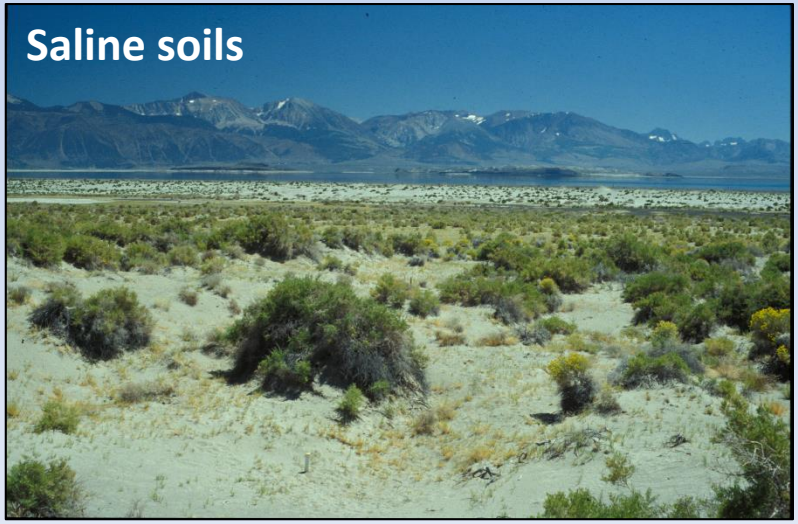
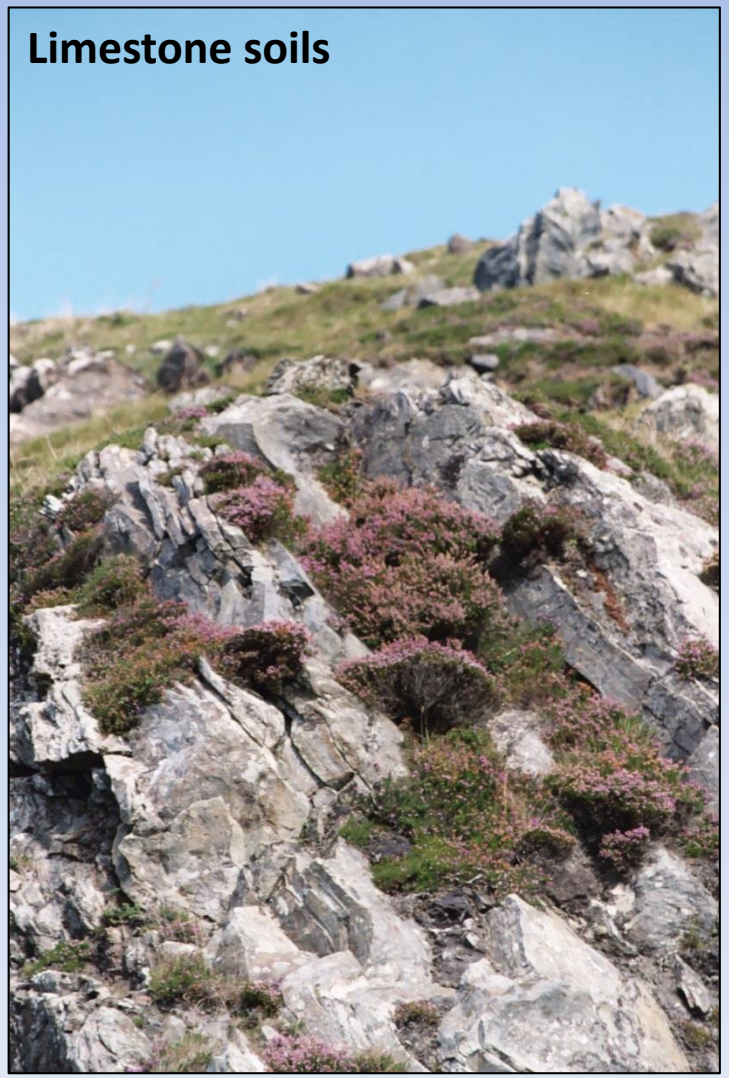
Chihuahuan Desert gypsum endemics: patterns of adaptation in relation to phylogeny and distribution extent

Clare Muller[1], Michael J Moore[2], Zoë Feder[2], and Rebecca E Drenovsky[1]

[1]Department of Biology, John Carroll University, University Heights, OH;
[2]Department of Biology, Oberlin College, Oberlin, OH

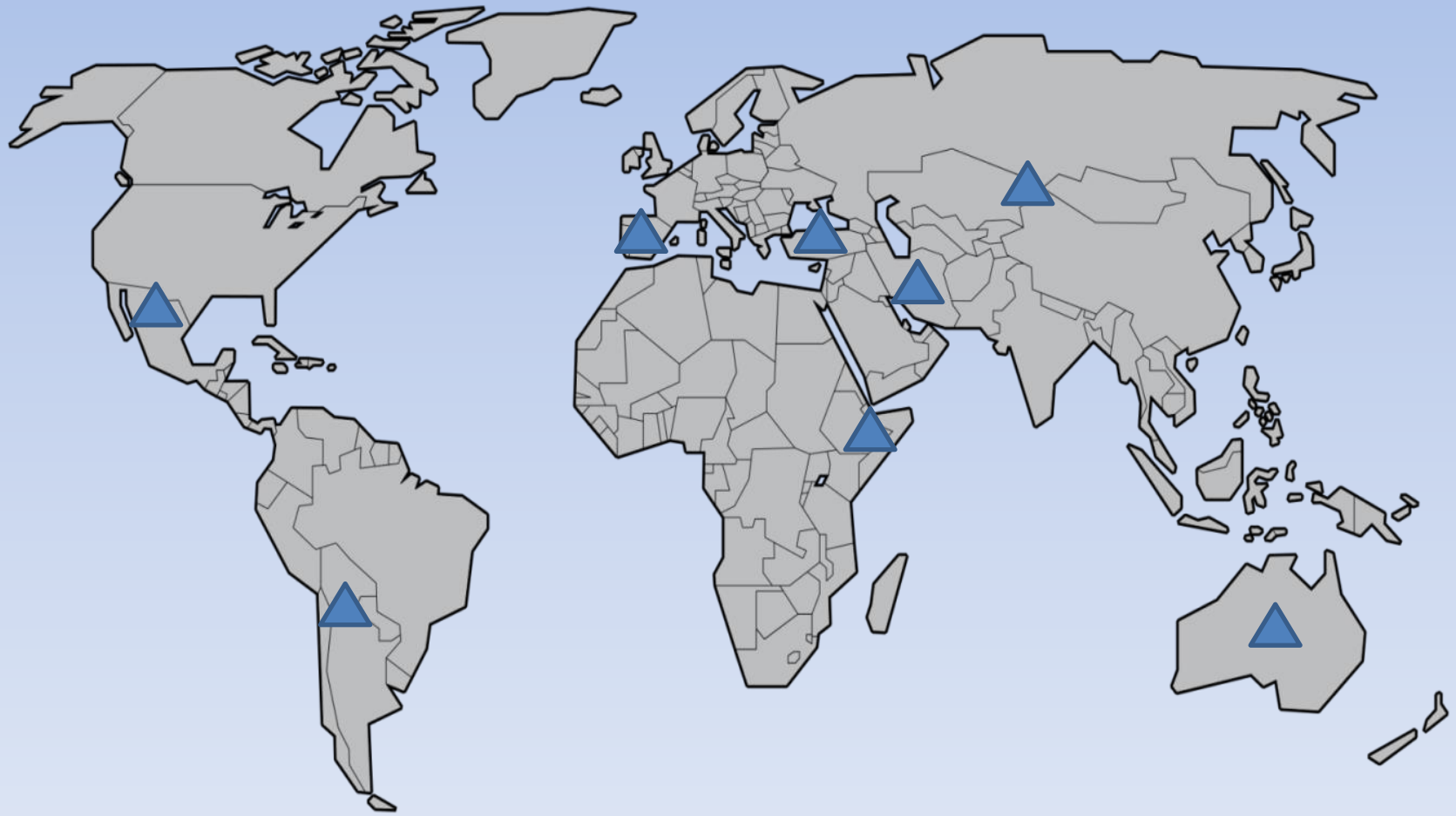
Edaphic stressors are drivers of plant evolution and community assembly



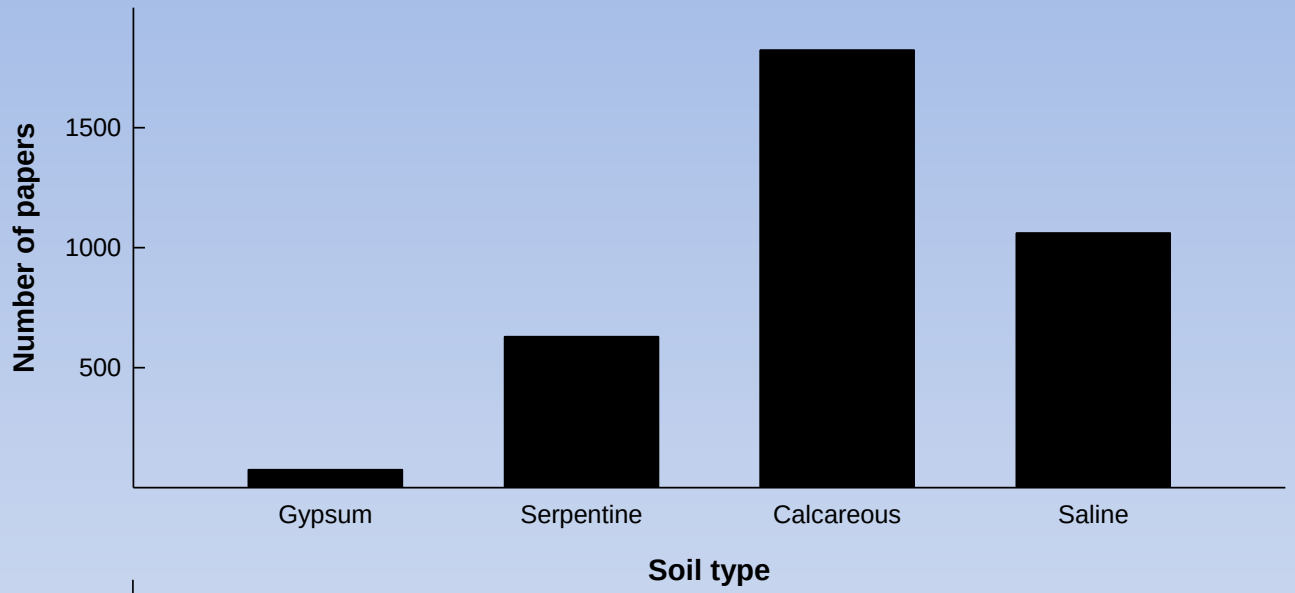


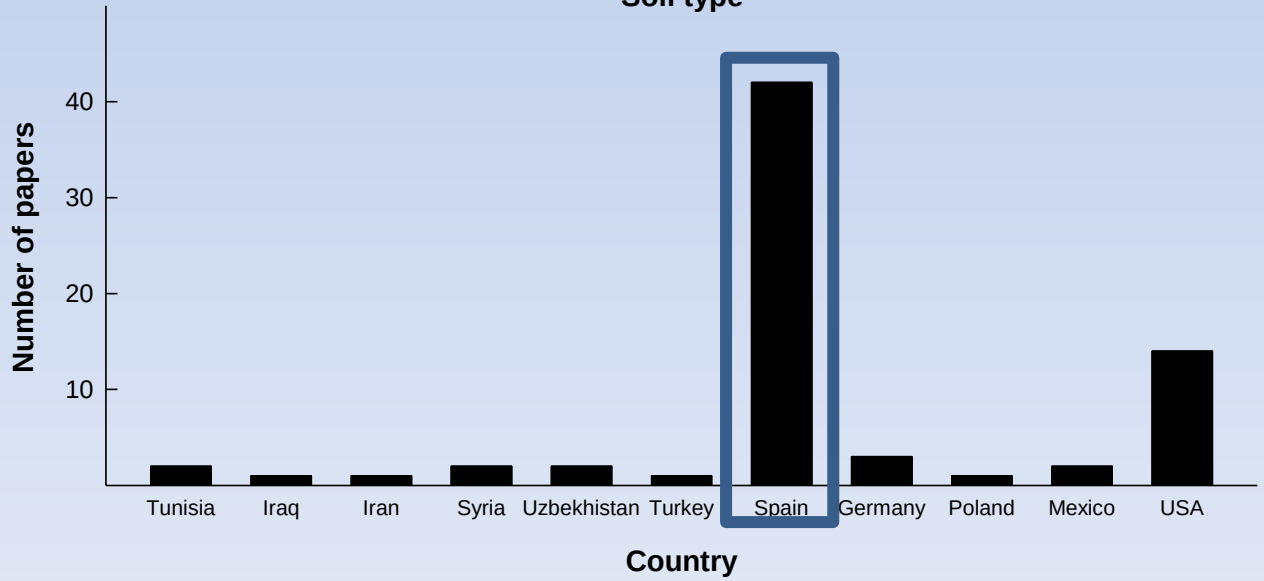
Edaphic stressors are drivers of plant evolution and community assembly

Gypsum soils occur worldwide



But are understudied vs. other soil types





Re-drawn from Escudero et al. (2014)

Spanish gypsophilic flora

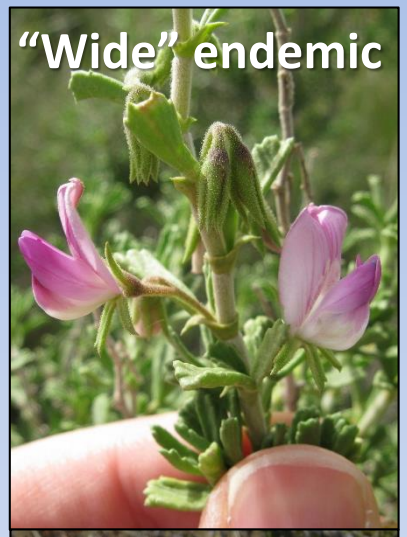
≈50 gypsophiles in ≈15 families

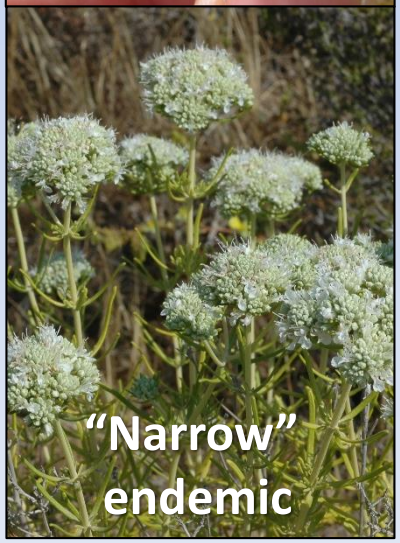
Some taxa accumulate leaf Ca and S

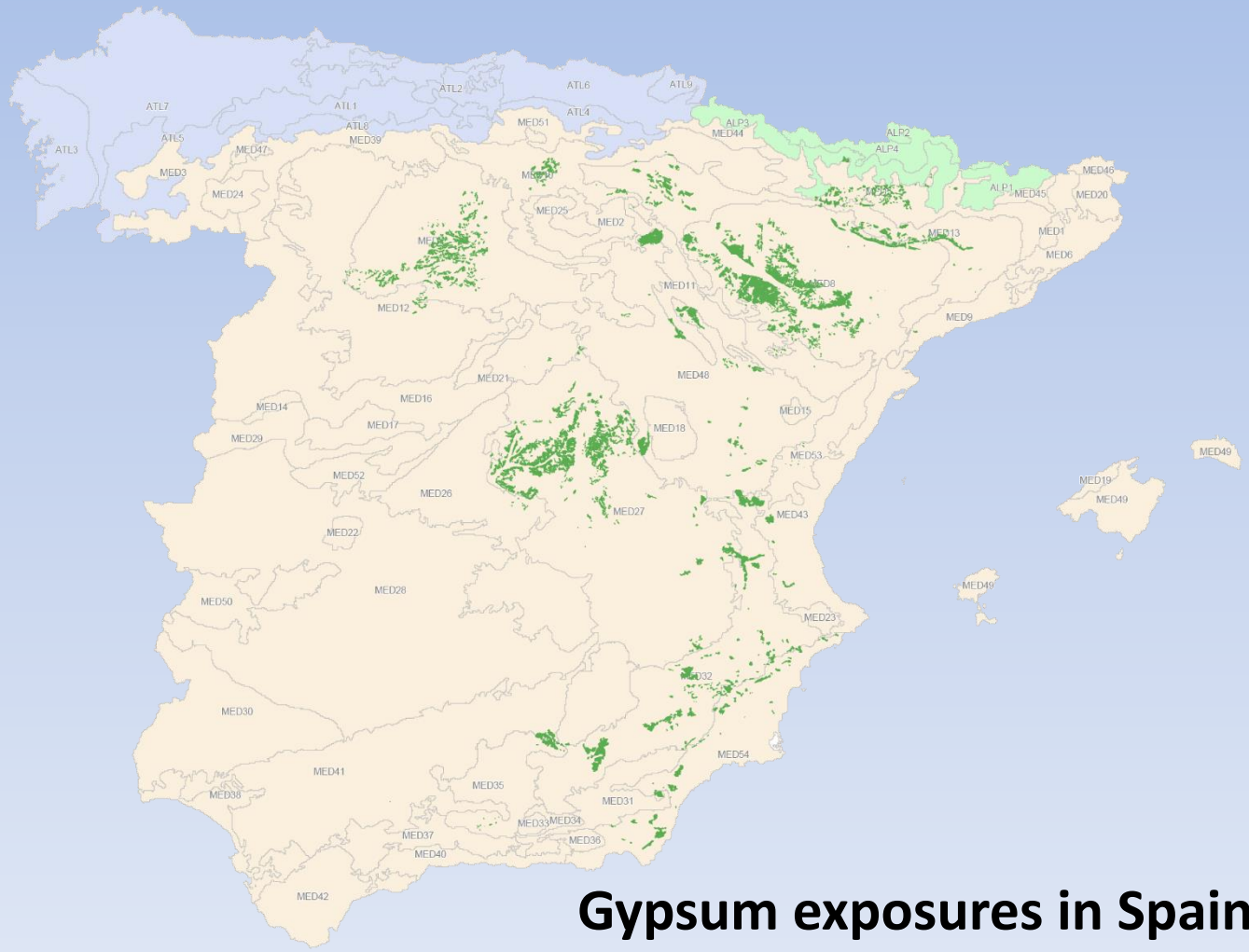
Other taxa do not

Palacio et al. 2007. Annals of Botany

Distribution extent is correlated with leaf Ca and S accumulation



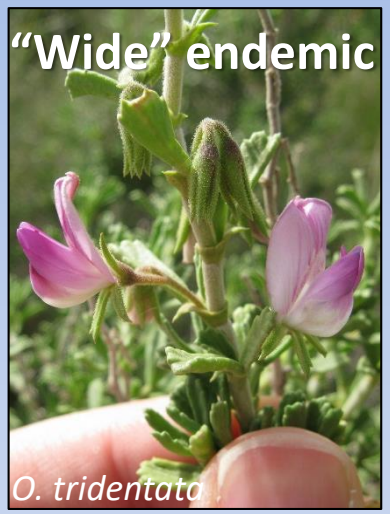


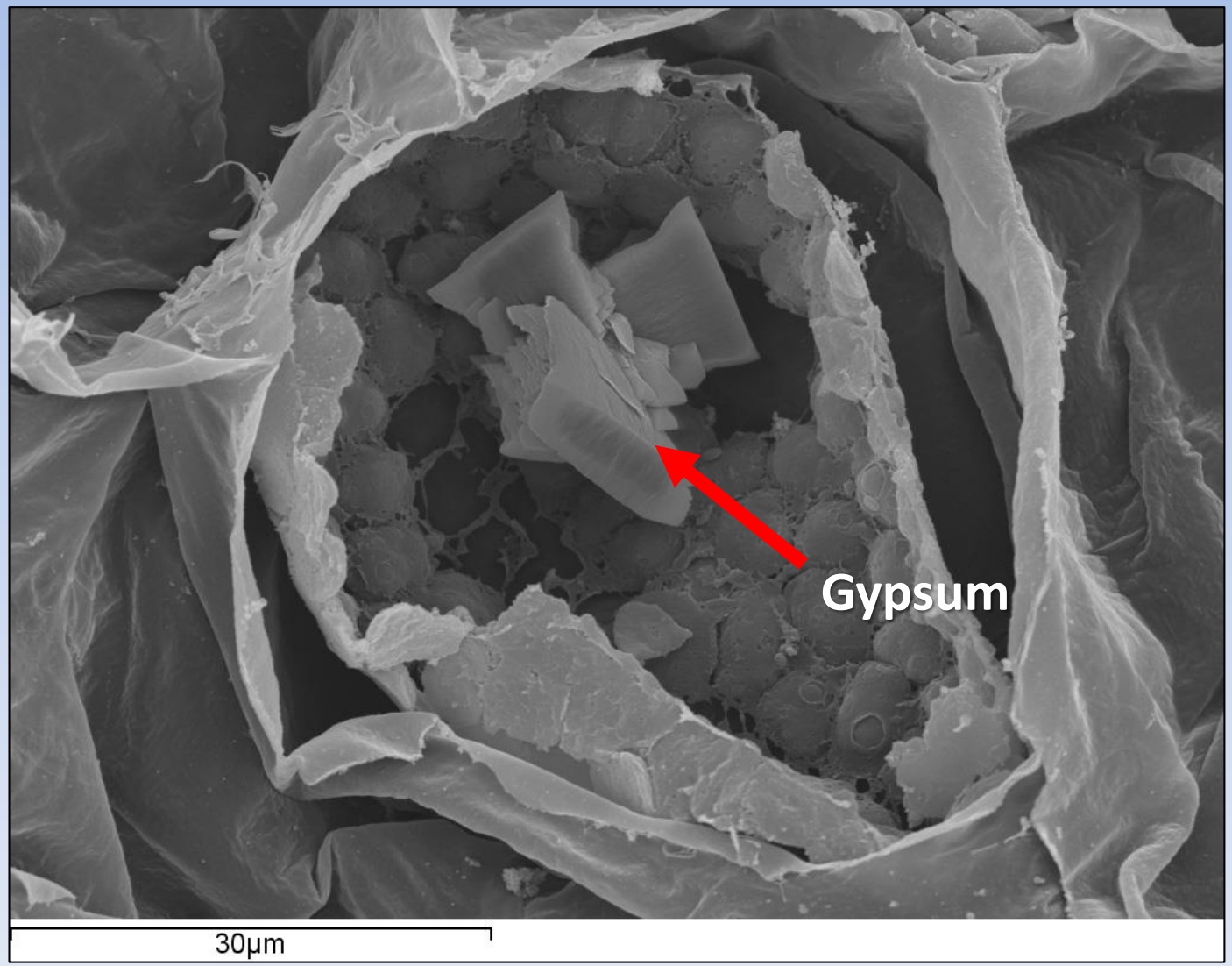


Gypsum exposures in Spain

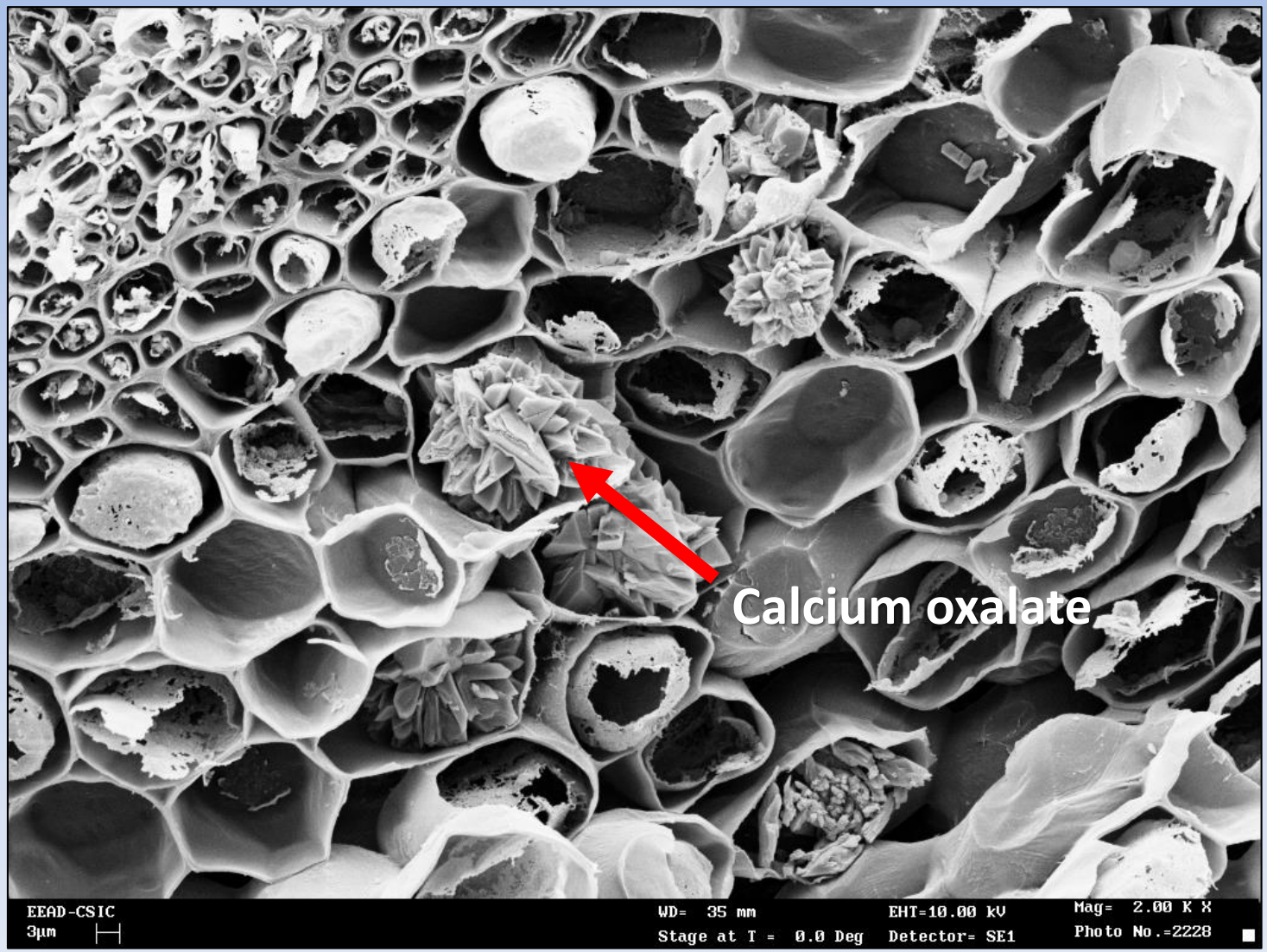
Courtesy Juan Mota

Widely distributed taxa can accumulate gypsum and, for some, oxalate crystals





Widely distributed taxa can accumulate gypsum and, for some, oxalate crystals

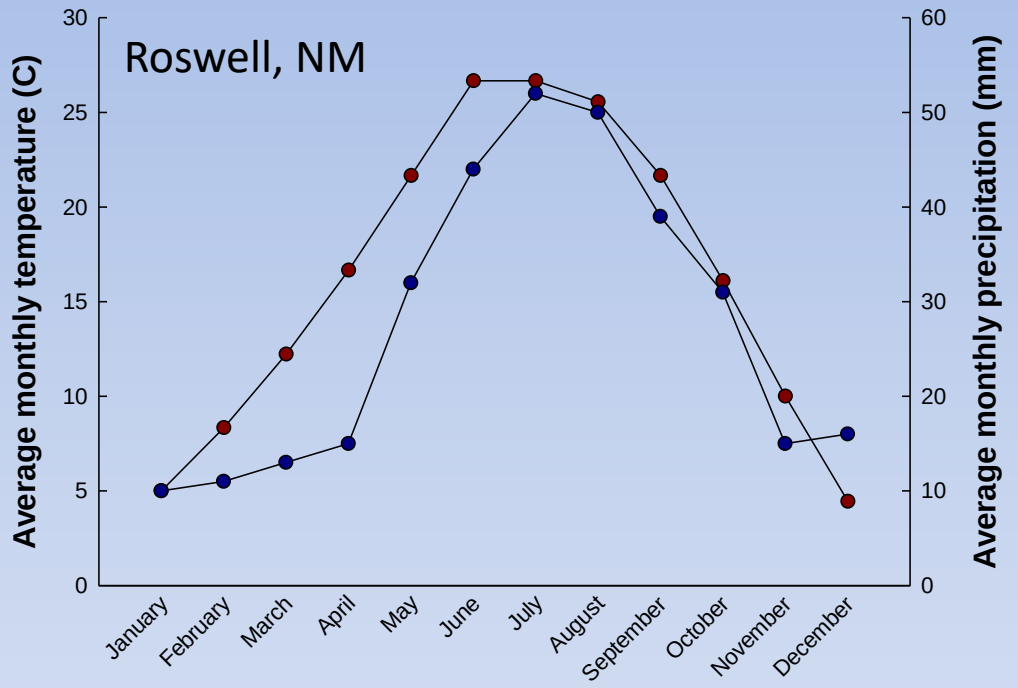


Are these leaf chemical signatures indicative of adaptive mechanisms?

The BIG questions…

1. Are there global patterns in the mechanisms supporting gypsum adaptation?
2. What are the roles of phylogeny, lineage age, and distribution extent in these patterns?

The Chihuahuan Desert as a study system



Amazing biodiversity provides phylogenetic context

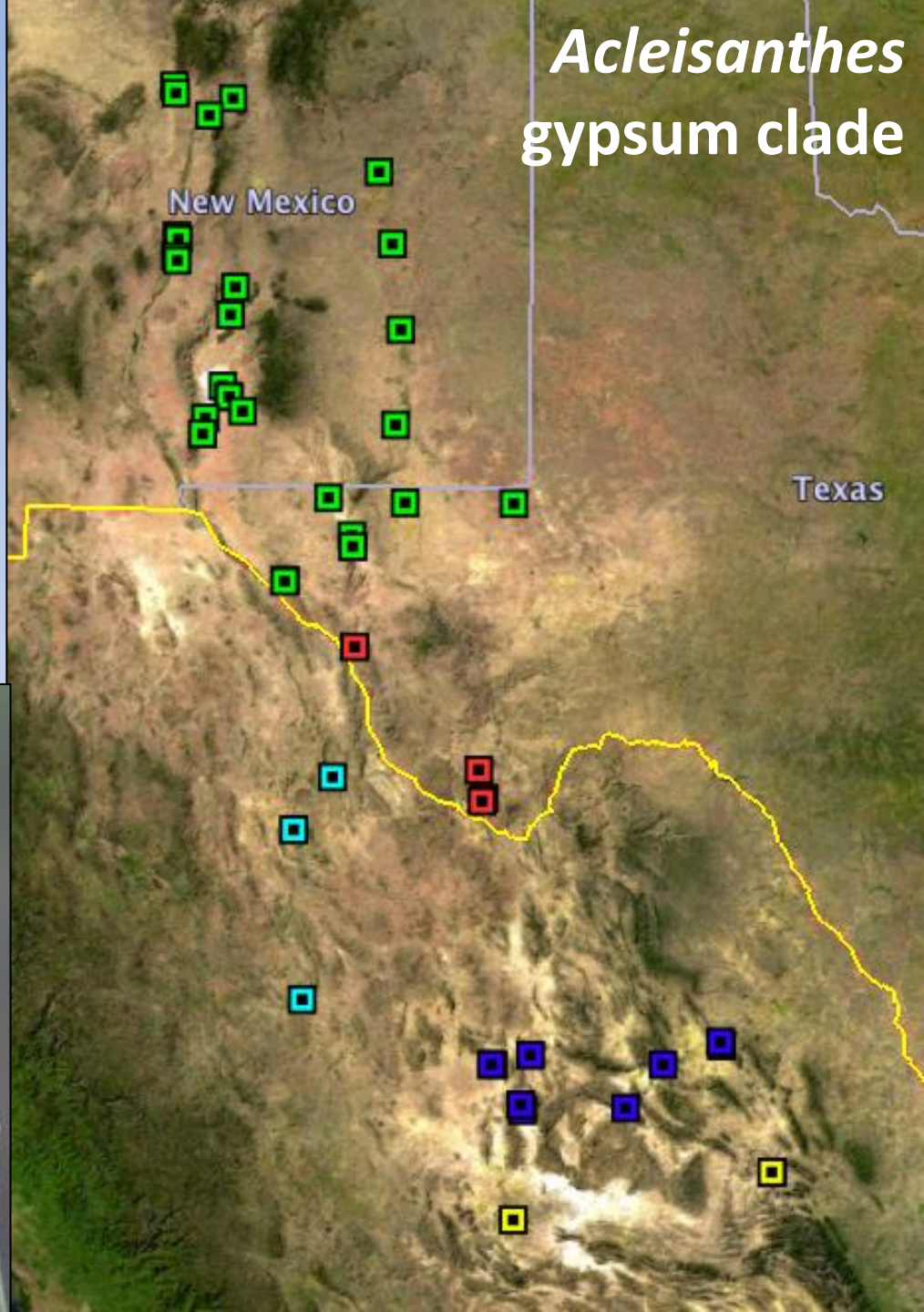
240+ species in 36 families

Extensive phylogenetic data

Some gypsum endemics are morphologically distinct

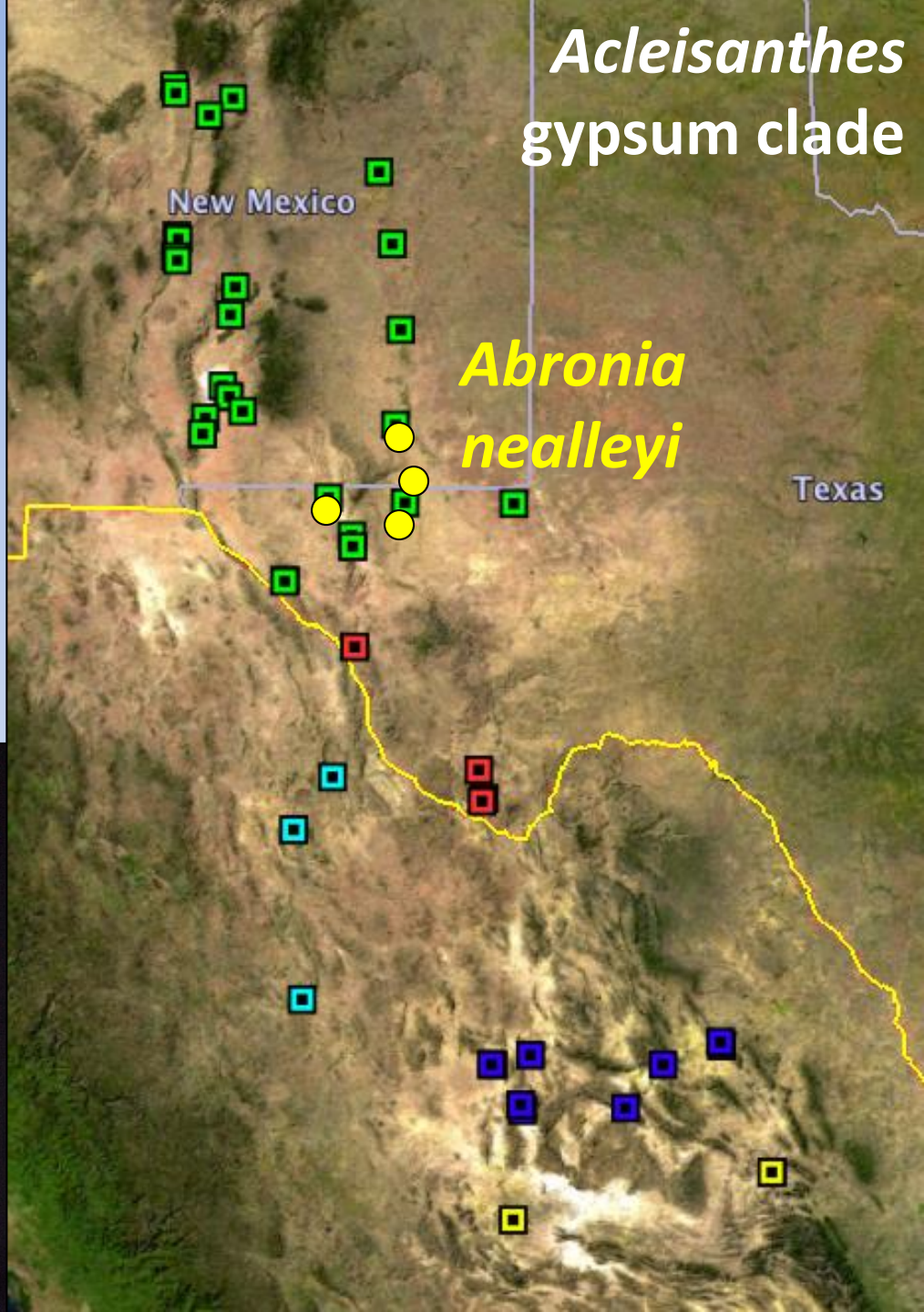
Others are less morphologically distinct

Some Chihuahuan Desert gypsum endemics are widely distributed…

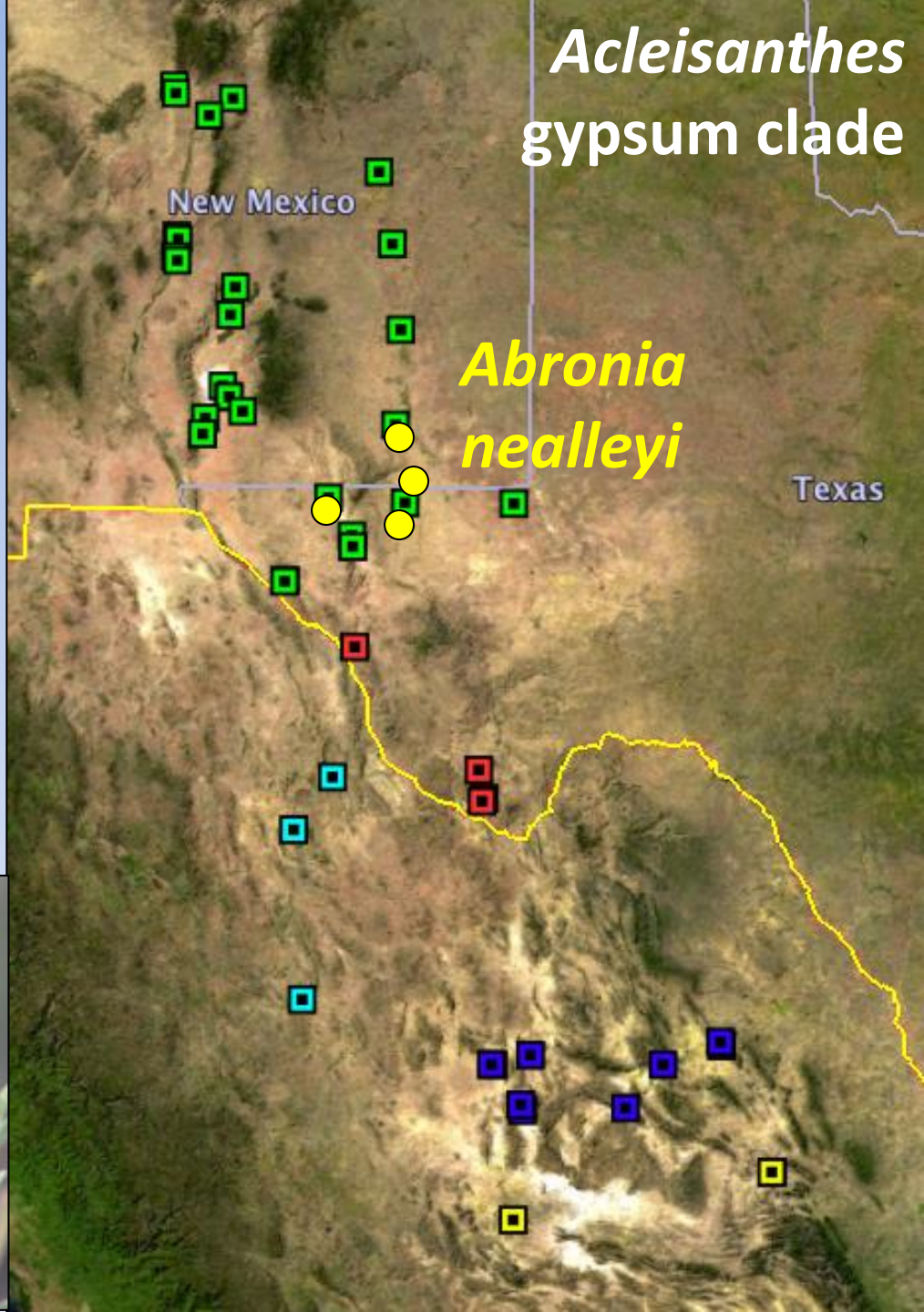


Some Chihuahuan Desert gypsum endemics are widely distributed…

…others are not



Morphology & distribution are correlated with lineage age

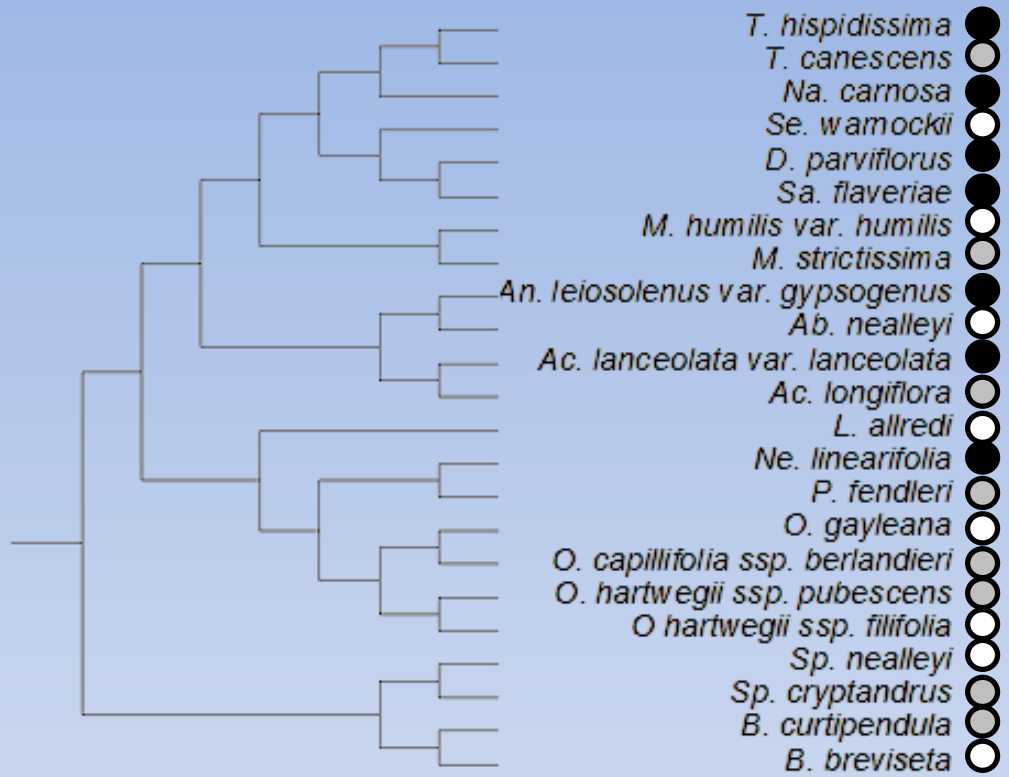


Field survey of Chihuahuan flora

Key questions: What are the leaf chemical signatures of gysophilic taxa and their **non-endemic** congeners and confamilials? Does **lineage age** matter?

Clare Muller (JCU)
& Mike Moore (Oberlin)

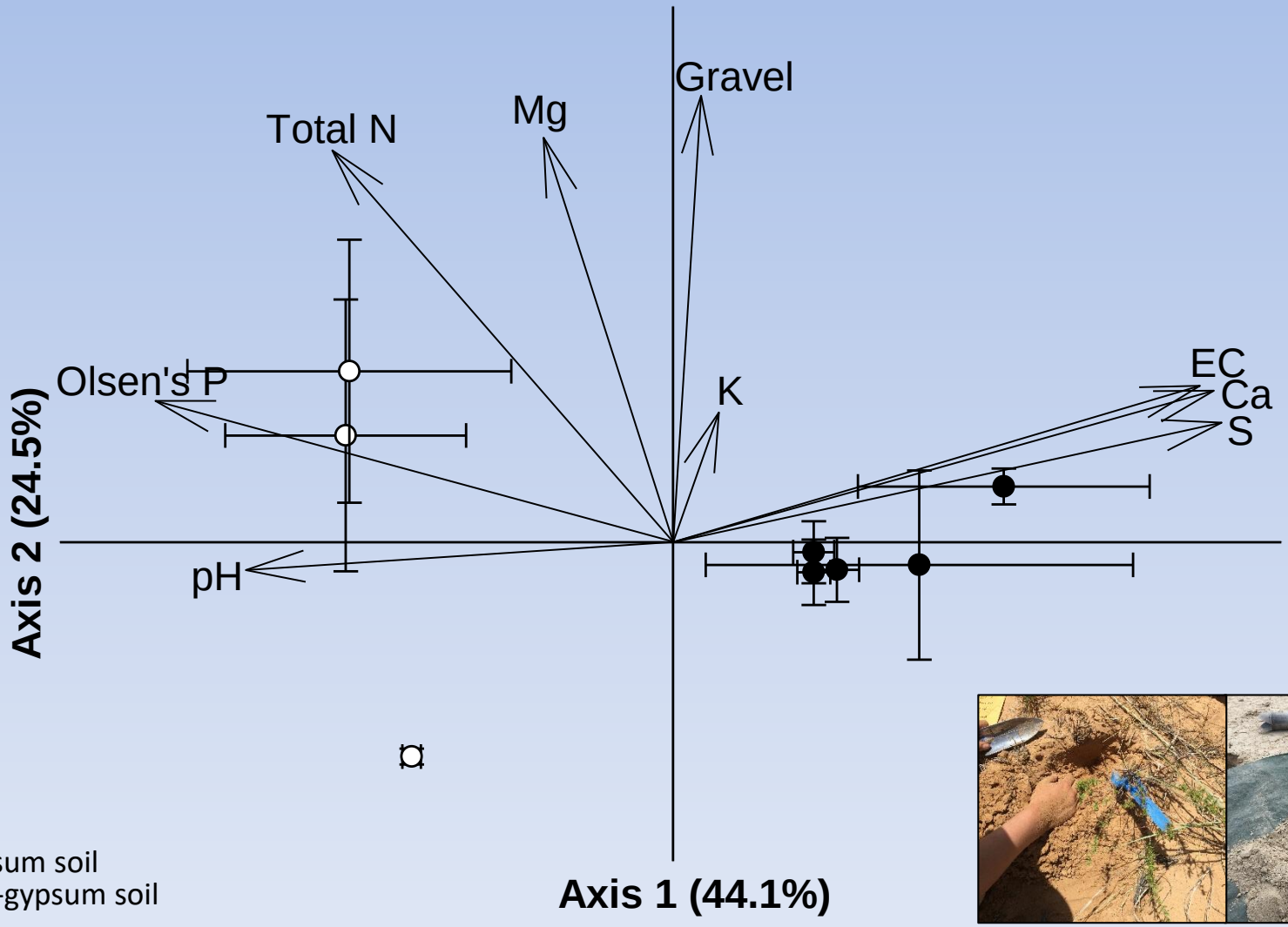
Sampling design



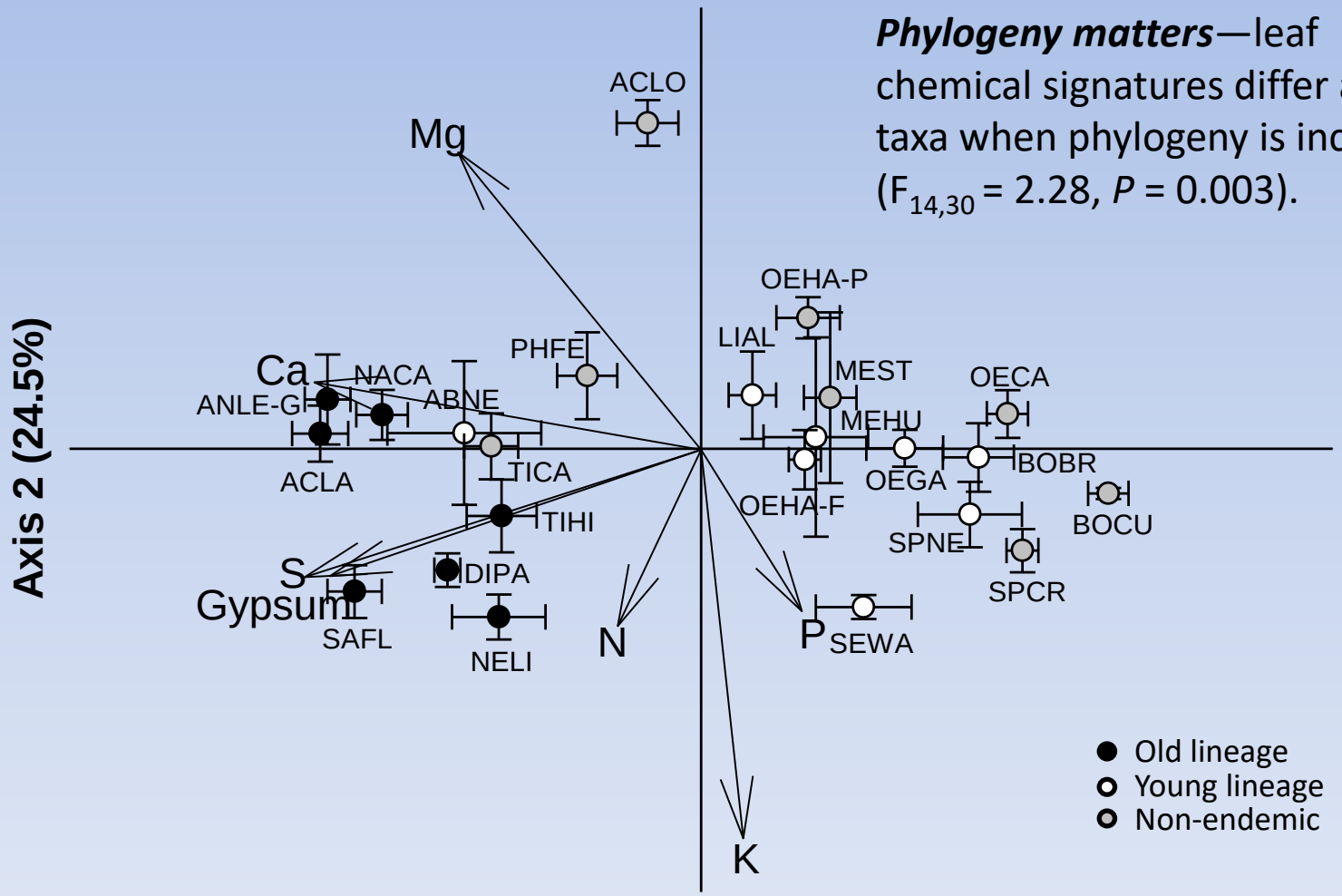
● Old lineage ○ Young lineage ○ Non-endemic

Muller et al. 2017. AJB 104:1442-1450

Chihuahuan soil chemistry

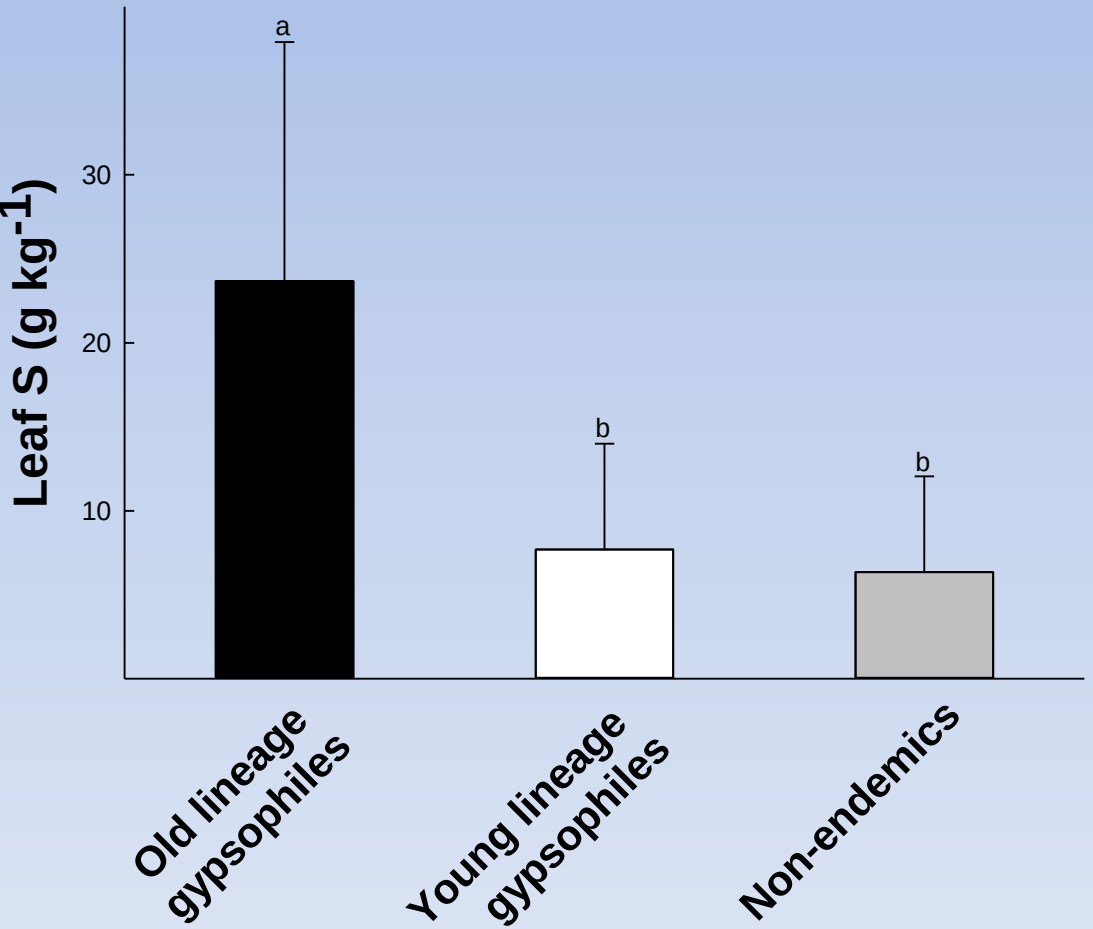


Chihuahuan leaf chemical signatures

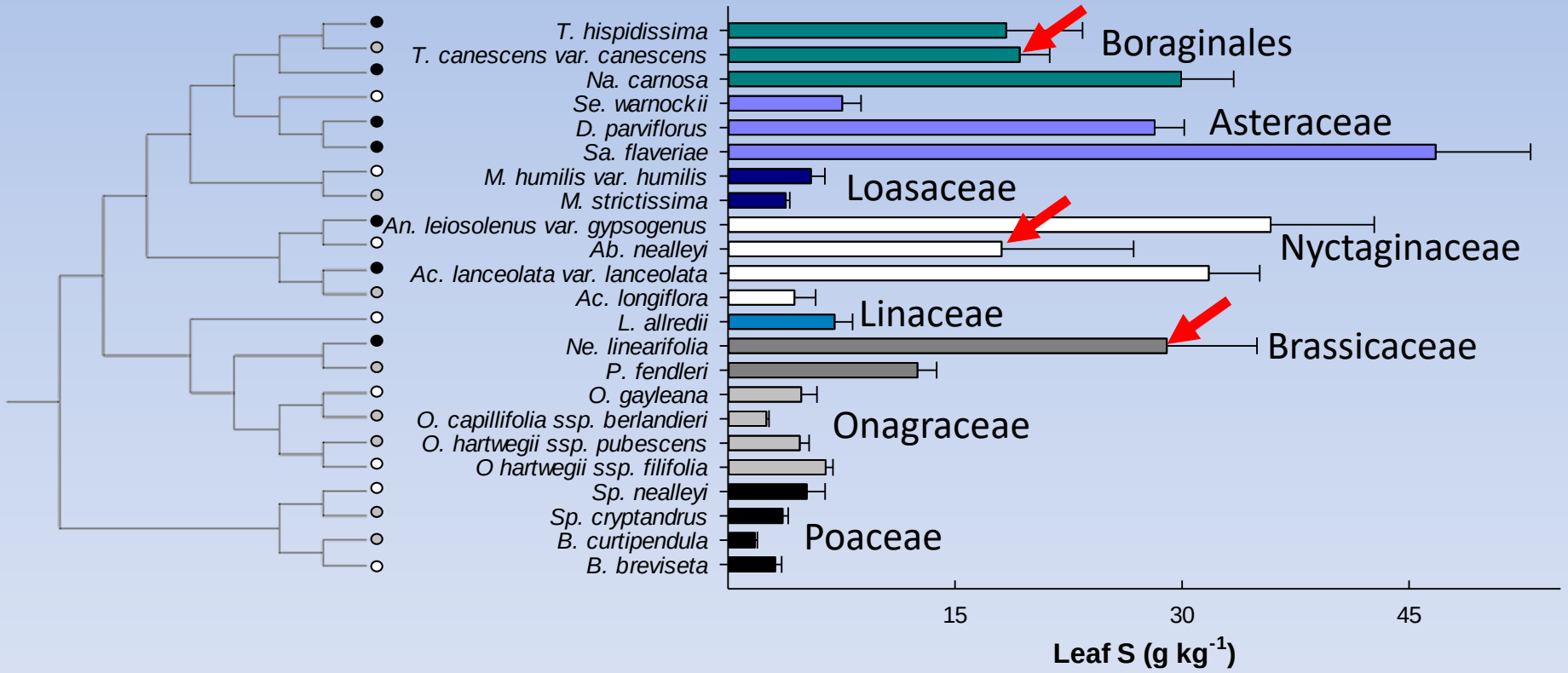


Phylogeny matters—leaf chemical signatures differ among taxa when phylogeny is included ($F_{14,30} = 2.28$, $P = 0.003$).

Leaf sulfur by functional group

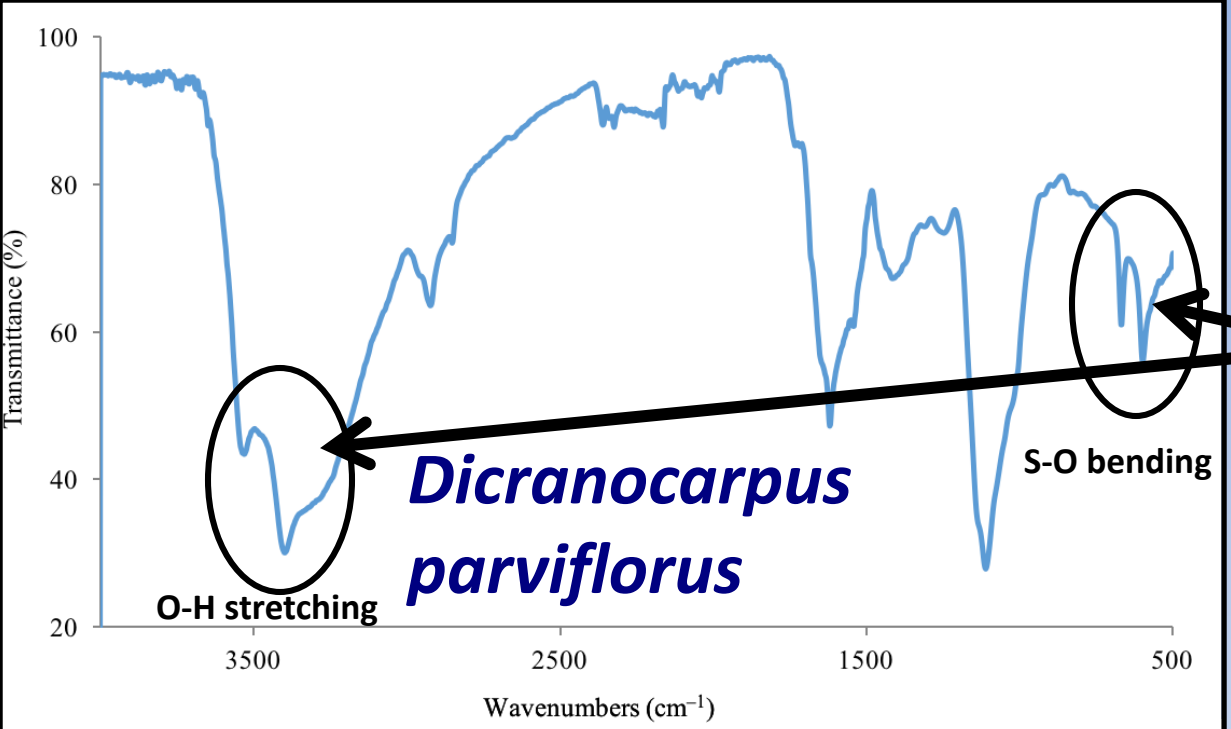


Leaf sulfur by family

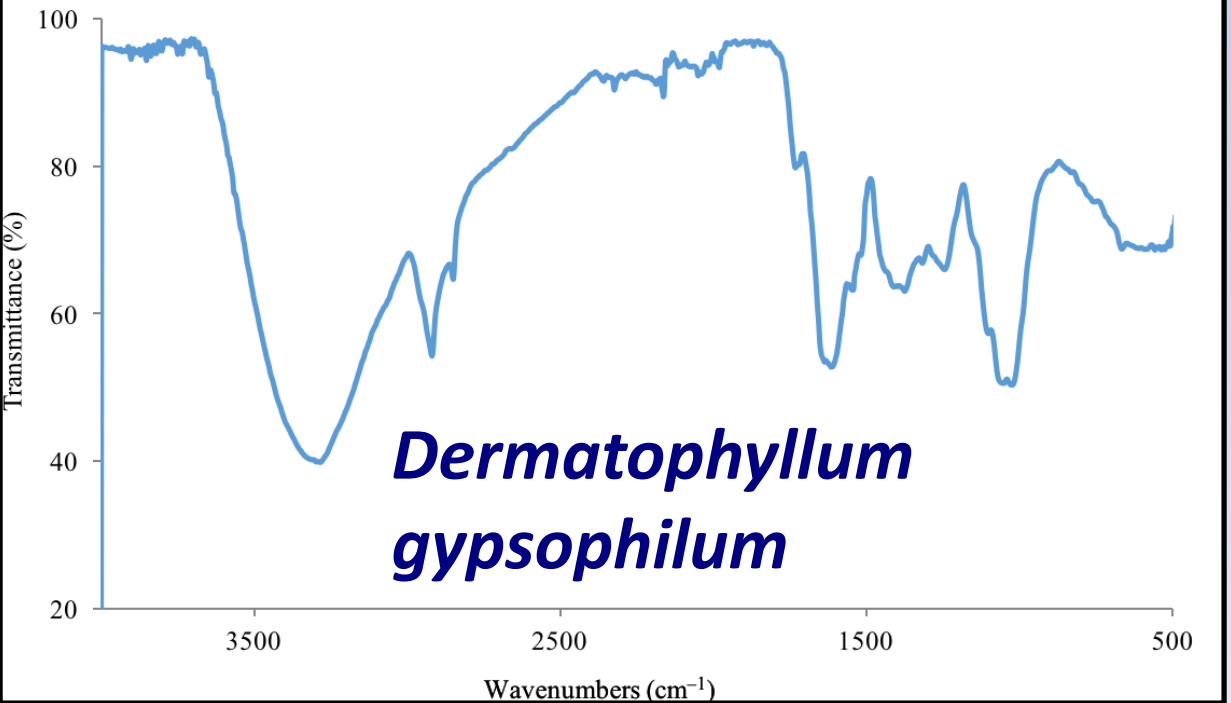


Leaf S differs among taxa when phylogeny is incorporated ($F_{2,20} = 10.26$, $P = 0.001$)

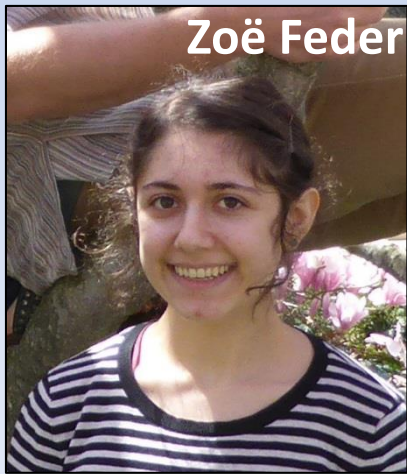
FTIR spectroscopy of leaves



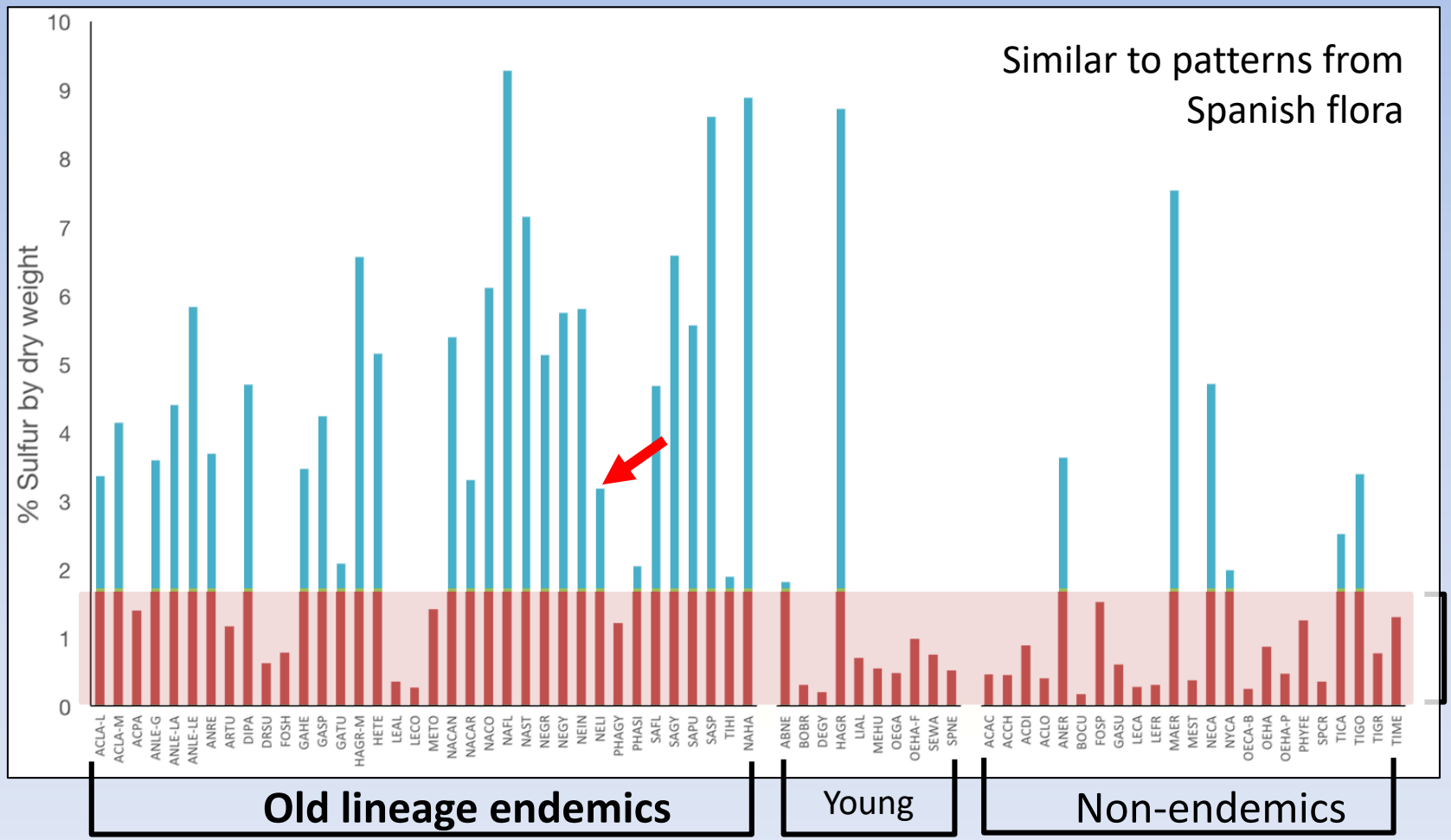
Peaks indicative of gypsum



Ellie Tiley
Keyi Feng



Gypsum detected in all samples with ≥1.8% sulfur



Chihuahuan Desert: summary

1. Leaf accumulation and assimilation of S and Ca (e.g., as gypsum) in older gypsophilic lineages is a potential mechanism supporting life on gypsum
2. Phylogeny is important for understanding patterns in foliar mineral nutrition

Global gypsophily

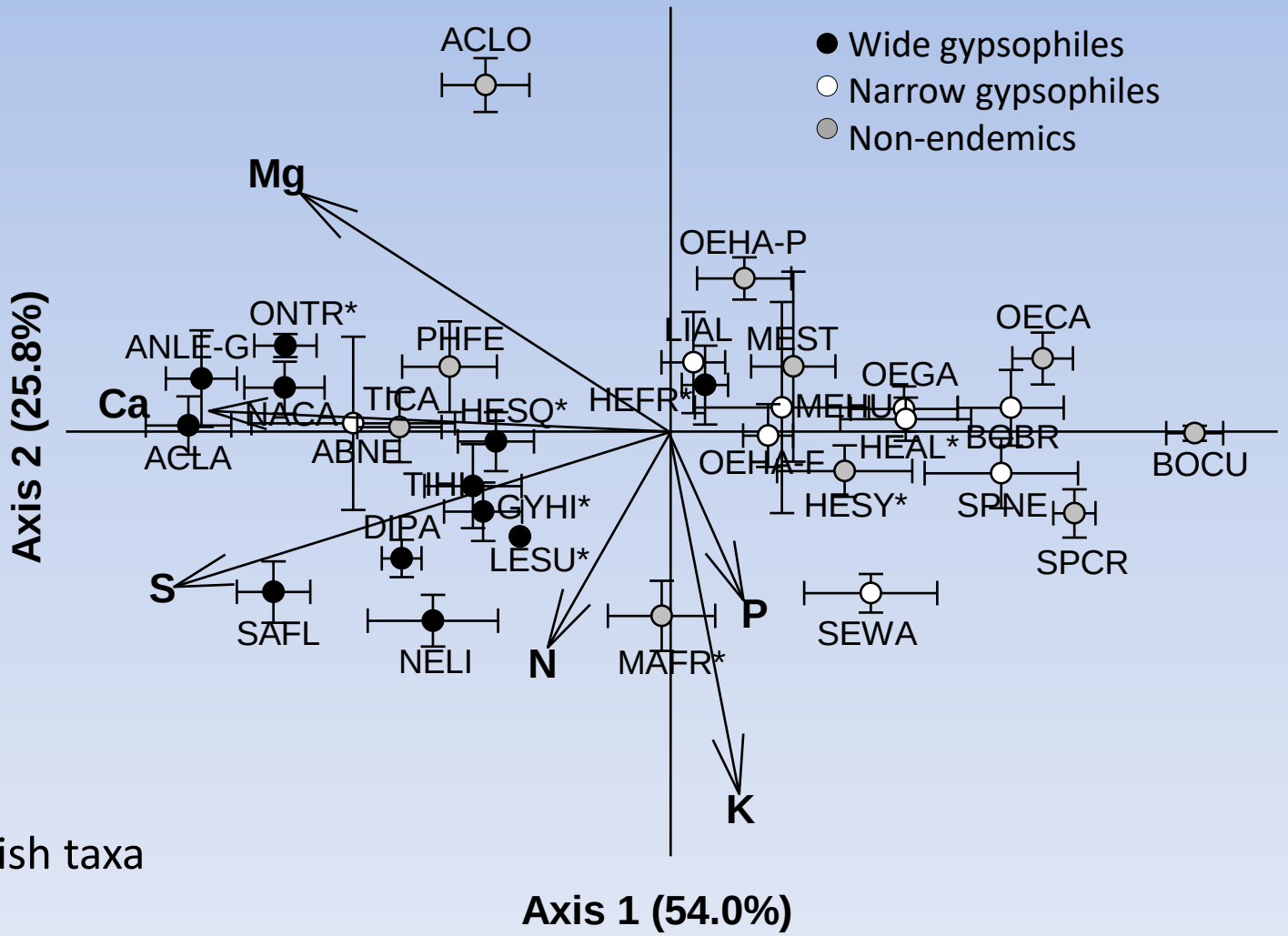
Are there shared foliar accumulation patterns for Spain and USA collections?

Are there indications of phylogenetic patterns in foliar chemistry for both gypsum floras?

Global gypsophily: Methods

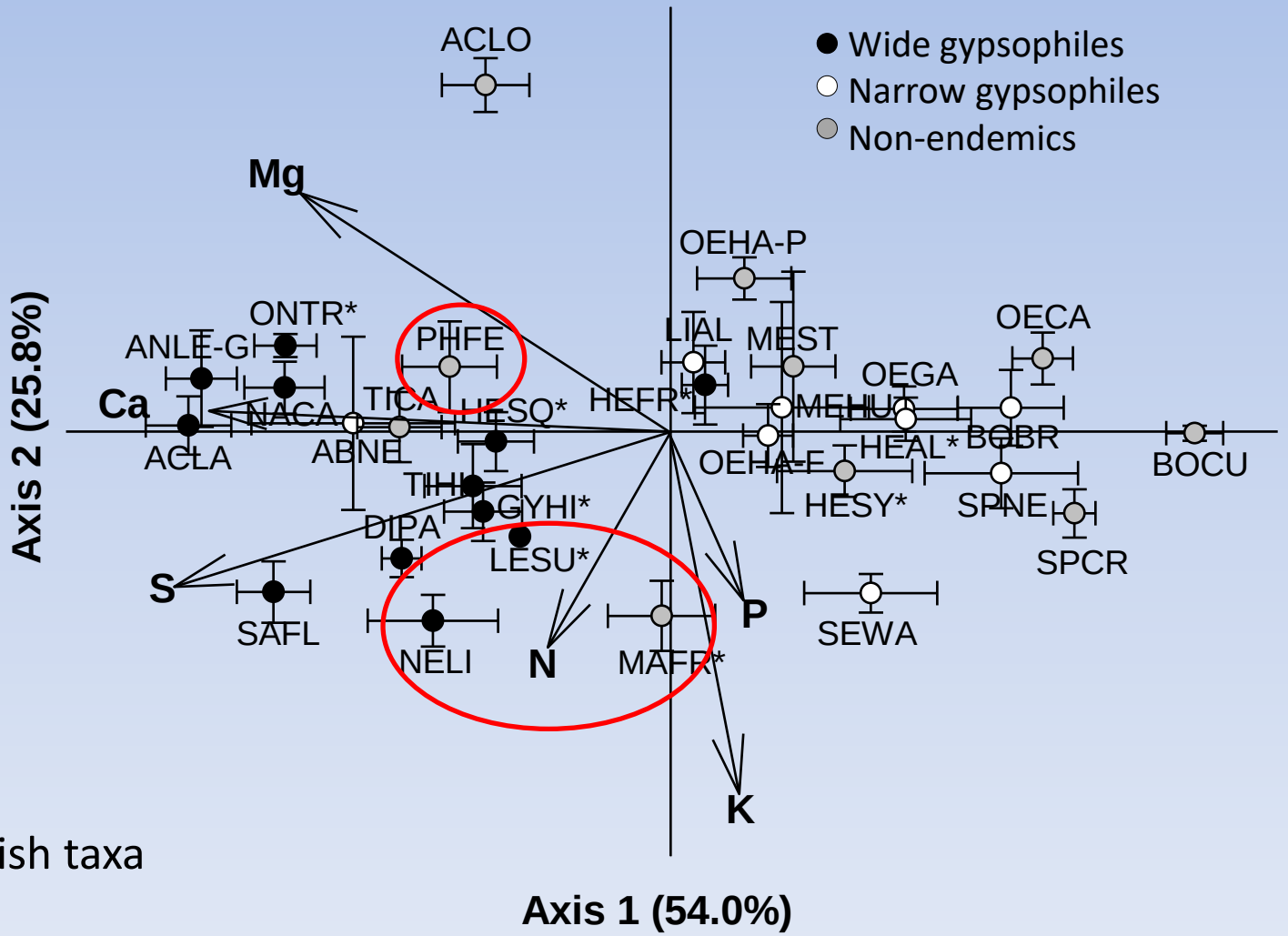
Congeners/confamilials of varying distributions sampled from Spain and USA

Chihuahuan & Spanish leaf chemical signatures



*Spanish taxa

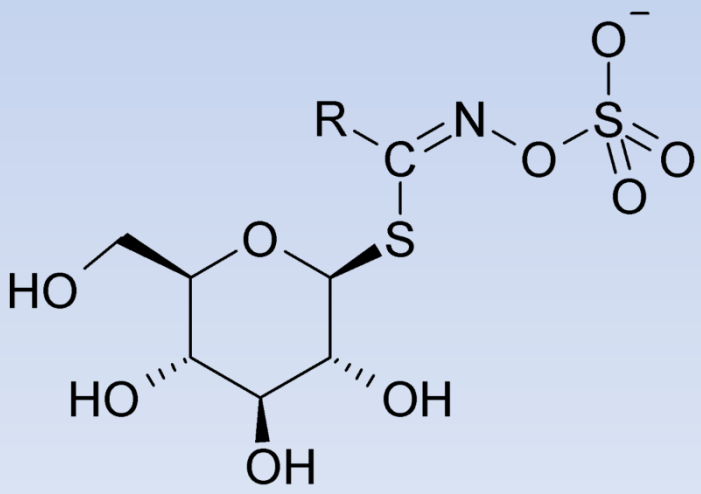
Chihuahuan & Spanish leaf chemical signatures: phylogenetic patterns



*Spanish taxa

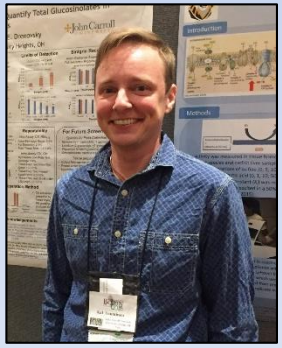
What's up with the mustards?

1. High leaf N & S
2. No gypsum accumulation in some
3. Glucosinolates?

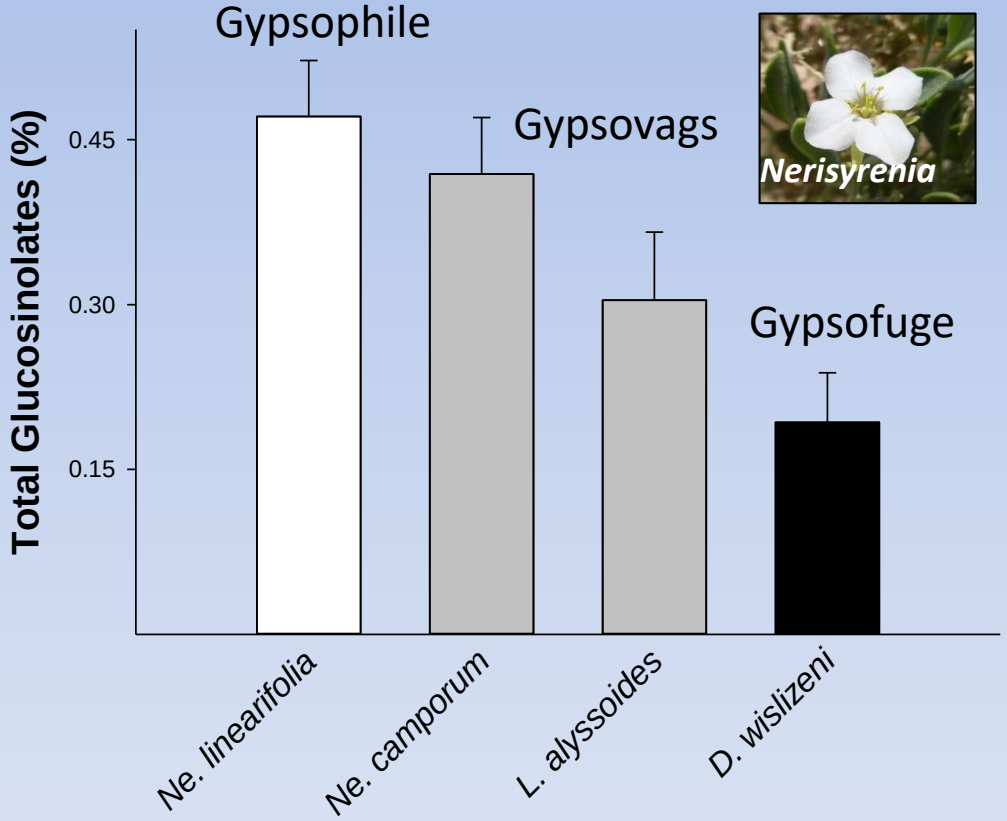


What's up with the mustards?

Preliminary data:
total glucosinolate levels correspond to gypsum association

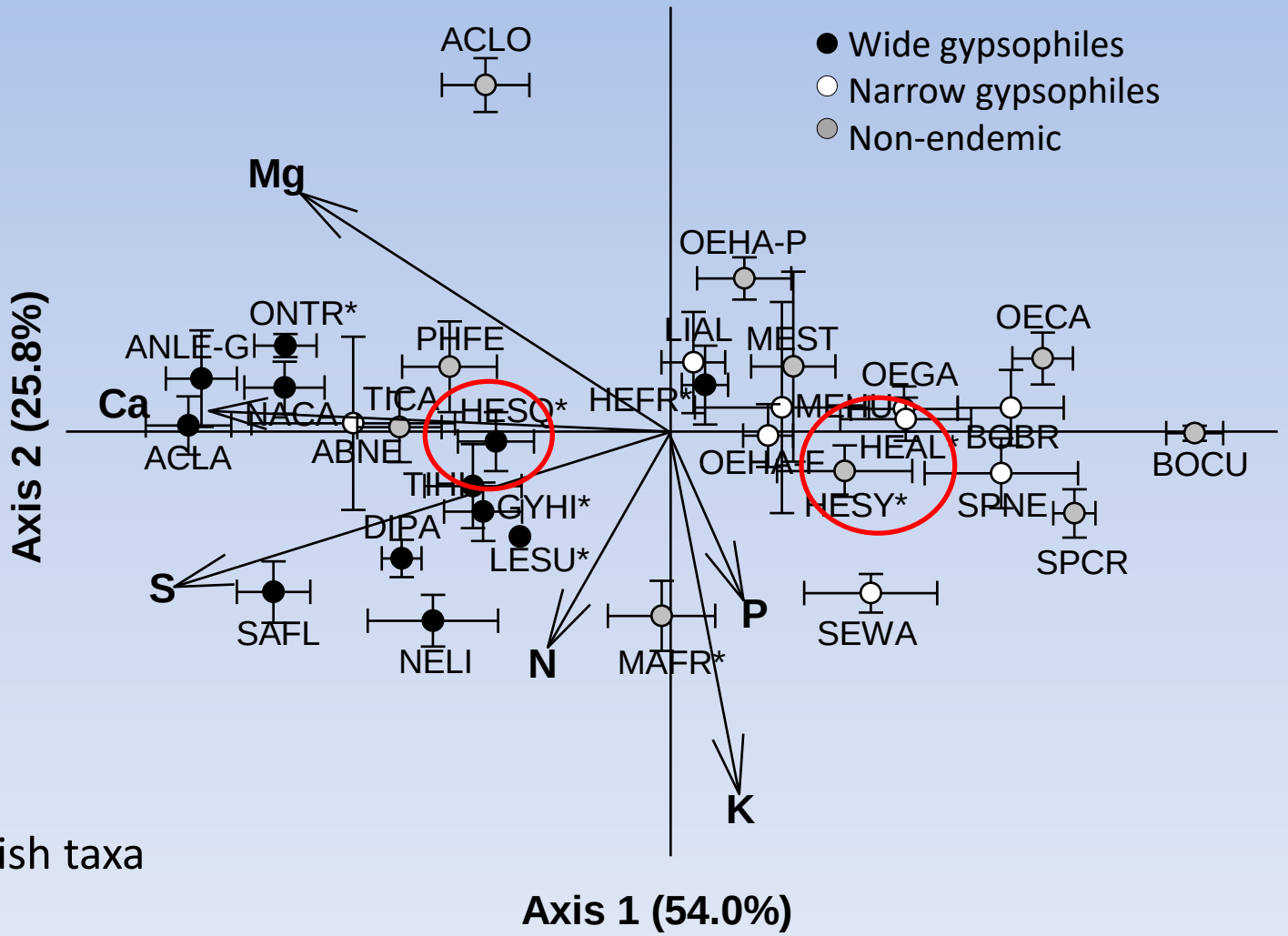


Kal Tuominen & Becca Reicholf



Preliminary field survey data

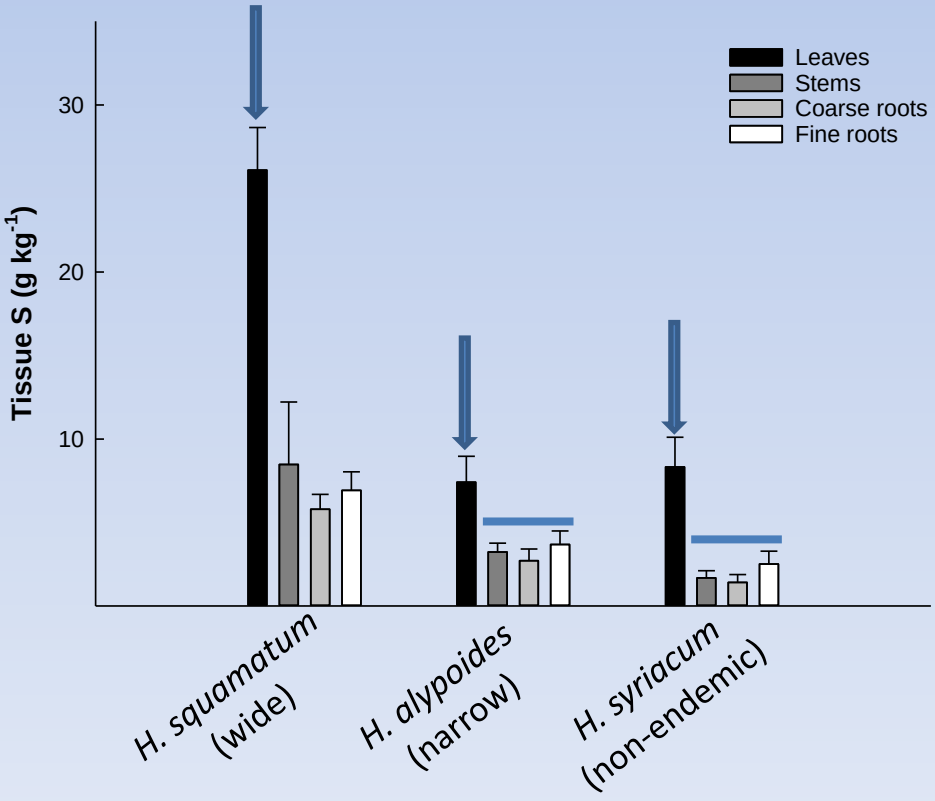
Chihuahuan & Spanish leaf chemical signatures: distribution extent patterns

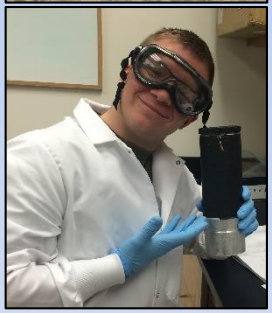


*Spanish taxa

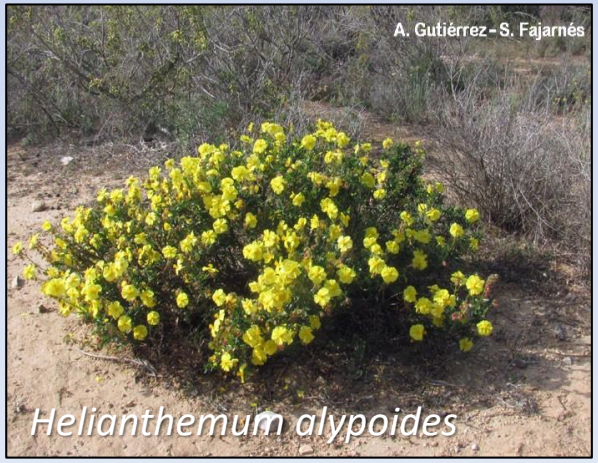
Why are so many narrow gypsophiles different in leaf chemistry?

Exclusion of excess elements rather than assimilation?





Clare Muller & Nate Heiden



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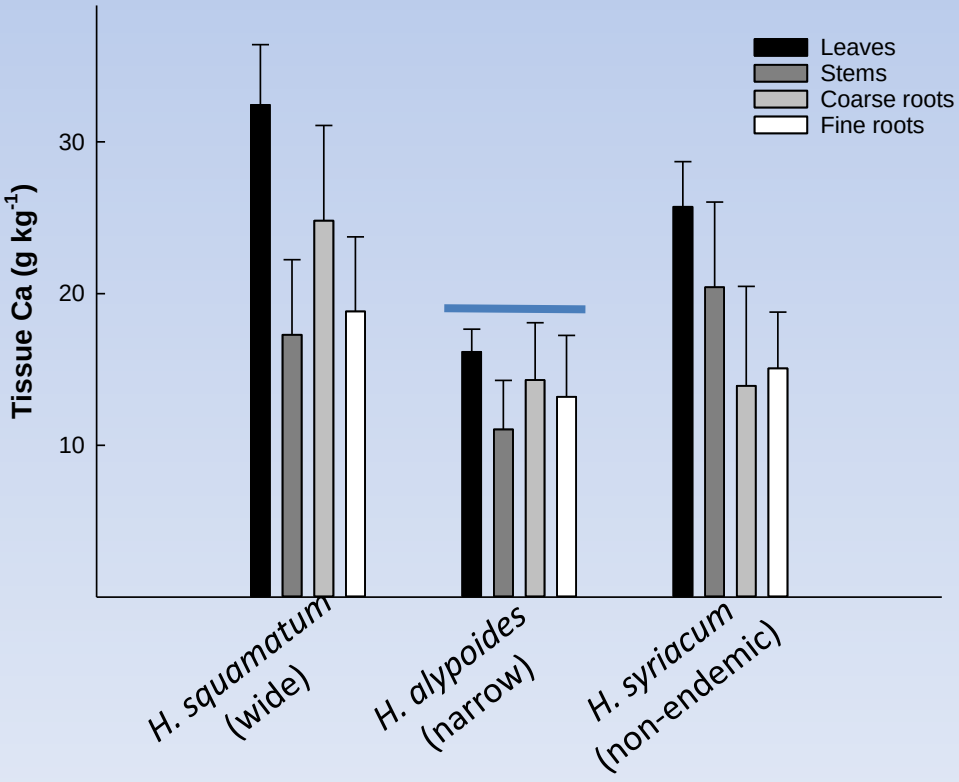
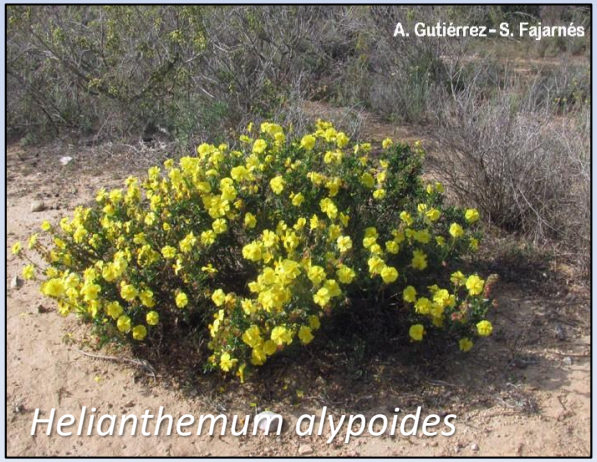
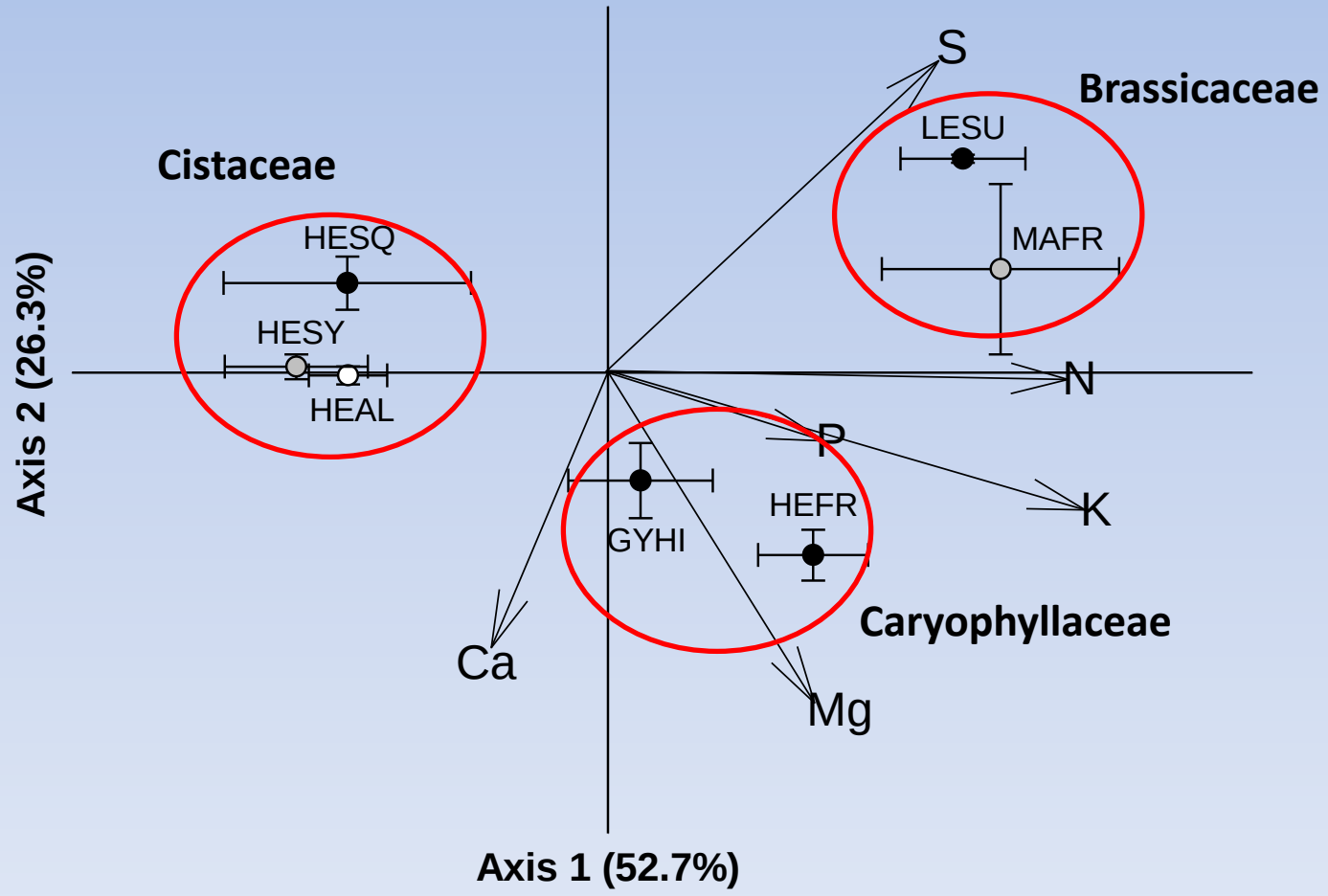




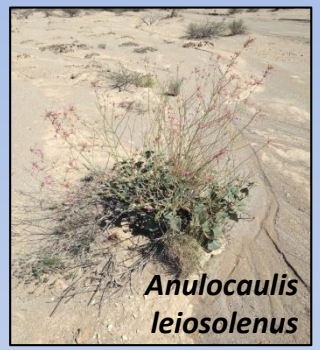
Why are fine root patterns so dependent on phylogeny?

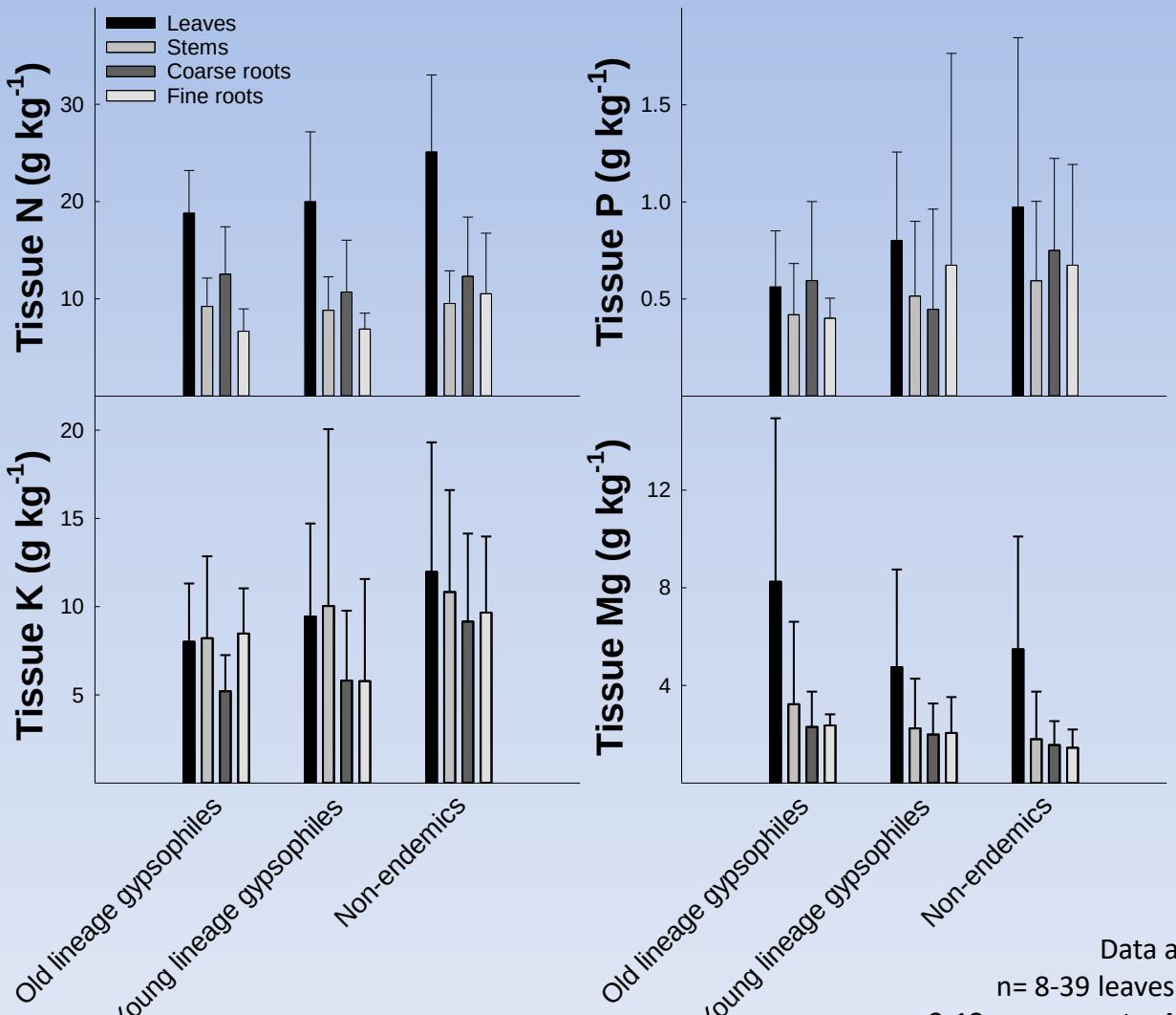


Do these patterns hold with more sampling?

Leaves, stems, coarse & fine roots collected from >40 Chihuahuan taxa from 17 sites

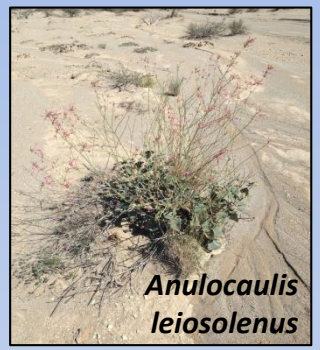
Tissue chemistry for broader sampling

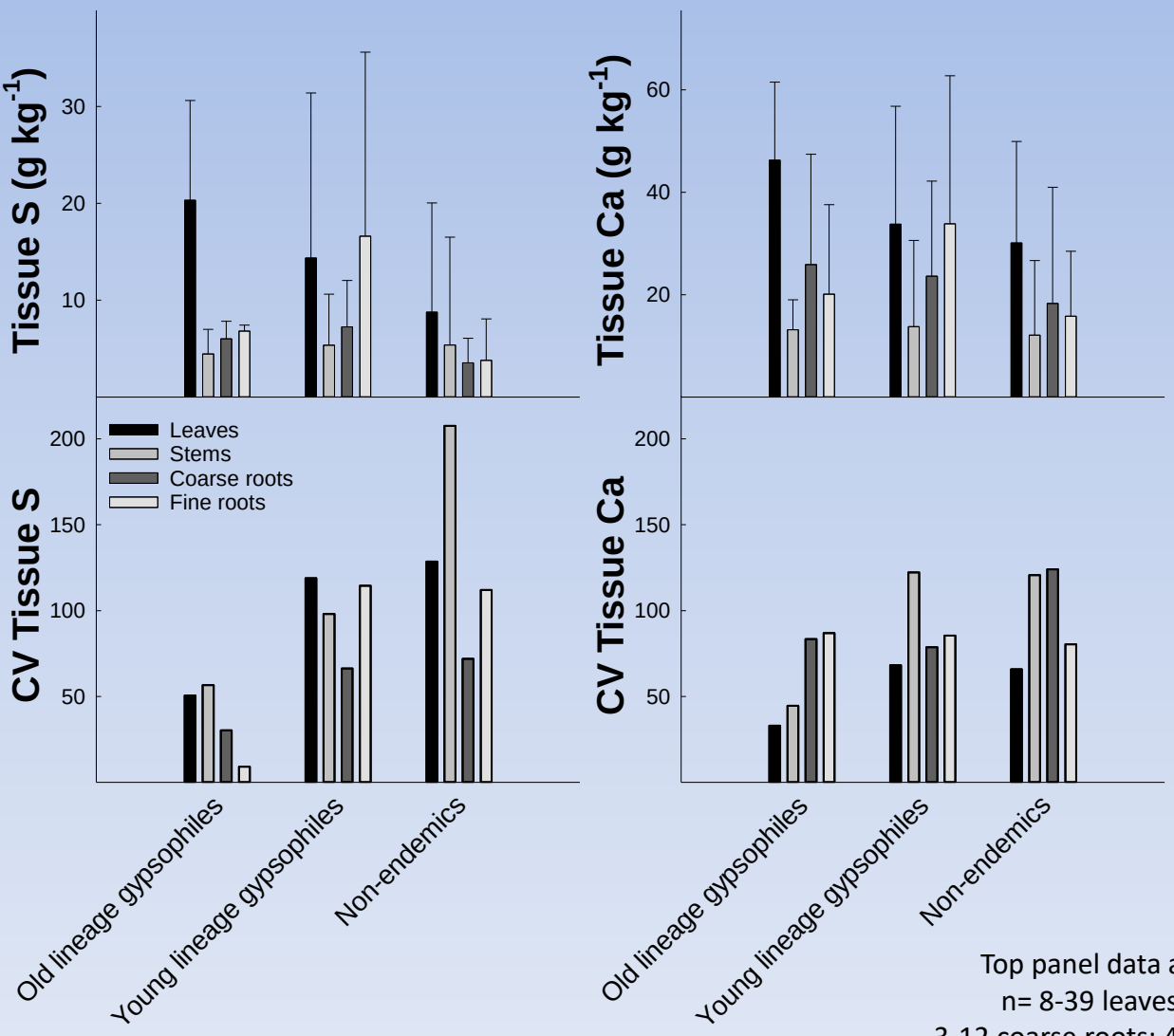




Data are means+SD
n= 8-39 leaves; 5-15 stems;
3-12 coarse roots; 4-12 fine roots

Tissue chemistry for broader sampling





Top panel data are means+SD
n= 8-39 leaves; 5-15 stems;
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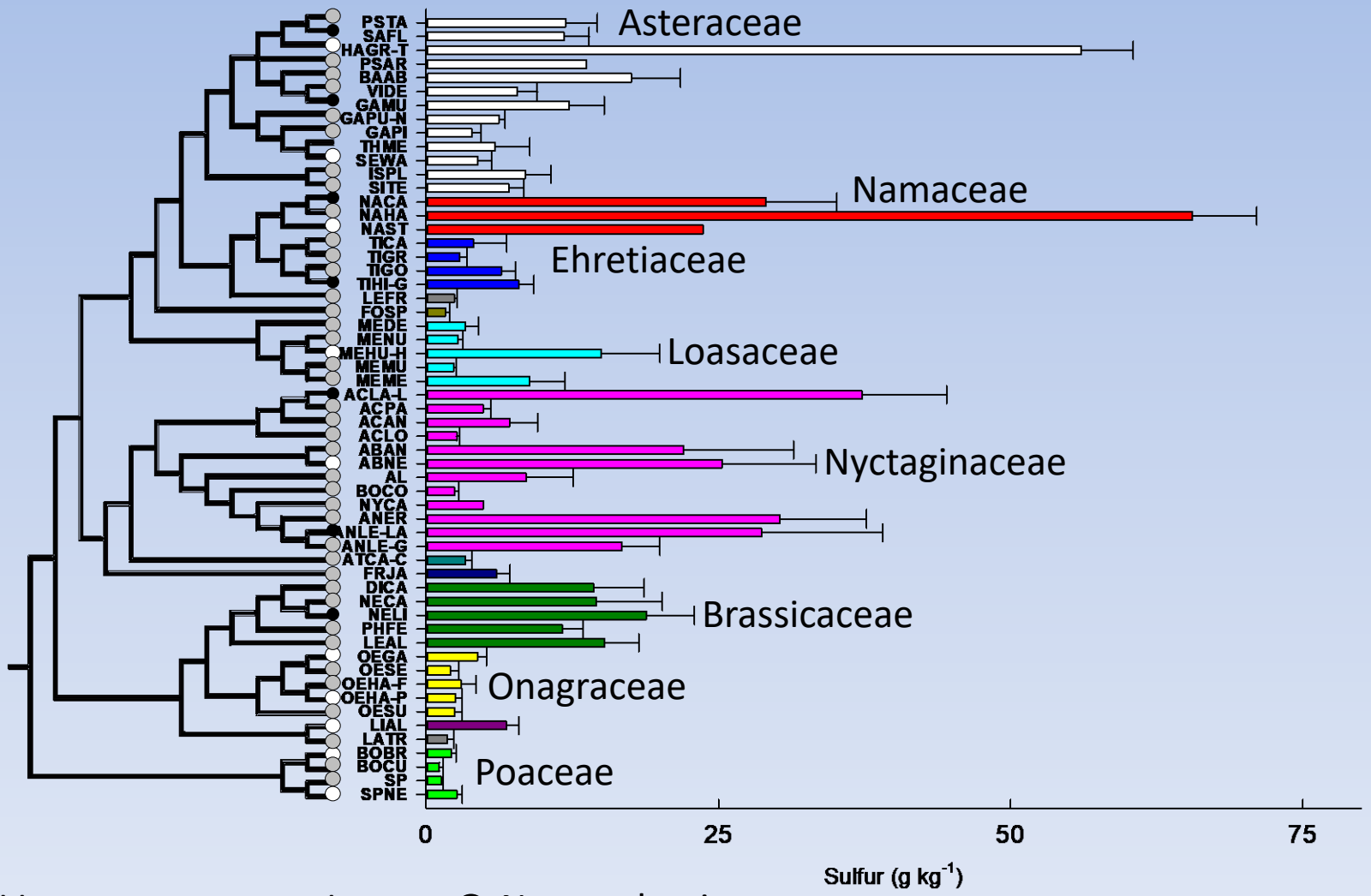
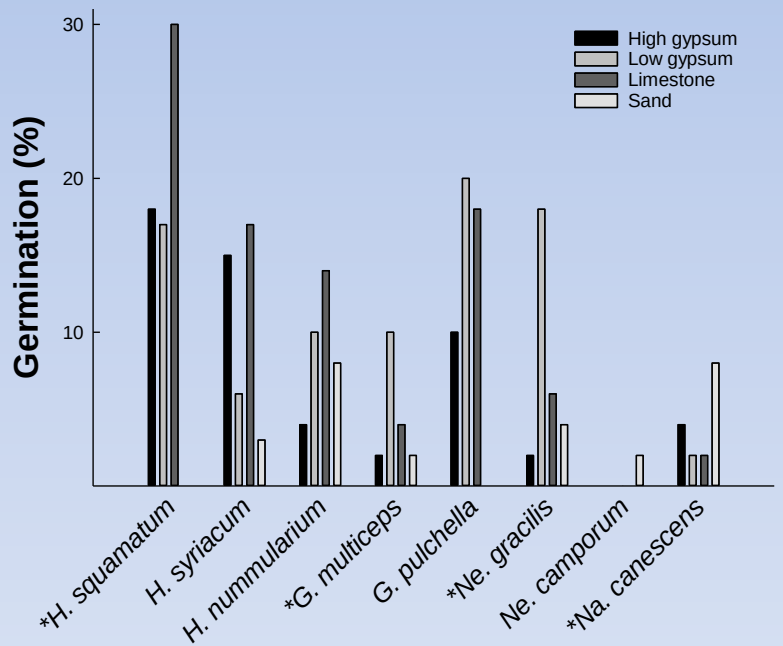
Leaf S across broader sampling



● Old lineage ○ Young lineage ○ Non-endemic

What patterns are evident under experimental conditions?



Nate Heiden, Fulbright Scholar
Working with Sara Palacio

Back to the BIG questions

1. **Global patterns:** Assimilation of excess Ca & S important in wide gypsophiles
2. **Phylogenetic patterns:** May be key to unraveling various adaptation mechanisms
3. **Whole plant patterns:** likely different between wide and narrow gypsophiles

Implications for community assembly

Traits supporting pre-adaptation:

1. Gypsum biomineralization
2. Role for defensive compounds?

Future research directions

We are just beginning…so many questions:

1. Global patterns
2. Whole plant patterns
3. Manipulative experiments
4. Role of defense compounds
5. Soil microbial communities
6. Many more!

GYPWORLD: Global research network

http://gypnet.weebly.com/

Acknowledgments

People: S. Palacio, M. Moore, M. Setter, M. Nichols, N. Pietrasiak, N. Heiden, K. Tuominen, B. Reicholf, M. Morcio, A. Quinoñes, M. Twarog, V. Fung, S. Pavsek, R. Nielsen, Z. Feder

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Access: BLM—NM Office