

Has climate change altered poison ivy physiology over the last century?

an empirical test using herbarium specimens

Alyssa McCormick^{a*}, Molly Ng^b, Ryan M. Utz^a, J. Mason Heberling^b



^a Falk School of Sustainability, Chatham University, Pittsburgh, PA USA, ^b Section of Botany, Carnegie Museum of Natural History, Pittsburgh, PA USA ; *email: alyssa.mccormick@chatham.edu

Can poison ivy get any worse?

Atmospheric [CO₂] has increased by nearly 50% since the Industrial Revolution, leading to ongoing changes in global climate. Plants need CO₂ for photosynthesis, but is more CO₂ better?

Some plants may benefit from increased [CO₂] and warming, while others may suffer. Plants balance increased CO₂ intake with water loss risk. Higher CO₂ has been linked to lower stomatal density and changes in water use efficiency –that is, higher photosynthesis per water loss.

Prior studies [1] indicates that **poison ivy (*Toxicodendron radicans*) exhibits higher water use efficiency and growth** under experimentally high [CO₂]. But it is unknown if this poison ivy has actually shown changes over the past century of [CO₂] change.

We used herbarium specimens to ask:

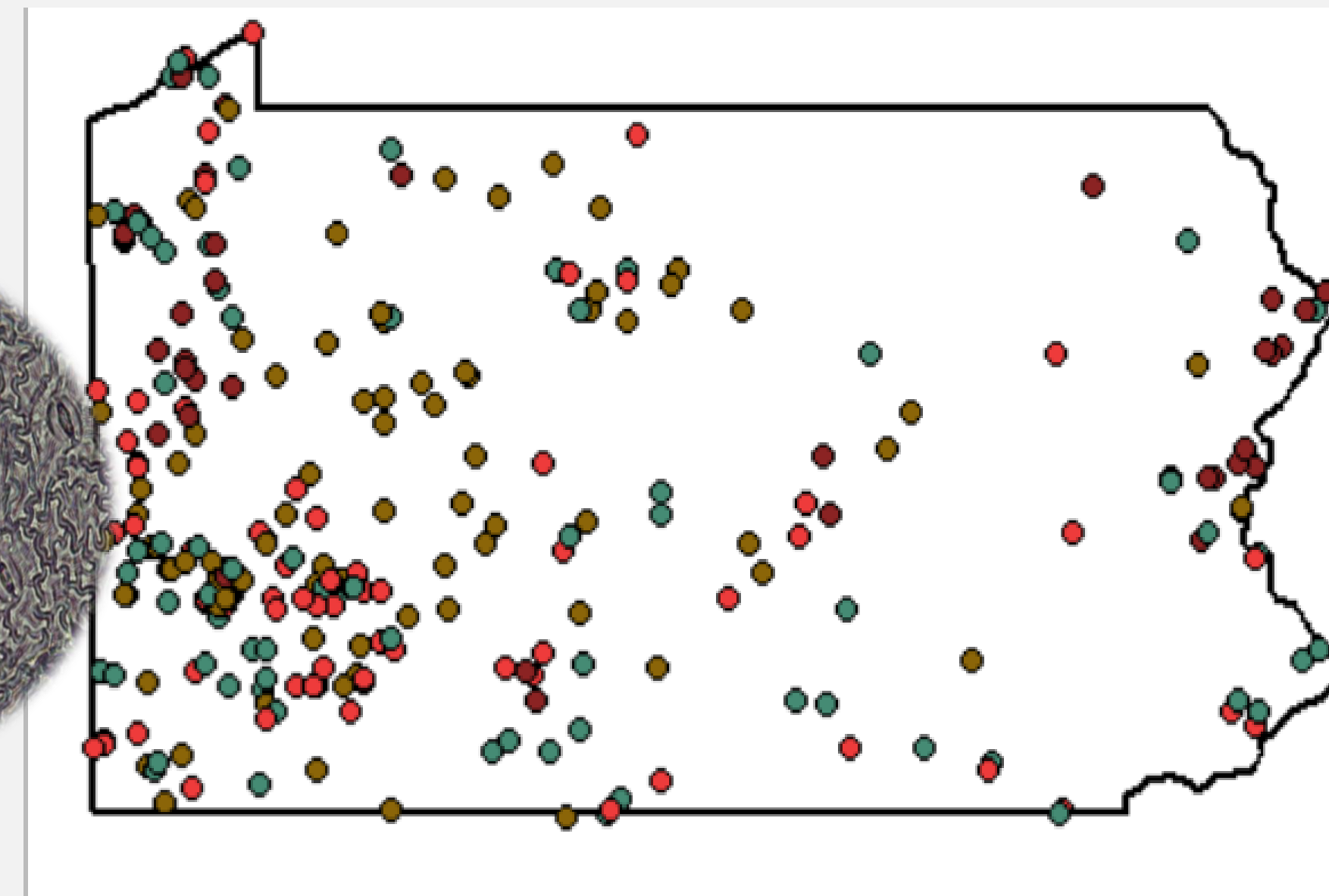
Have poison ivy traits shifted over the past century?

Have other species responded similarly?



$\delta^{13}\text{C}$
 Δ leaf
iWUE

329 specimens
4 species
Collected across PA
Over 179 years!



Poison Ivy
Toxicodendron radicans



Virginia Creeper
Parthenocissus quinquefolia



Staghorn Sumac
Rhus typhina



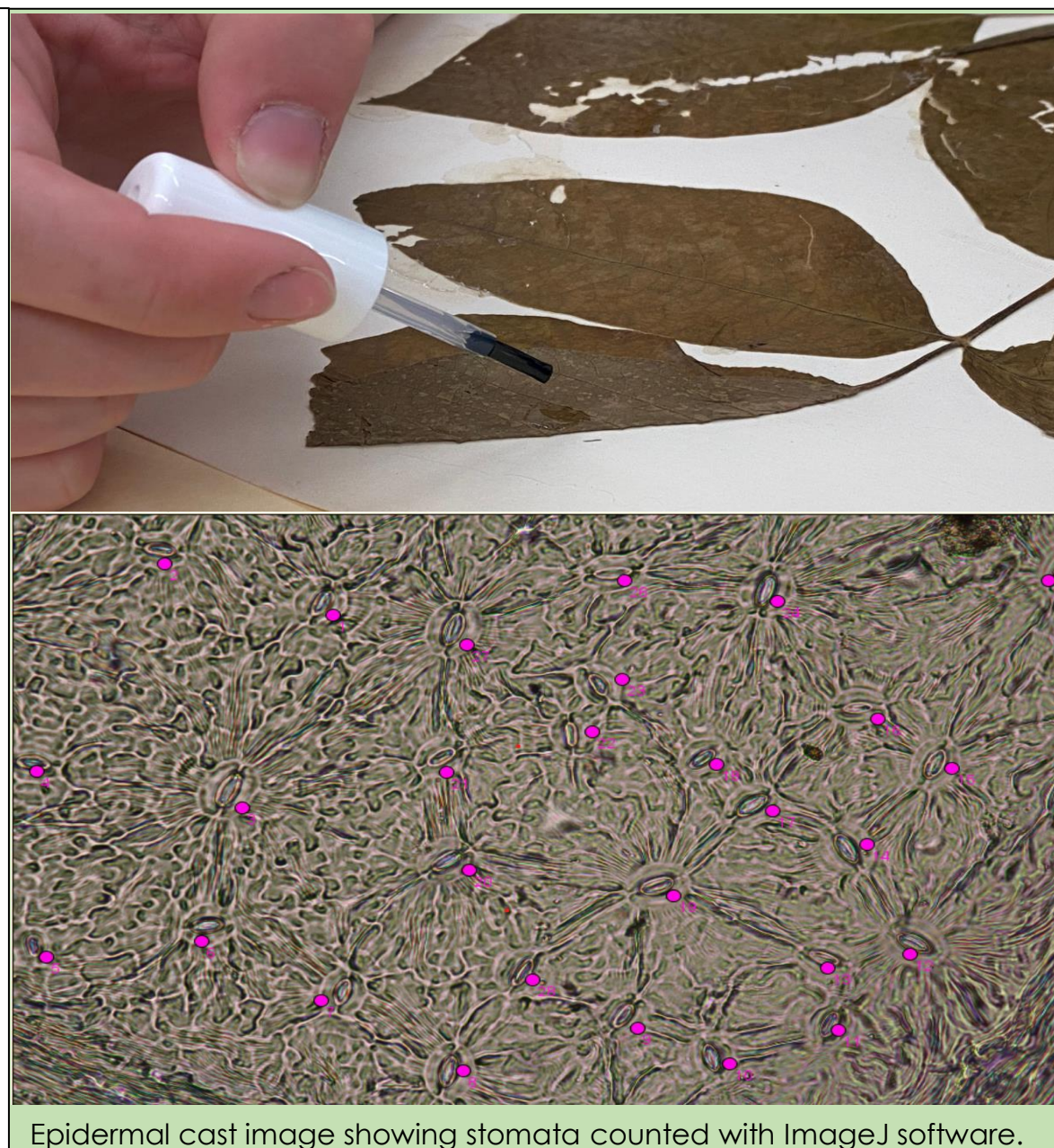
Poison Sumac
Toxicodendron vernix

Approach: digging into the herbarium record

Herbarium Specimens – We measured traits from 329 herbarium specimens collected in Pennsylvania from 1840-2019. Poison ivy was compared to a commonly co-occurring ecological analog (woody vine), Virginia creeper (*Parthenocissus quinquefolia*), as well as two tree species in the same plant family as poison ivy (Anacardiaceae), poison sumac (*Toxicodendron vernix*) and staghorn sumac (*Rhus typhina*).

Stomatal Density - We used clear nail varnish to make an epidermal cast of leaf underside for each specimen. Slides were imaged under a microscope, and stomata counted digitally.

Leaf Chemistry – 111 specimens were analyzed for leaf elemental and isotopic chemical traits (nitrogen, carbon). C₃ plants discriminate against the heavier stable carbon isotope (¹³C). $\Delta^{13}\text{C}$ leaf (‰) is a measure of C isotope fractionation in leaf tissue and commonly used as a metric of iWUE [2].



Epidermal cast image showing stomata counted with ImageJ software.

A century of CO₂ change

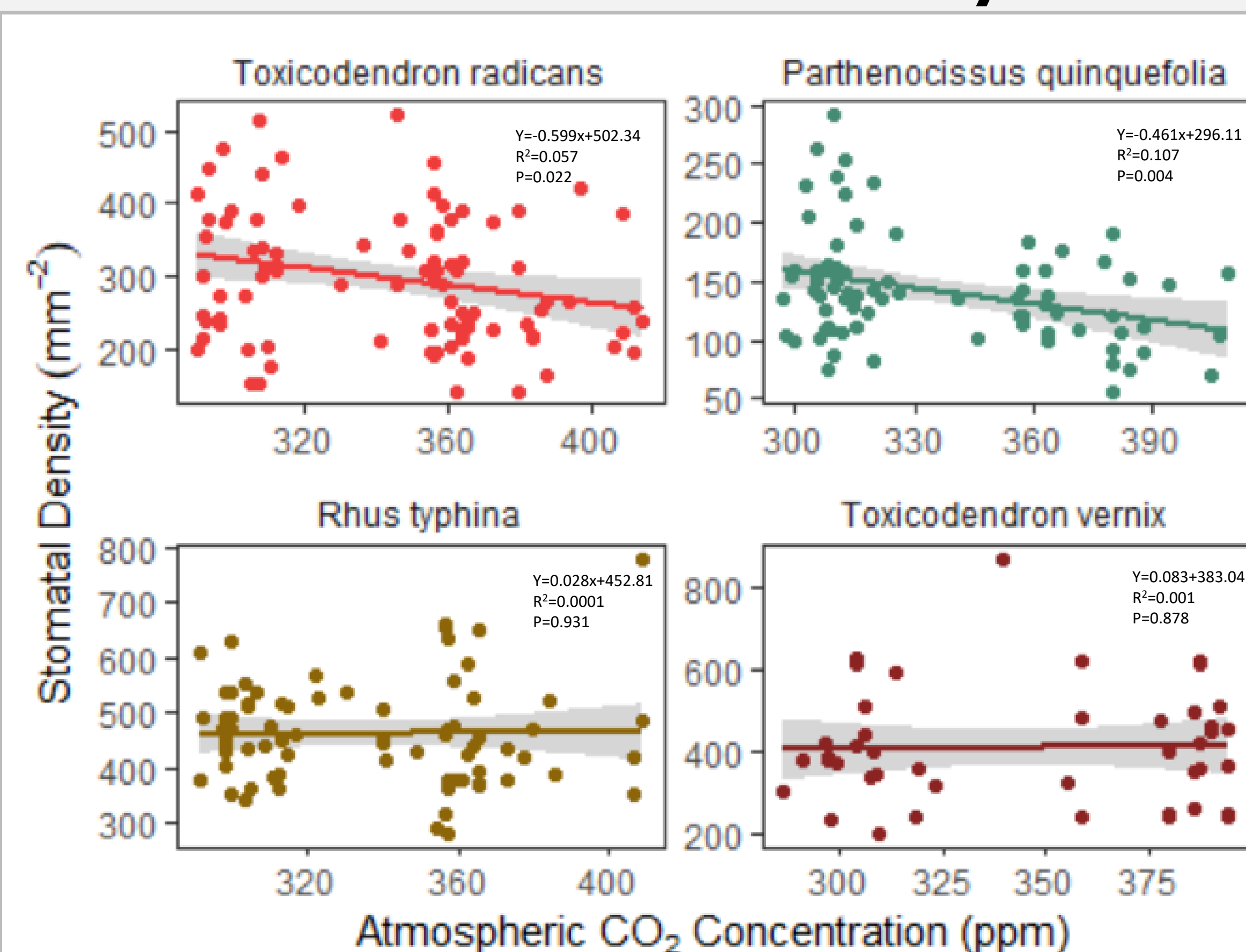
Stomatal density differed among species. Recent specimens compared to those collected pre-1920 show

- Poison ivy = 20.5% decrease
- Virginia creeper = 24.2% decrease
- Staghorn sumac = 0.3% decrease
- Poison Sumac = 12.8% increase

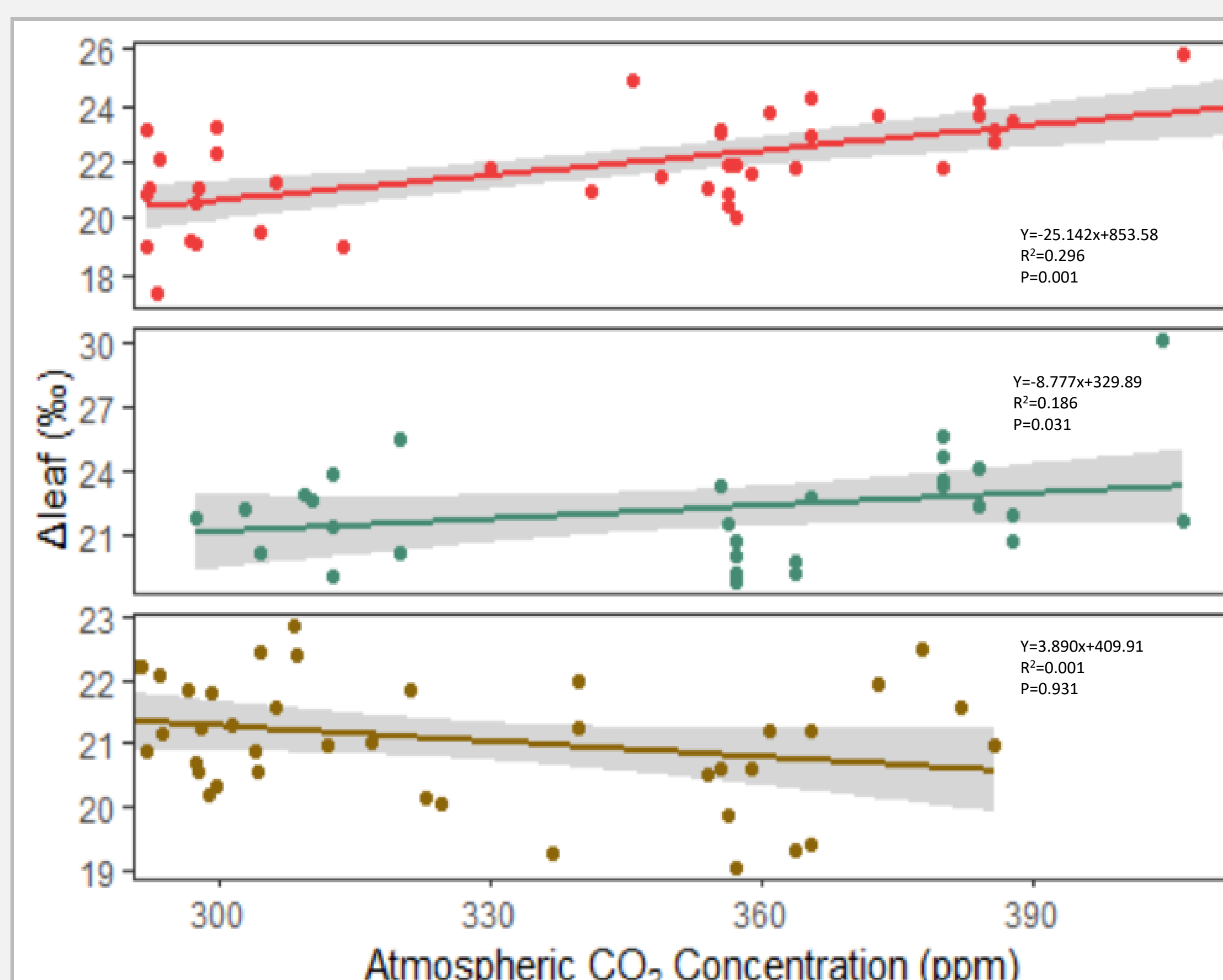
$\Delta^{13}\text{C}$ leaf also differed among species. Recent specimens compared to those collected pre-1920 show

- Poison Ivy = 12.9 % increase
- Virginia Creeper = 7.9% increase
- Staghorn Sumac = 0.0% change

Stomatal density



Δ Leaf



What does this mean?

- Similar growth forms exhibit a similar response to [CO₂] increase.
- Herbarium specimens allow us to answer questions at time scales not possible via experimentation

References:

[1] Mohan, J.E., Ziska, L.H., Schlesinger, W.H., Thomas, R.B., Sicher, R.C., George, K., Clark, J.S. (2006). Biomass and toxicity responses of poison ivy (*Toxicodendron radicans*) to elevated atmospheric CO₂. PNAS, 103(24), 9086-9089. <https://doi.org/10.1073/pnas.0602392103>

[2] Miller-Rushing, A> J., Primack, R. B., Templer, P.H., Rathbone, S., Mukunda, S. Long-term relationships among atmospheric CO₂, stomata, and intrinsic water use efficiency in individual trees. *American Journal of Botany*, 96(10), 1779-1786. <https://doi.org/10.3732/ajb.0800410>