Drivers of nutrient acquisition, allocation, and their influence on plant responses to environmental change

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LEMONTREE Experimental Working Group
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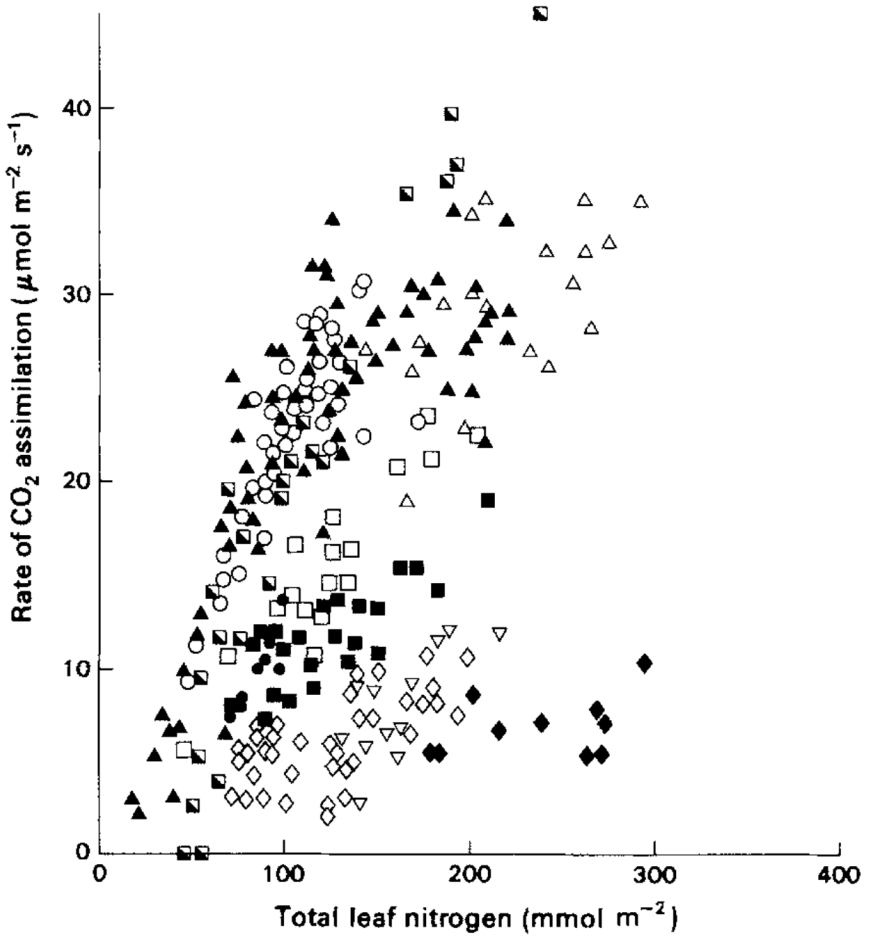
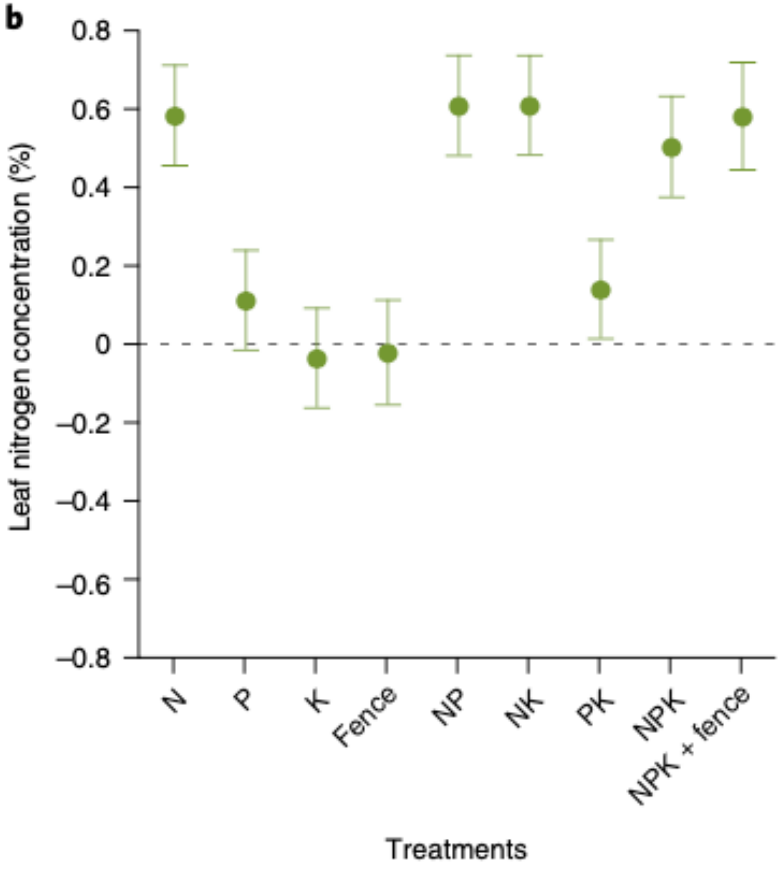
Leaf nitrogen is a common surrogate for estimating leaf-level photosynthetic capacity



Evans (1989) *Oecologia*

Soil nitrogen has been shown to positively influence leaf nitrogen



Firn et al. (2019) *Nature*

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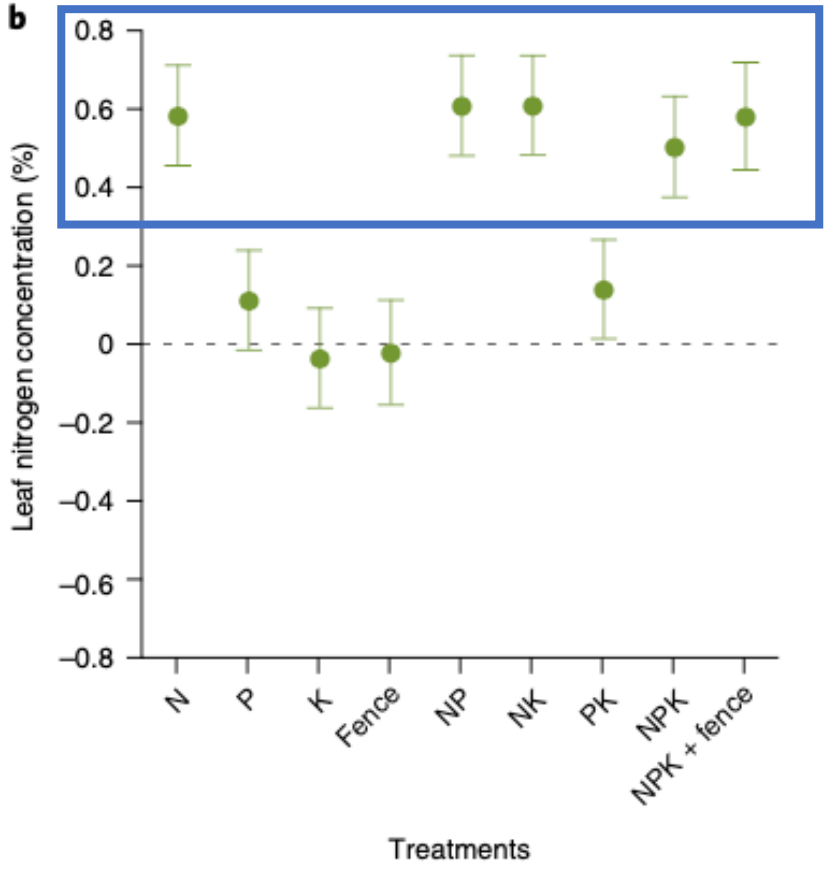
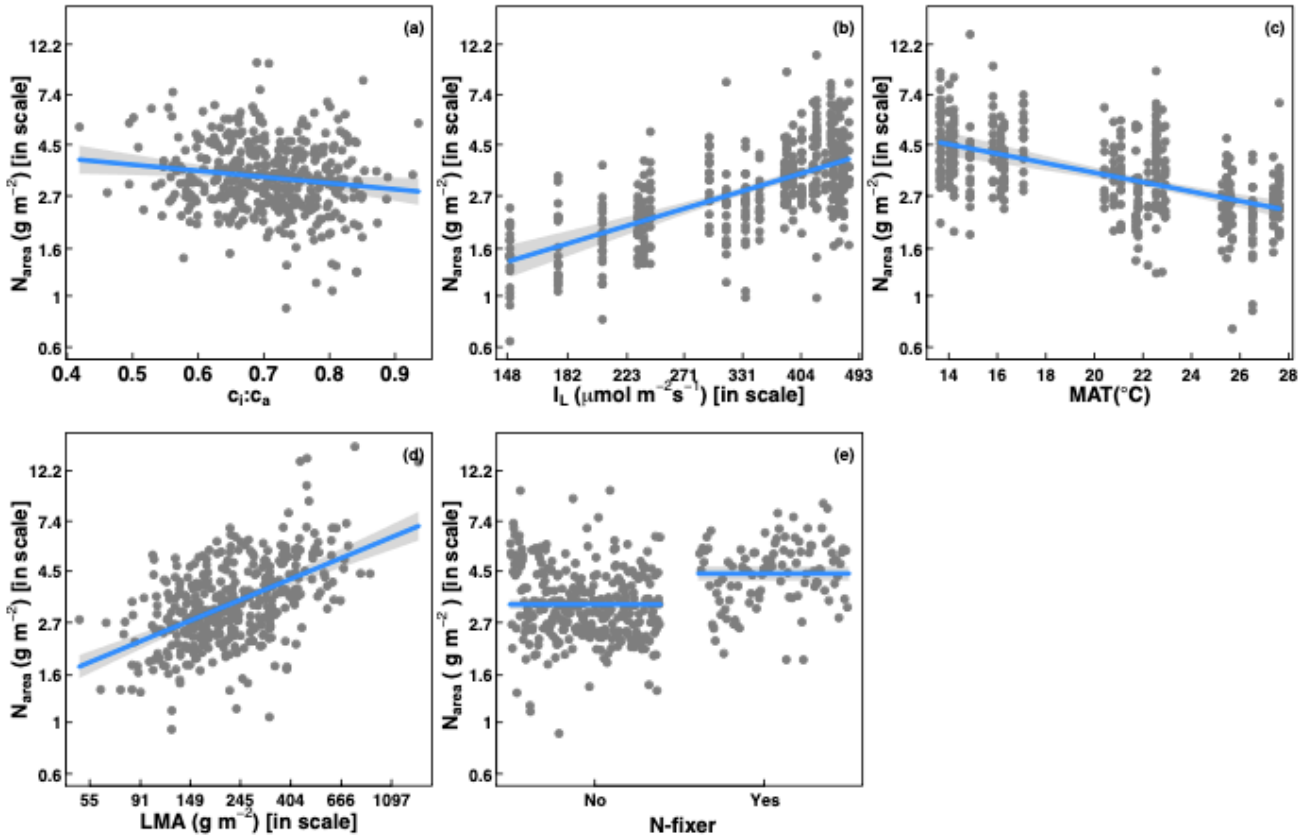


Plots that received nitrogen had higher leaf nitrogen content

Firn et al. (2019) *Nature*

However, leaf nitrogen can also be predicted independent of soil nitrogen

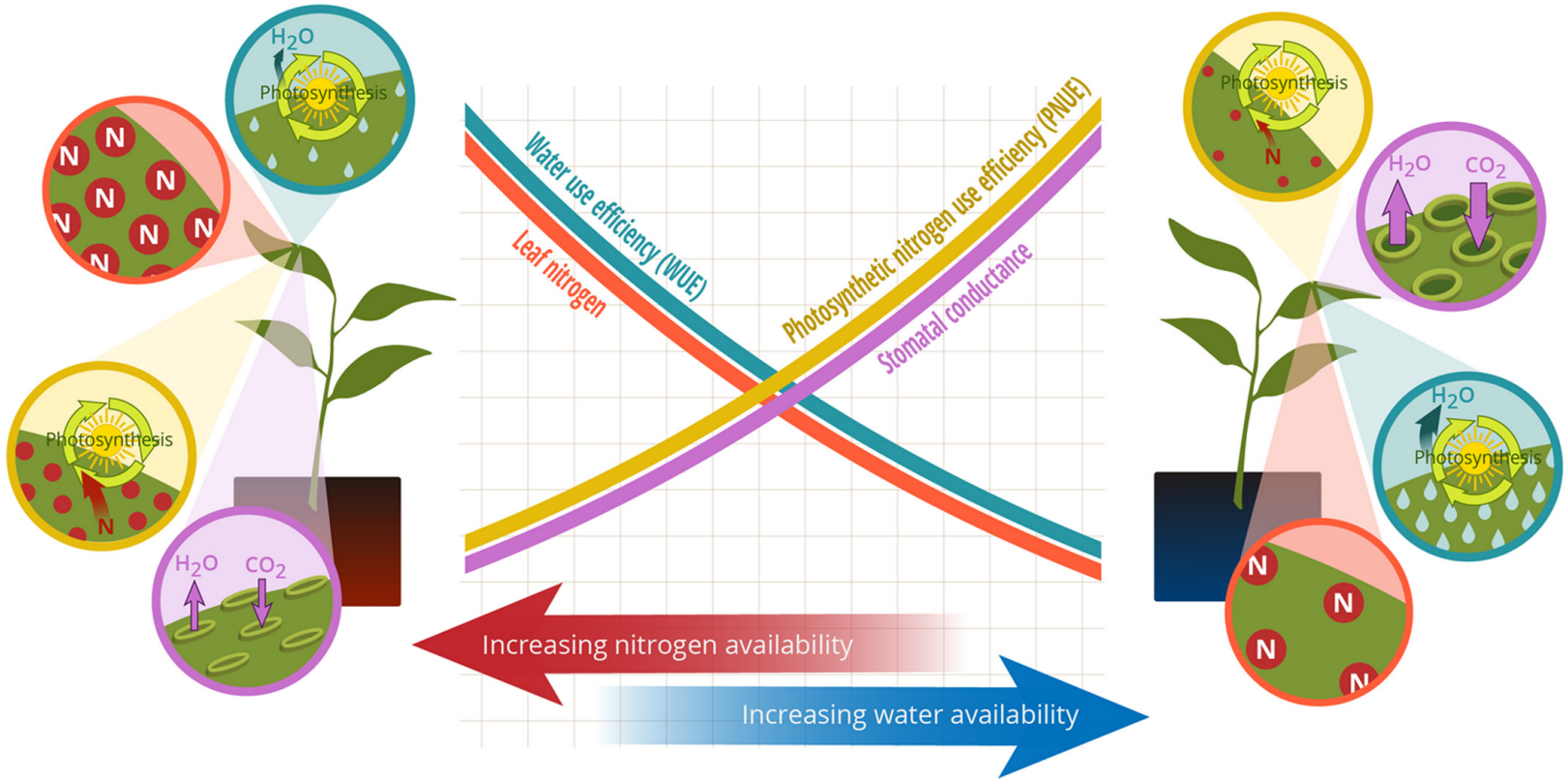


Dong et al. (2017) *Biogeosciences*

Leaf nitrogen is likely a product of plant allocation responses to soil nitrogen and climate

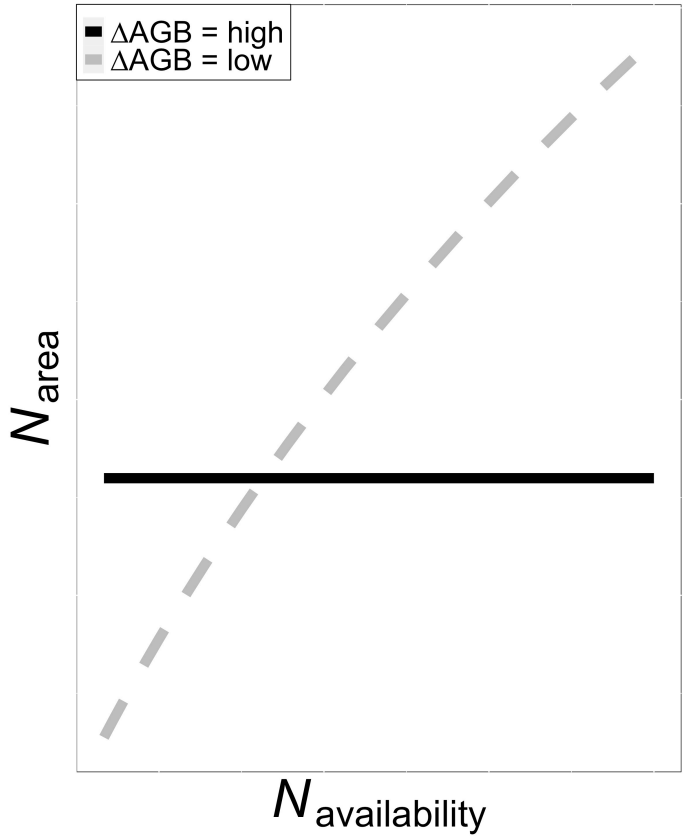
Yet, we do not fully understand when and where soil nitrogen impacts nitrogen allocation to leaf tissue vs. other tissues

Option #1: Maintain photosynthesis with greater water-use efficiency at expense of photosynthetic nitrogen-use efficiency



Bialic-Murphy *et al*. (2021) *Ecol. Letters*

Option #2: Invest extra nitrogen toward whole plant growth at expense of leaf nitrogen



Smith et al. (*in prep*)

Experiment #1: Impacts of soil resource availability and soil pH on leaf and whole plant processes

Study Questions

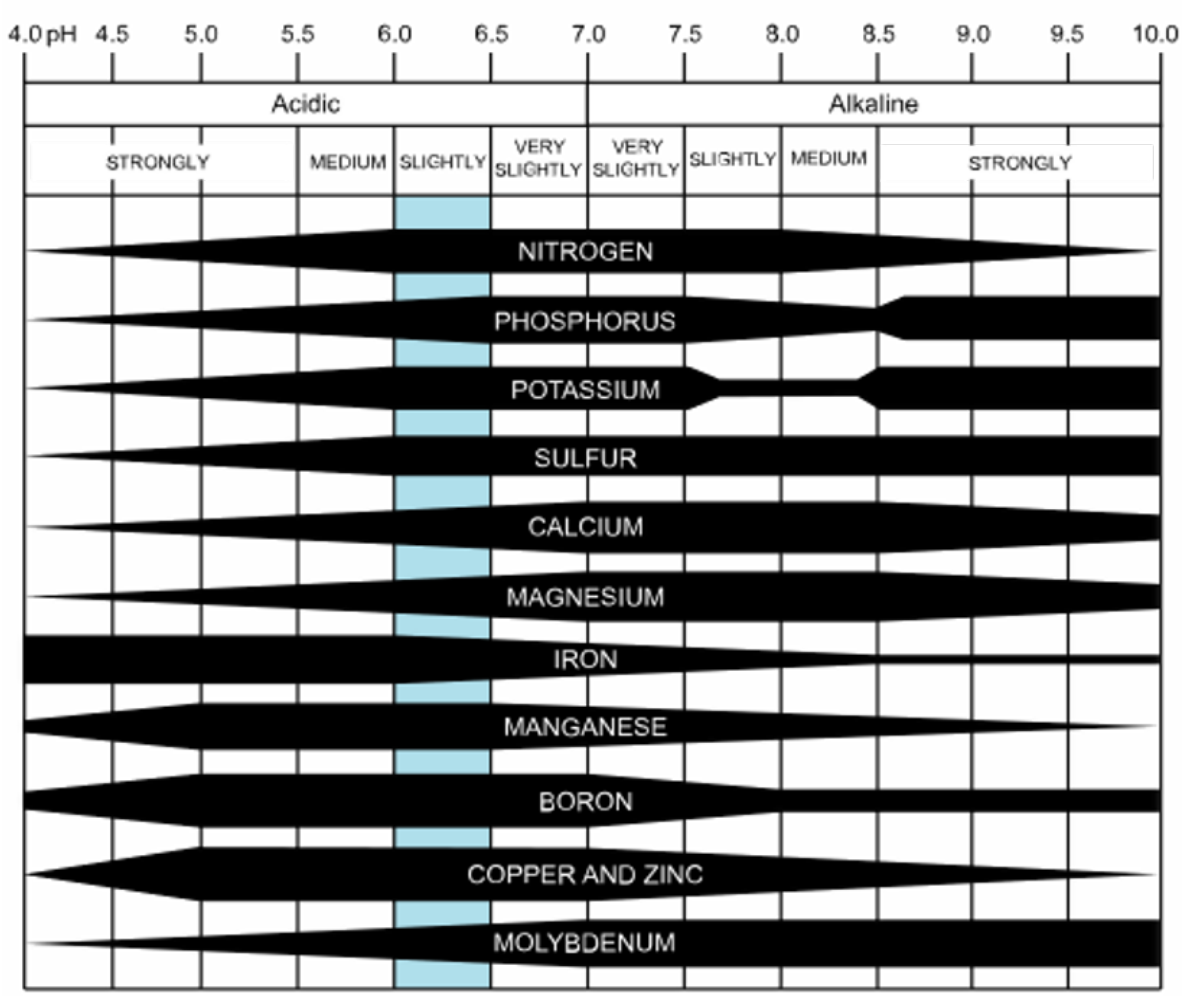
How do leaf and whole plant processes respond to soil nutrient availability in a closed canopy system?

What is the role of soil pH (if any) on modifying leaf and whole plant responses to soil nutrient availability?

Impacts of soil pH on nutrient availability

Many nutrient fertilizers acidify soils, which could negate positive impacts of fertilization on nutrient availability

In the northeast United States, chronic high rates of nitrogen deposition are paired with high rates of sulfur deposition



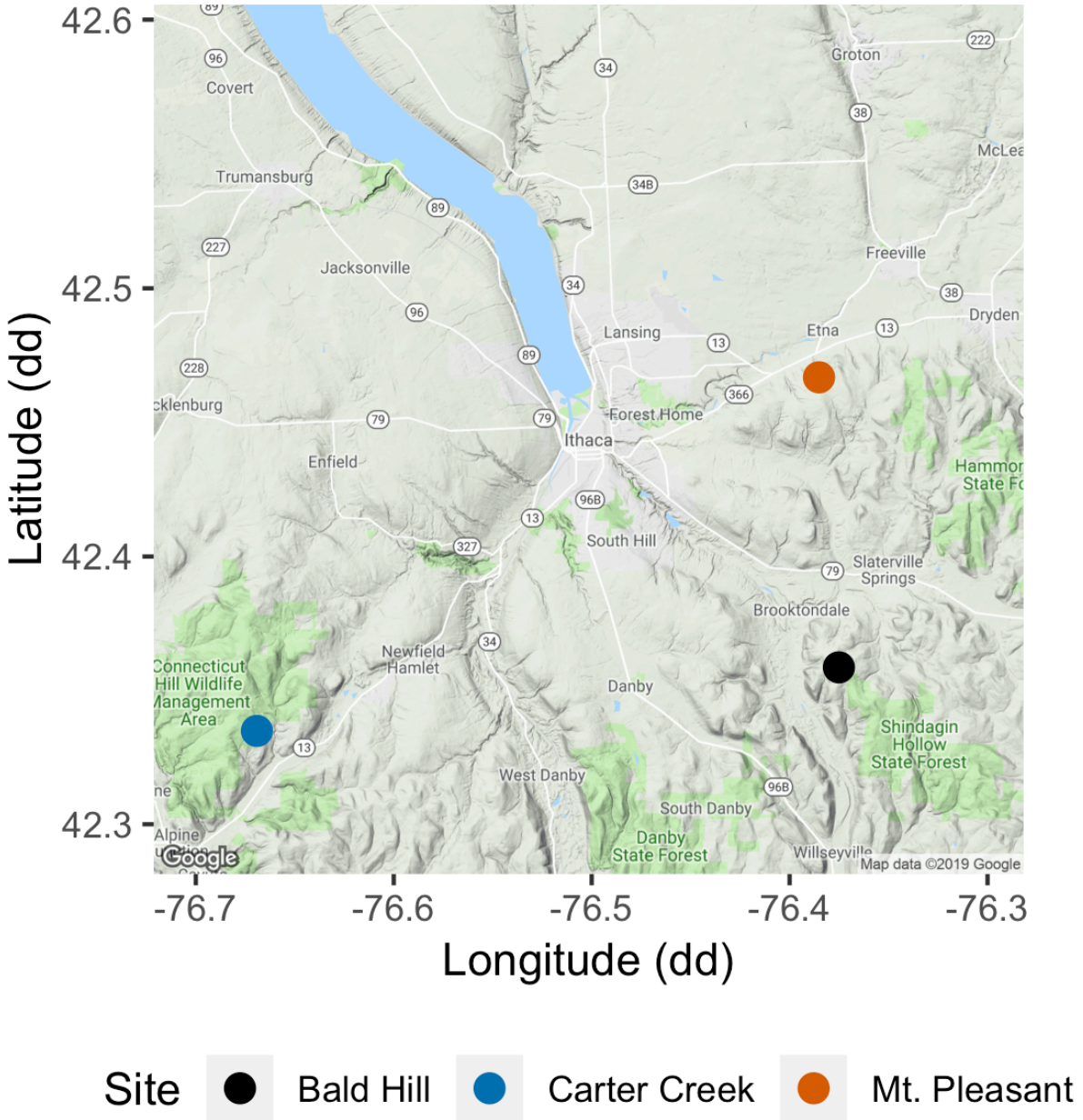
Study system

Soil fertilization treatments

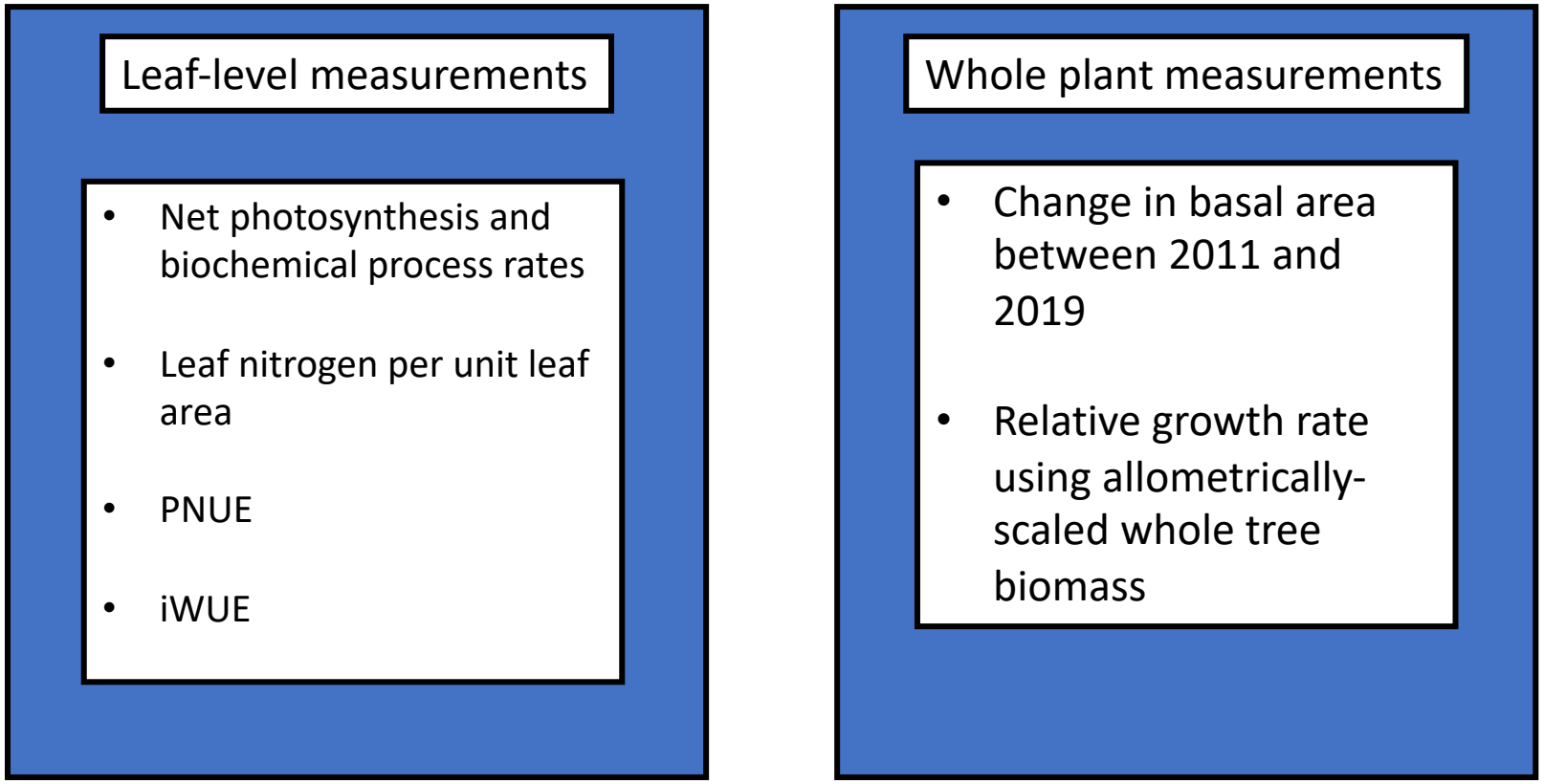
- 0 kg ha^{-1} yr^{-1} N; 0 kg ha^{-1} yr^{-1} S
- 0 kg ha^{-1} yr^{-1} N; 57 kg ha^{-1} yr^{-1} S
- 50 kg ha^{-1} yr^{-1} N; 0 kg ha^{-1} yr^{-1} S
- 50 kg ha^{-1} yr^{-1} N; 57 kg ha^{-1} yr^{-1} S

Sites

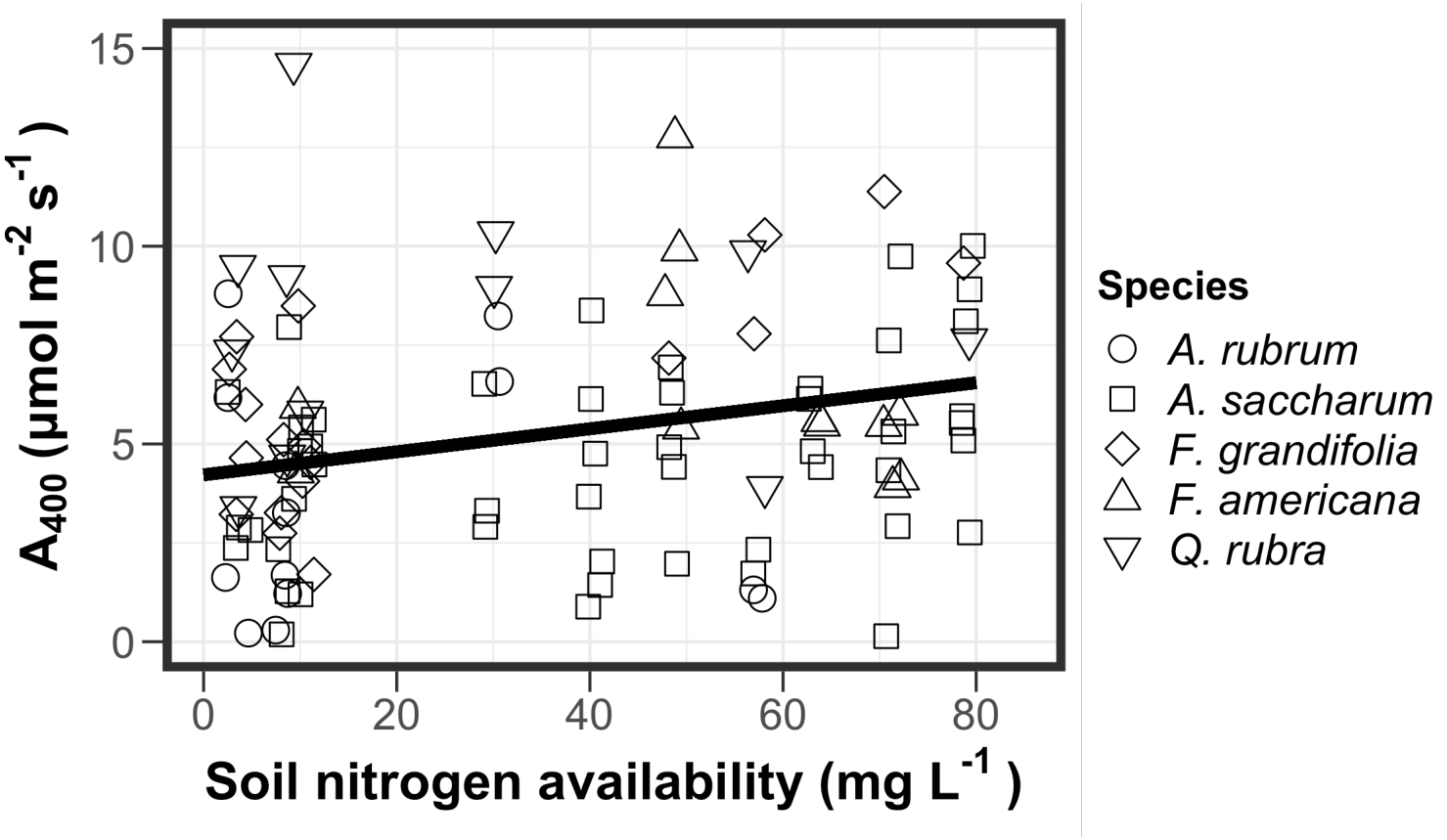
- Bald Hill
- Mount Pleasant
- Carter Creek



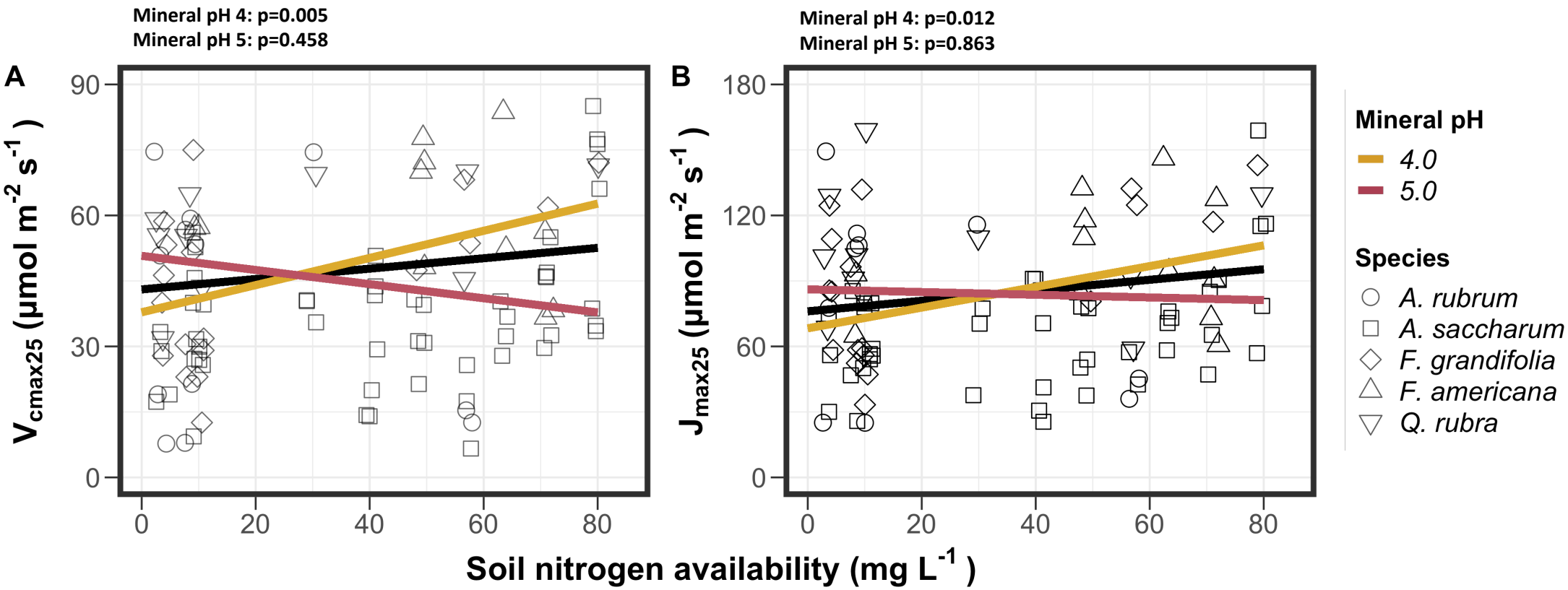
Plant measurements



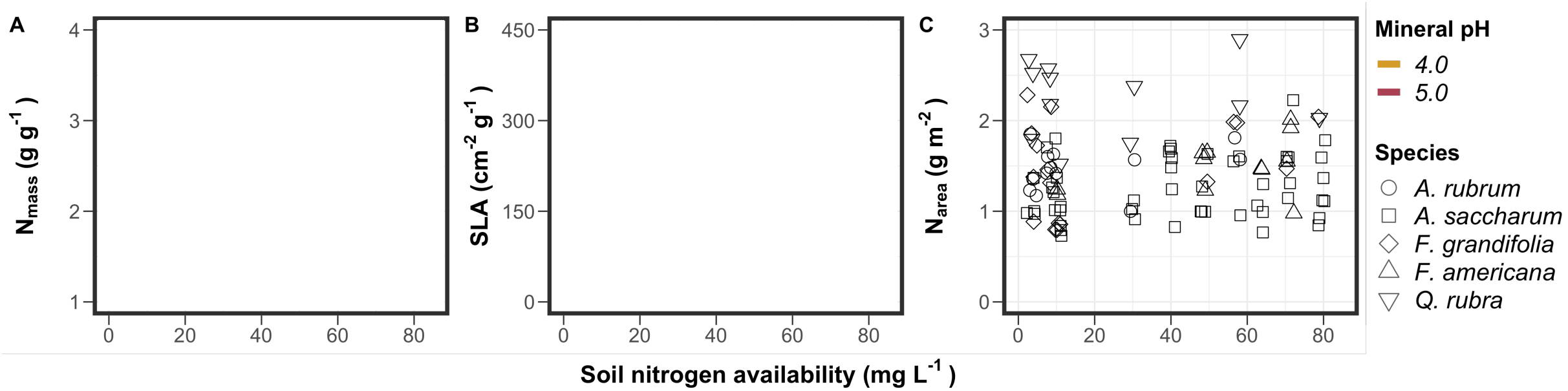
Soil nutrient availability generally increases net photosynthesis



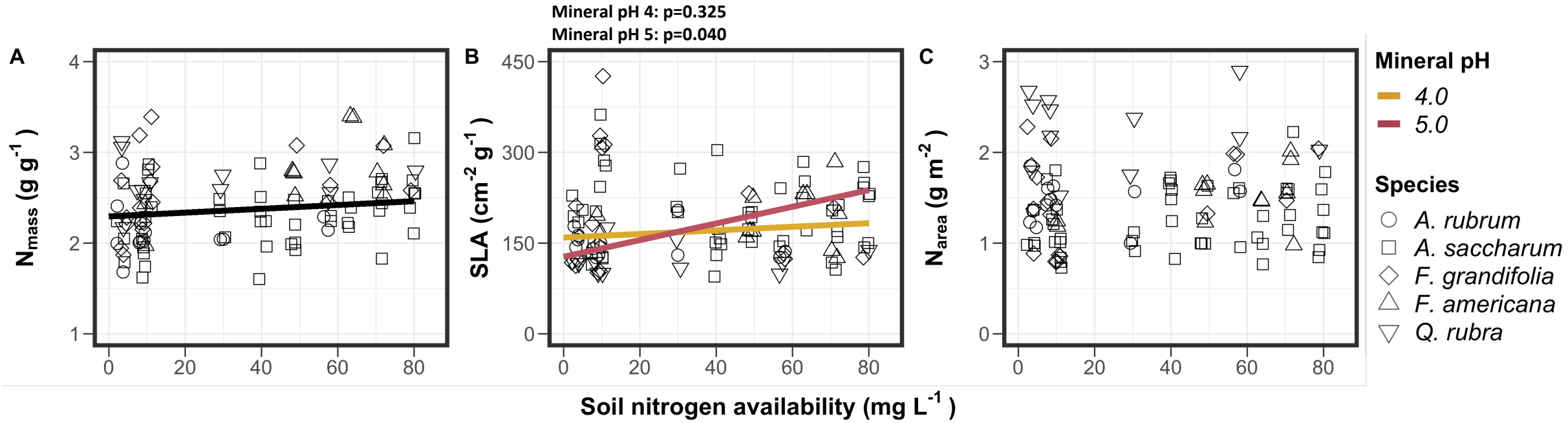
Soil nutrient availability generally increased V_{cmax25} and J_{max25}, but was driven by an interaction with soil pH



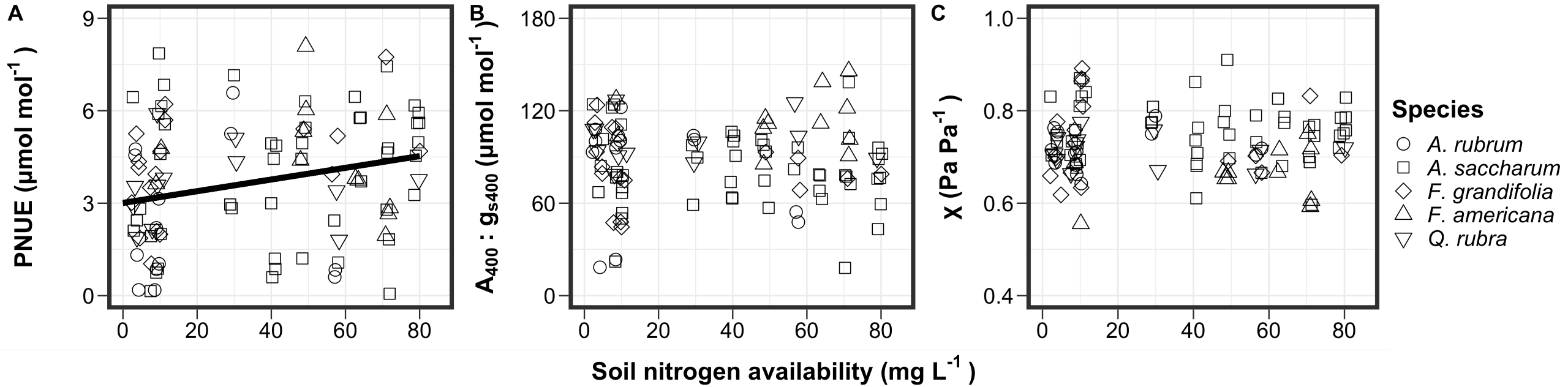
Despite increases in leaf photosynthetic processes, soil nutrient availability did not affect leaf nitrogen allocation…



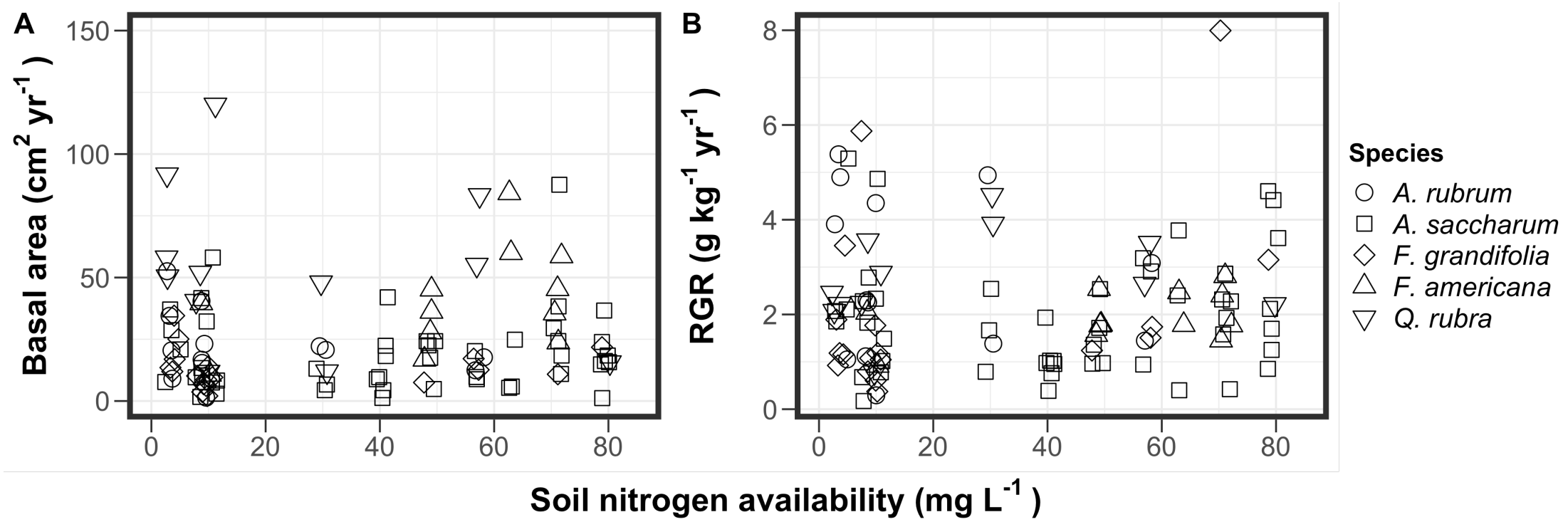
… a pattern driven by an increase in leaf nitrogen content with increasing soil nitrogen availability



Soil nitrogen availability increased PNUE but had no effect on water-use efficiency

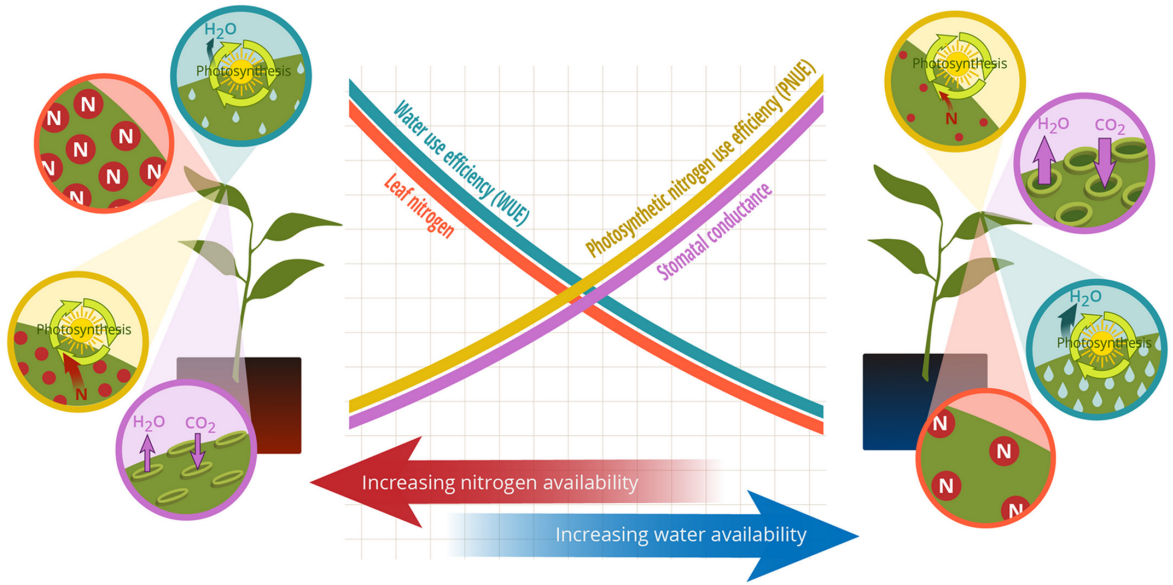


Soil nutrient availability had no effect on tree stem growth or growth rate regardless of soil nutrient availability



Revisiting Option 1

Did soil N allow photosynthesis rates to be achieved with higher water-use efficiency at the expense of nitrogen-use efficiency?

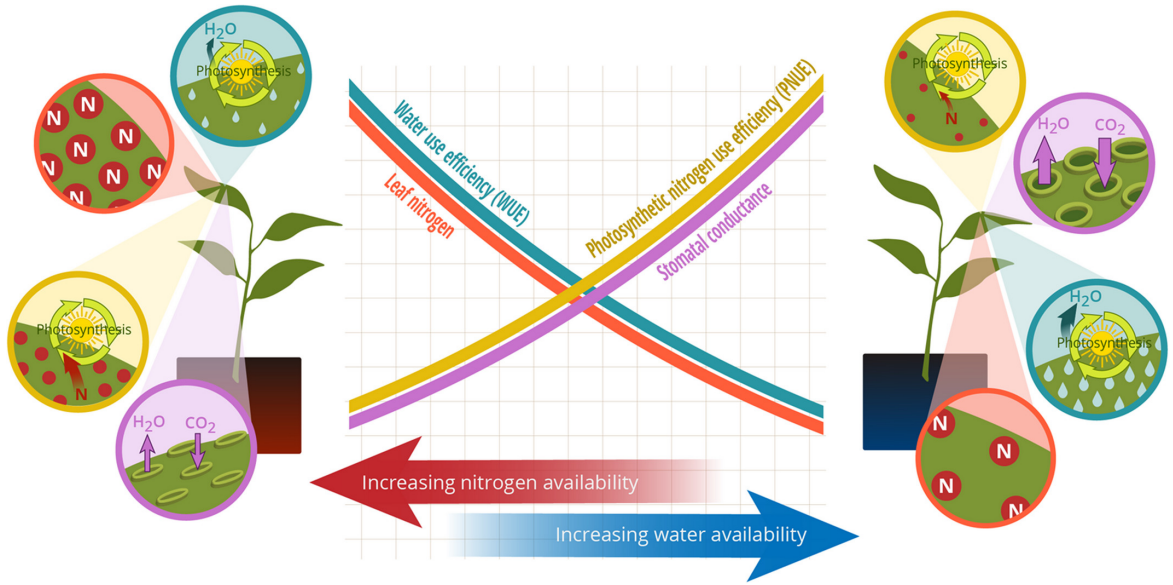


Bialic-Murphy *et al*. (2021) *Ecol. Letters*

Revisiting Option 1

Did soil N allow photosynthesis rates to be achieved with higher water-use efficiency at the expense of nitrogen-use efficiency?

No, effects of soil nitrogen on leaf photosynthesis were context dependent on soil pH and did not indicate strong water-nitrogen tradeoffs



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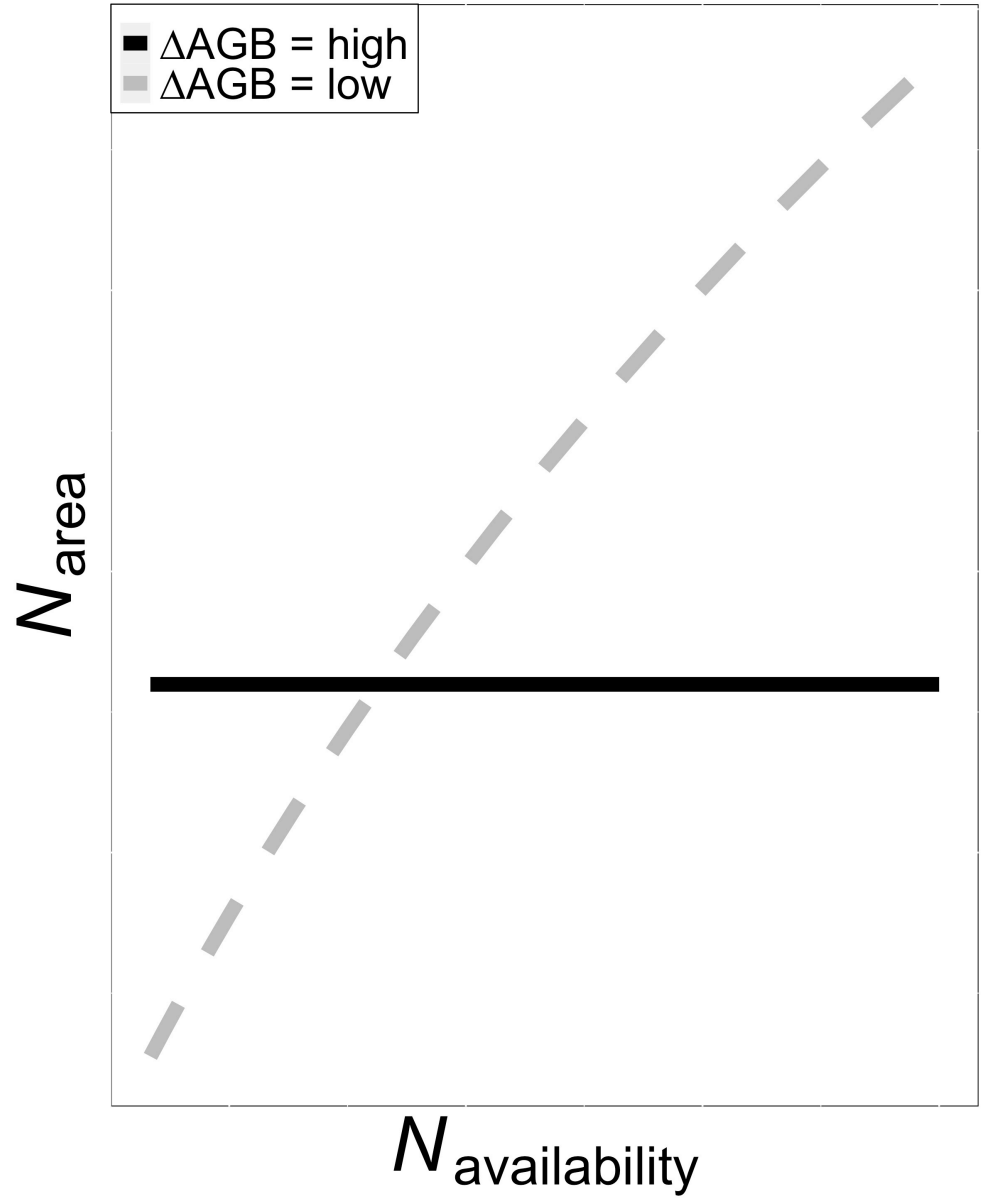
Revisiting Option 2

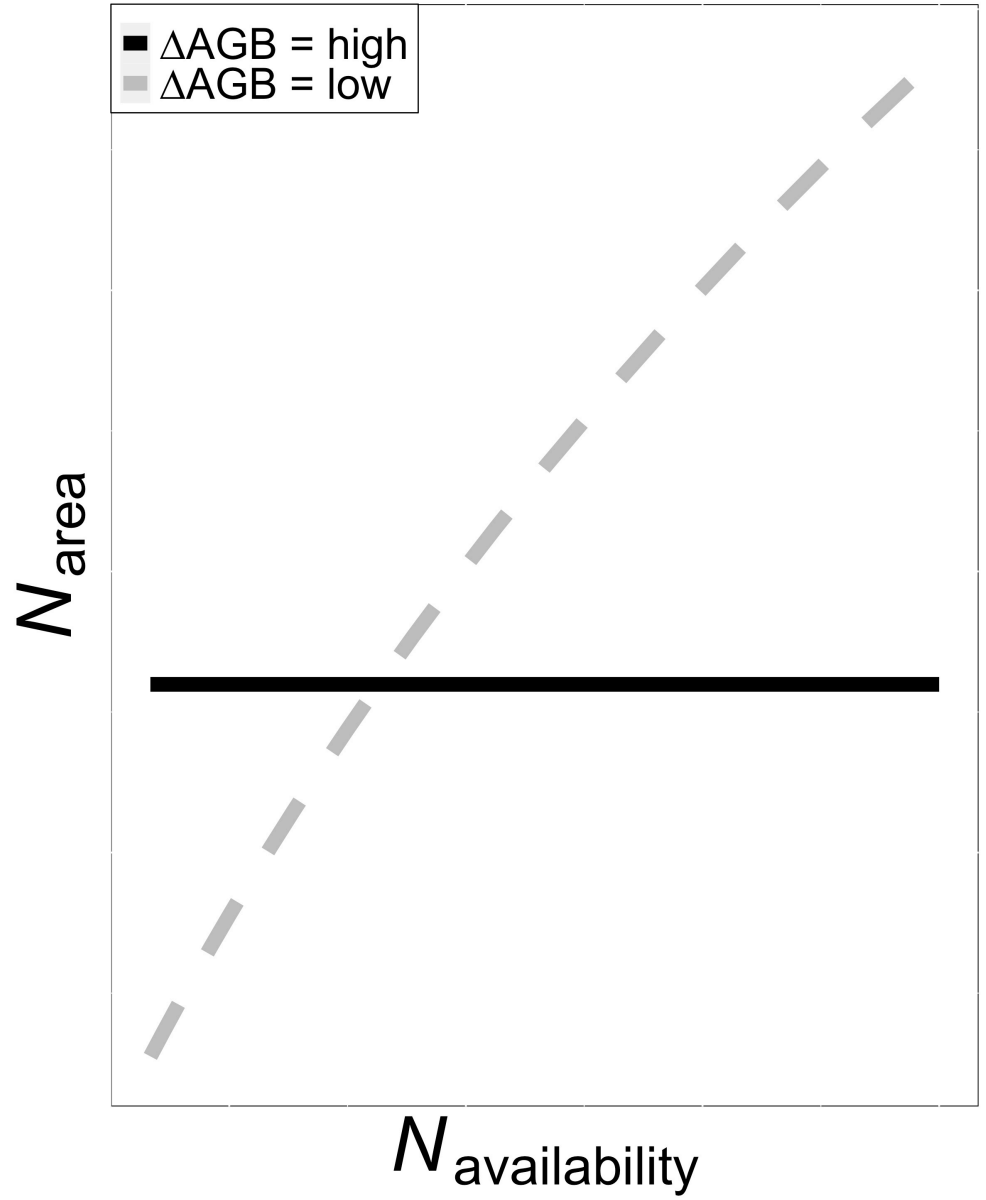
Did soil N invoke tradeoffs between biomass production and N_{area}?



Revisiting Option 2

Did soil N invoke tradeoffs between biomass production and N_{area}?

Maybe? Trees had limited growth responses to soil nutrients, but strong leaf photosynthetic responses to soil nutrients



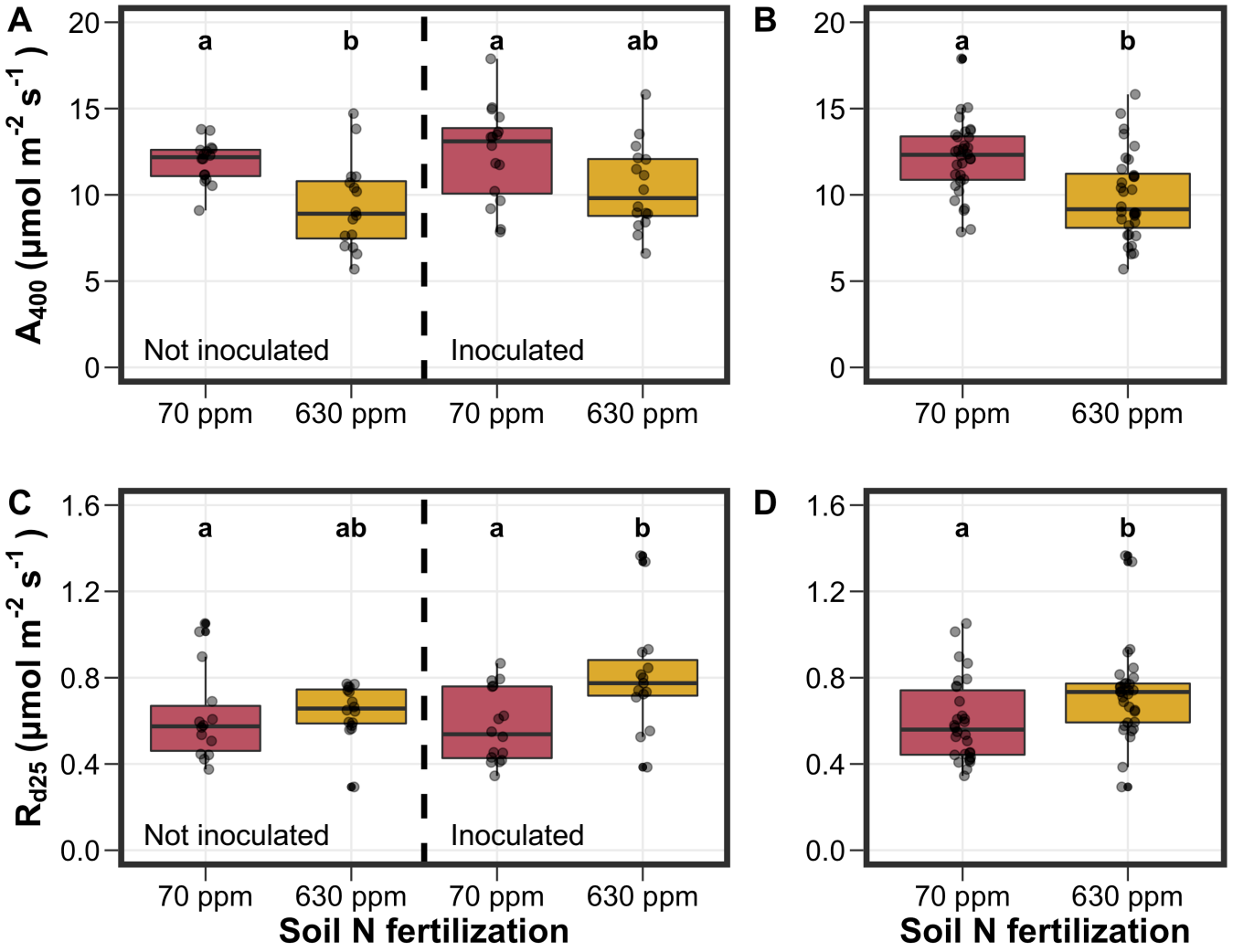
Experiment #2: Impacts of soil resource availability and BNF inoculation on leaf and whole plant processes

Experimental setup

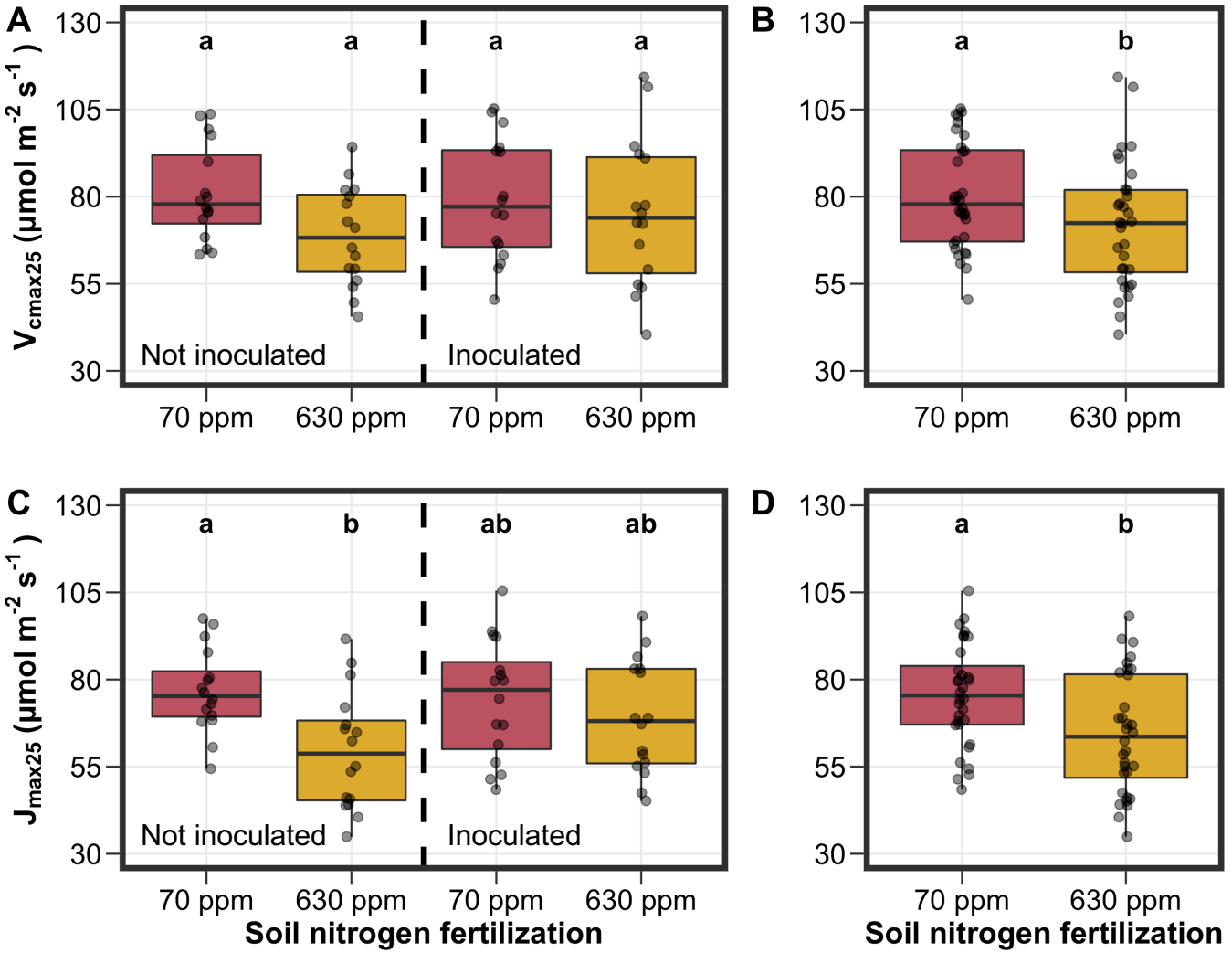
Soil fertilization	x	Inoculation with *B. japonicum*
70 ppm N		+ BNF
630 ppm N		- BNF

A/C_i curves, dark respiration, and fluorescence measurements taken ~5-6 weeks after planting; destructive harvest of focal leaf immediately following curves

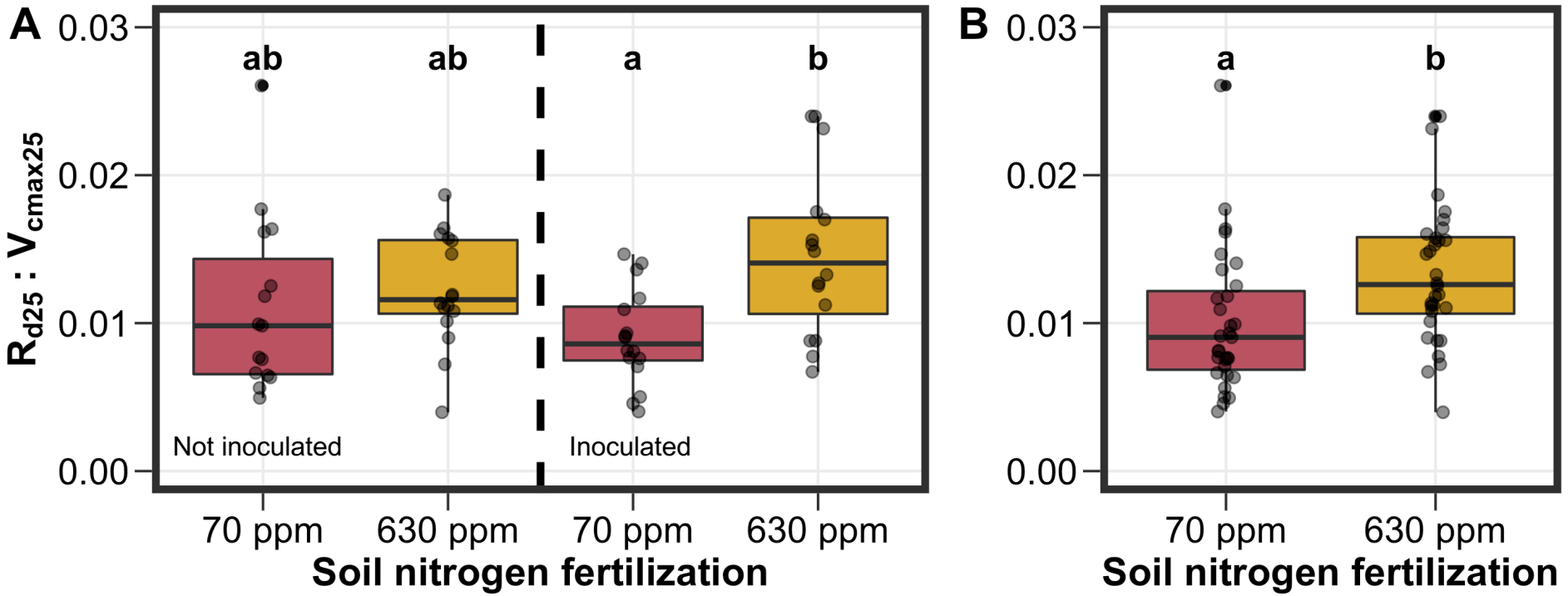
Increasing nitrogen fertilization reduces net photosynthesis but increases dark respiration



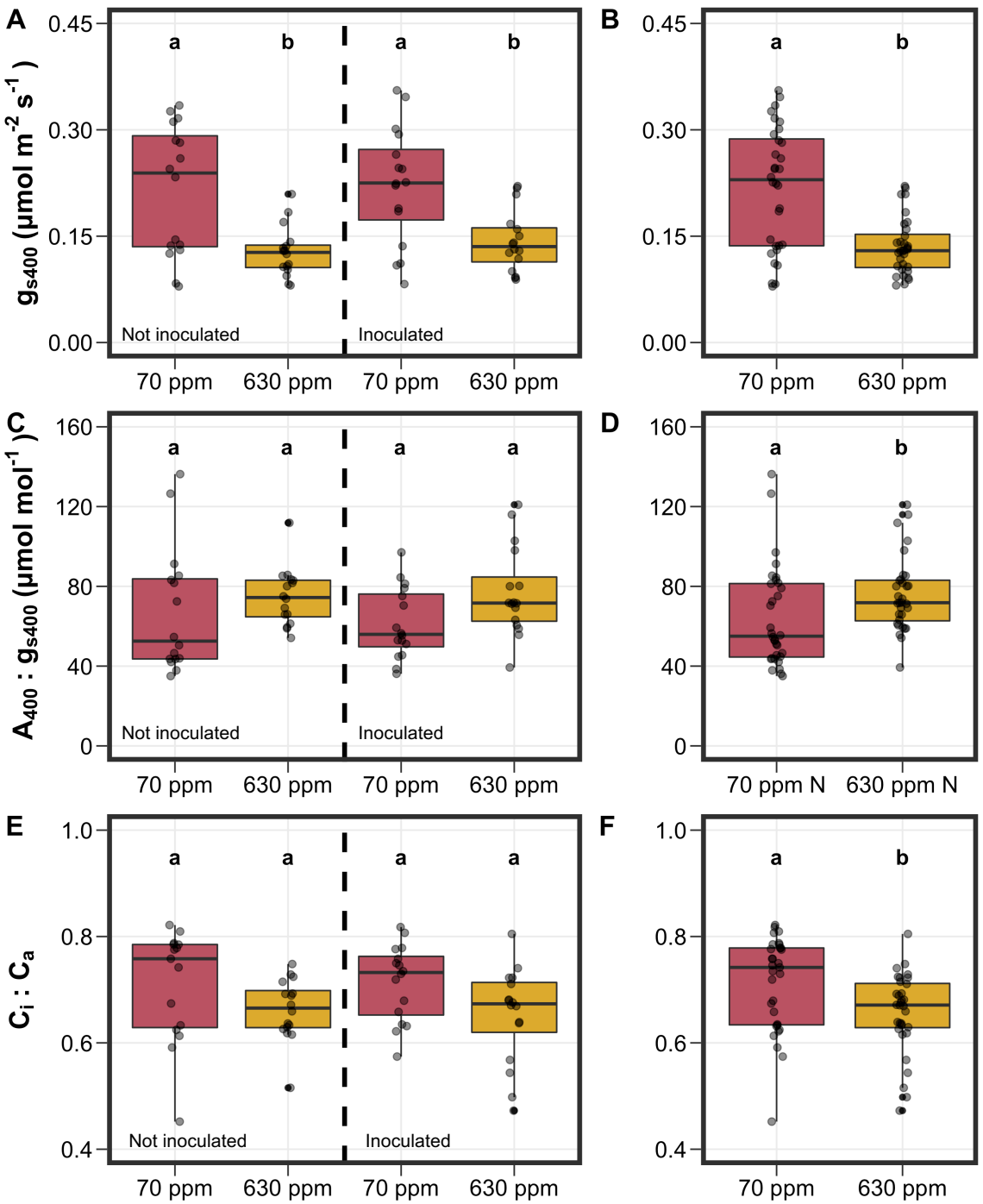
Increasing nitrogen fertilization reduces maximum Rubisco carboxylation and RuBP regeneration rates



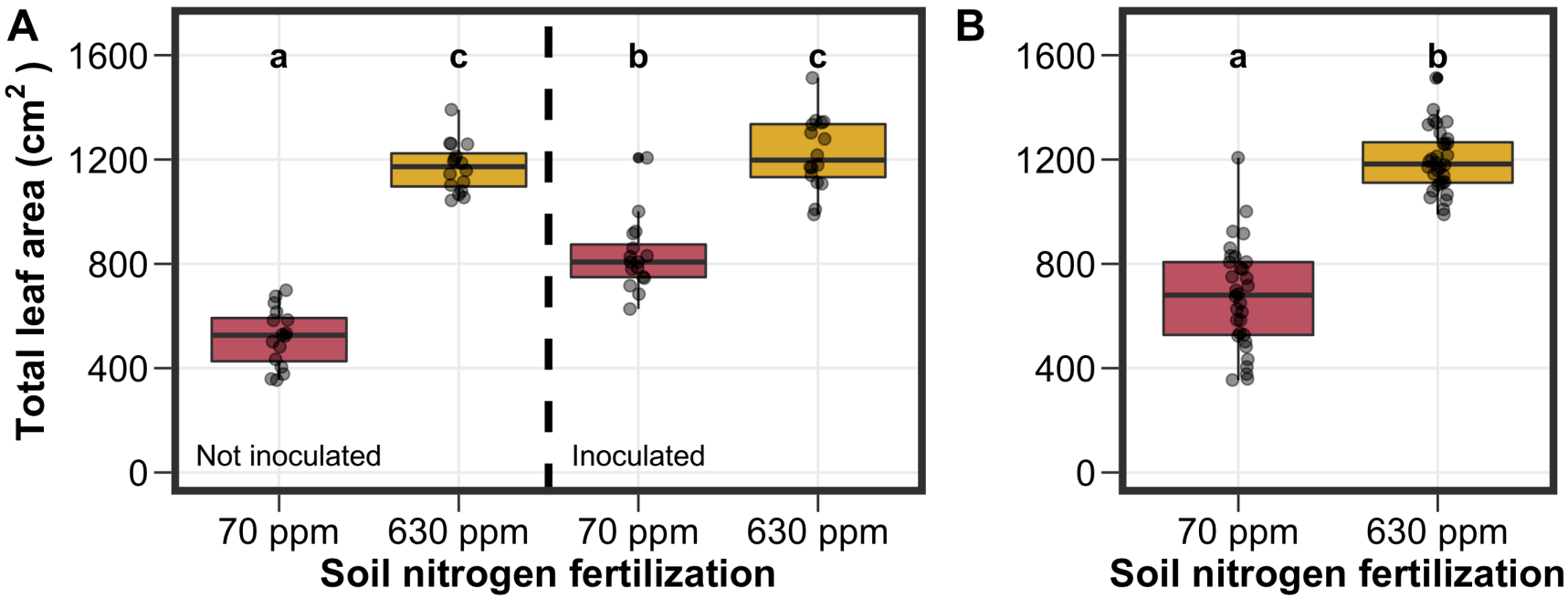
Increasing nitrogen fertilization generally increases R_{d25}:V_{cmax25}, although is dependent on inoculation status



Increasing nitrogen fertilization generally decreased stomatal conductance and increased water-use efficiency



Total leaf area is driven by interaction between inoculation status and nitrogen fertilization



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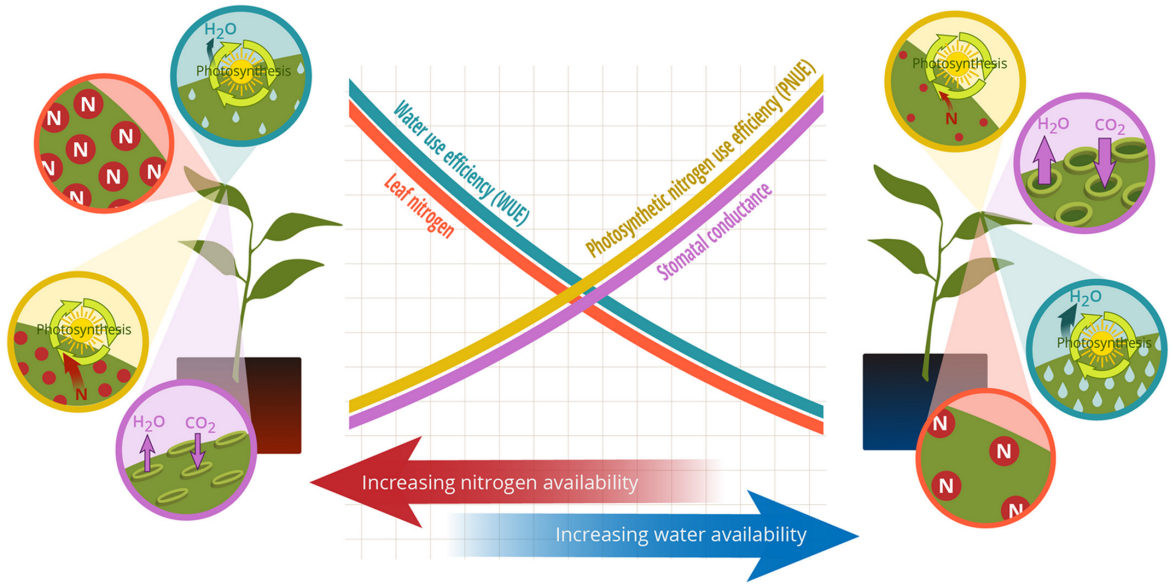

Bialic-Murphy *et al*. (2021) *Ecol. Letters*

Revisiting Option 1

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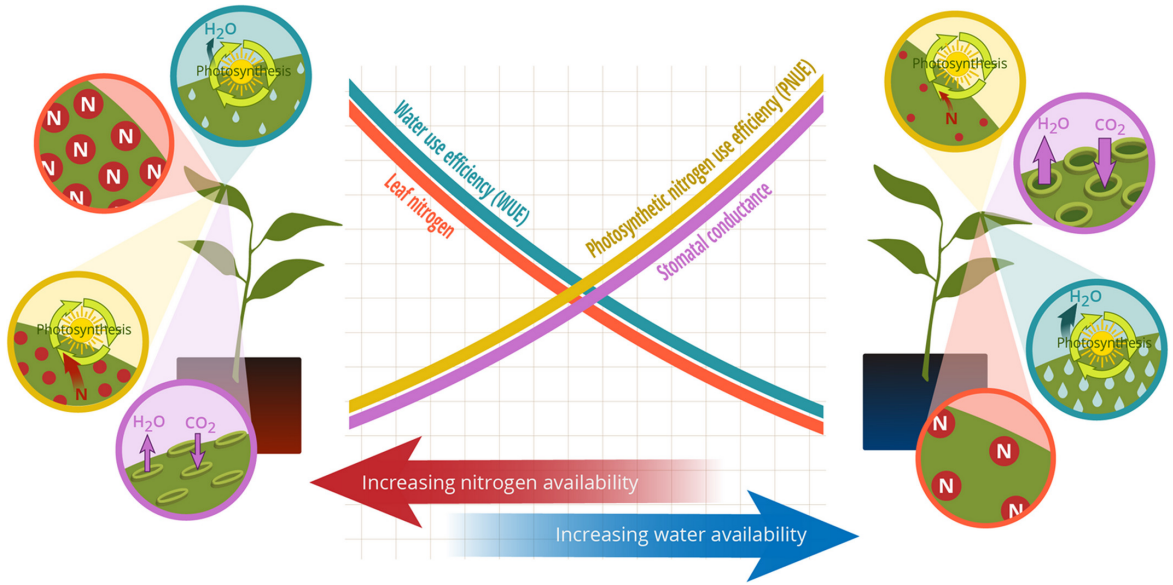
Photosynthesis was achieved through an increase in water-use efficiency, although we need to process focal leaves to fully answer the N/water tradeoff hypothesis



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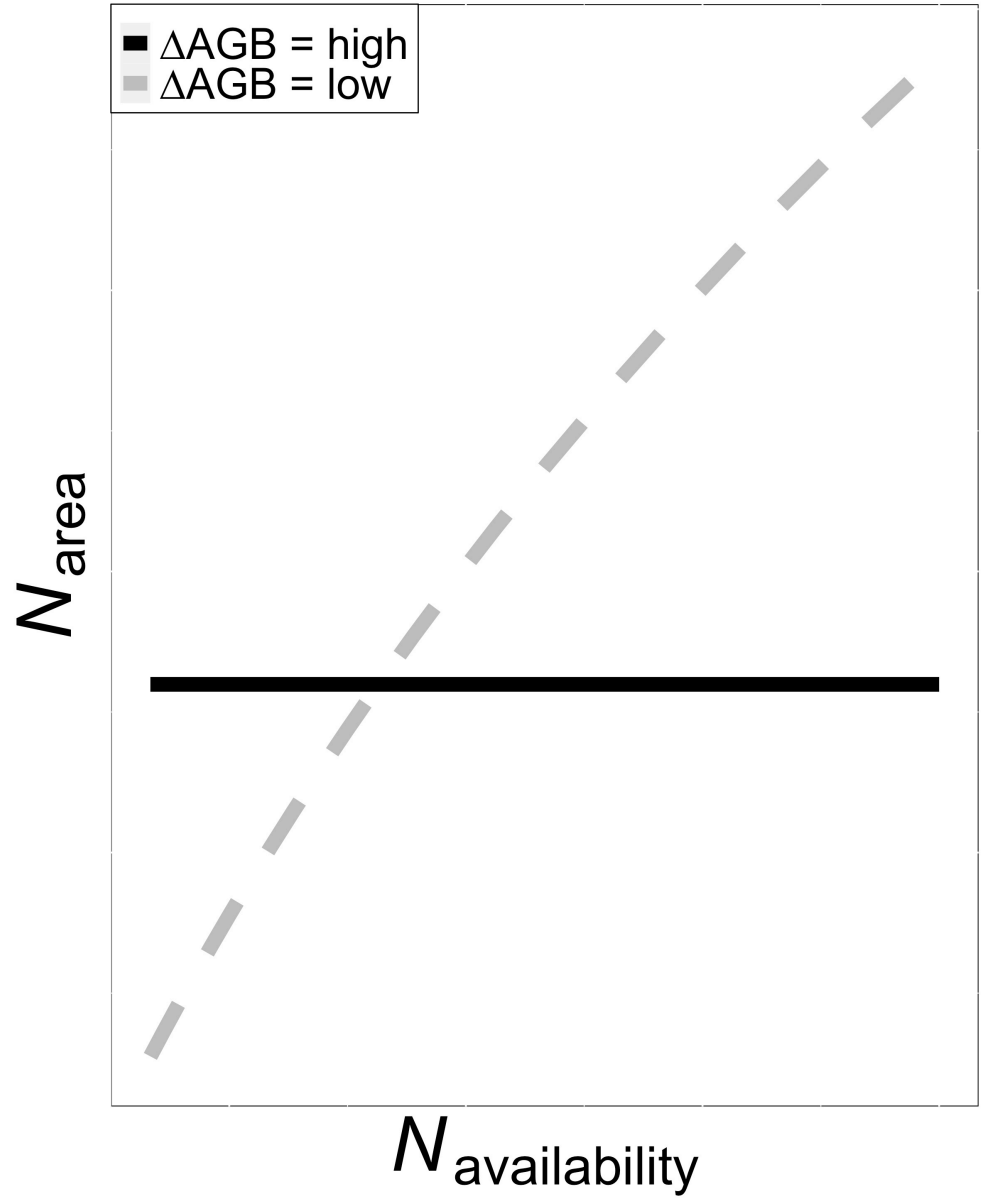
Did soil N invoke tradeoffs between biomass production and N_{area}?



Revisiting Option 2

Did soil N invoke tradeoffs between biomass production and N_{area}?

Yes (at least for now). There was a strong increase in total leaf area with increasing soil nitrogen fertilization but a rather weak response of leaf photosynthesis to fertilization