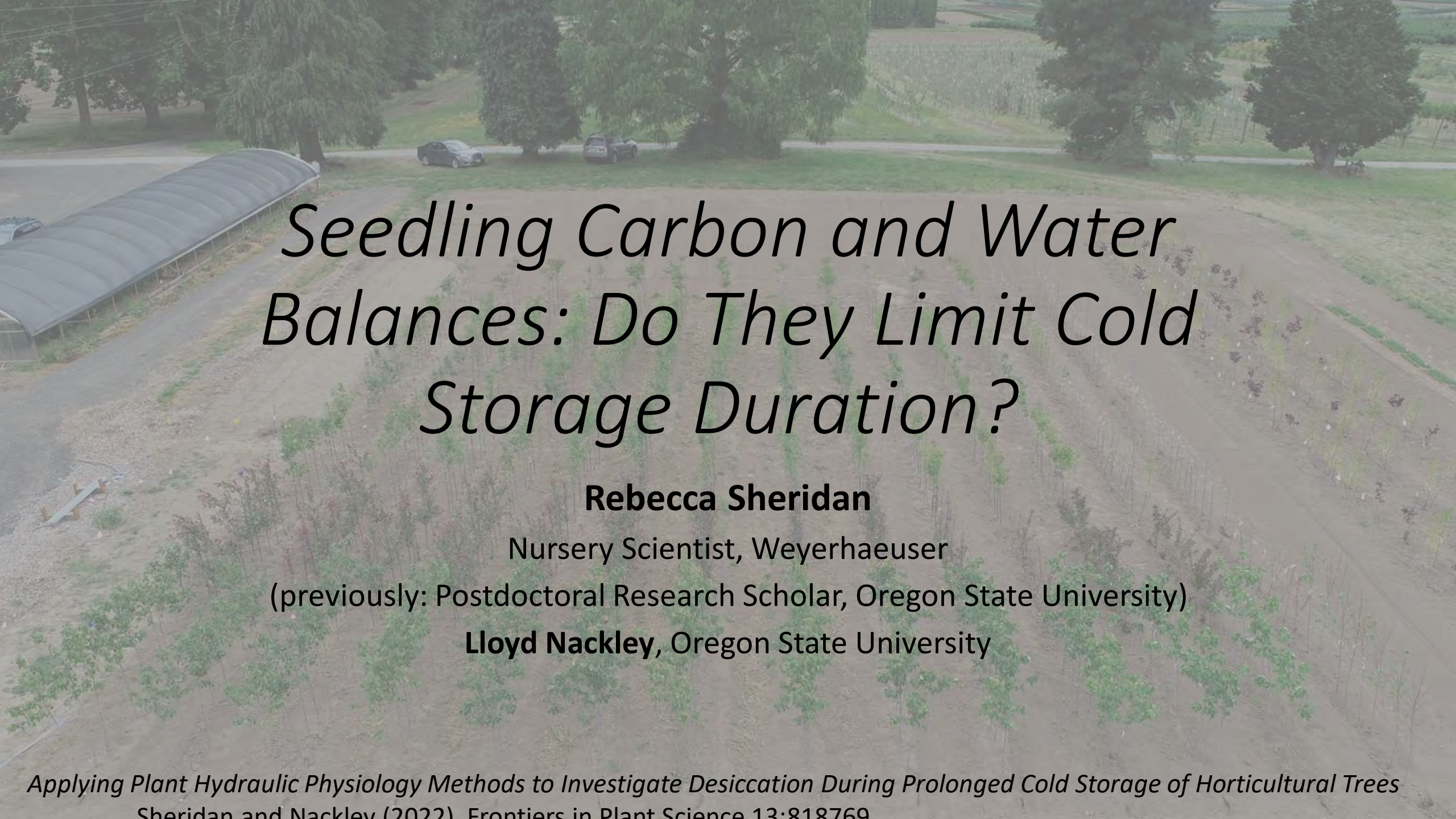

Seedling Carbon and Water Balances: Do They Limit Cold Storage Duration?

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Applying Plant Hydraulic Physiology Methods to Investigate Desiccation During Prolonged Cold Storage of Horticultural Trees
Sheridan and Nackley (2022). Frontiers in Plant Science 13:818769

Outline

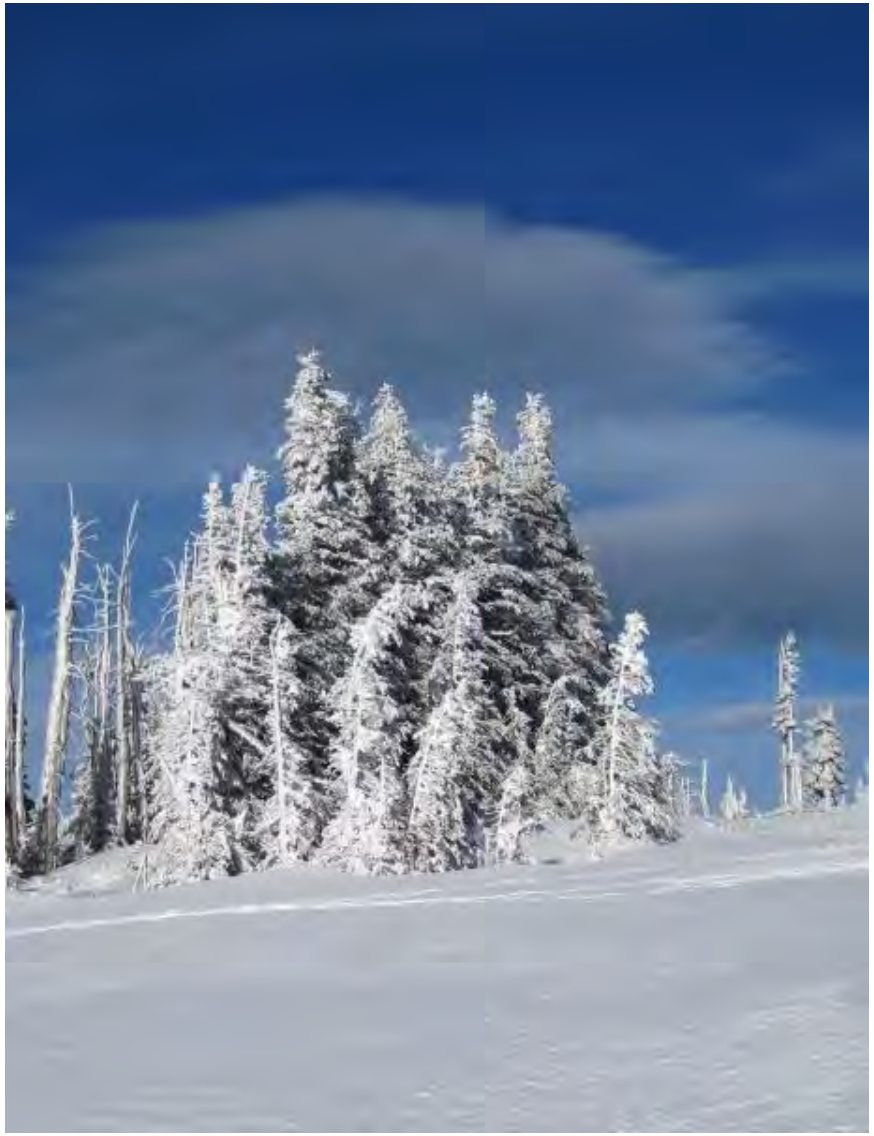
- Operational needs for cold storage
- Challenges for plants in cold storage (or winter)
  - Water relations: desiccation and hydraulic failure
  - Winter energy supply: carbon starvation
- Experiment: do we see plants hit biological limits in extended cold storage?
- Biologically-informed cold storage decisions in nursery systems

Cold Storage Basics

- Temperature- and humidity-controlled environment to bridge the gap between the end of the nursery growth cycle and outplanting
  - Generally, cooler storage is 1 to 2℃ and freezer storage is -2 to -1℃
- For some plants, provides chilling hours required to move through dormancy
- Allows lifting, handling, shipping, and outplanting to happen while plants are dormant
  - Matching nursery production cycles to environmental cycles is could become more unpredictable in the face of climate change

Limits to Cold Storage: Research Questions

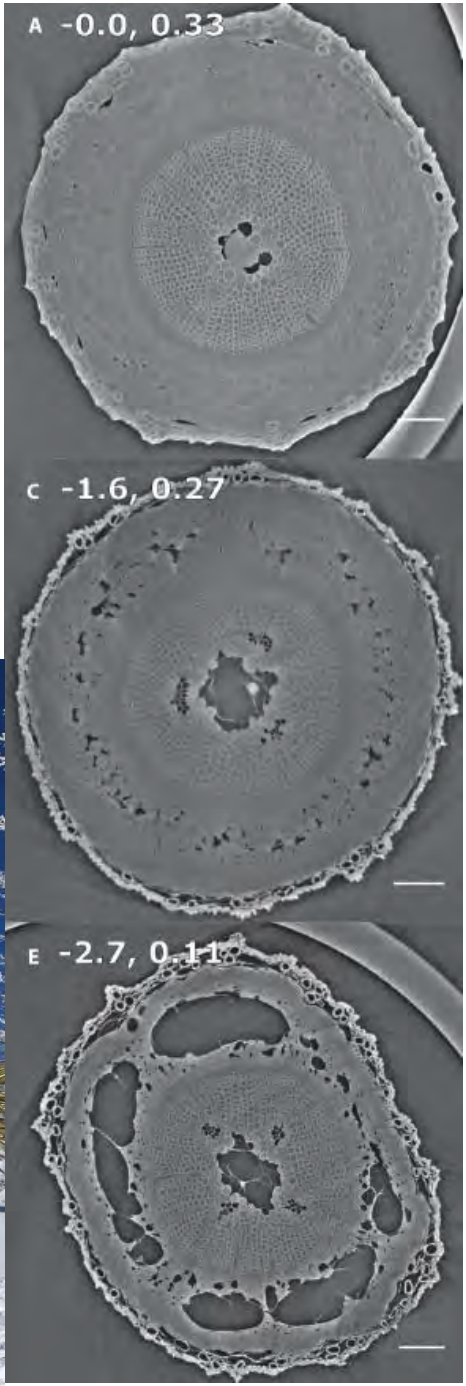
- Plants cannot be kept in cold storage indefinitely: what fails first?
  - Water relations or non-structural carbohydrate supply?



#whatkillstrees

Limits to Cold Storage: Water Relations

- Plants need water through the winter to maintain tissues and resume growth
- Water relations could be disrupted in cold storage by :
  - Tissue desiccation
  - Xylem failure
  - Root desiccation or lack of water supply
  - Freeze-thaw cycles that damage xylem



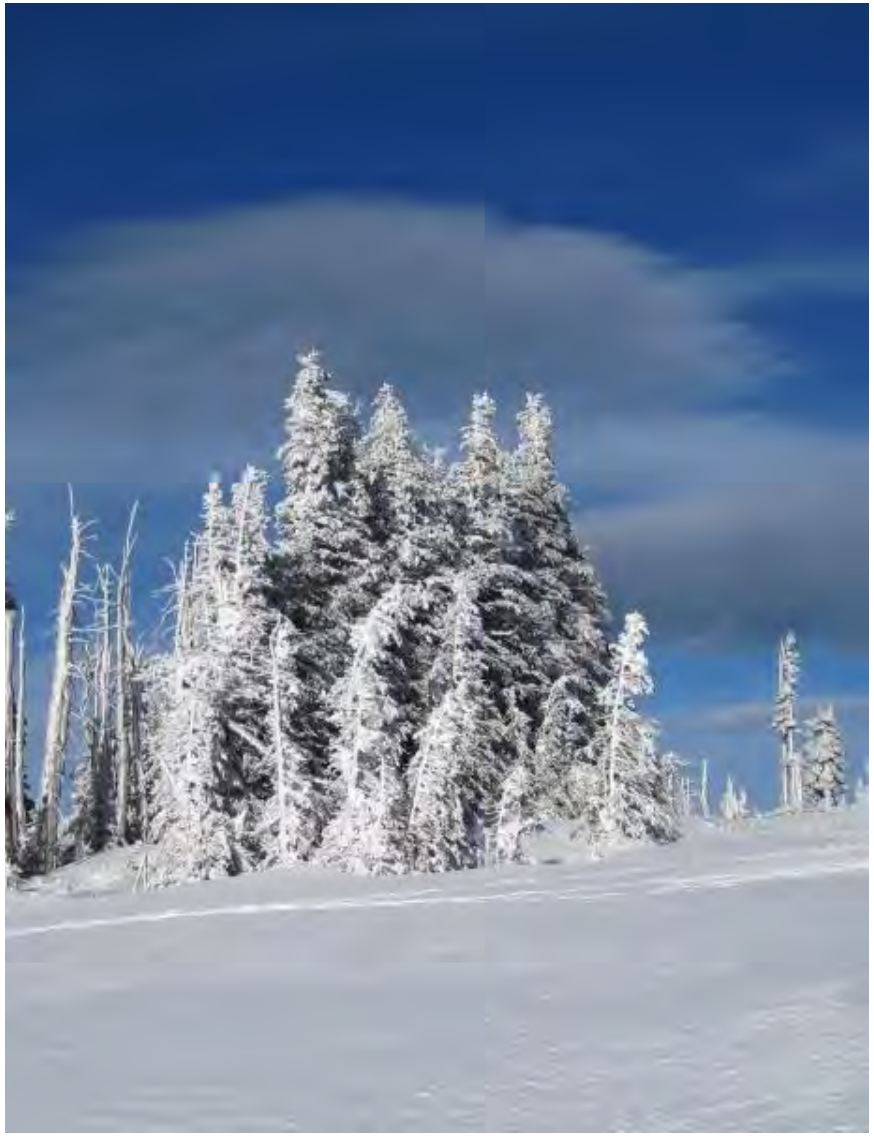
(Miller et al. 2020)

Limits to Cold Storage: Non-Structural Carbohydrates (NSC)

- Non-structural carbohydrates are the sugars and starch that plants use for energy storage, osmotic adjustment to avoid freeze damage, and other physiological processes
- Carbon starvation during cold storage could occur because:
  - Respiration
  - Loss of tissue with NSC reserves (e.g. through root pruning)
  - Changes in dormancy status
  - Attempts at growth while still in dark conditions

Limits to Cold Storage: Research Questions

- Plants cannot be kept in cold storage indefinitely: what fails first?
  - Water relations or non-structural carbohydrate supply?
- Are there negative effects on outplanting performance, short of mortality?
- Can we estimate how long trees could be kept in cold storage before there are negative effects to outplanting performance?



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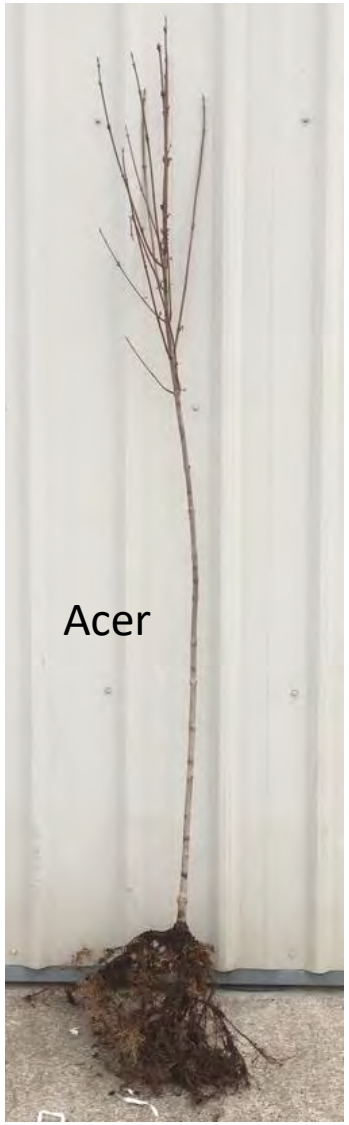
Approach: Plant Material



Species	Cultivar Name	Stocktype
Acer rubrum 'Franksred'	Red Sunset® maple	4-foot whips; 4- and 5-foot branched saplings
Amelanchier x. grandiflora	Autumn Brilliance® serviceberry	3- and 4-foot whips
Gleditsia triacanthos 'Skycole'	Skyline® honeylocust	3- and 4-foot whips
Gymnocladus dioicus	Kentucky coffeetree	4-foot whips
Malus 'Prairifire'	Prairie fire crabapple	5-foot whips on hardy rootstock
Quercus rubra	Red oak	4-foot whips

- Lifted from bareroot beds in Fall 2019
- Held in cold storage at 1-2℃ with roots in paper mulch
- Removed from cold storage, measured, and planted in irrigated and weeded field over 14 weeks* beginning March 19th, 2020

Approach: Measurements

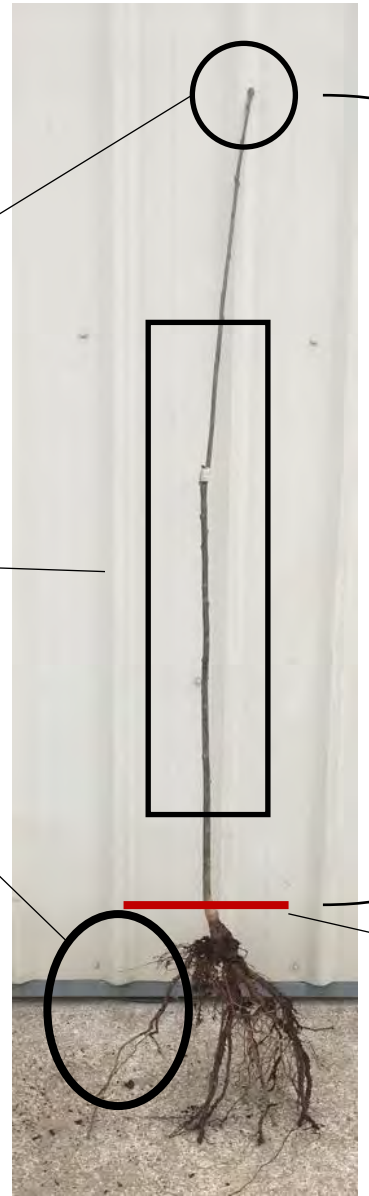
Measured once on subsample:

Stem segment:
Hydraulic Conductance and Vulnerability to Embolism

Measured on each sample at planting:

Terminal Shoots:
Stem Water Potential
Relative Water Content
Nonstructural carbohydrates

Lateral Roots:
Relative Water Content,
Nonstructural carbohydrates



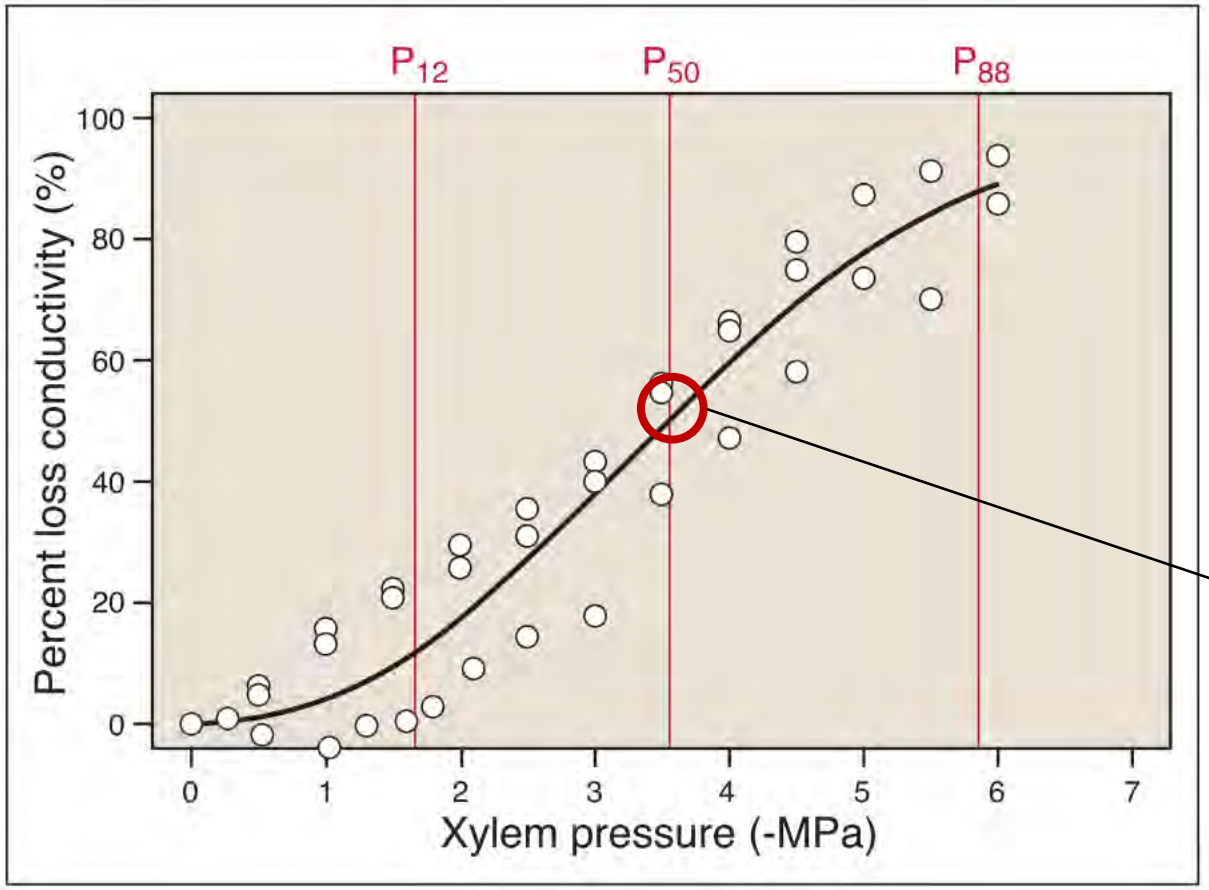
Measured at planting and end of growing season:

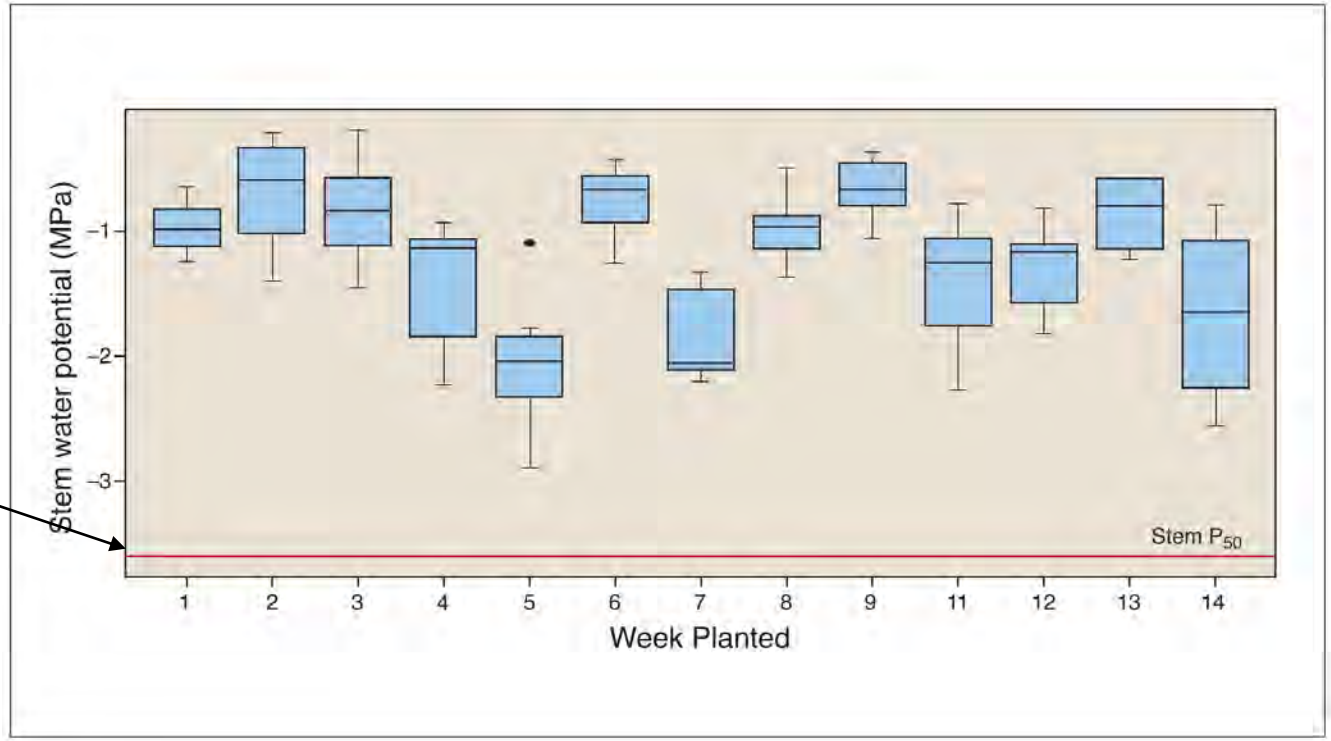
Height:
From root collar to base of terminal bud

Caliper/root collar diameter

Approach: Water Relations

- Identifying thresholds to water stress using vulnerability curves

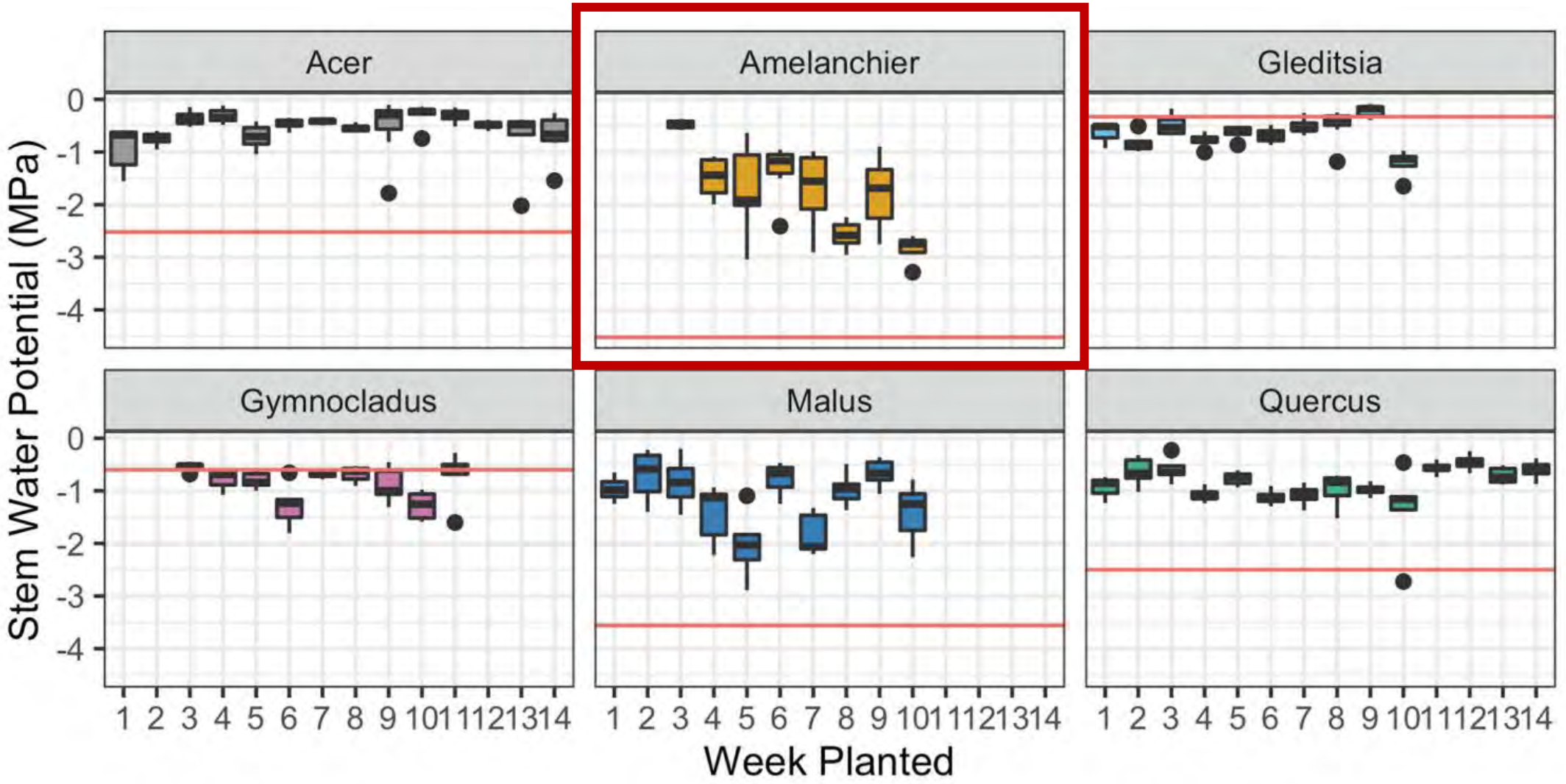




(Sheridan and Nackley 2021, TPN 64:2 p. 70-79)

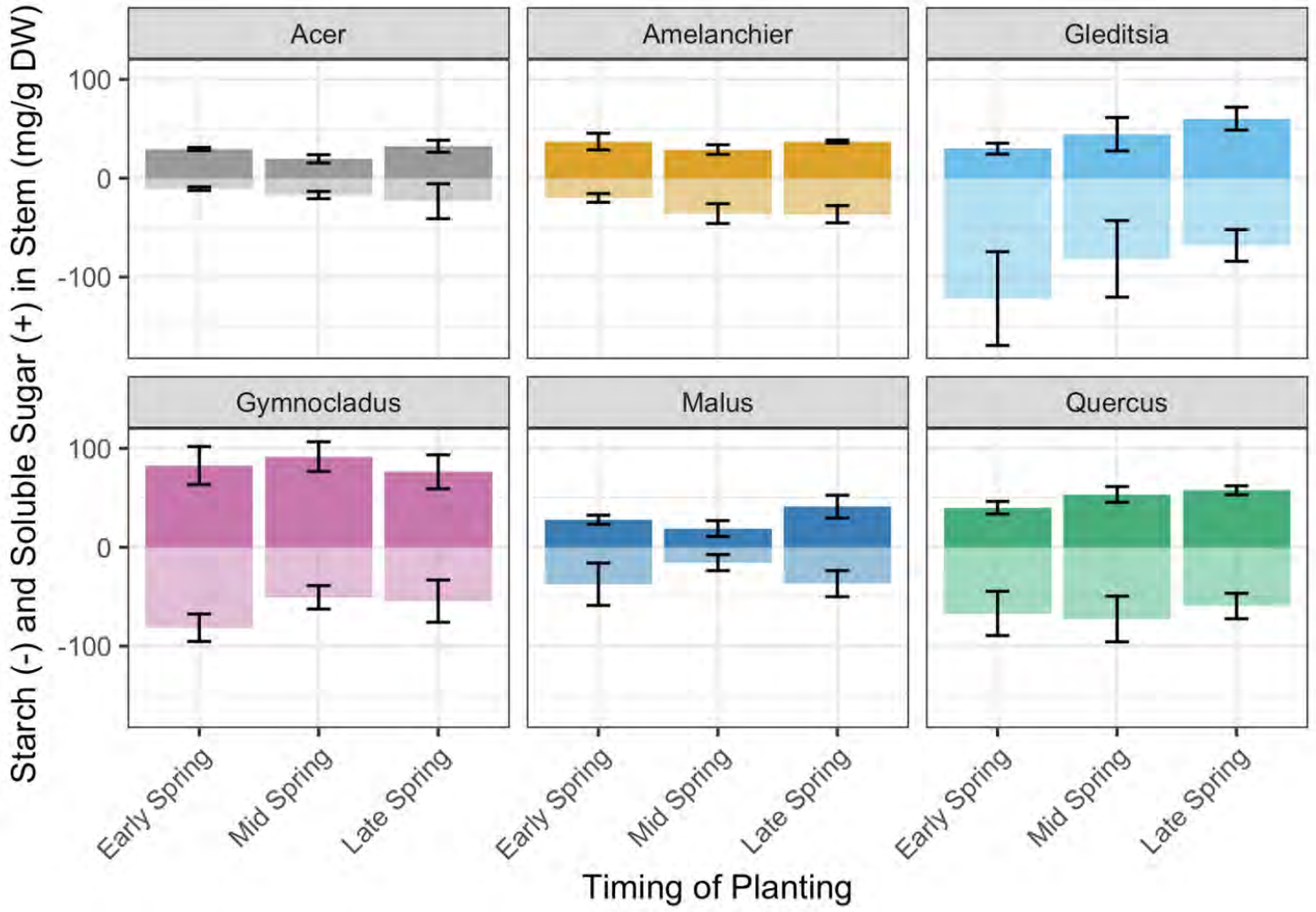
Results: Water Relations

- Trends in stem water potential over the spring planting window

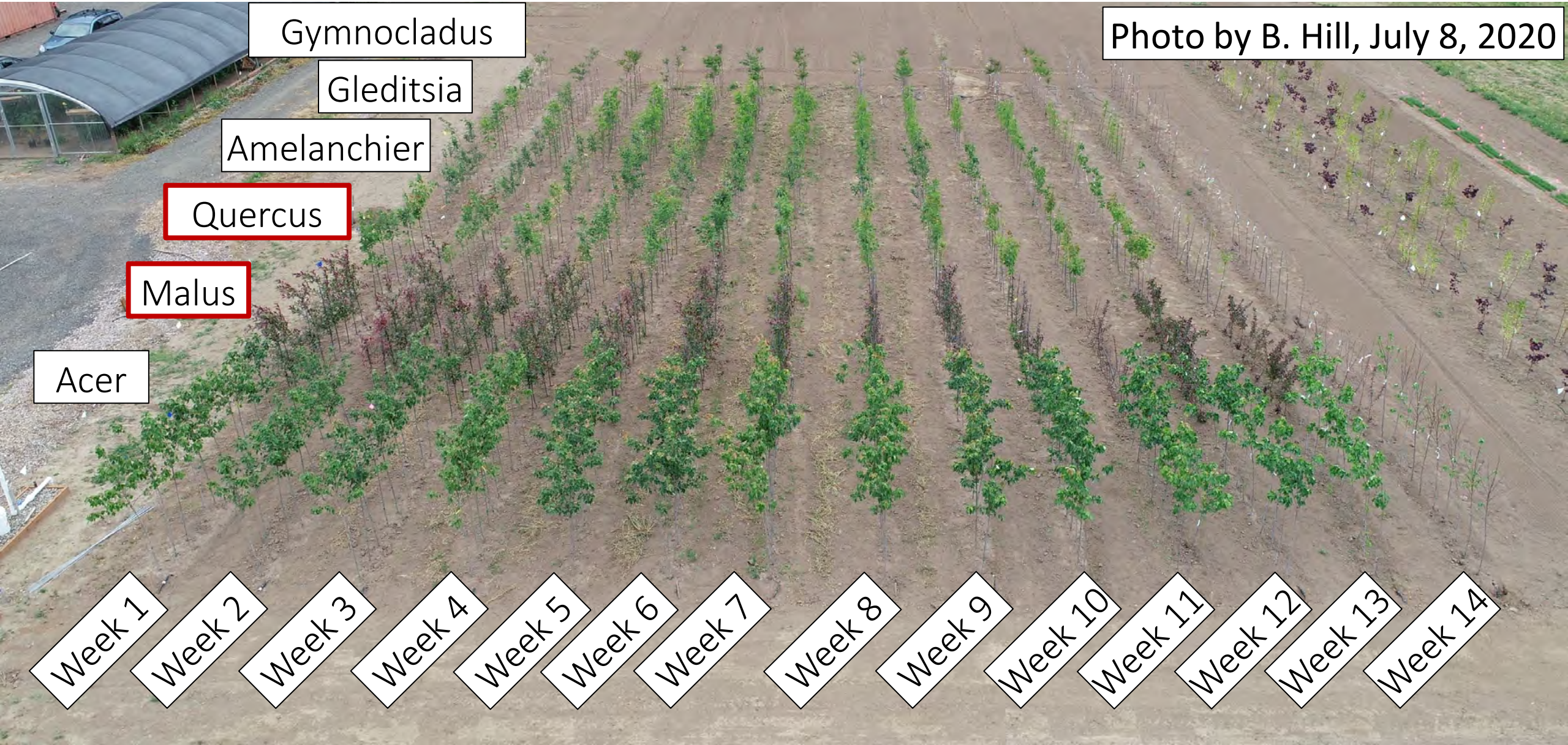


Results: Non-Structural Carbohydrates

- No trends in stem NSC concentrations over spring outplanting window



Results: Outplanting



Results: Outplanting

Gymnocladus

Gleditsia

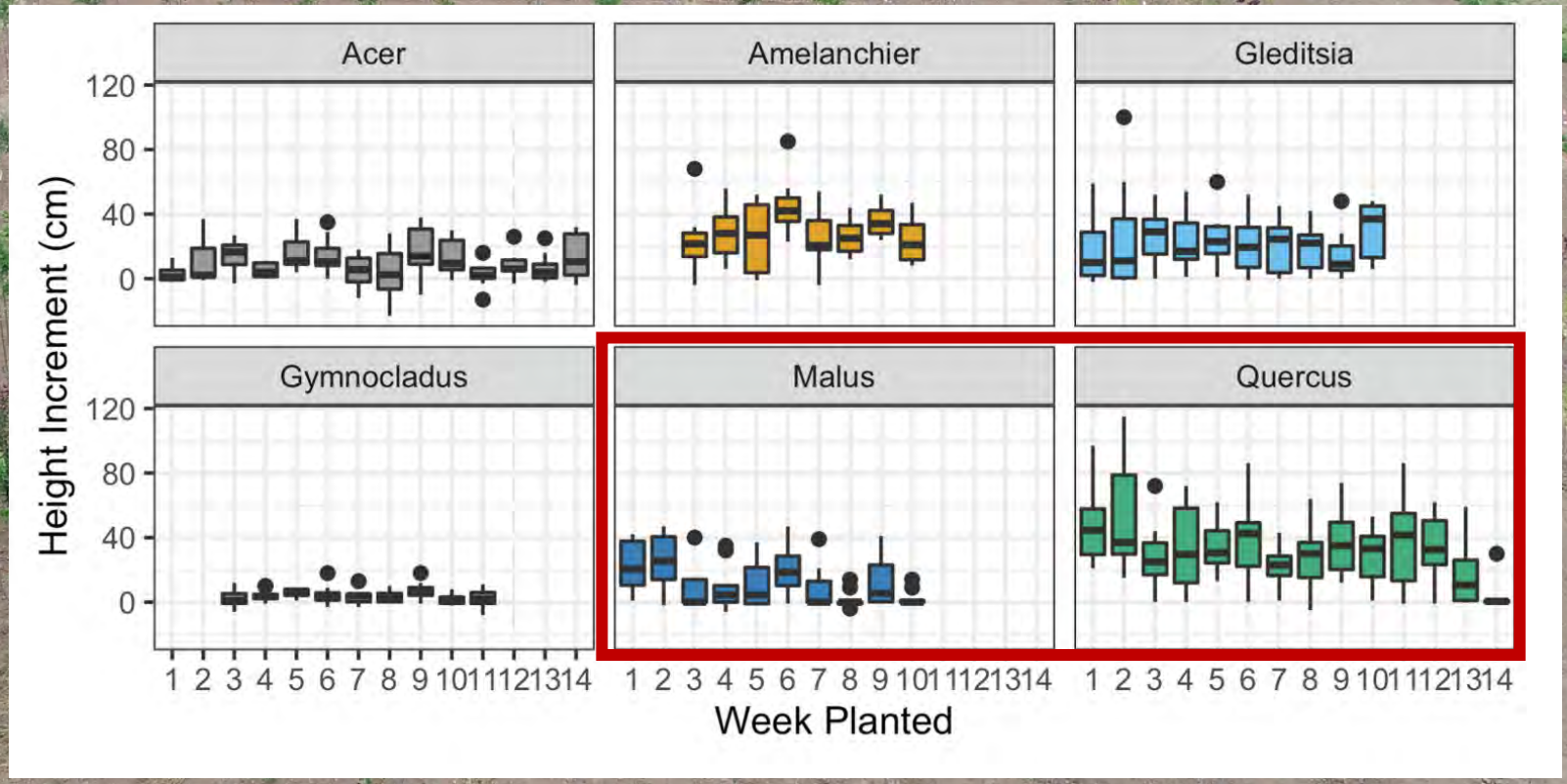
Amelanchier

Quercus

Malus

Acer

Photo by B. Hill, July 8, 2020



Week 1

Week 2

Week 3

Week 4

Week 5

Week 6

Week 7

Week 8

Week 9

Week 10

Week 11

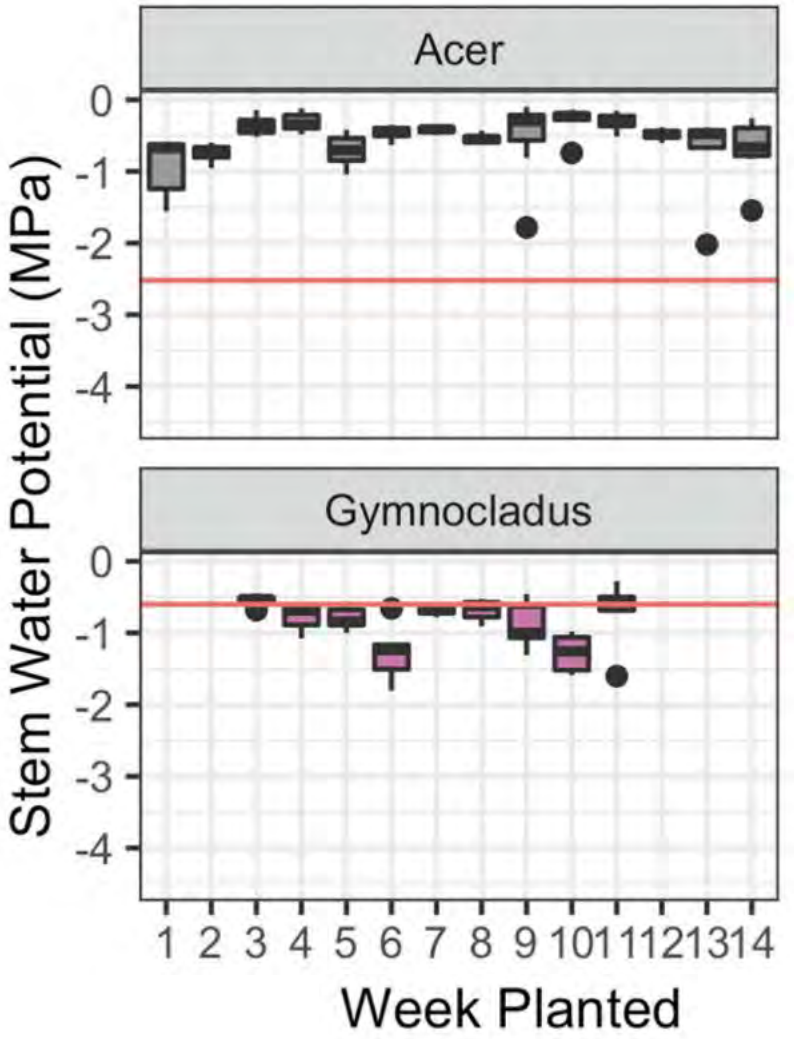
Week 12

Week 13

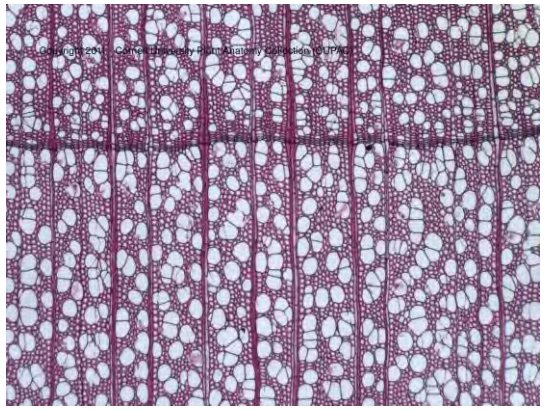
Week 14

Water Relations: A Tale of Two Xylem Anatomies

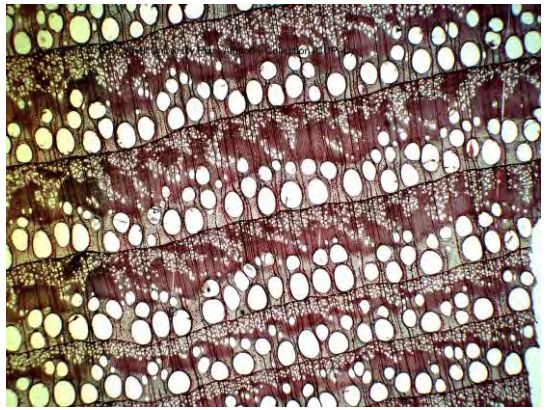
- Why can some cultivars crossing hydraulic thresholds in cold storage without diminished outplanting performance?



Diffuse porous



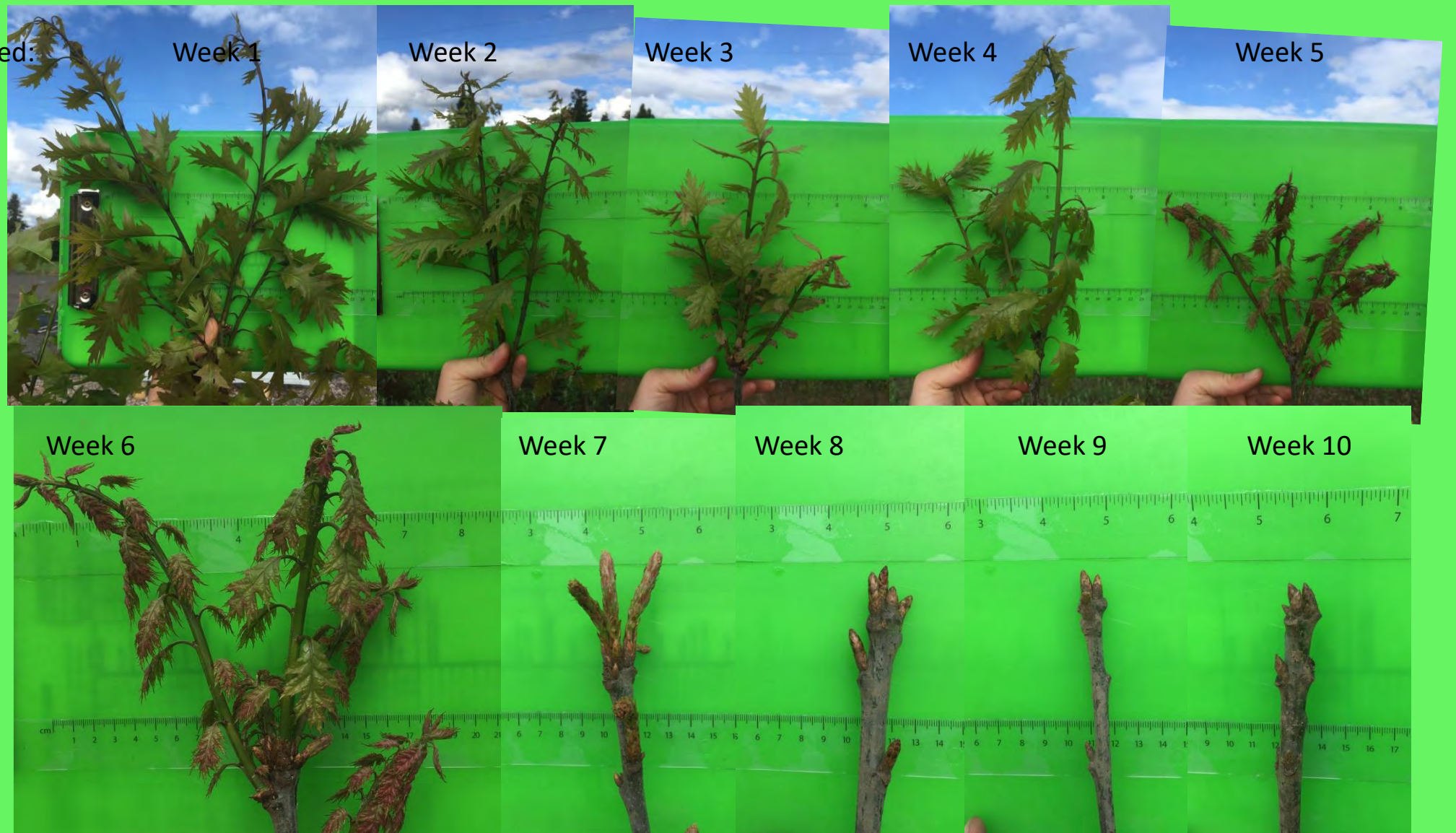
Ring porous



http://cupac.bh.cornell.edu

Results: Outplanting

Quercus, May 21, 2020



Take-aways:

- Plants are still vulnerable to stresses during winter or cold storage
  - Water is needed for physiological processes, growth, and to mobilize NSC reserves
  - NSC reserves are needed for growth, freeze protection, and water stress tolerance
  - Water relations and carbon dynamics are linked for outplanting success
- Understanding physiological mechanisms helps us predict and screen for plant responses to stress

Take-aways

- Appropriate operational cold storage conditions can maintain plant quality
- Even though we did not see detrimental effects for the trees in this experiment, we still recommend monitoring temperature, humidity, and seedling metrics through time in cold storage
- Extending time in cold storage will also have effects on phenology that could impact outplanting performance

Acknowledgements

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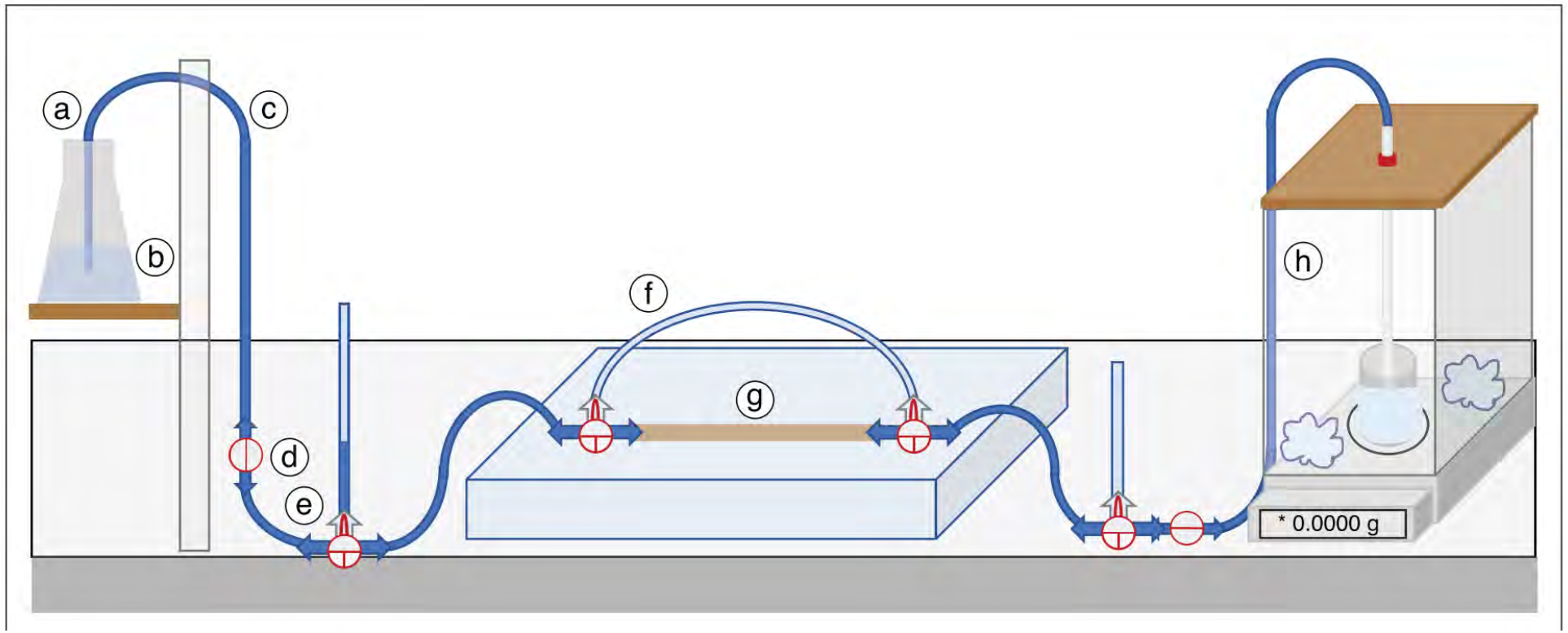
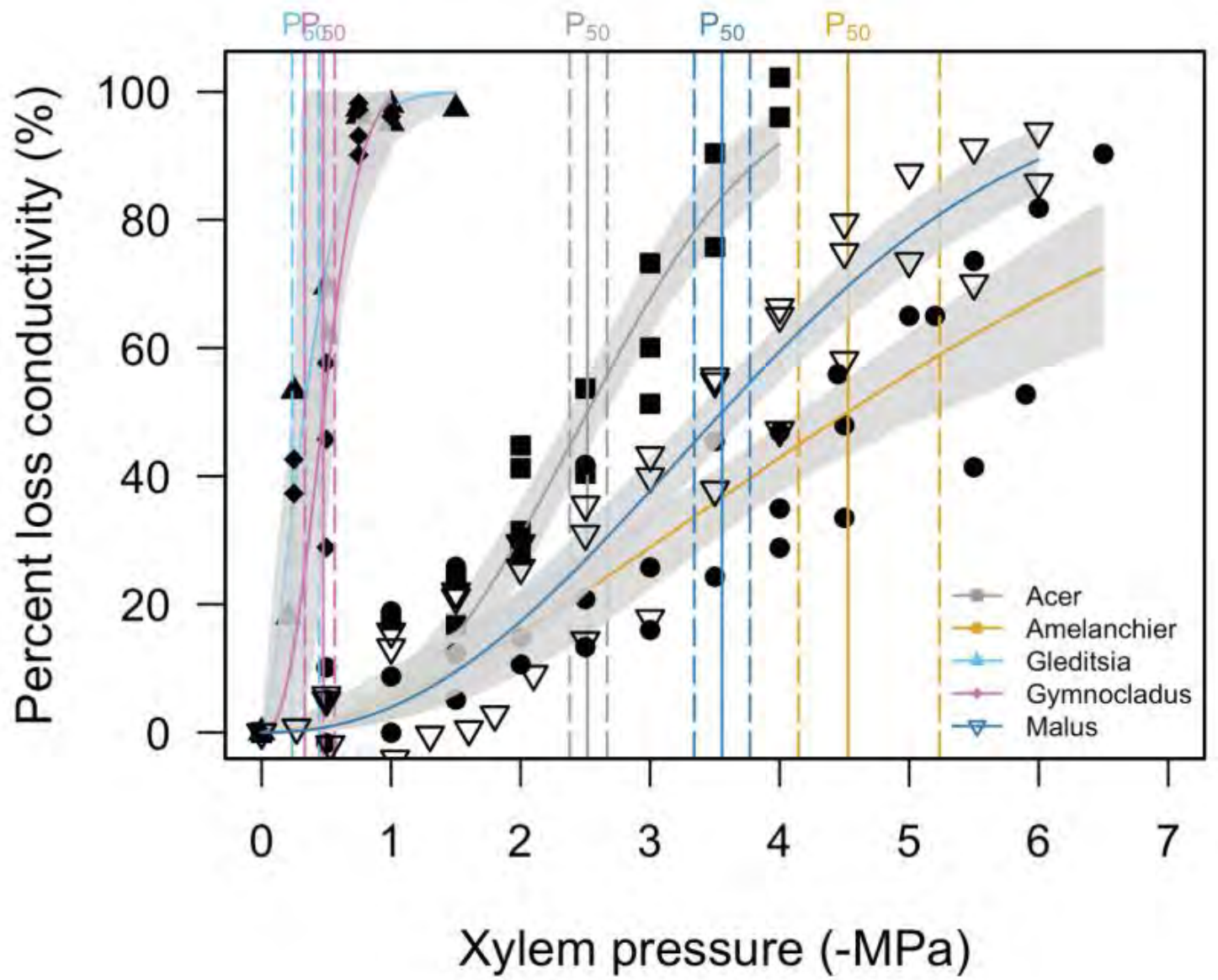
Questions?

Approach: Water Relations

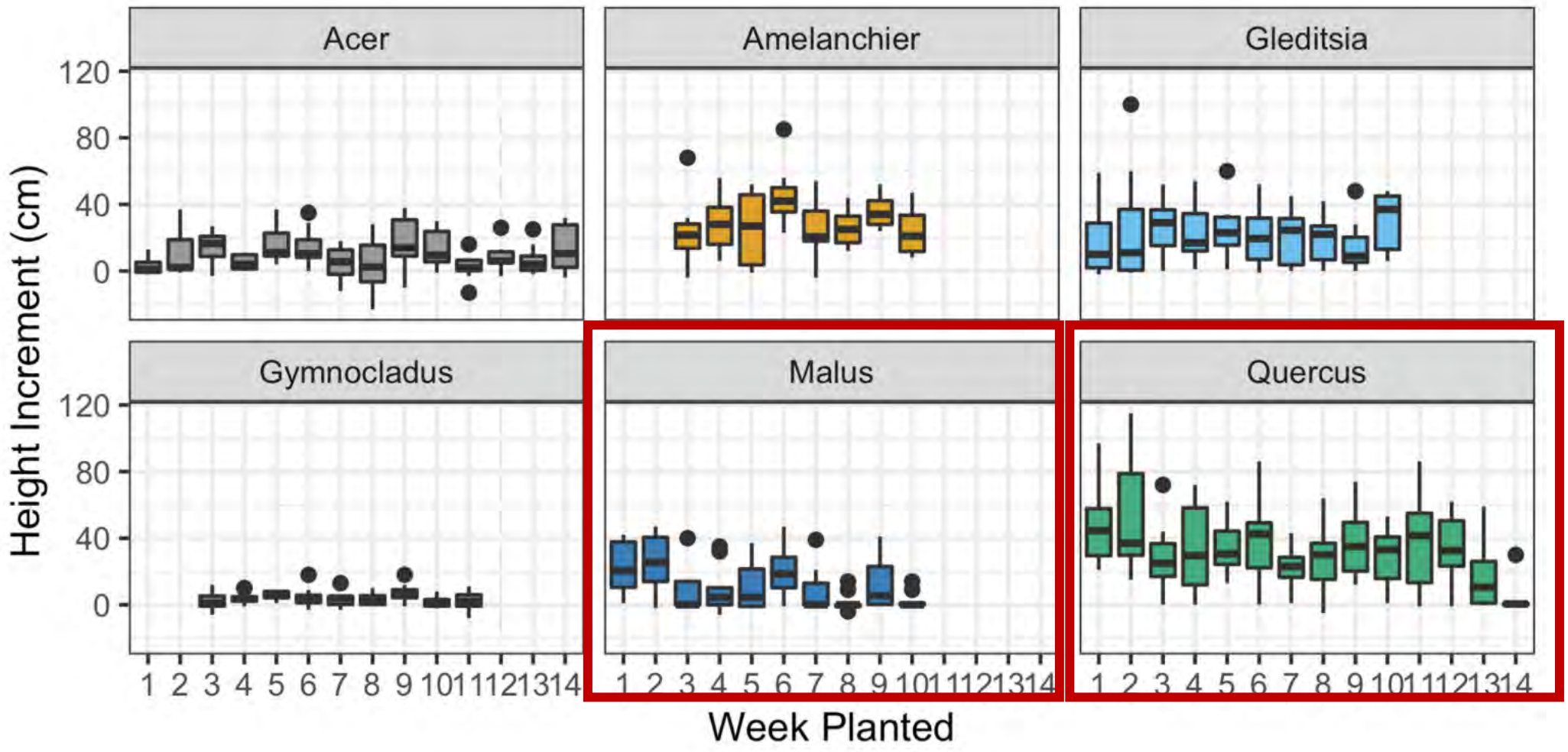


(Sheridan and Nackley 2021, TPN 64:2 p. 70-79)

Results: Water Relations



Results: Outplanting



Results: Outplanting