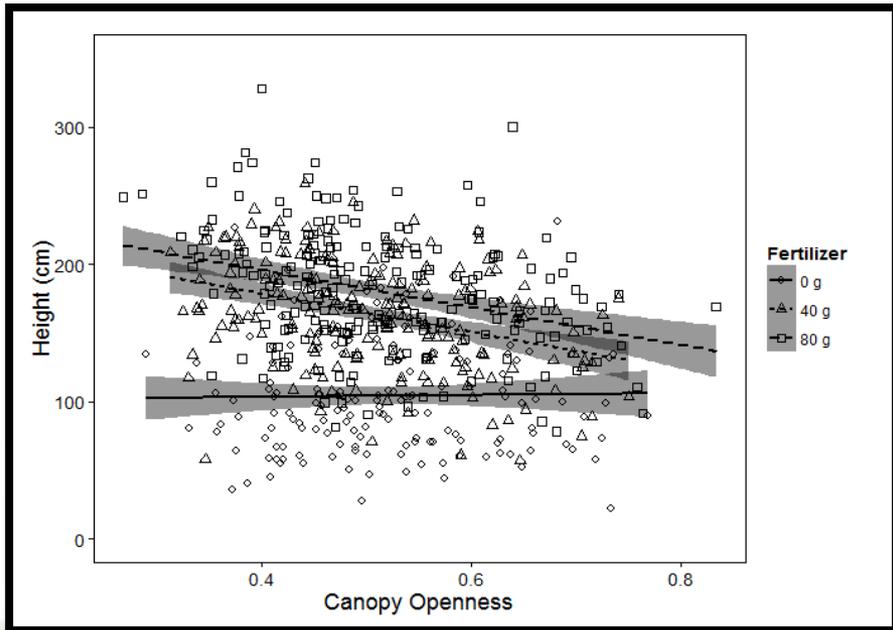
Canopy: $p = 0.8537$

Fert: $p < 0.001$

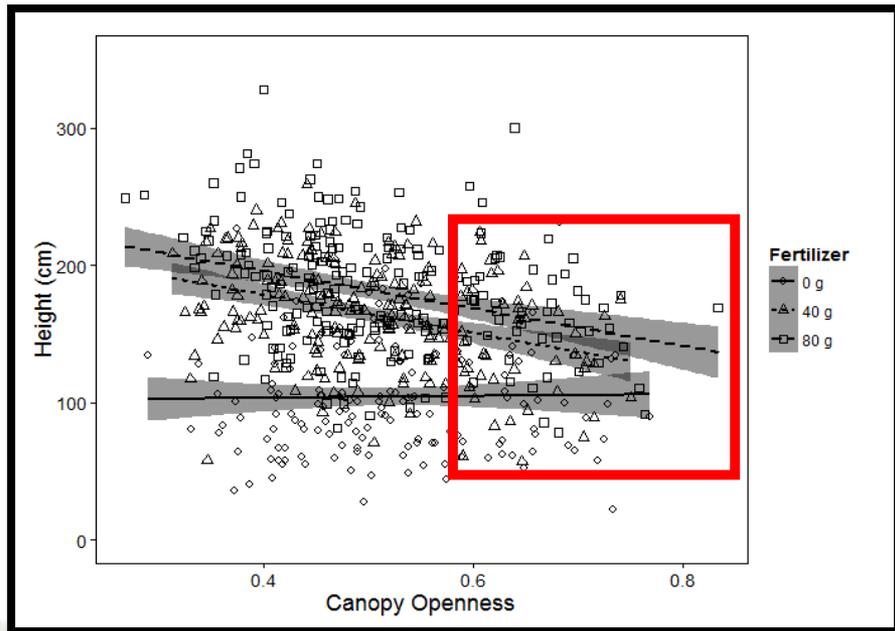
Results: slenderness



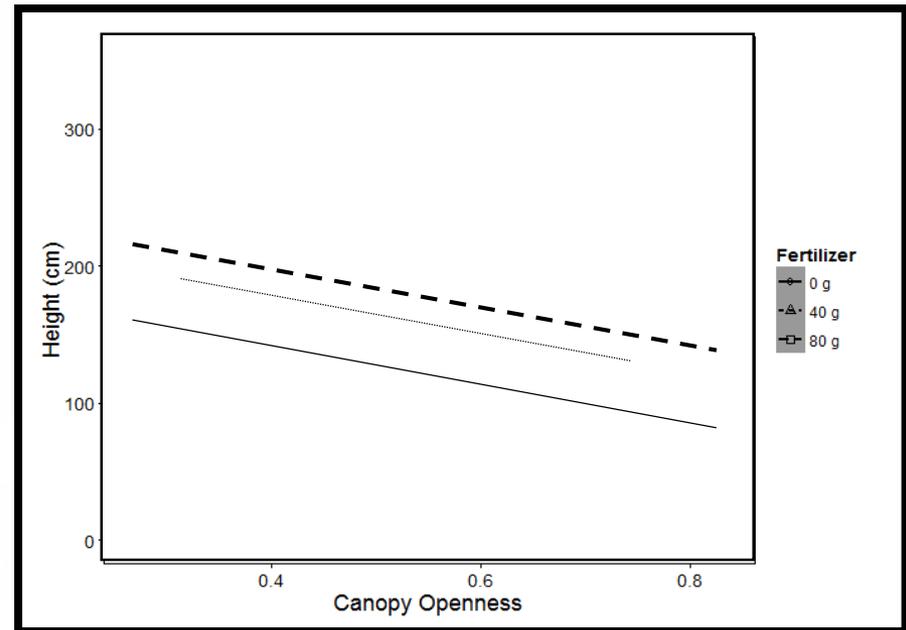
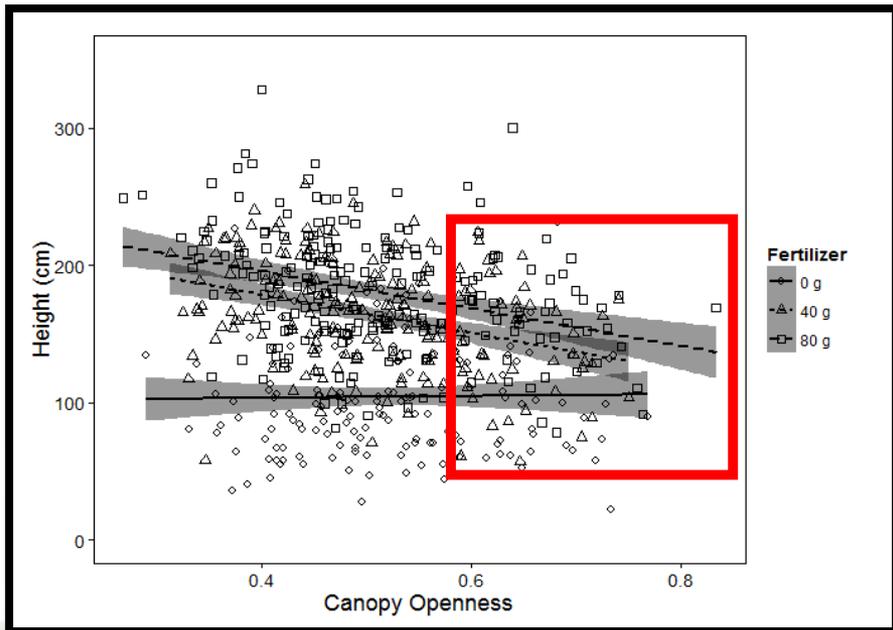
Results: importance of frost



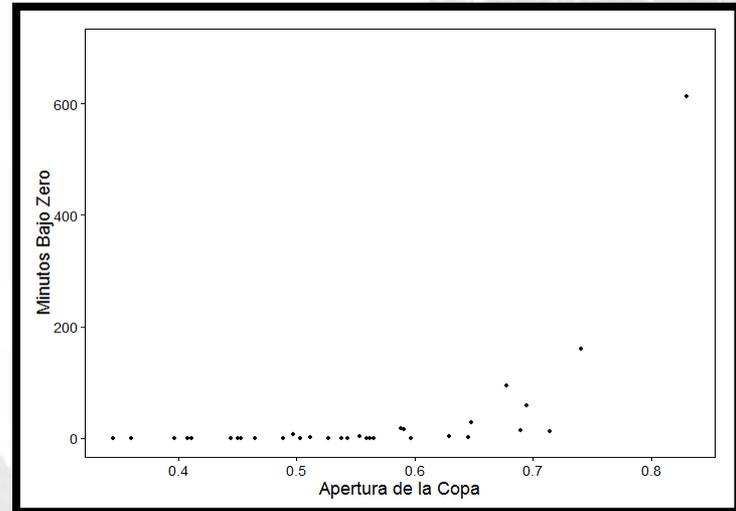
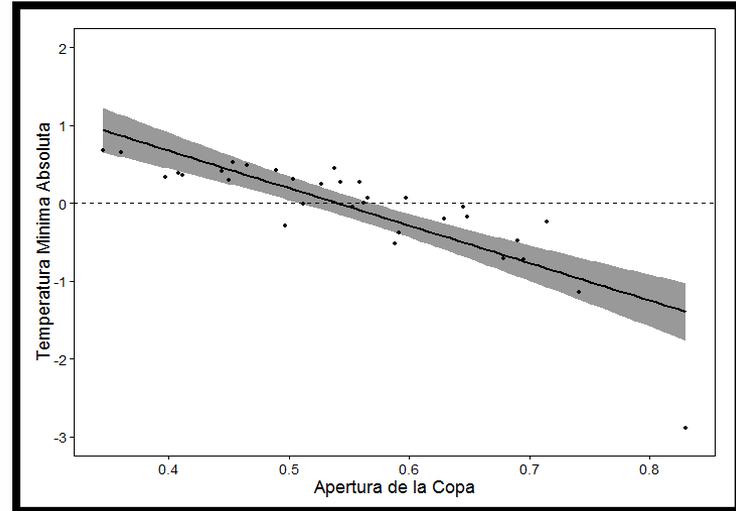
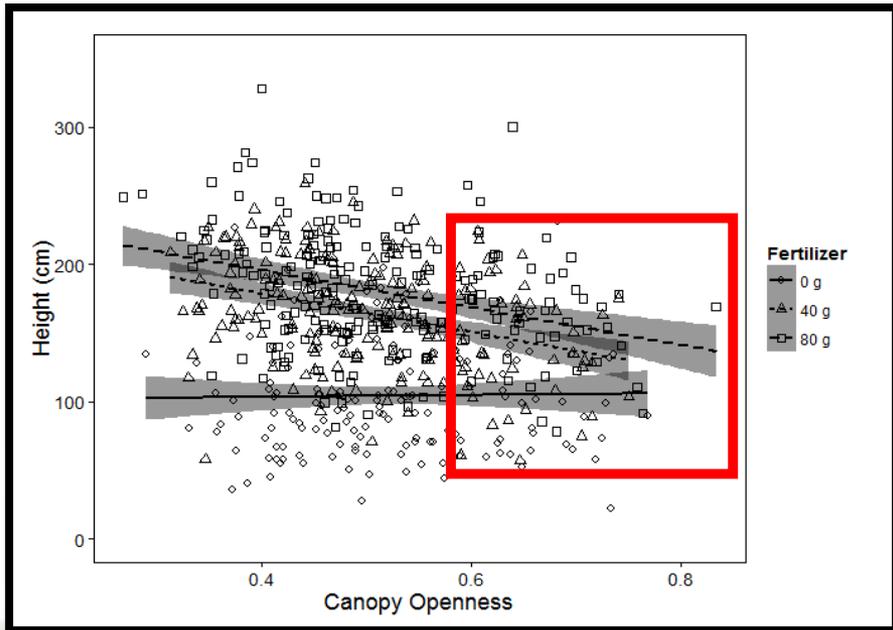
Results: importance of frost



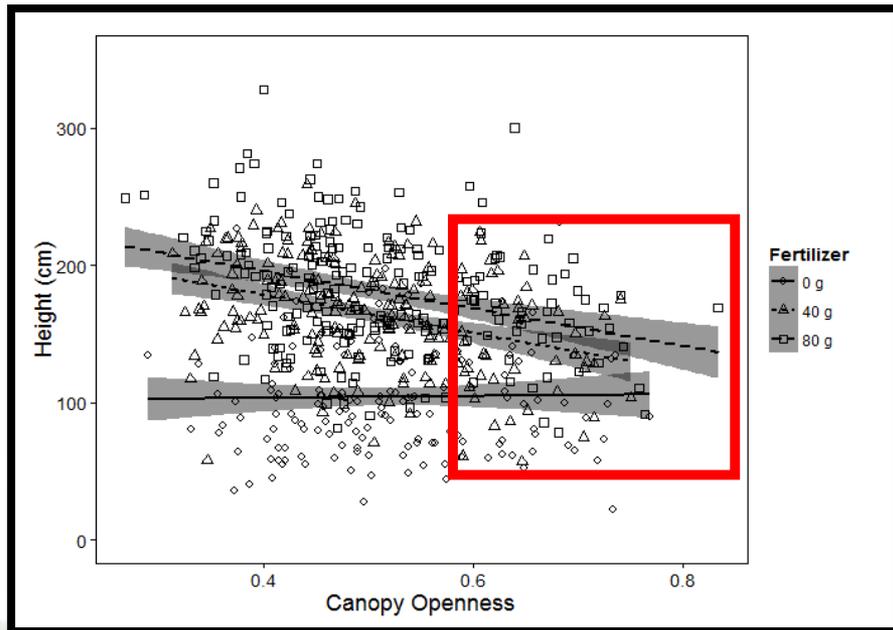
Results: importance of frost



Results: importance of frost



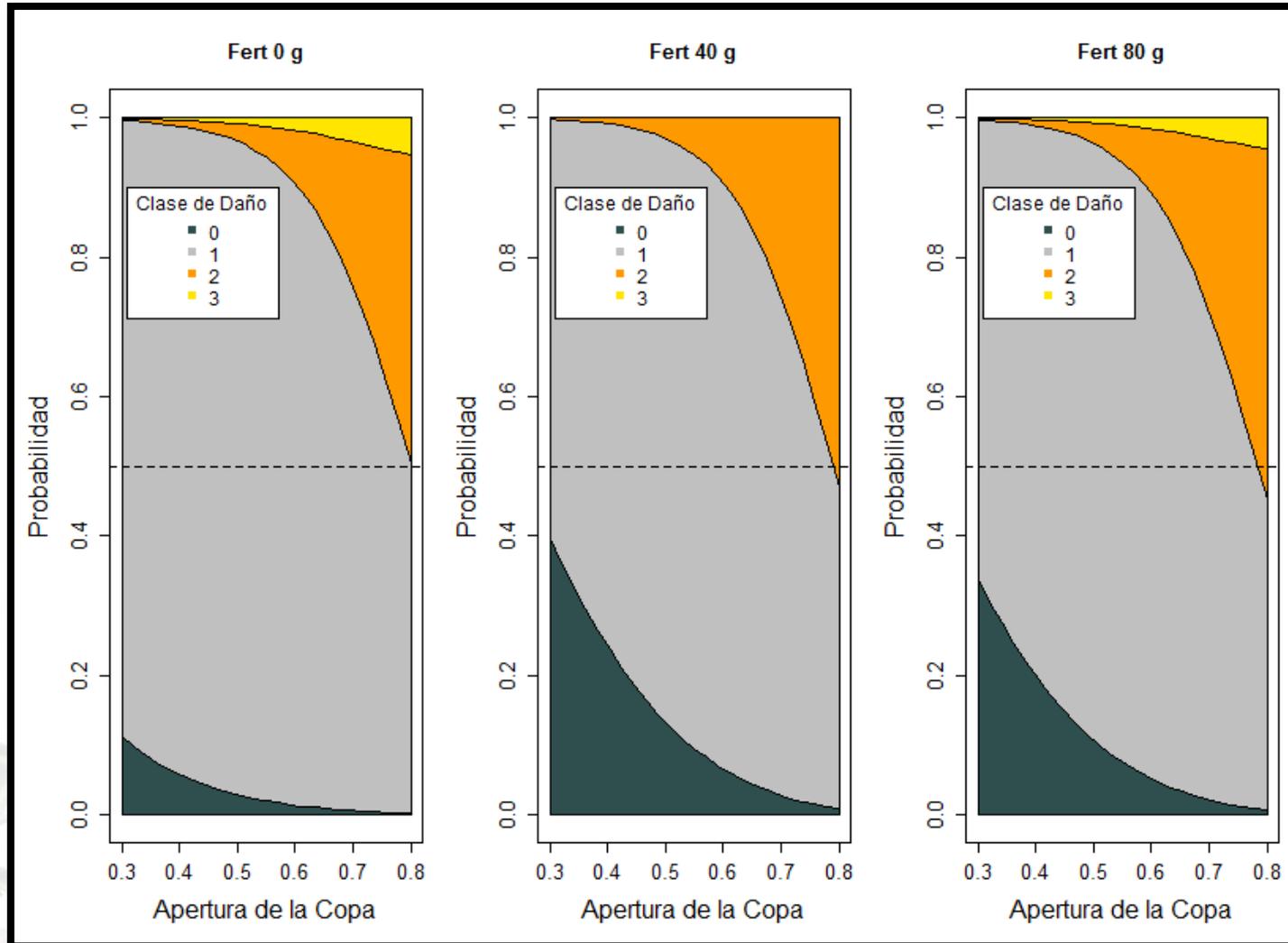
Results: importance of frost



Potential explanations:

- $\uparrow \text{Open} + \uparrow \text{FERT} \rightarrow \uparrow \text{frost damage}$
- $\uparrow \text{Open} + \uparrow \text{FERT} \rightarrow \uparrow \text{CHO, proteins}$
- $\uparrow \text{Open} \rightarrow \uparrow \text{ or } \downarrow \text{ w\u00e1ter availability}$

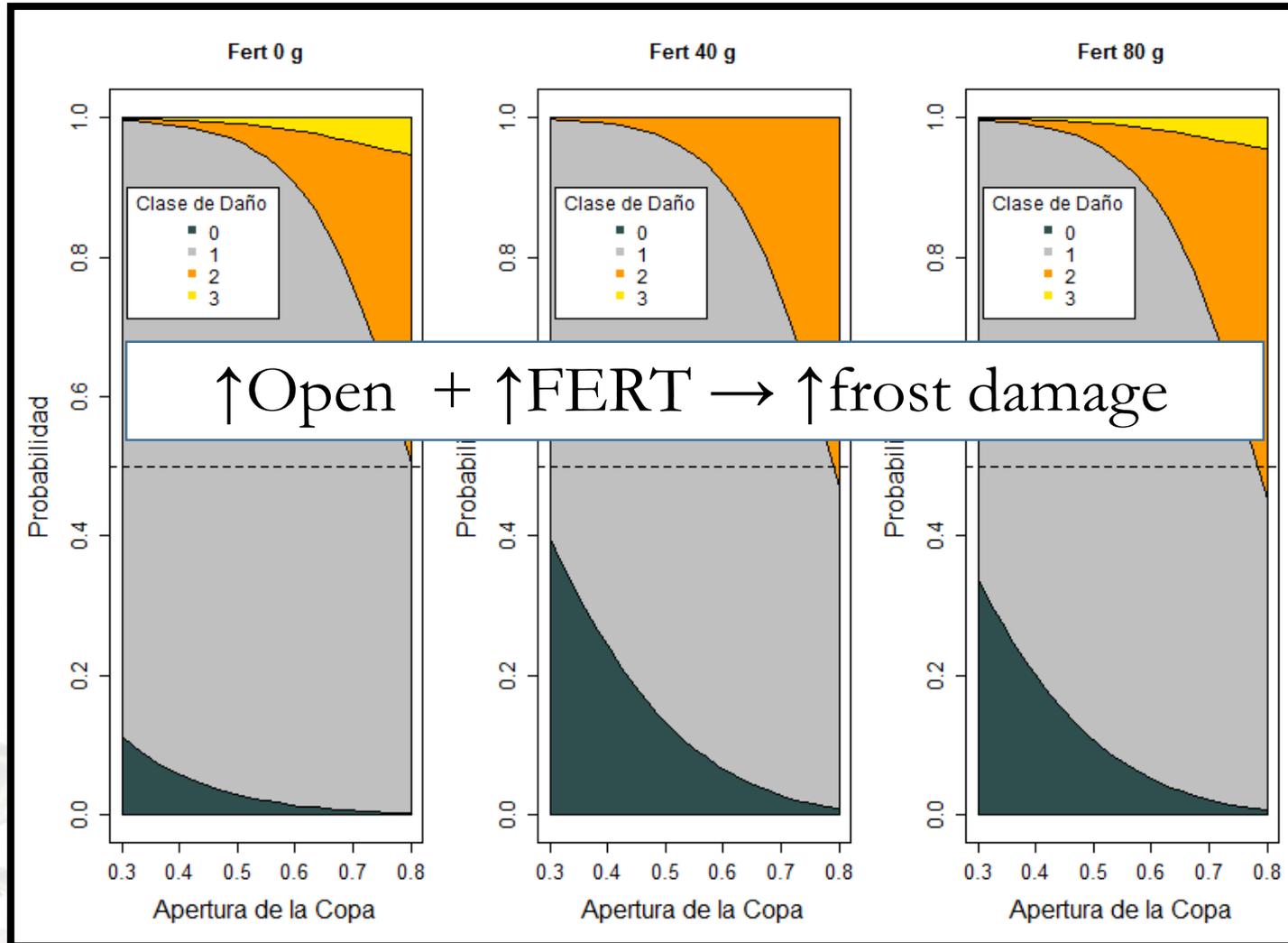
Results: frost damage



Canopy: $p < 0.001$

Fert: $p < 0.01$

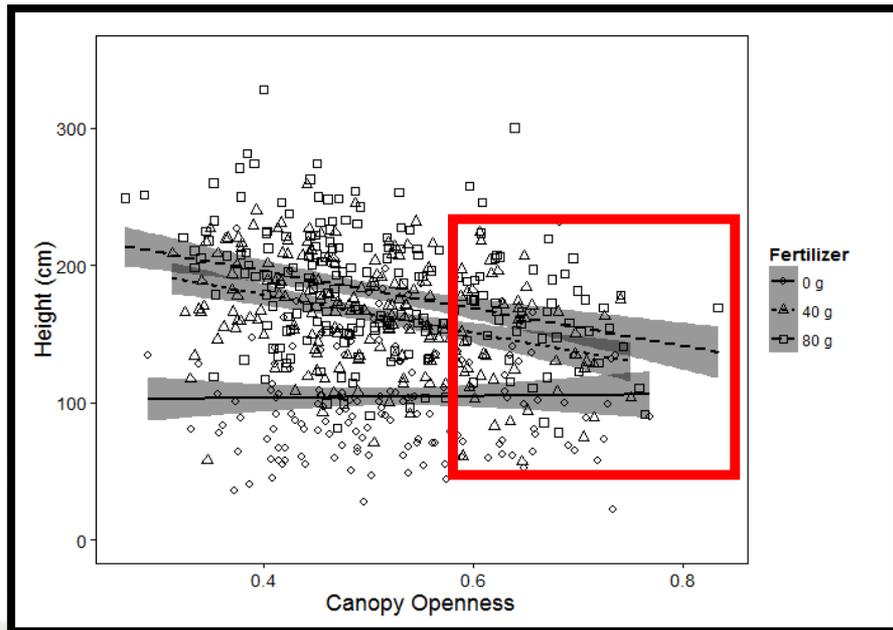
Results: frost damage



Canopy: $p < 0.001$

Fert: $p < 0.01$

Results: importance of frost



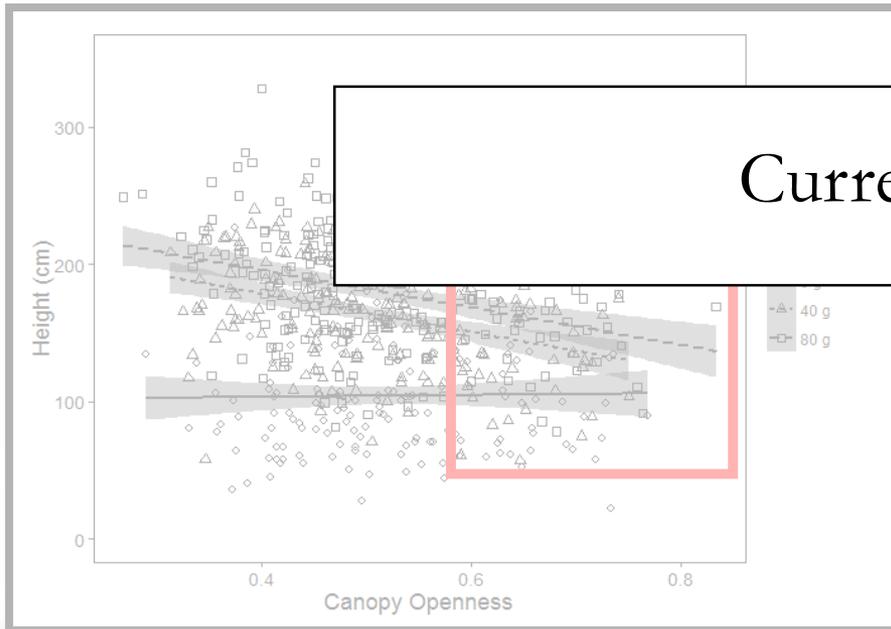
Potential explanations:

- $\uparrow\text{Open} + \uparrow\text{FERT} \rightarrow \uparrow\text{frost damage}$
- $\uparrow\text{Open} + \uparrow\text{FERT} \rightarrow \uparrow\text{CHO, proteins}$

Resultados: importancia de las heladas

Explicaciones potenciales:

Current work



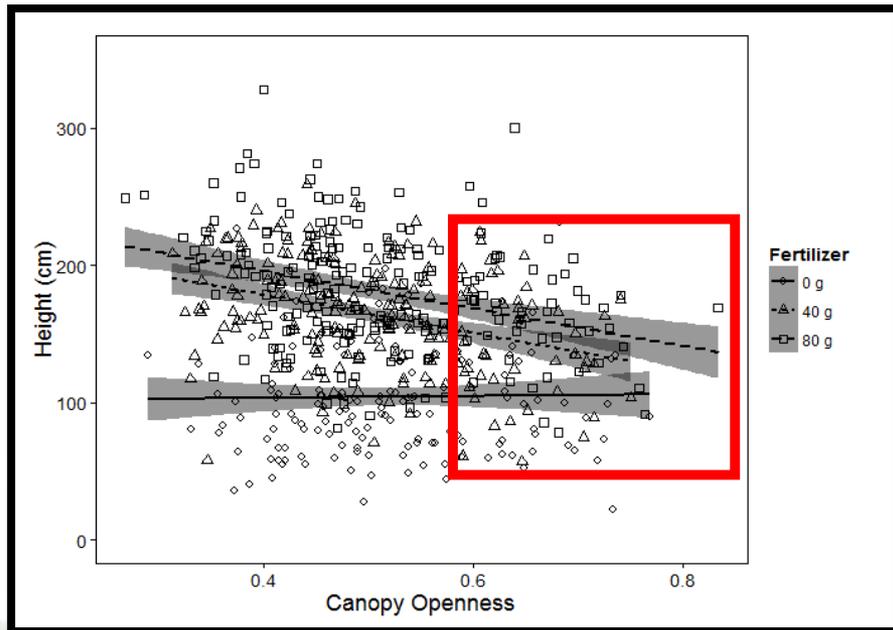
daño por helada

CHO, proteínas

apertura

PERI

Results: importance of frost



Potential explanations:

- $\uparrow \text{Open} + \uparrow \text{FERT} \rightarrow \uparrow \text{frost damage}$
- $\uparrow \text{Open} + \uparrow \text{FERT} \rightarrow \uparrow \text{CHO, proteins}$
- $\uparrow \text{Open} \rightarrow \uparrow \text{ or } \downarrow \text{ w\u00e1ter availability}$

Upcoming work

- Analysis of adaptiveness of heteroblastic plasticity
- Analysis of frost response in the field (soluble sugars)
- Morphological (form) responses to moderate shading
- Quantifying acclimation and frost tolerance of leaves versus phyllodes



Citations

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Thanks! Questions?

