Do high levels of carbon reserves shape local-adaptation to drought in temperate trees?

Seminar for the Institute for Temperate Forest Sciences (ISFORT) Université du Québec en Outaouais (Canada)

Lecture for the PhD program in Vegetal Biology & Biotechnology (University of Talca)

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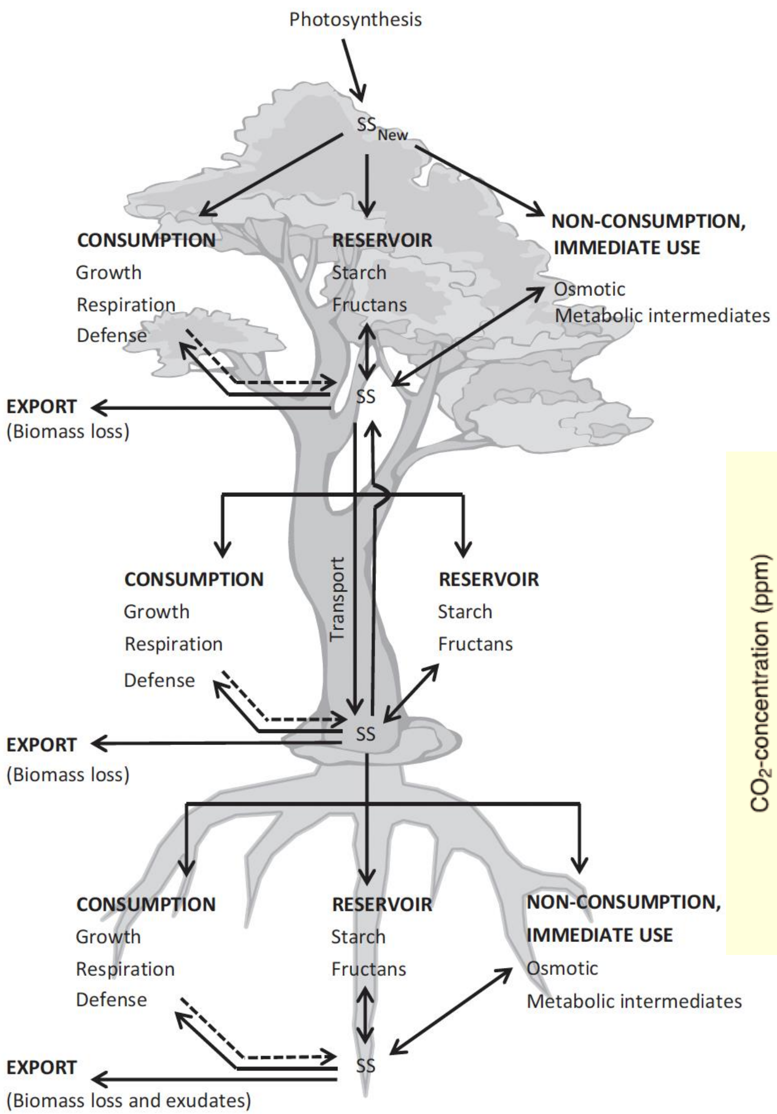
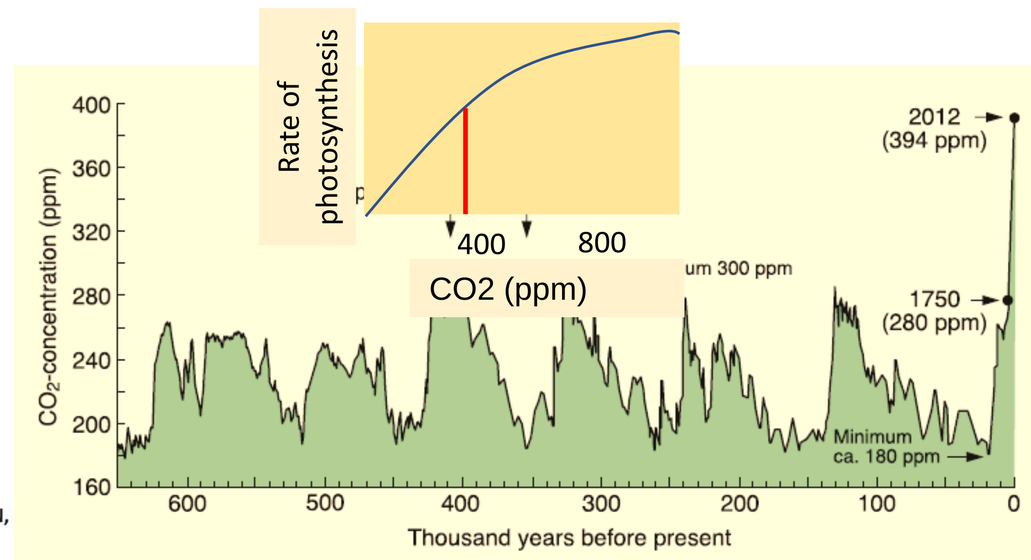
What are carbon (C) reserves?



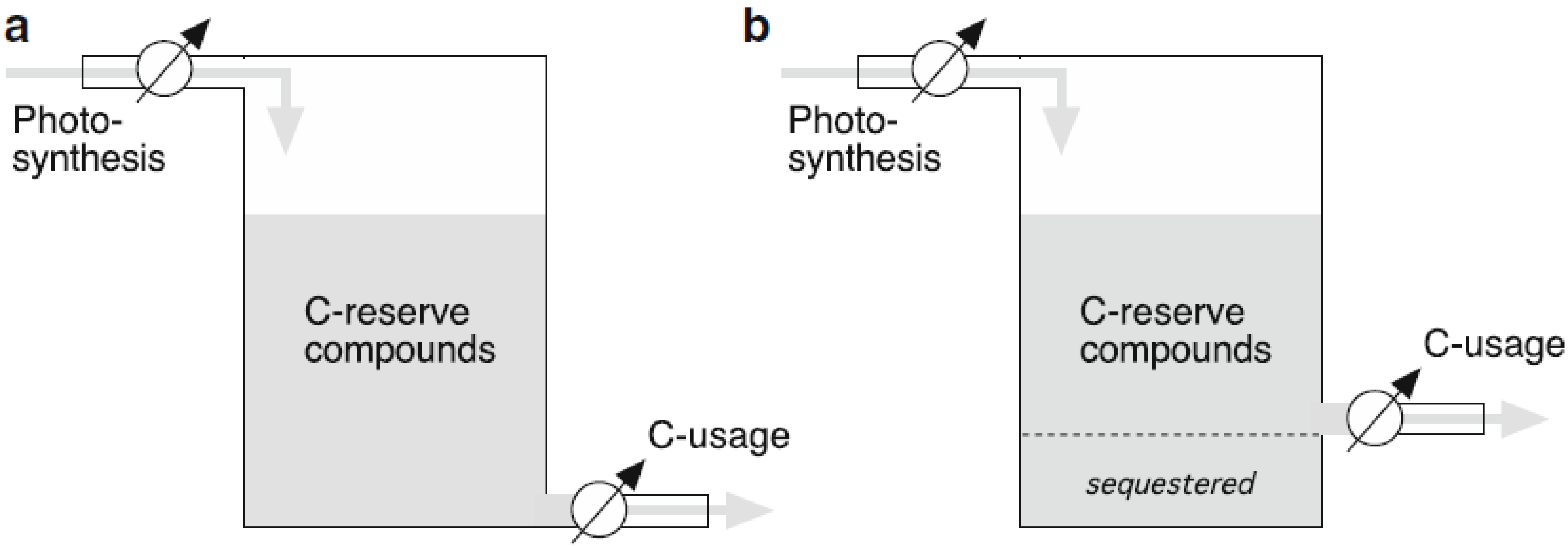
- C is the main element compounding plants
- Trees store close 90% of all biomass carbon on earth



Is growth C limited under natural conditions?

Martínez-Vilalta et al. (Ecological Monographs, 2016)

The comparative analysis of C-reserve concentrations in plant tissue as a tool to assess the C-supply status of trees



expanding reserve concentrations
whenever the C-influx from photosynthesis outbalances the net usage of C

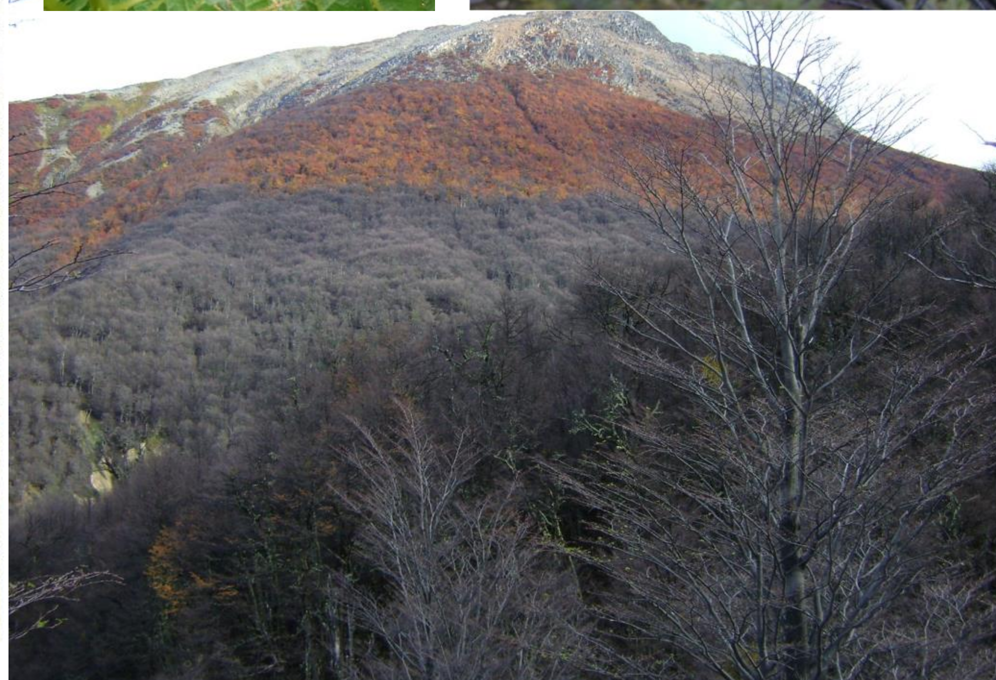
shrinking C-reserves
if the demand for C-assimilates is higher than the current photosynthetic activity.

Hoch 2015, *Progress in Botany*

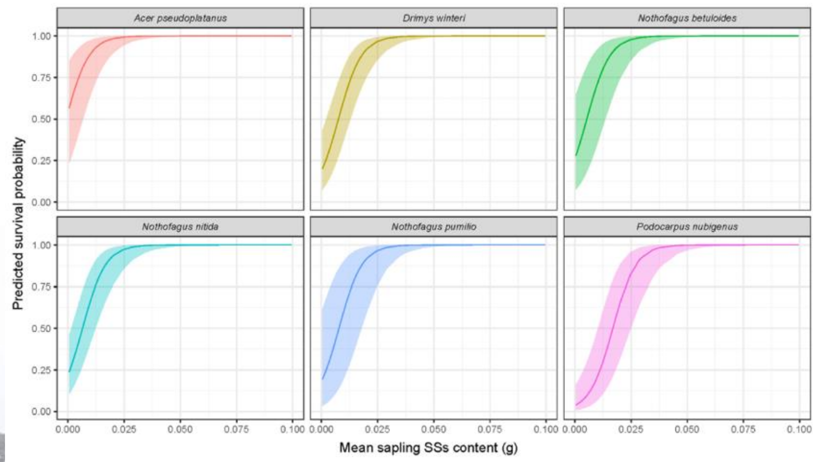
Mobile C-pool = CHO pool

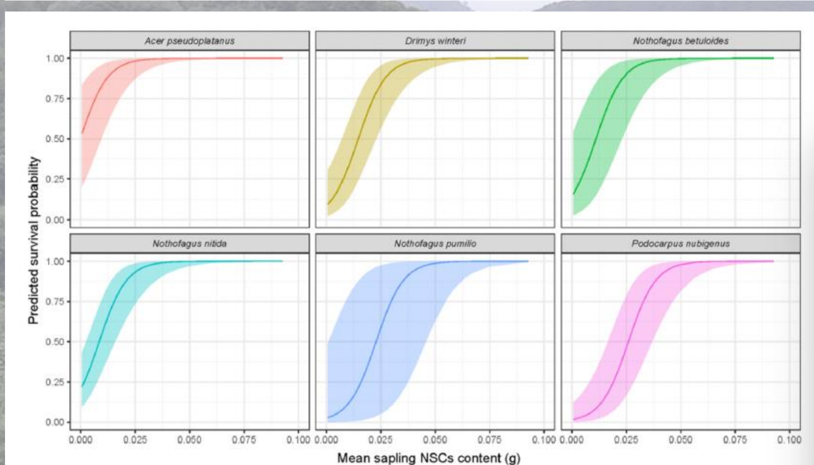
- **Non-structural carbohydrates (NSC, TNC)**
  - **Polysacharides (starch, fructans)**
  - Mono- di- or oligosacharides
- Sugar alcohols
- Organic acids
- **Lipids**
- Phenolics
- Isoprene polymers
- Terpenoids

Why are they important for trees?

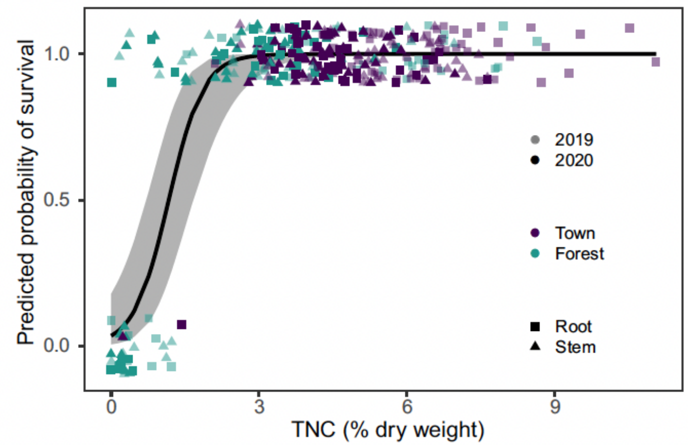


NSC and sugars predict plant survival under C stress





Piper et al. Functional Ecology, 2022



Barker Plotkin et al. Functional Ecology, 2021

New Phytologist

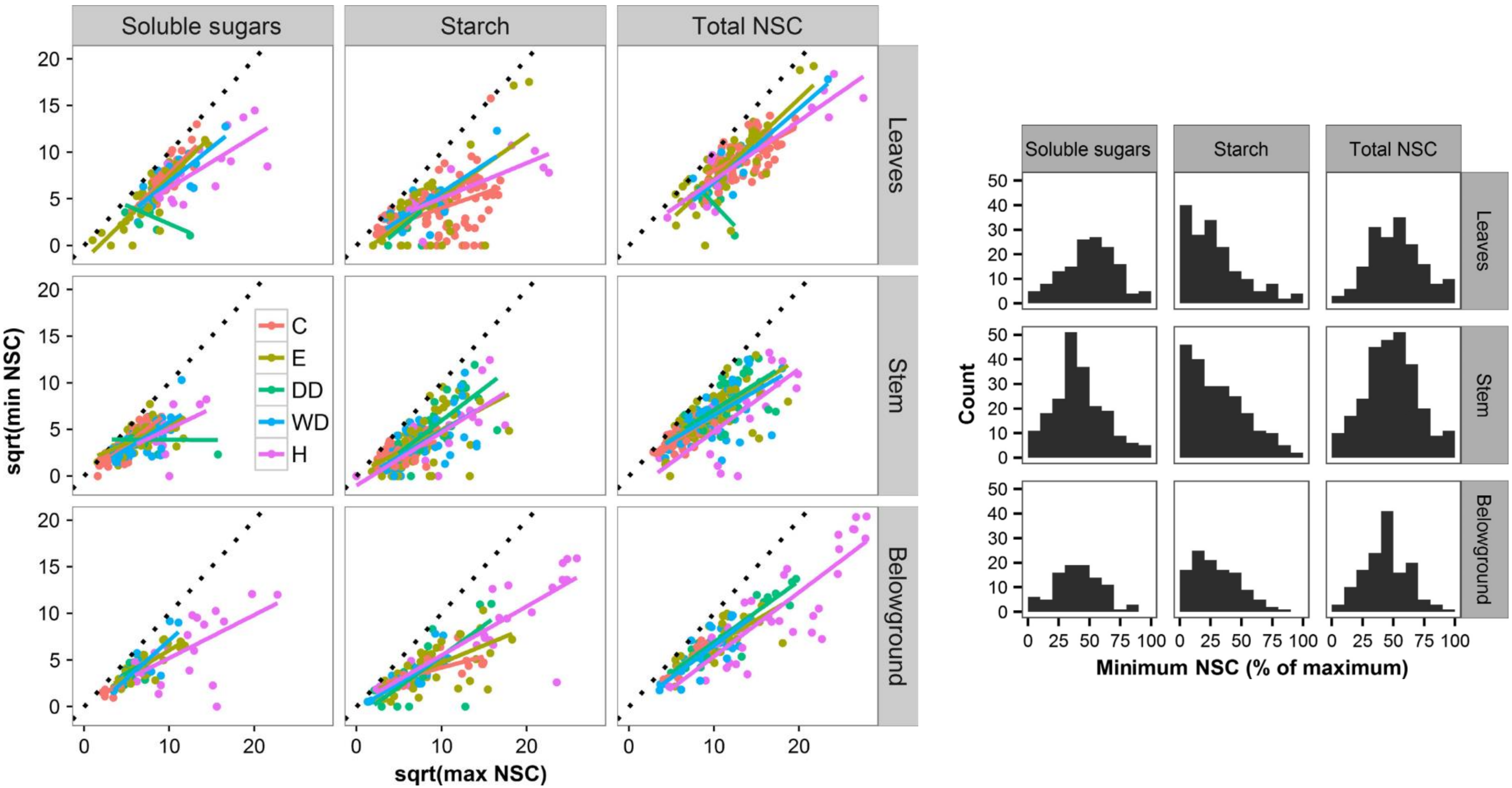
Full paper | Full Access

Plant carbohydrate storage: intra- and inter-specific trade-offs reveal a major life history trait

Meghan Blumstein, Anna Sala, David J. Weston, Noel Michelle Holbrook, Robin Hopkins

First published: 06 May 2022 | https://doi.org/10.1111/nph.18213 | Citations: 2

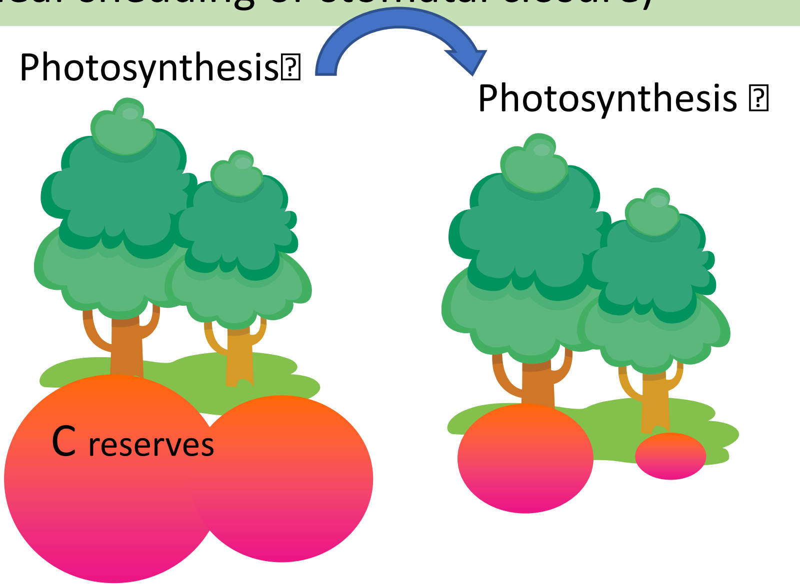
Globally, plants keep high levels of C reserves



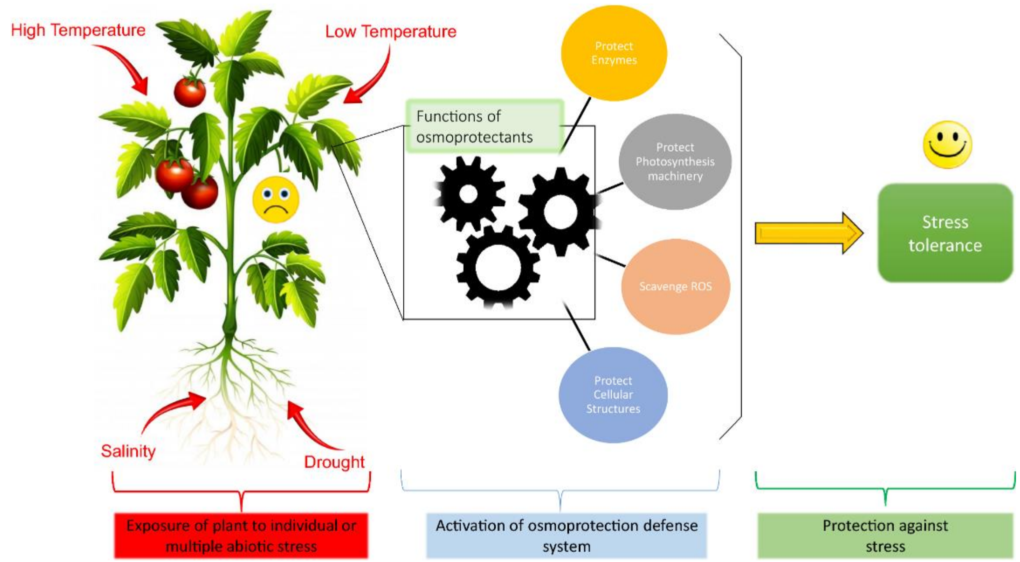
Martínez-Vilalta et al. Ecological Monographs, 86(4), 2016

Roles of C reserves in drought resistance

1. Energy supply (drought avoidance e.g. leaf shedding or stomatal closure)

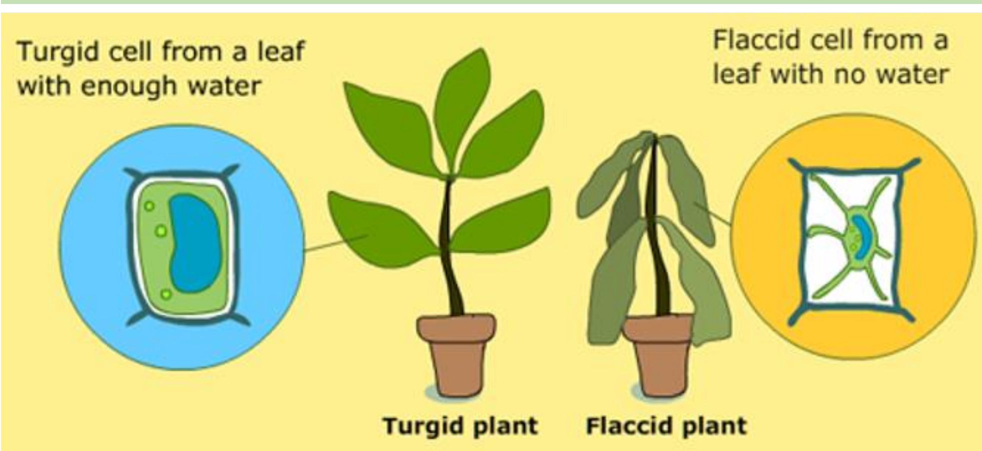


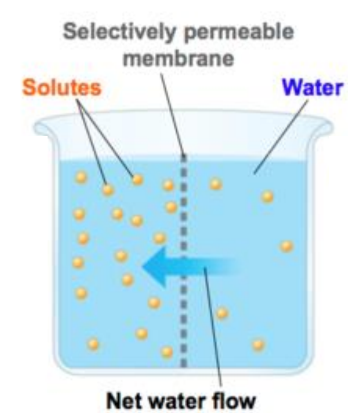
2. Osmoprotection (dehydration tolerance)



Zulfiqar et al. *Planta* **251,** 3 (2020)

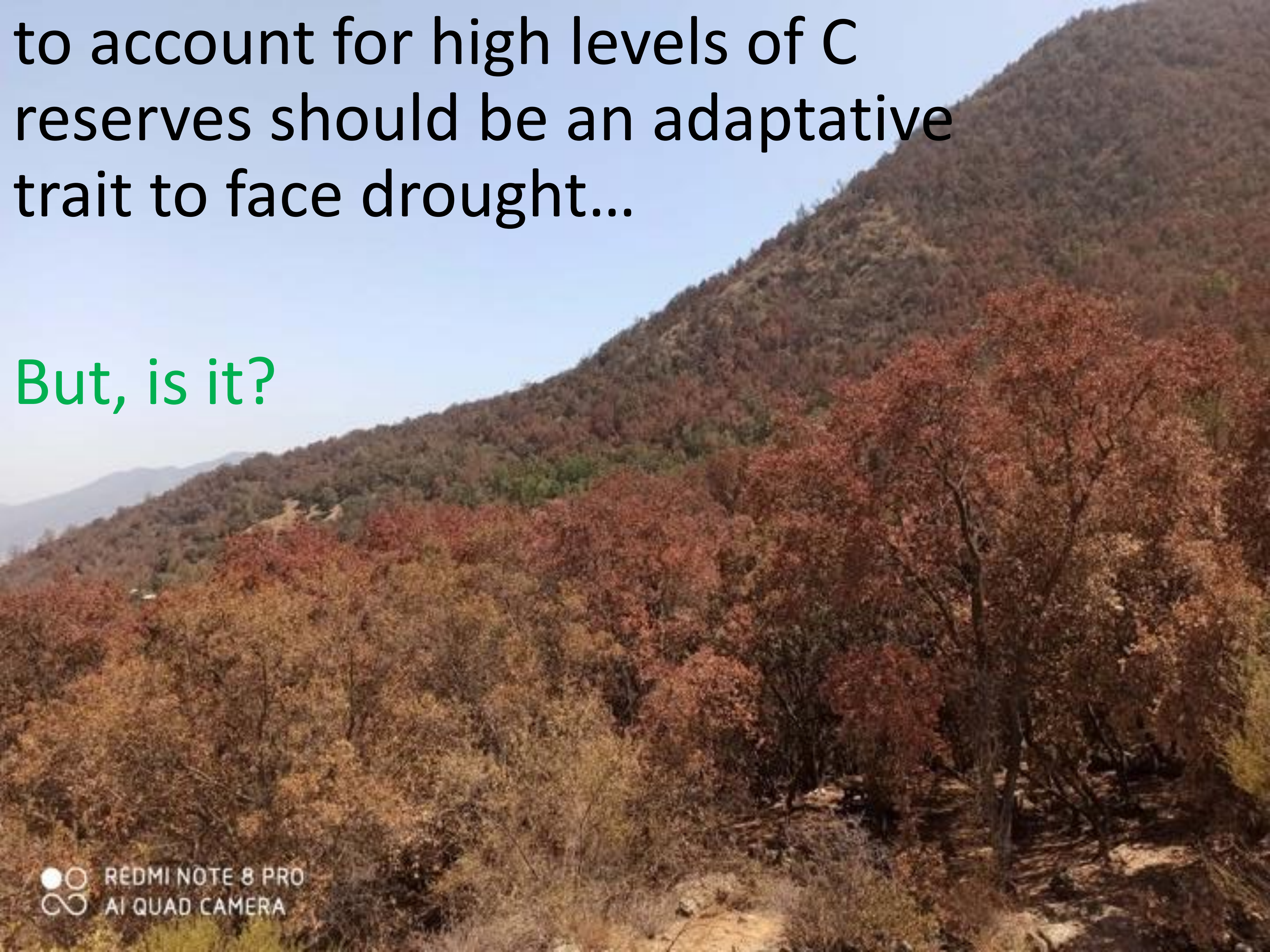
3. Osmoregulation (dehydration tolerance)





to account for high levels of C reserves should be an adaptative trait to face drought…

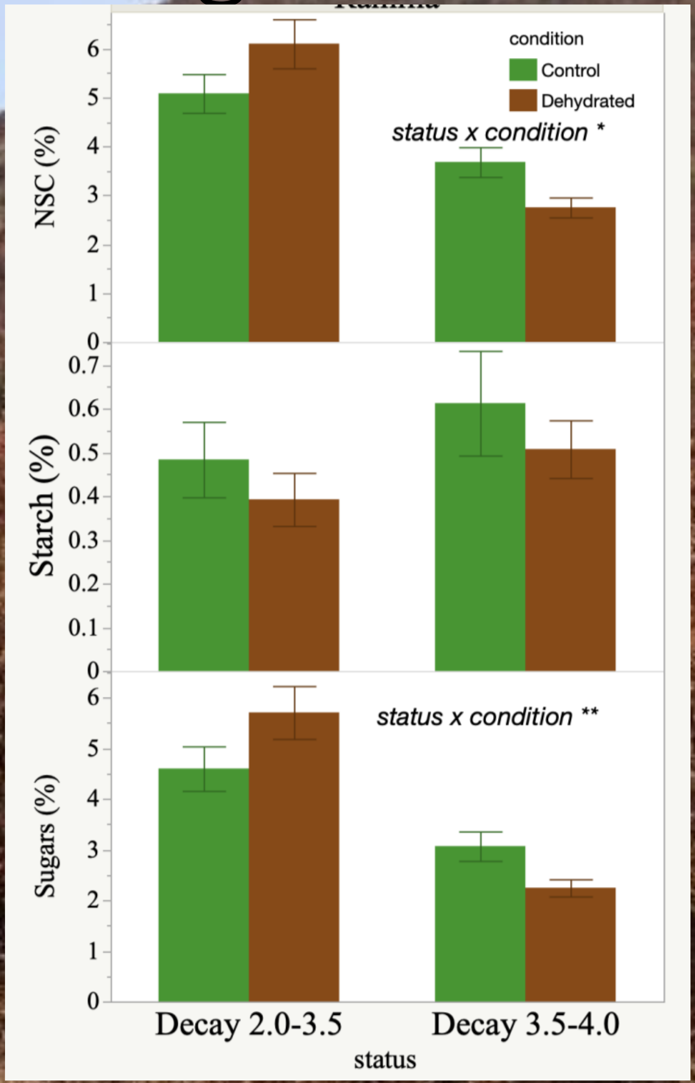
But, is it?



let's take a look at the patterns: C reserves in trees under drought

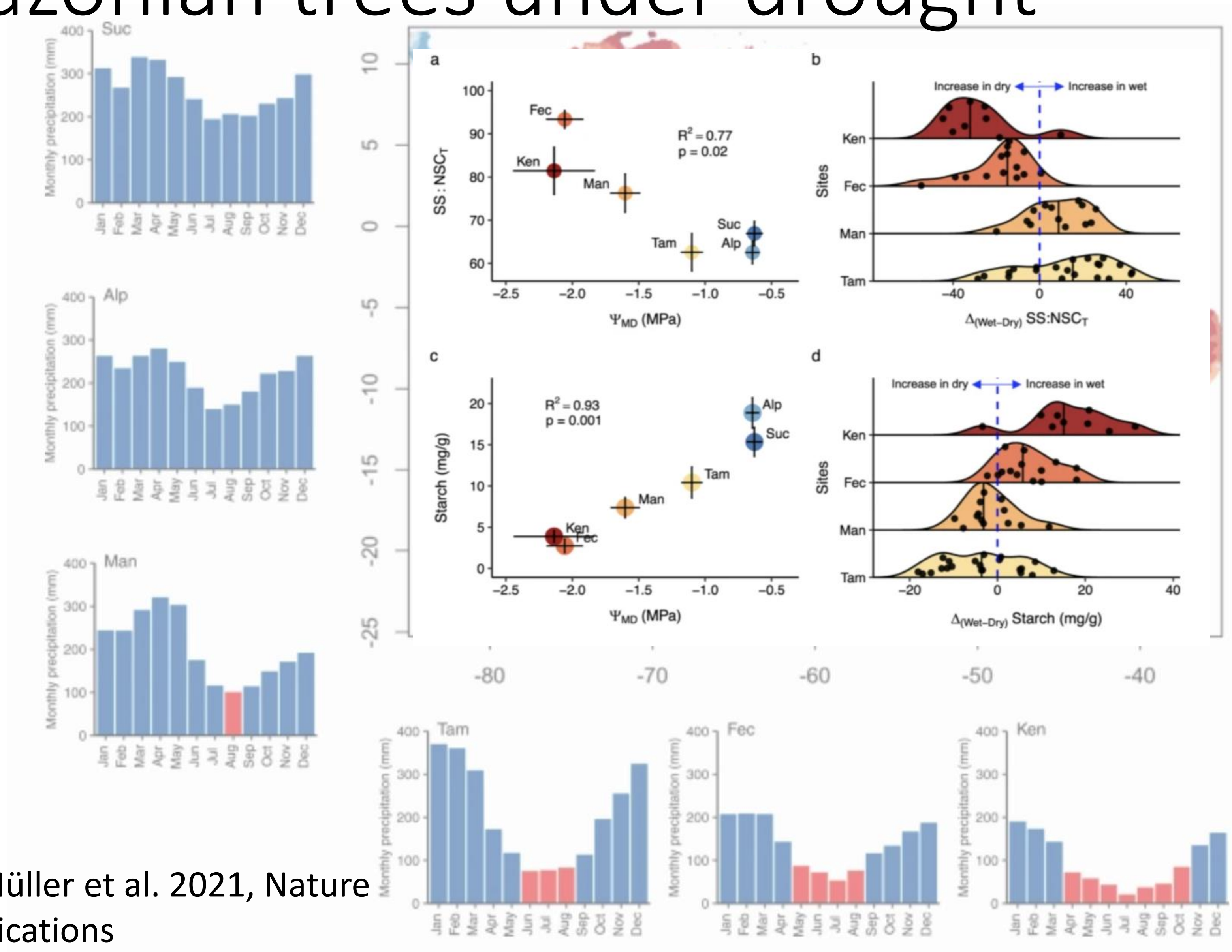
Parque Nacional La Campana, Central Chile, 2020 (after a megadrought)

Especie	n	Defoliación	Pérdida de verdor	Decaimiento
Retanilla_trinervia	14	3.3	3.9	4.0
Persea_meyeniana	3	2.7	4.0	4.0
Aristiguetia_salvia	19	1.8	3.8	3.9
Rhaphithamnus_spinosus	6	2.8	3.8	3.8
Adenopeltis_serrata	18	2.4	3.8	3.8
Cestrum_parqui	5	2.6	3.4	3.6
Dasyphyllum_excelsum	16	2.3	3.6	3.6
Azara_celastrina	9	3.4	3.1	3.6
Lobelia_excelsa	2	3.0	3.5	3.5
Myrceugenia_obtusa	74	2.4	3.4	3.5
Azara_petiolaris	5	3.4	2.8	3.4
Kageneckia_oblonga	9	2.7	3.0	3.3
Peumus_boldus	27	2.6	2.9	3.1
Sophora_macrocarpa	20	1.9	2.9	3.0
Citronella_mucronata	22	2.5	2.6	3.0
Quillaja_saponaria	37	2.4	2.8	2.9
Schinus_latifolius	11	2.5	2.3	2.8
Lithraea_caustica	17	2.5	1.8	2.5
Cryptocaria_alba	68	2.1	2.2	2.5
Beilschmedia_miersii	5	1.4	2.0	2.0



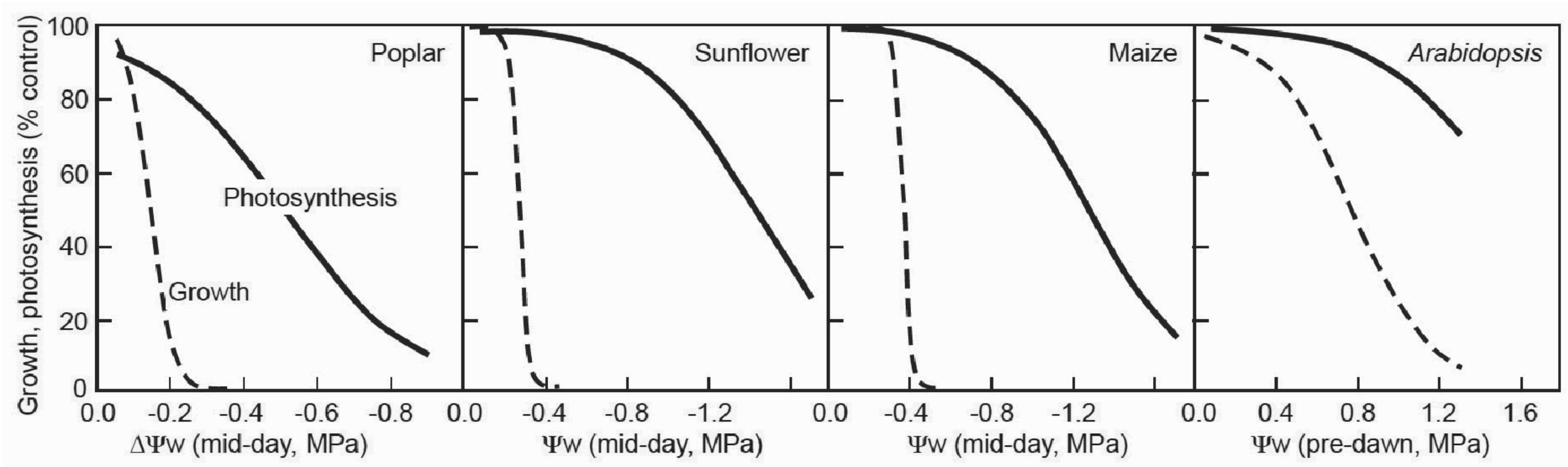
Paula & Piper, (in prep.)

A similar pattern: C reserves in Amazonian trees under drought



Signori-Müller et al. 2021, Nature Communications

At moderate drought, trees often have more C reserves



Growth is more sensitive to drought than photosynthesis

High levels of C reserves under moderate drought could just reflect C surplus…

Muller et al. 2011, *Journal of Experimental Botany*

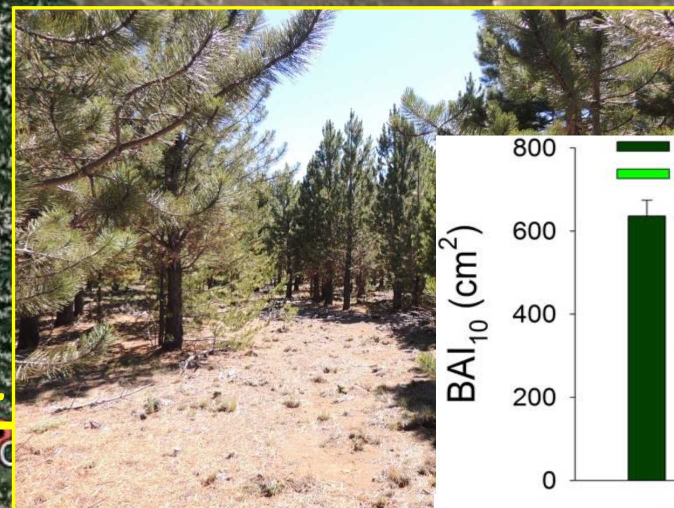
- Is high C reserves in trees under drought a **plastic**, or a **genotypic-adaptative** response?

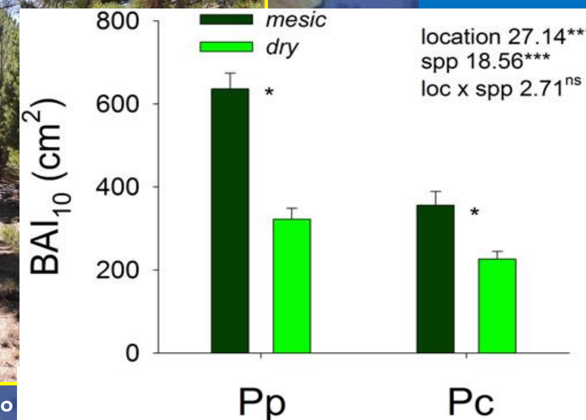
  - Expectations:

- plastic: expressed only under drought. No difference between genotypes from dry vs humid sites when both are compared under adequate watering
- adaptative: Genotypes from dry environments accounting for higher C reserves than Genotypes from humid environments in common garden

Sugar accumulation as an acclimation response to drought in pine plantations (Piper et al. 2017, Tree Phys.)

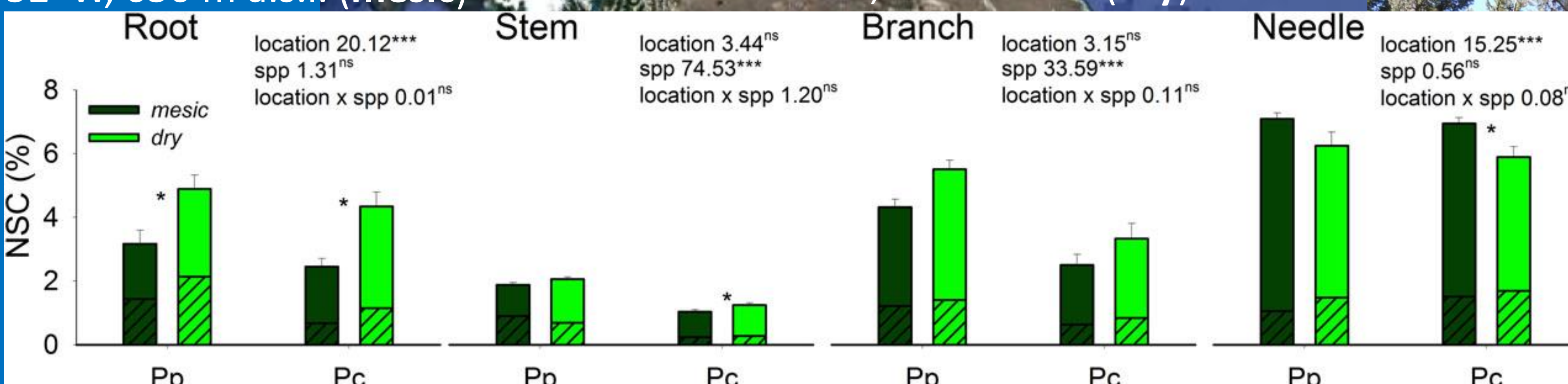
Pinus ponderosa and *P. contorta* at two contrasting climates





Reserva Coyhaique, 45° 59′ S, 71° 52′ W, 650 m a.s.l. (**mesic**)

Coyhaique Alto, 45° 33′ S, 72° 04′ W, 730 m a.s.l. (**dry**)



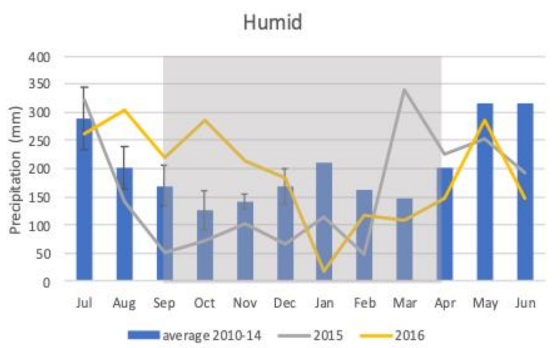
Questions

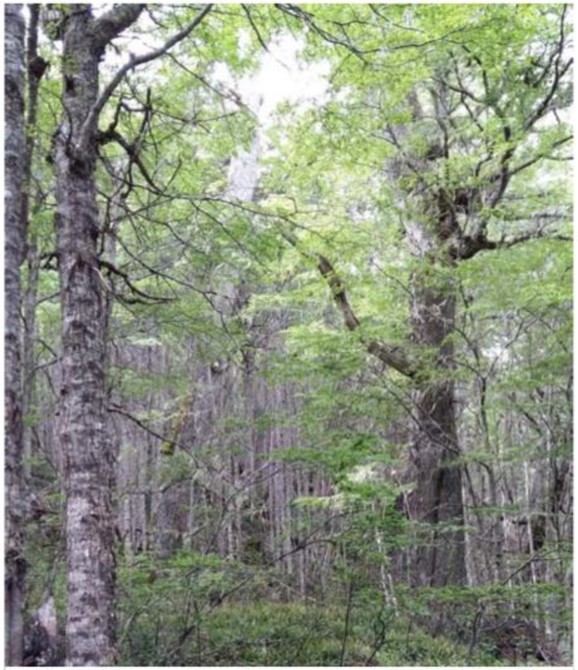
- **Do high NSC and SS concentrations reflect local adaptation to drought?**

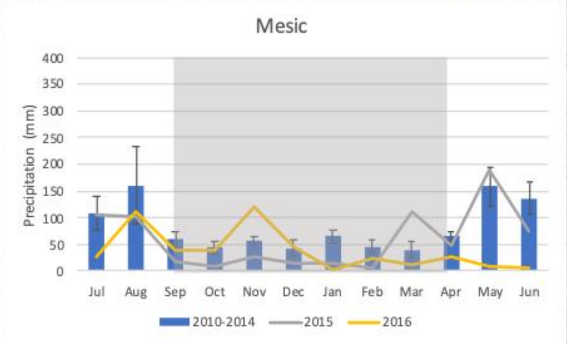
- Because a same limiting resource cannot be similarly allocated at different plant functions at the same time, more C reserves could imply less growth and viceversa:

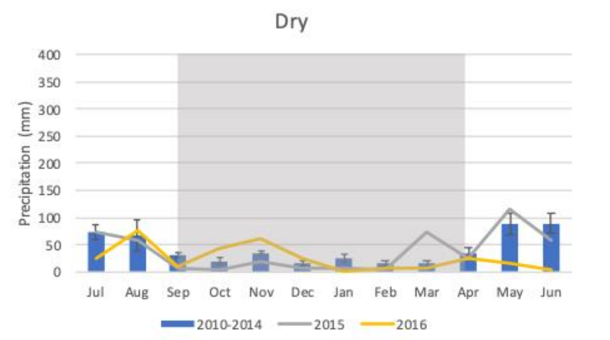
Does high NSC concentrations come at the cost of lower growth (growth-storage tradeoff)?

Embothrium coccineum (Proteaceae), an exceptionally wide-niche breath tree species









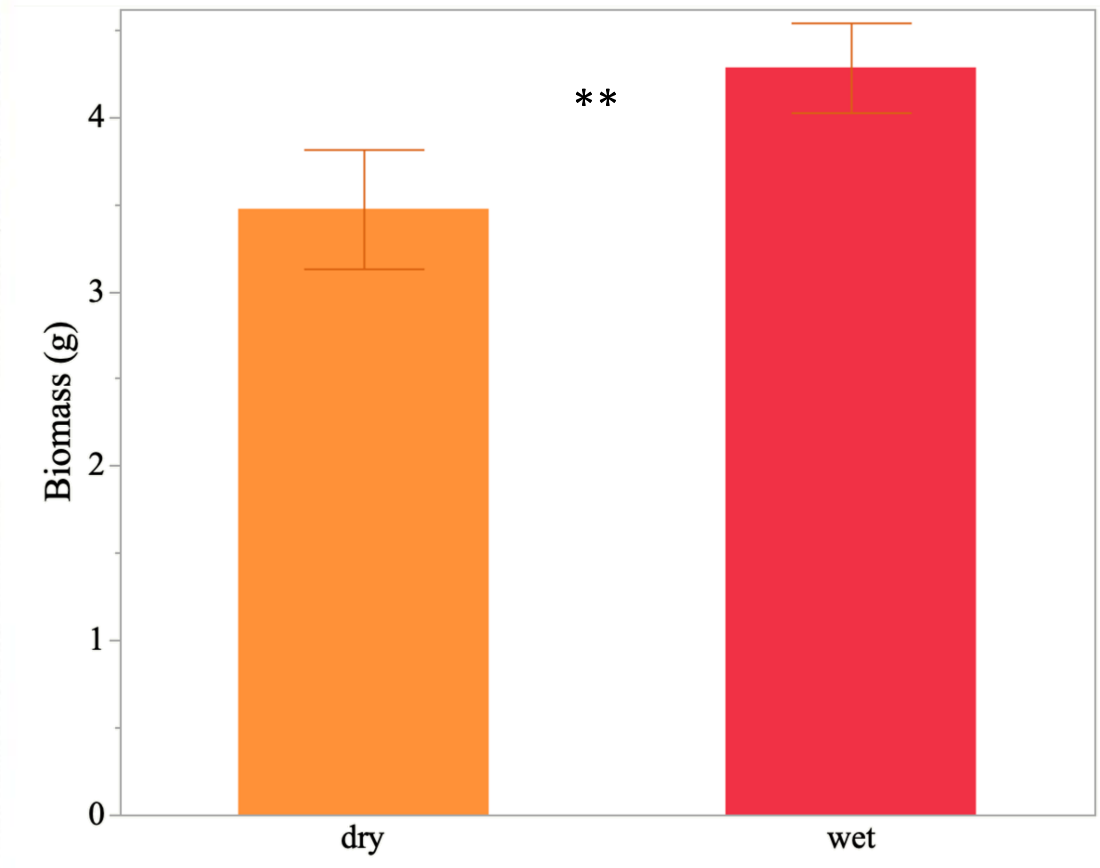
Fajardo & Piper (Functional Ecology 2021)

Common Garden Experiment for three years, dry- and moist-origin ecotypes

- NSC and SS concentrations at spring, summer and autumn
- Biomass
- LMM testing for population climate and season, with seed size as covariate

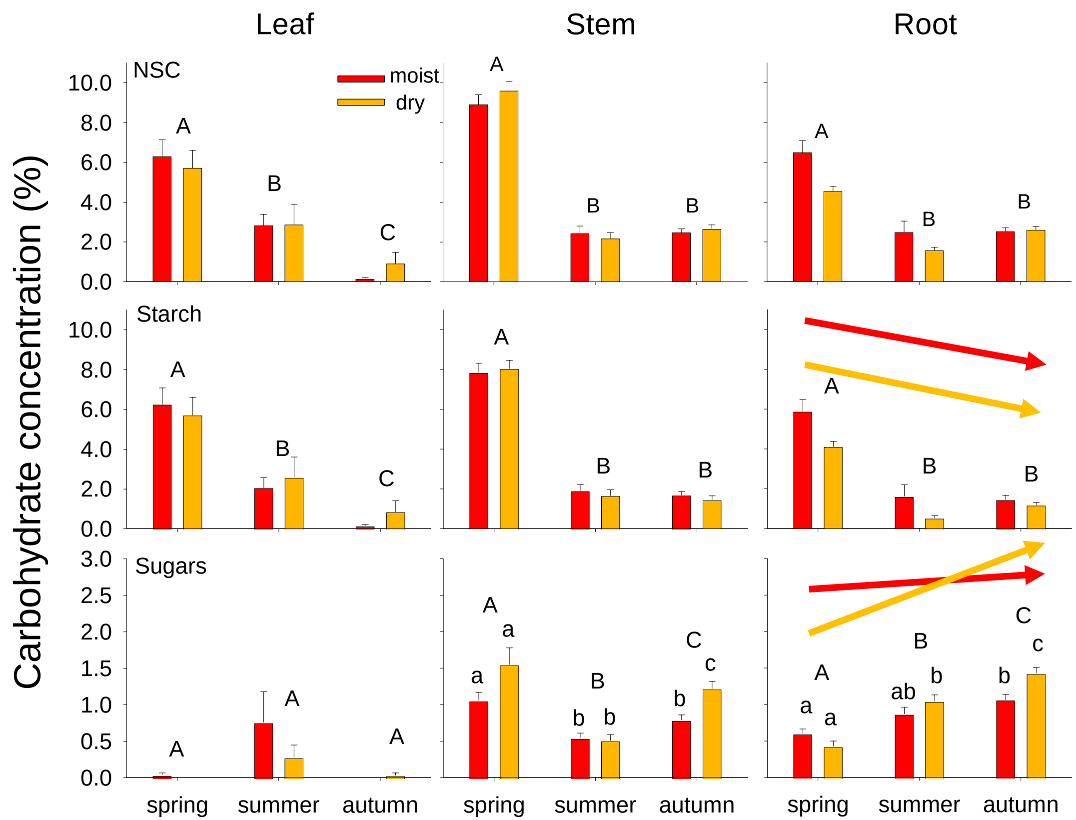
Piper & Fajardo, (in prep.)

Results



Piper & Fajardo, (in prep.)

Results



Piper & Fajardo, (in prep.)

Discussion

- Do high NSC and SS concentrations reflect local adaptation to drought?

  No

- Does high NSC concentration come at the cost of lower growth (growth-storage tradeoff)?

  No

Piper & Fajardo, (in prep.)

Discussion

- By default, results suggest that higher NSCs concentrations in plants at dry climates (e.g Sala & Hoch 2009), result from C surplus driven by the higher sensitivity of growth than photosynthesis to drought (Körner 2003; Muller et al. 2011).

Piper & Fajardo, (in prep.)

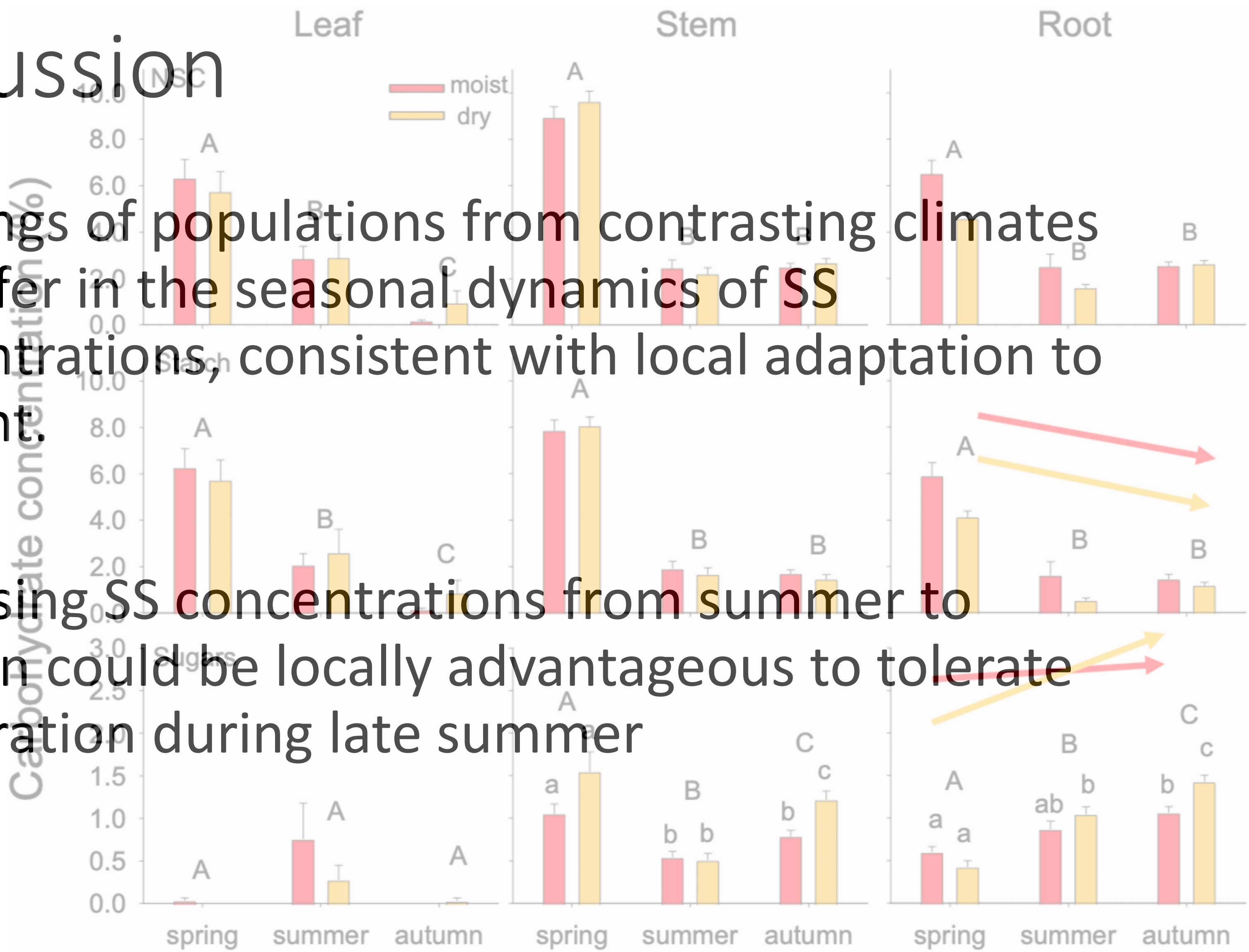
Discussion

- no role of drought as a selective driver of a growth-storage tradeoff, thus growth and storage **do not compete** for C availability.

Growth stimulation under increasing atmospheric CO_2 concentrations in trees of arid environments should therefore not be expected.

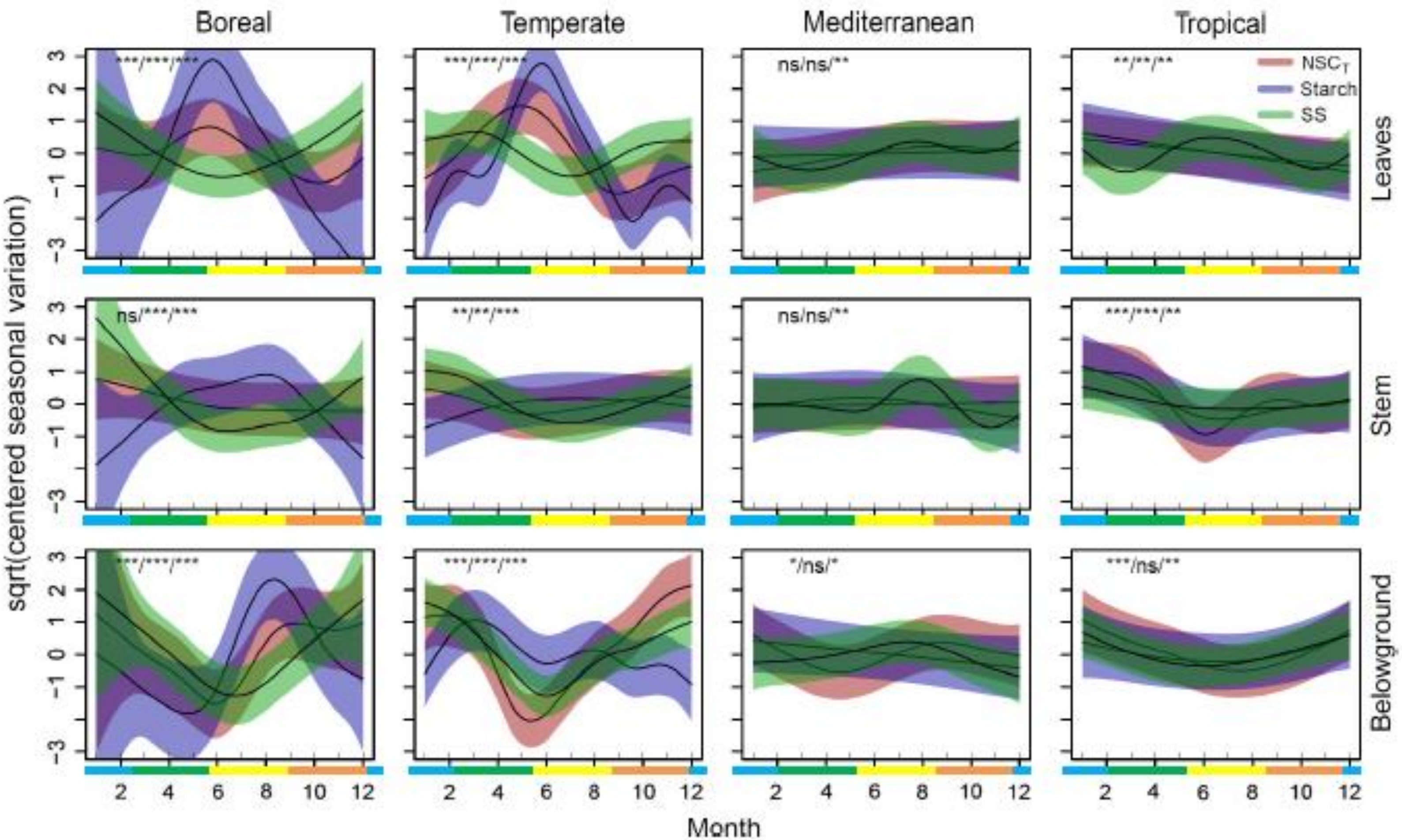
Piper & Fajardo, (in prep.)

Discussion



- Seedlings of populations from contrasting climates did differ in the seasonal dynamics of SS concentrations, consistent with local adaptation to drought.
- Increasing SS concentrations from summer to autumn could be locally advantageous to tolerate dehydration during late summer

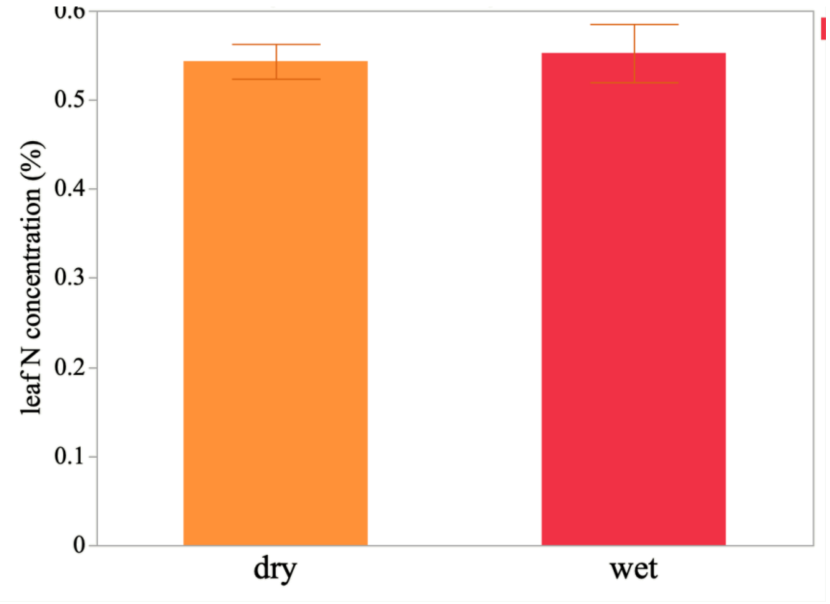
Increasing SS concentrations at the driest period is a constitutive attribute of drought-adapted plants(previous examples of Signori Muller et al. 2020, Paula & Piper, in prep)



Mediterranean plants acumulate sugars (SS) at the driest season

Martínez-Vilalta et al. (Ecological Monographs, 2016)

Discussion



higher SS requirements of dry ecotypes were not met from higher photosynthesis; they may have limited capacity to respond to natural disturbance events that cause C stress.

Plants with less starch are less tolerant of herbivory

Núcleo Milenio LiLi Límite de la vida Patagónica

Aknowledgments

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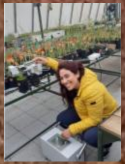

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