Nitrogen supply and demand control plant responses to elevated CO_2 at difference scales

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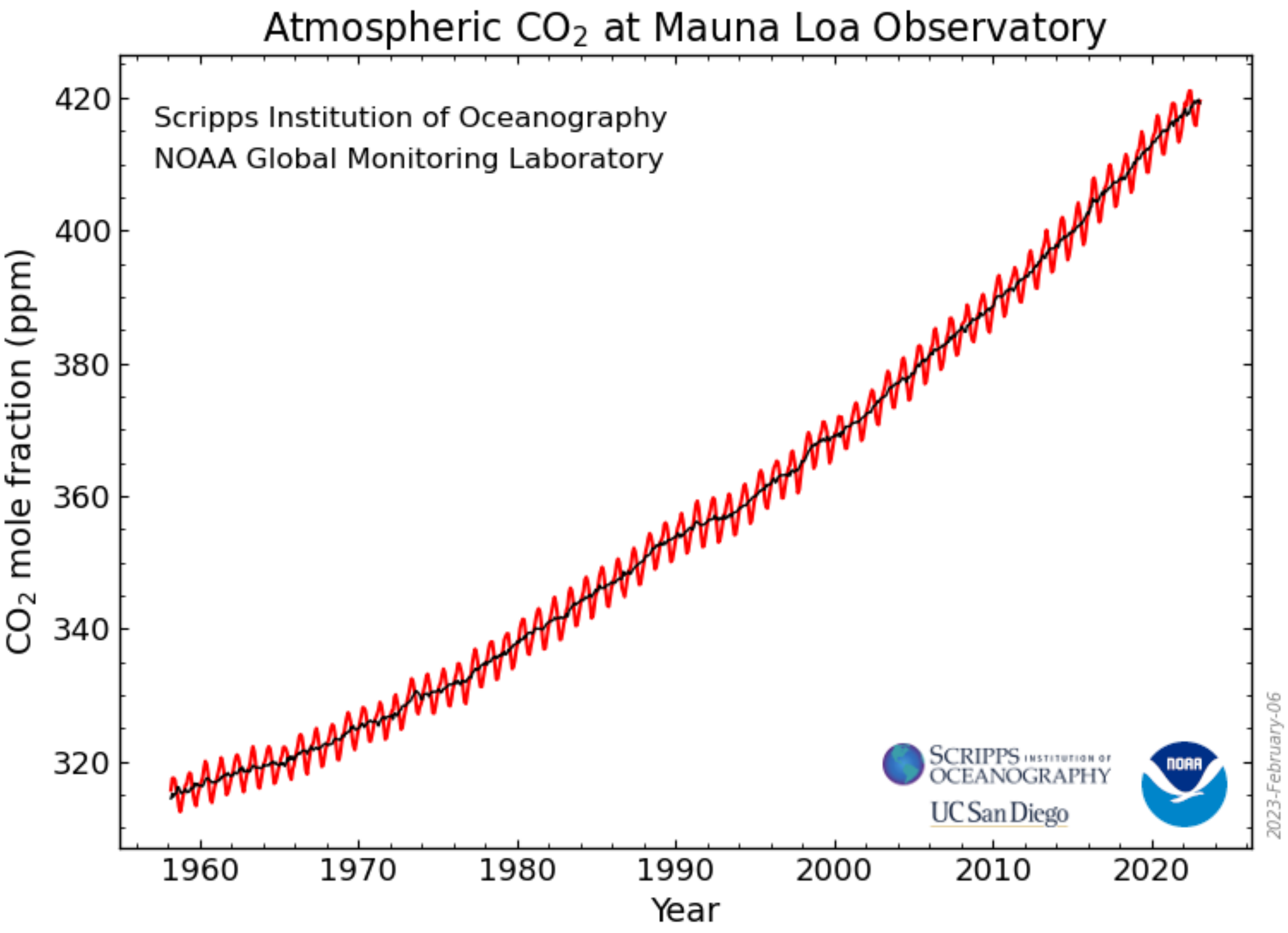
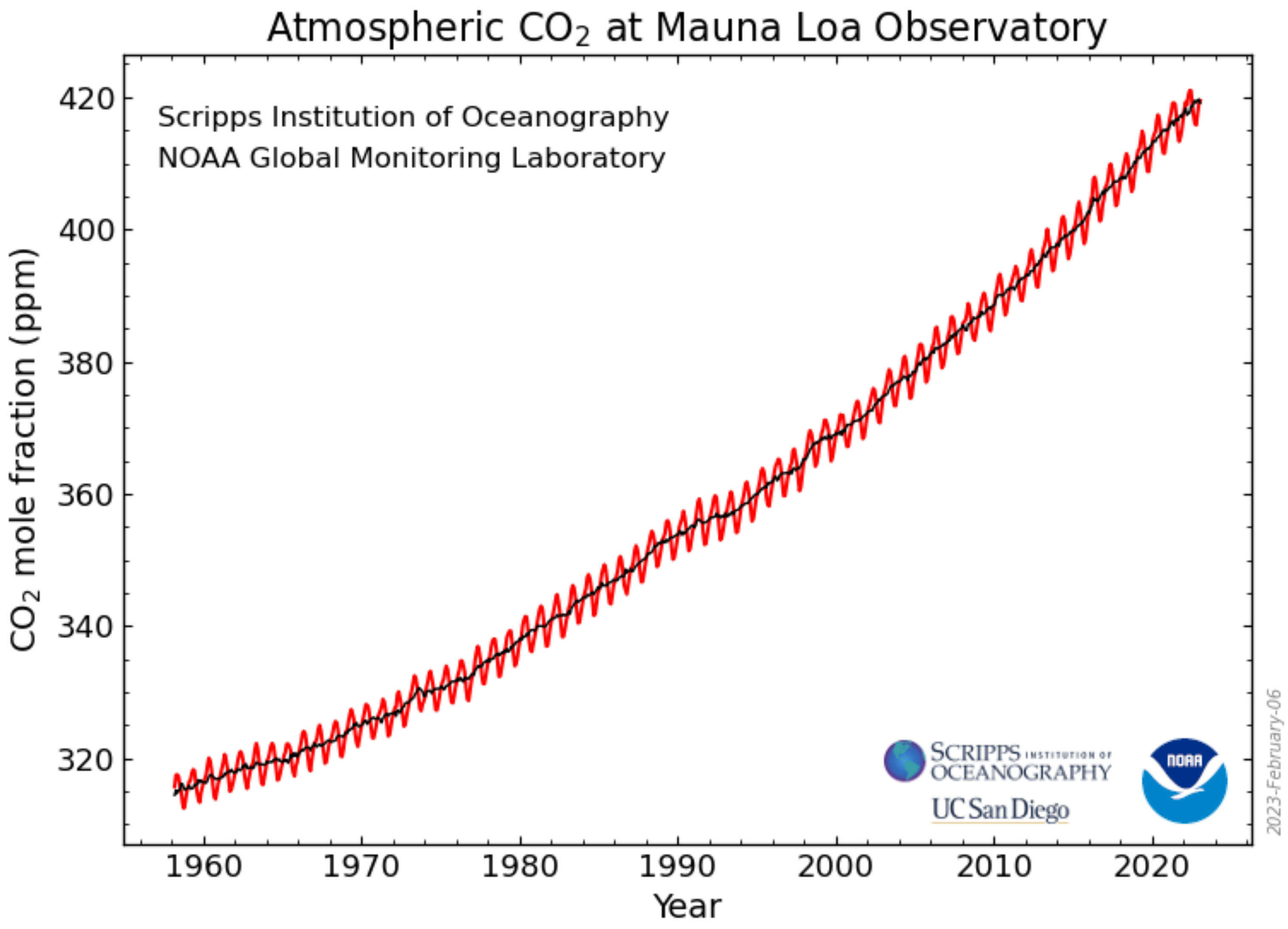
LEMONTREE
Land Ecosystem Models based On New Theory, obseRvations and ExperimEnts



https://gml.noaa.gov/ccgg/trends/

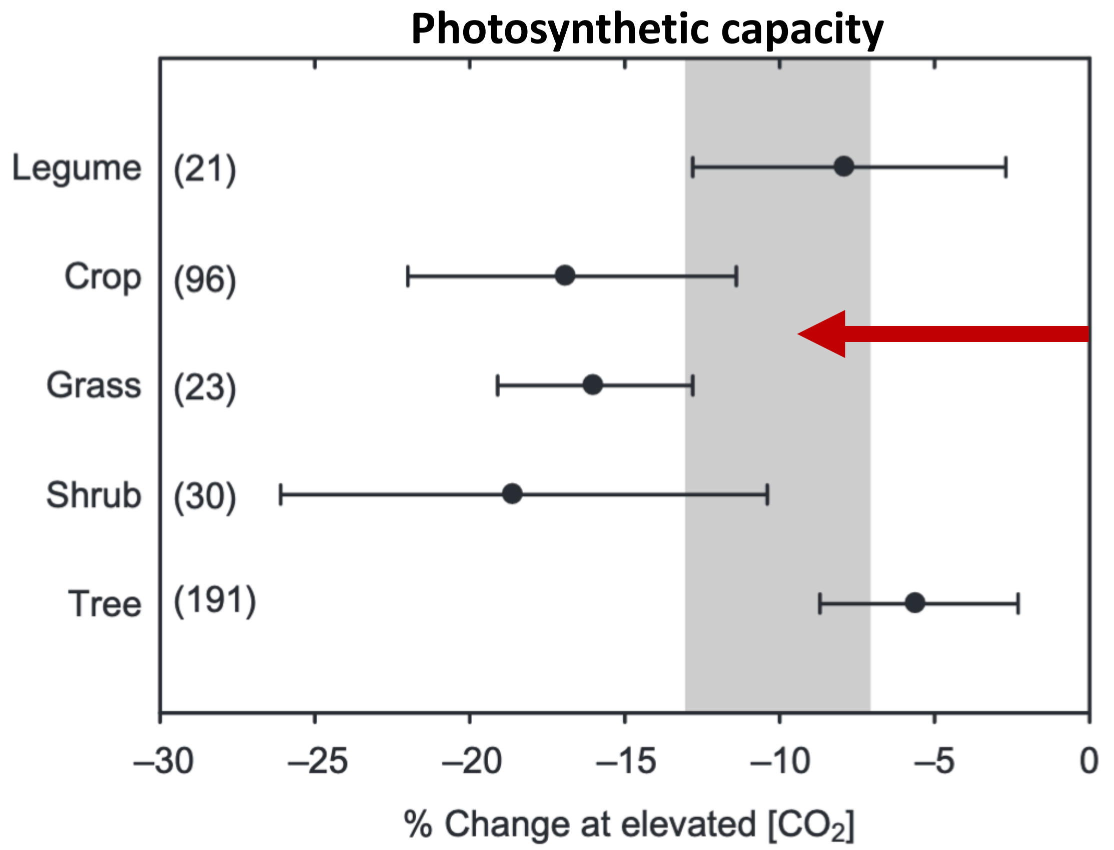


33% increase in CO_2 concentration since 1960

61% of this increase has occurred since 1990

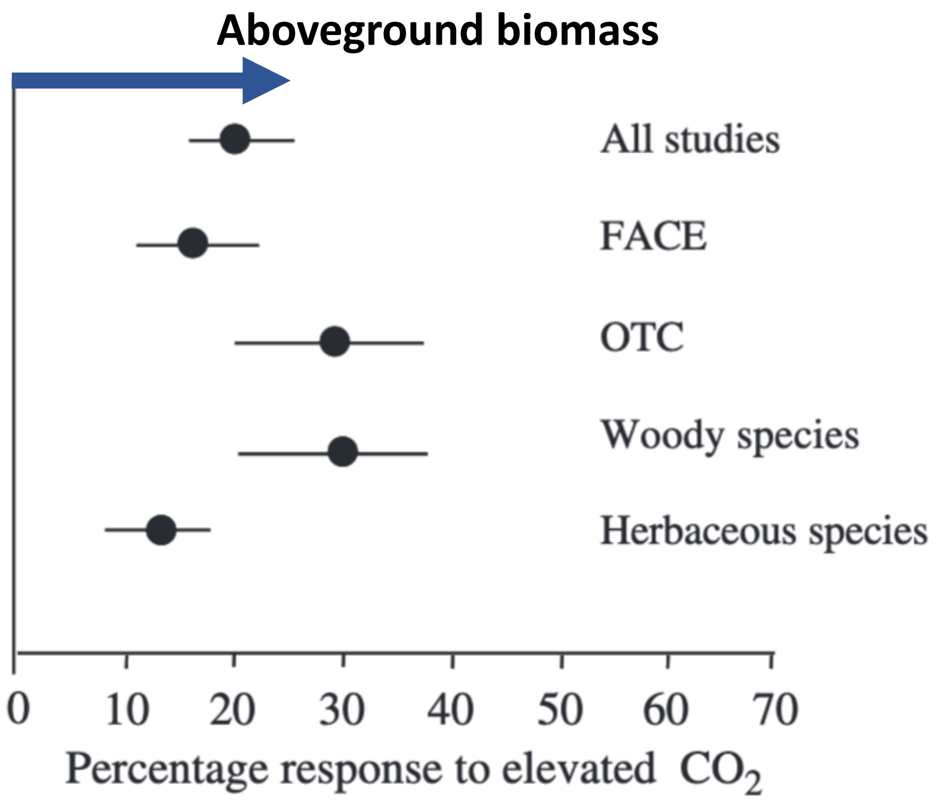
https://gml.noaa.gov/ccgg/trends/

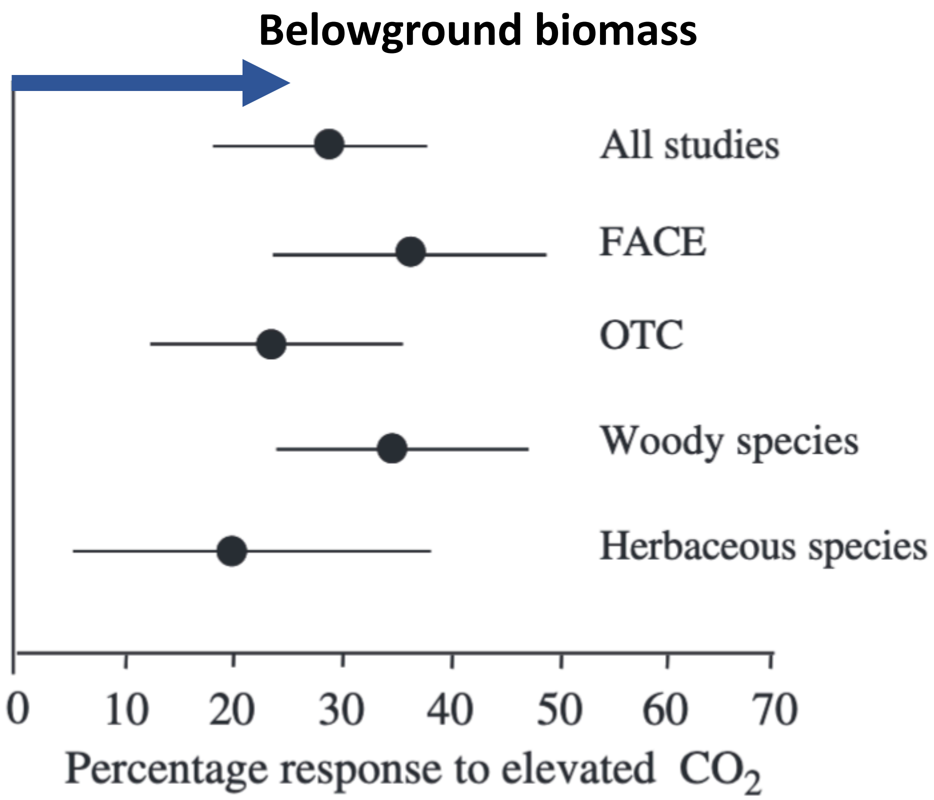
Plants grown under elevated CO_2 exhibit **reductions** in photosynthetic capacity



Ainsworth & Rogers (2007) *PC&E*

Reduced photosynthetic capacity under elevated CO_2 often corresponds with **increased** whole-plant growth





de Graaf et al. (2006) *Global Change Biology*

Some have hypothesized that nitrogen availability regulates plant responses to elevated CO_2

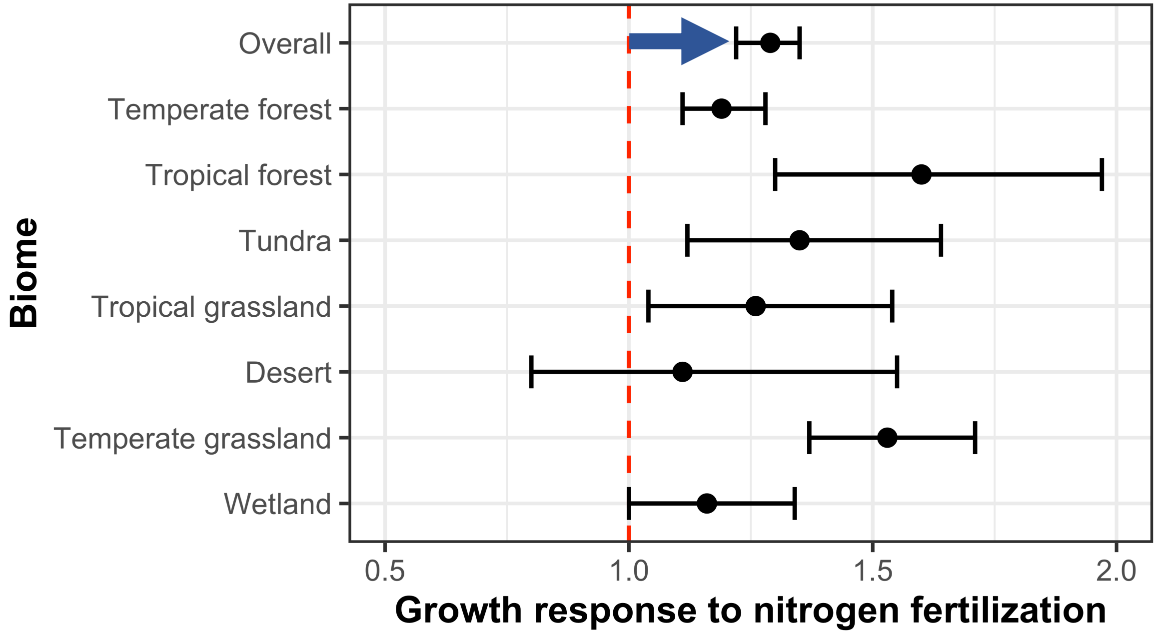


Figure adapted from Table 1 in LeBauer & Treseder (2008) *Ecology*

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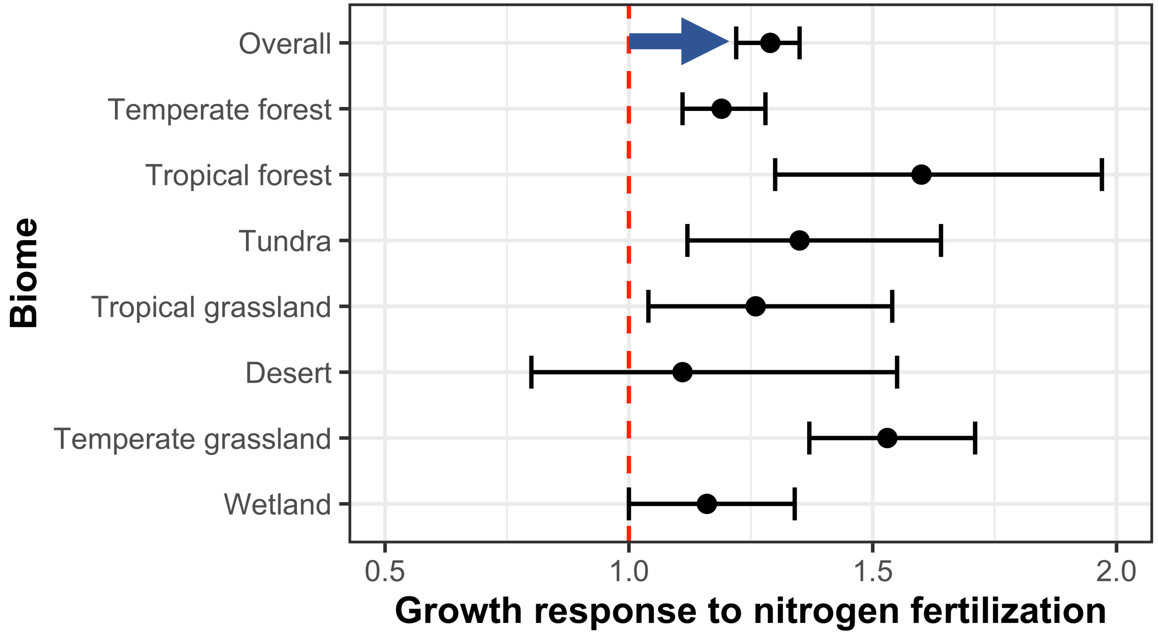

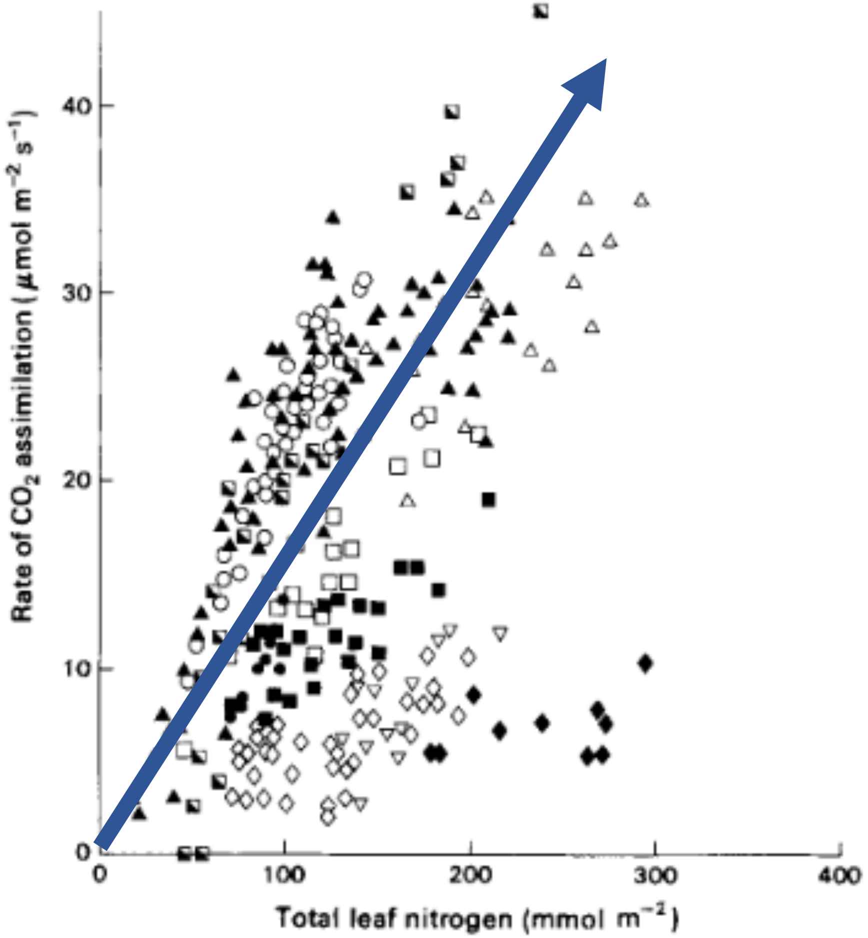

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Evans (1989) *Photosynthesis Research*

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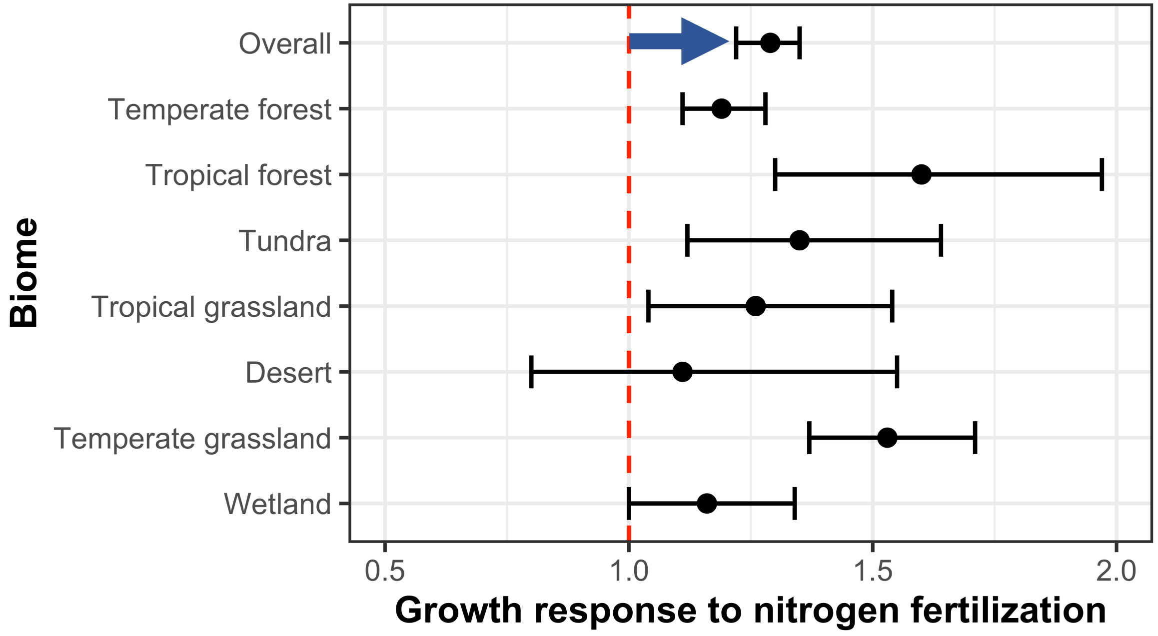
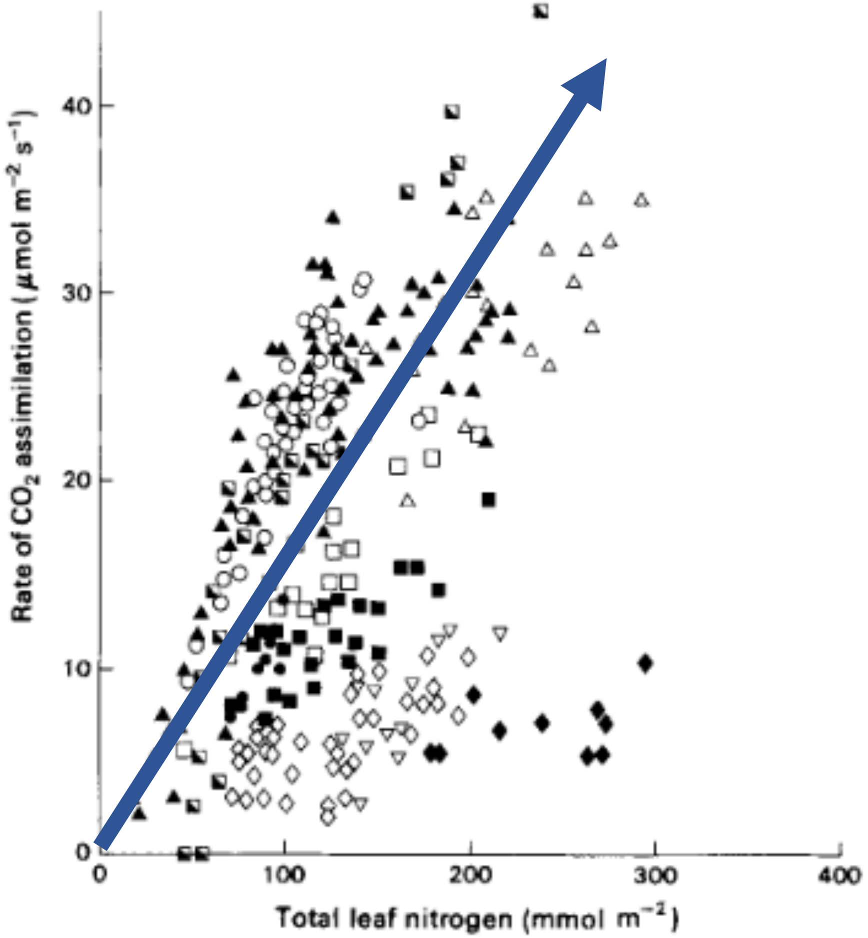


Increased demand to build and maintain photosynthetic enzymes might deplete plant-available soil N pools



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However, an alternative hypothesis suggests that plant demand to build and maintain photosynthetic enzymes drives the leaf response to CO_2

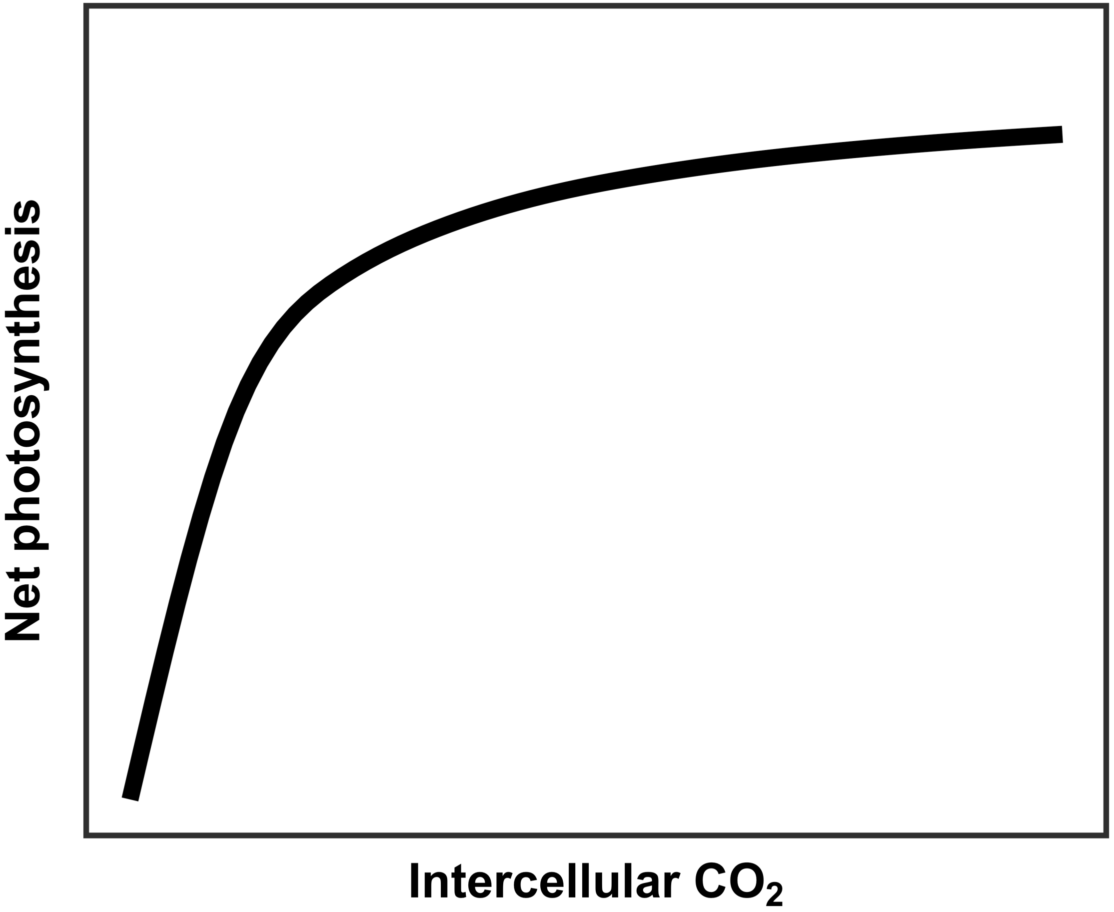

Figure adapted from Moore et al. (1999) *PC&E*

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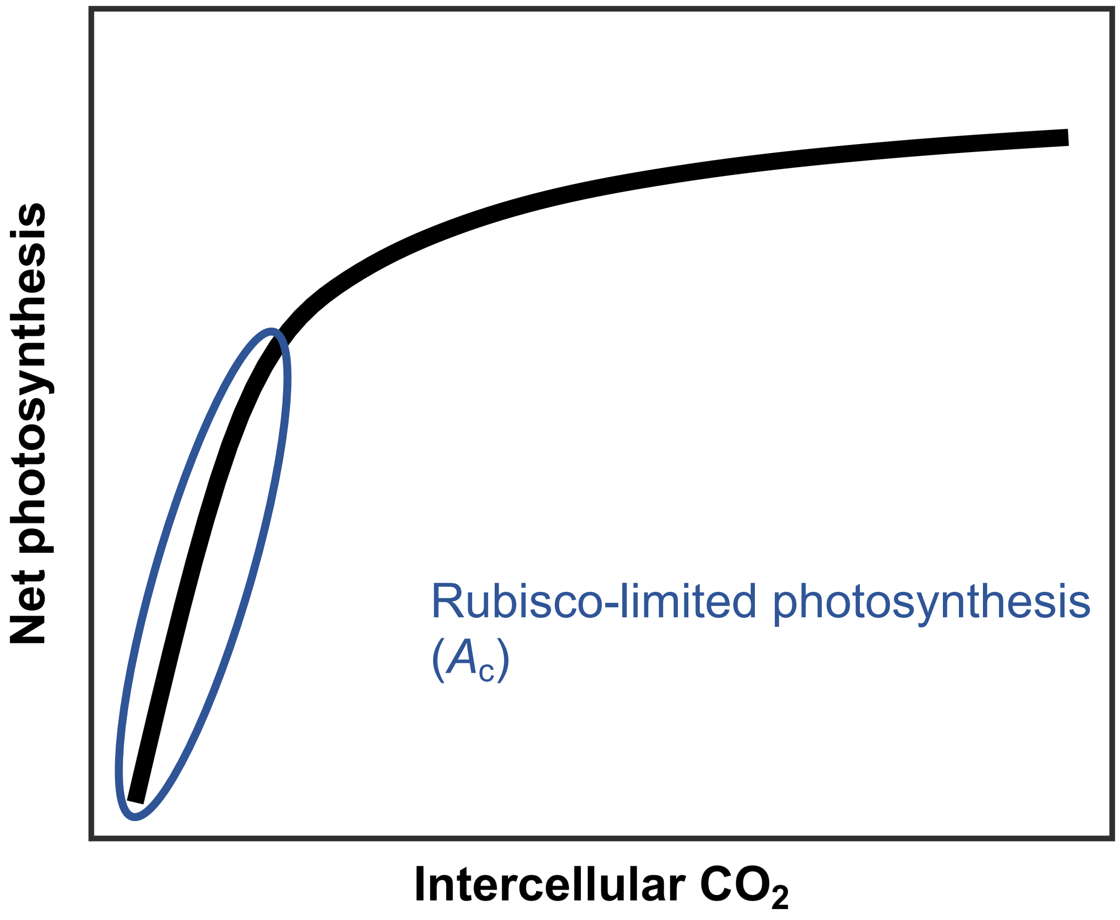

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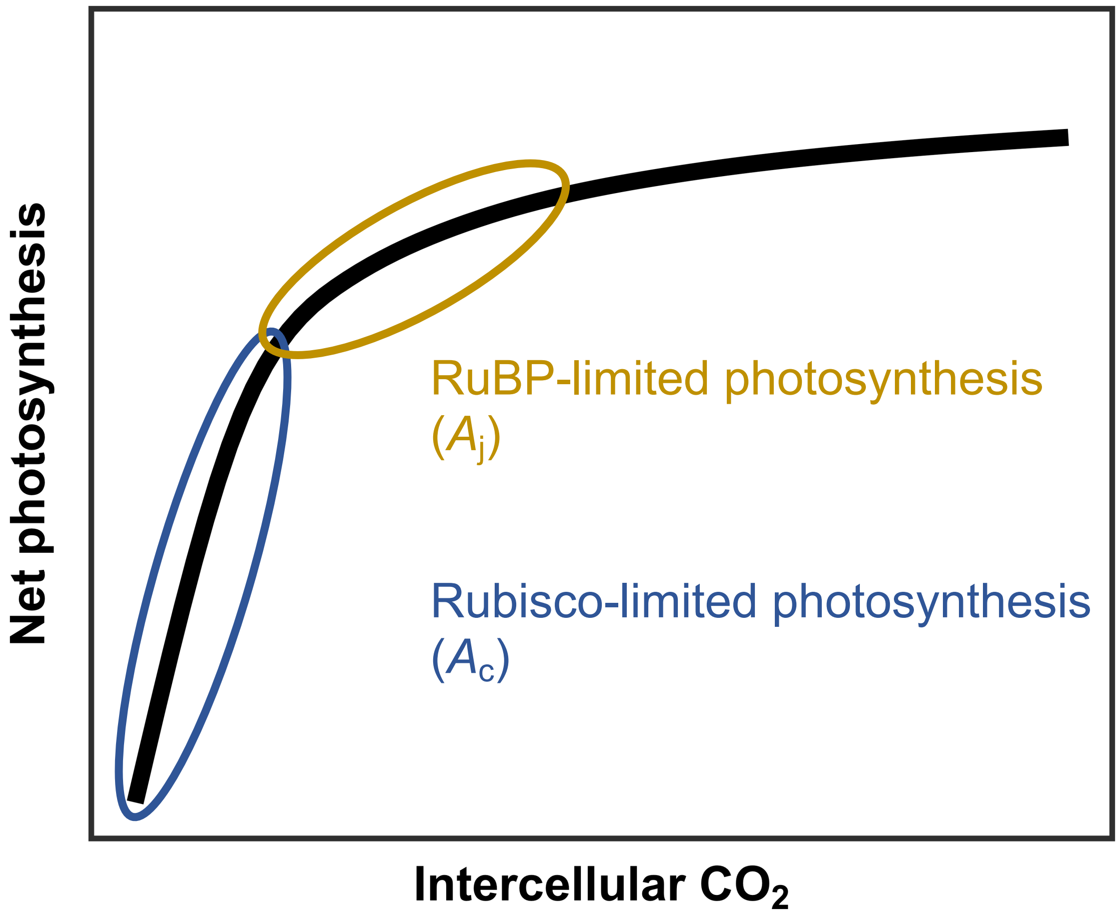

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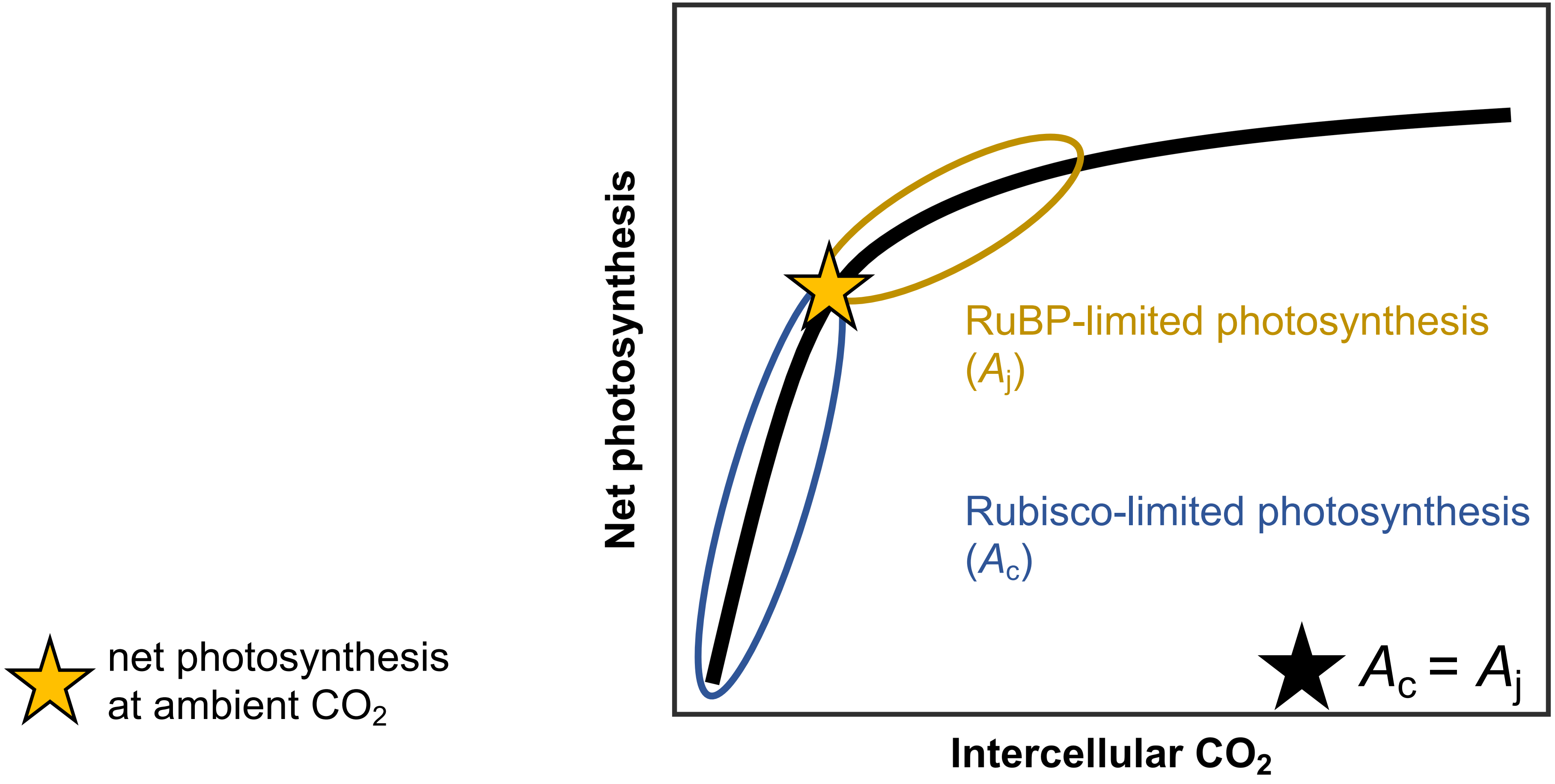

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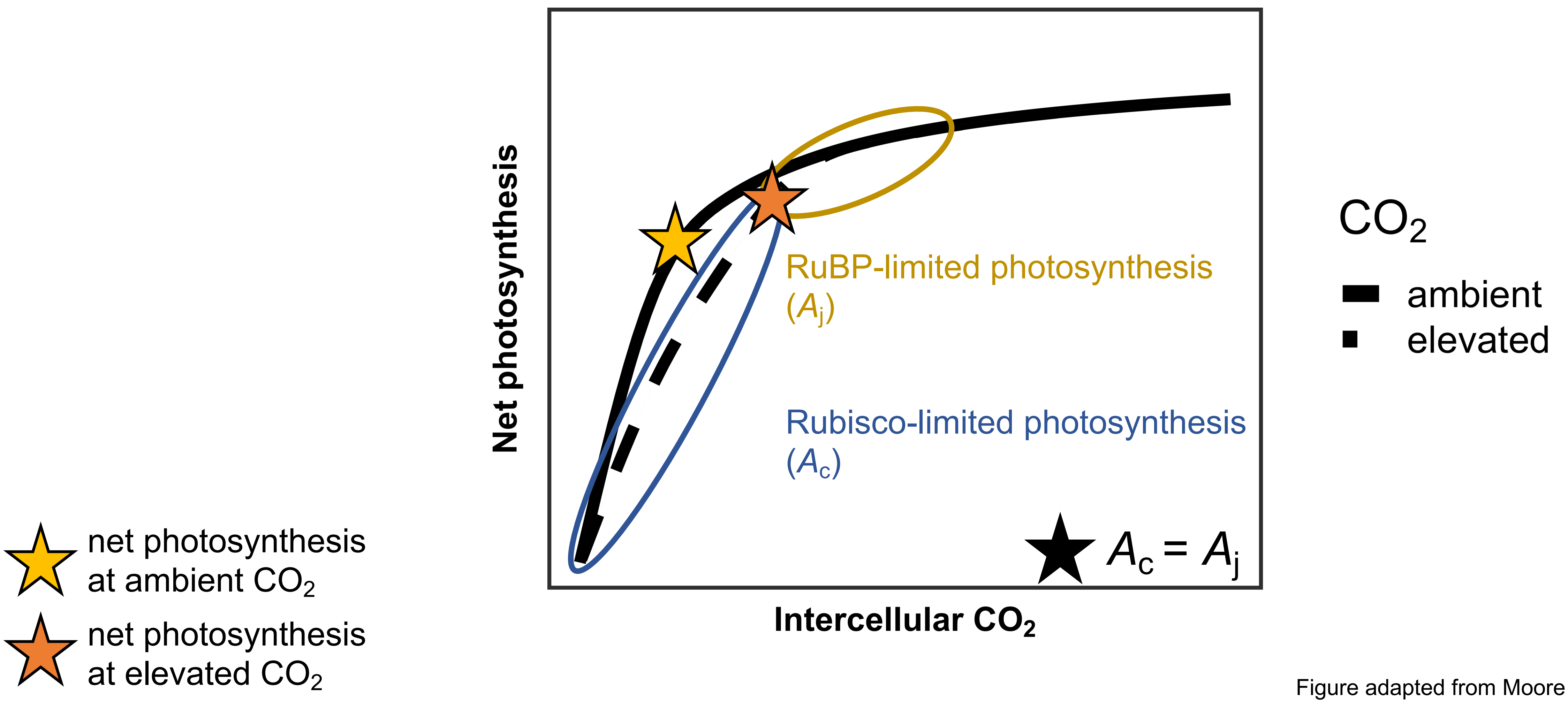

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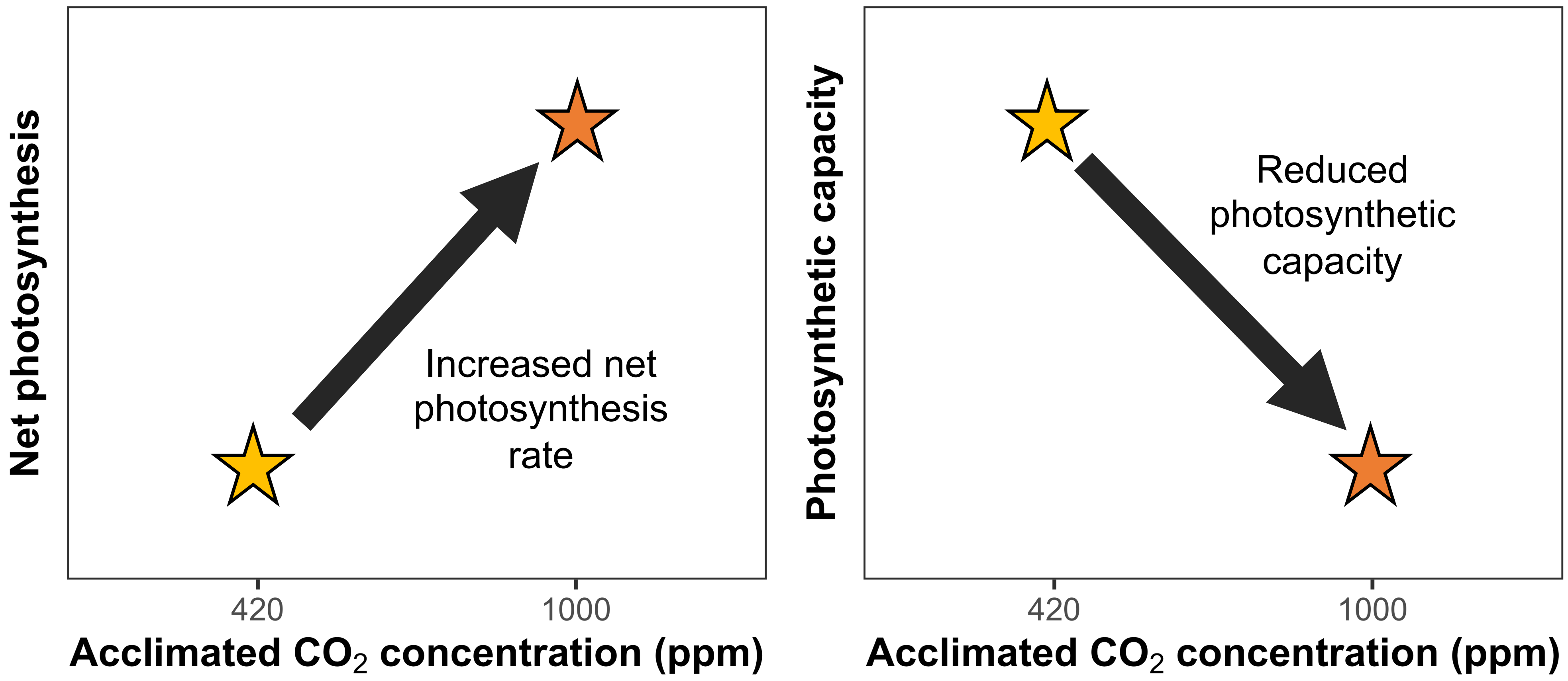
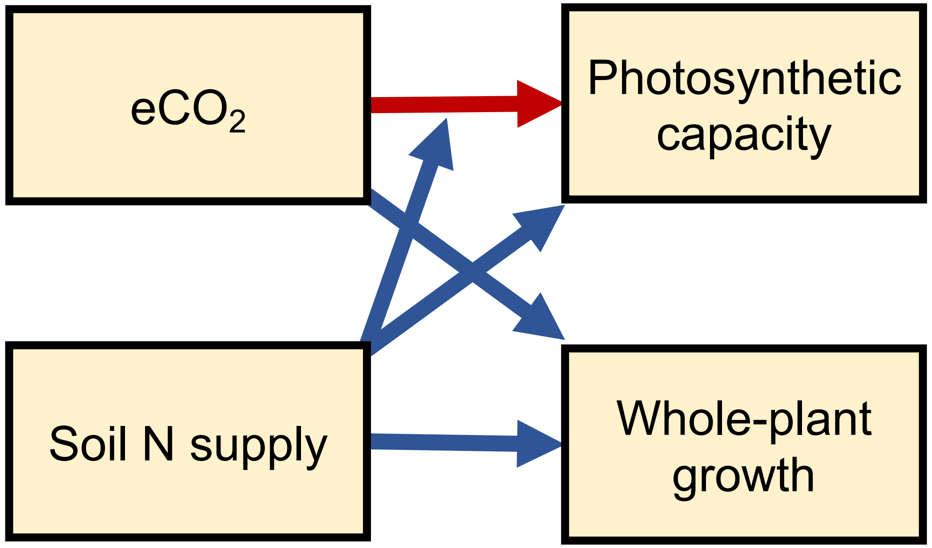
Optimal resource investment to photosynthetic enzymes increases leaf photosynthesis at lower photosynthetic capacity



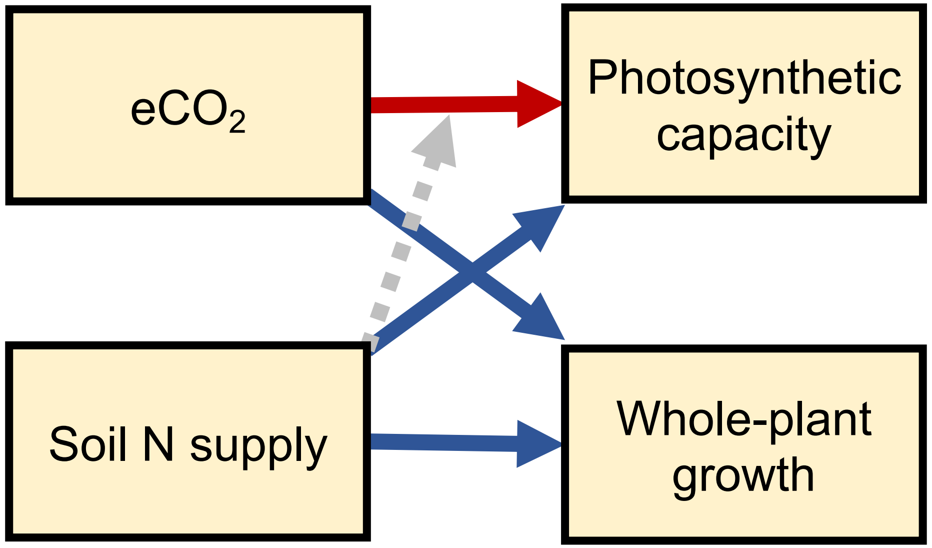
Study Question

How does soil nitrogen availability modify leaf and whole plant responses to CO_2?

Nitrogen limitation hypothesis



Optimality hypothesis



= net positive effect
= net negative effect
= null effect

Experiment setup

Acquisition strategy

+ BNF

- BNF

CO_2 treatments

ambient (420 ppm)

elevated (1000 ppm)

Soil N treatments

0 ppm N

35 ppm N

70 ppm N

105 ppm N

140 ppm N

210 ppm N

280 ppm N

350 ppm N

630 ppm N

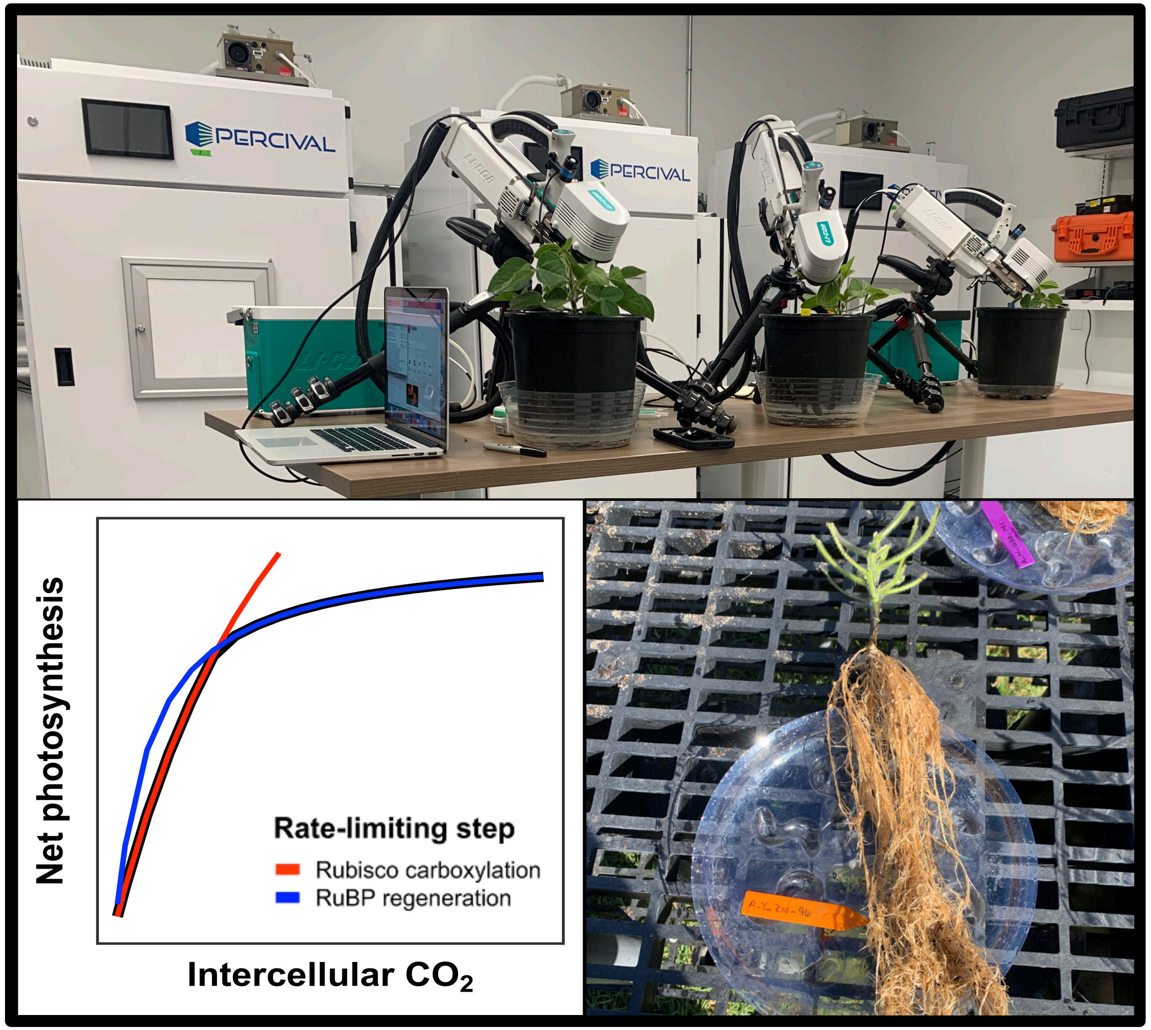
Perkowski et al. (in prep)

Measurements

- Photosynthetic capacity
  - V_{cmax25}
  - J_{max25}
  - J_{max25}:V_{cmax25}

- Total biomass

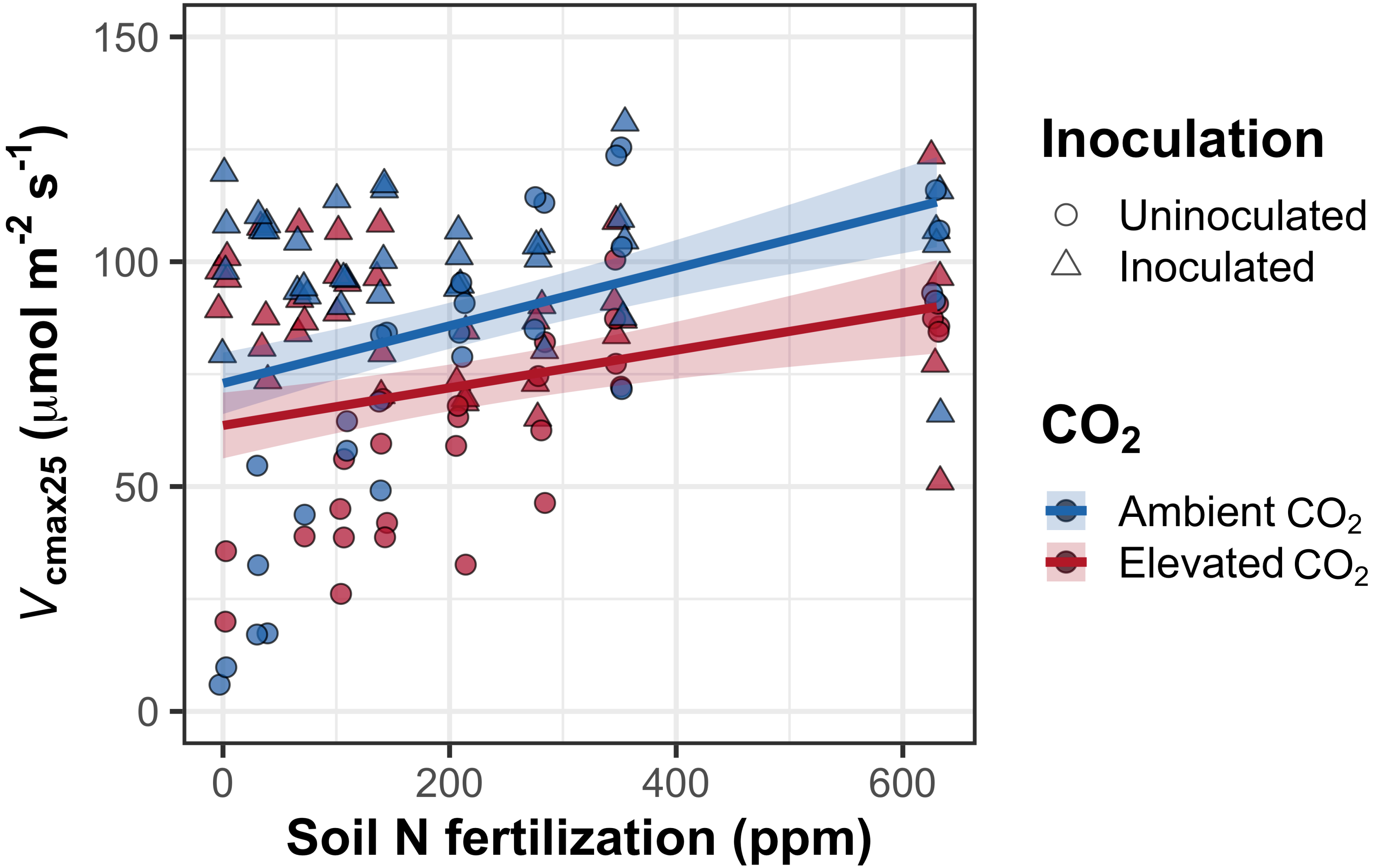
- % leaf N derived from atmosphere



Perkowski et al. (in prep)

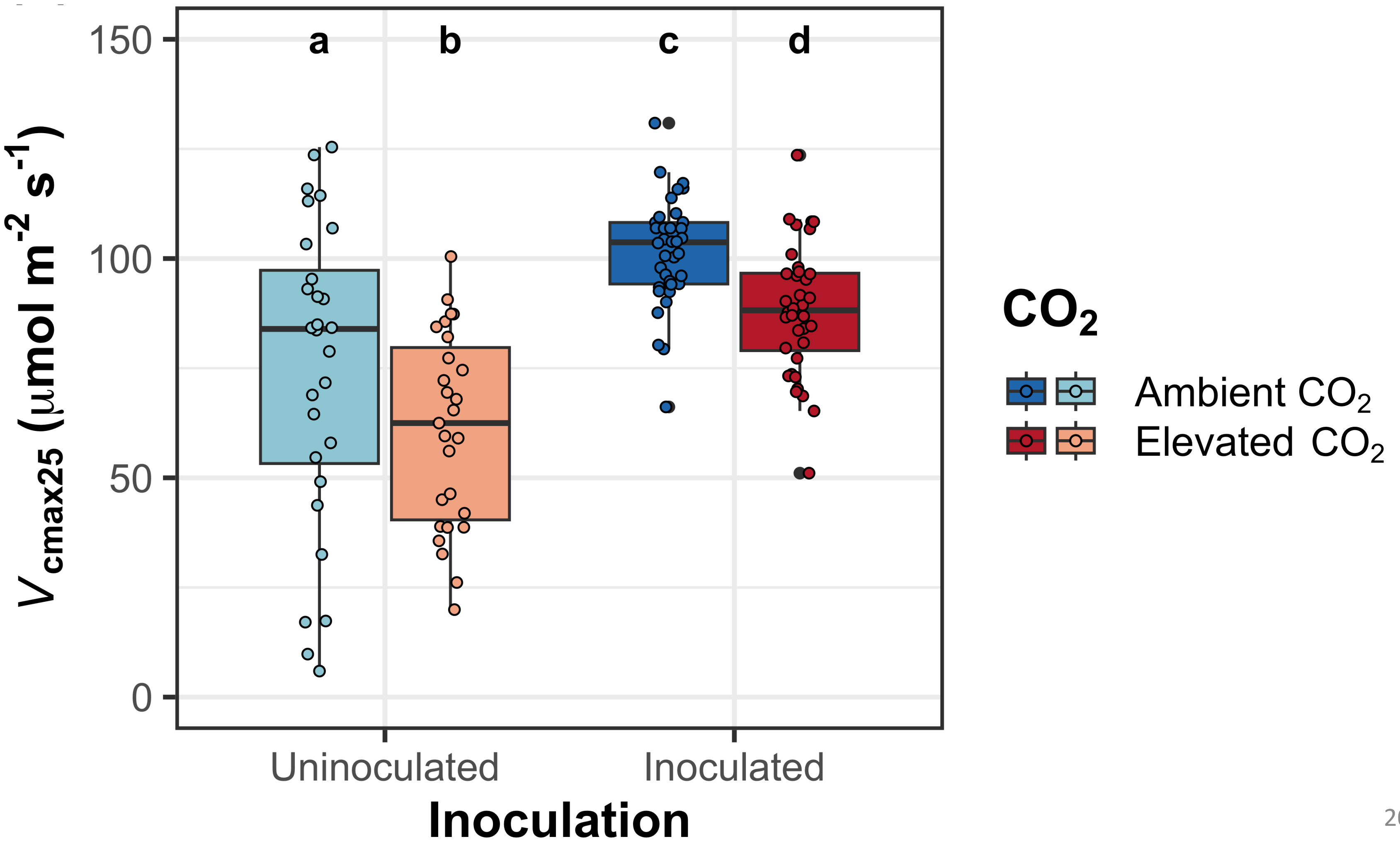
Increasing fertilization <u>did not modify</u> the **reduction** in photosynthetic capacity under elevated CO_2

CO_2:	***p*<0.001**
Fertilization (N):	***p*<0.001**
Inoculation (I):	***p*<0.001**
CO_2*N interaction:	**NS**



Inoculation also <u>did not modify</u> the **reduction** in photosynthetic capacity under elevated CO_2

CO_2: ***p*<0.001**
Fertilization (N): ***p*<0.001**
Inoculation (I): ***p*<0.001**
CO_2*N interaction: **NS**
CO_2*I interaction: **NS**



Elevated CO_2 **decreased** V_{cmax25} **more strongly** than J_{max25}. Fertilization did not modify this effect

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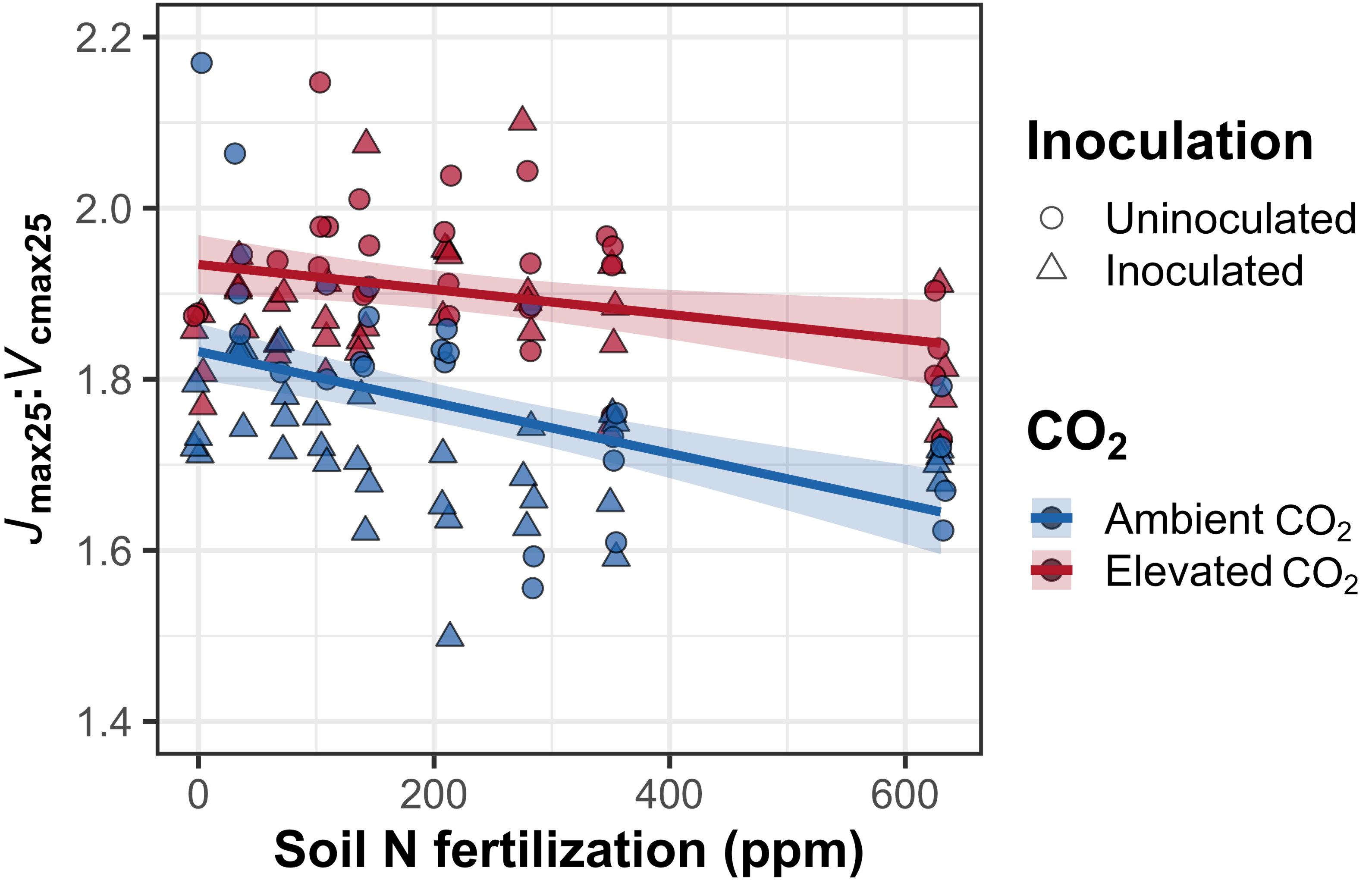

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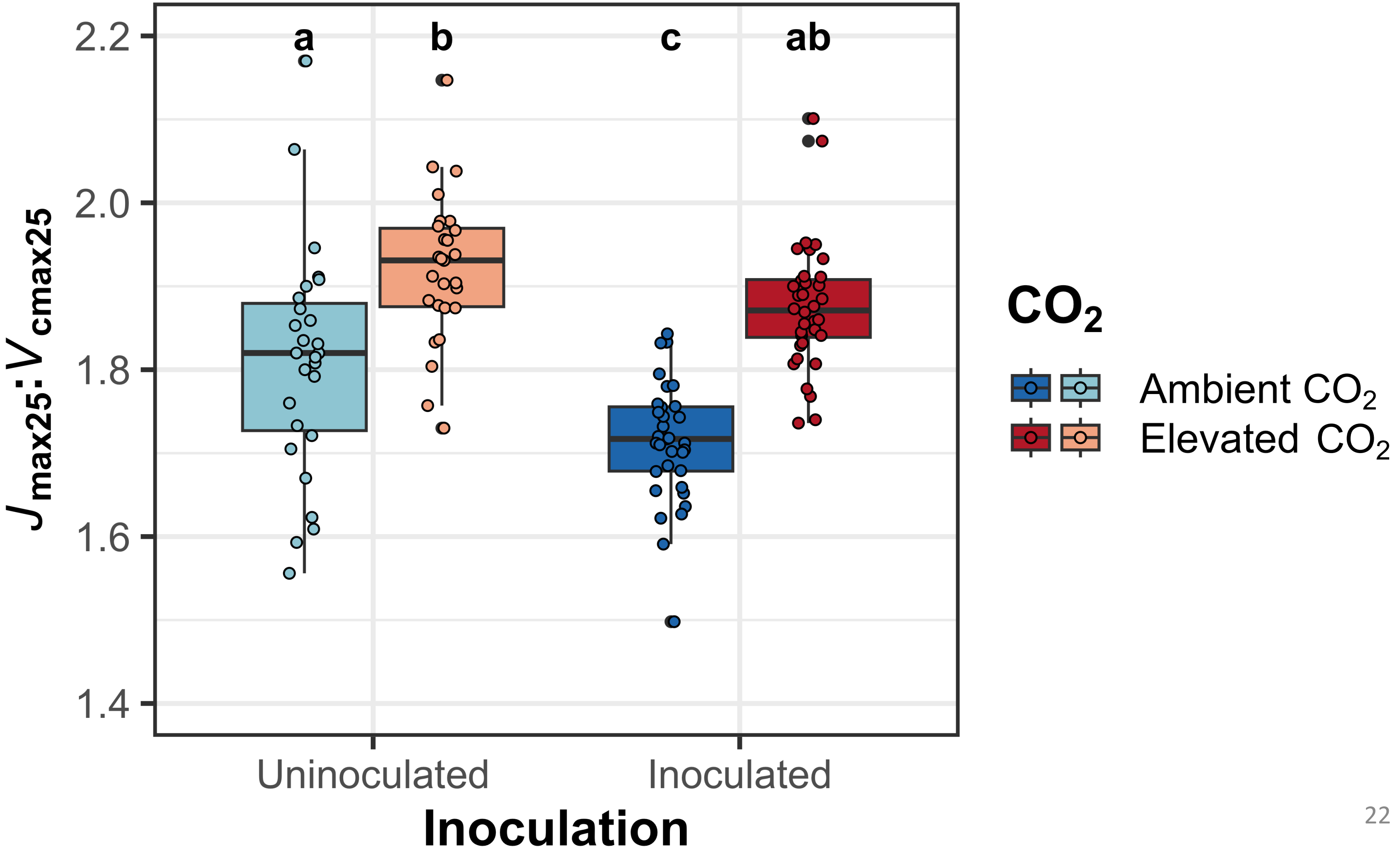
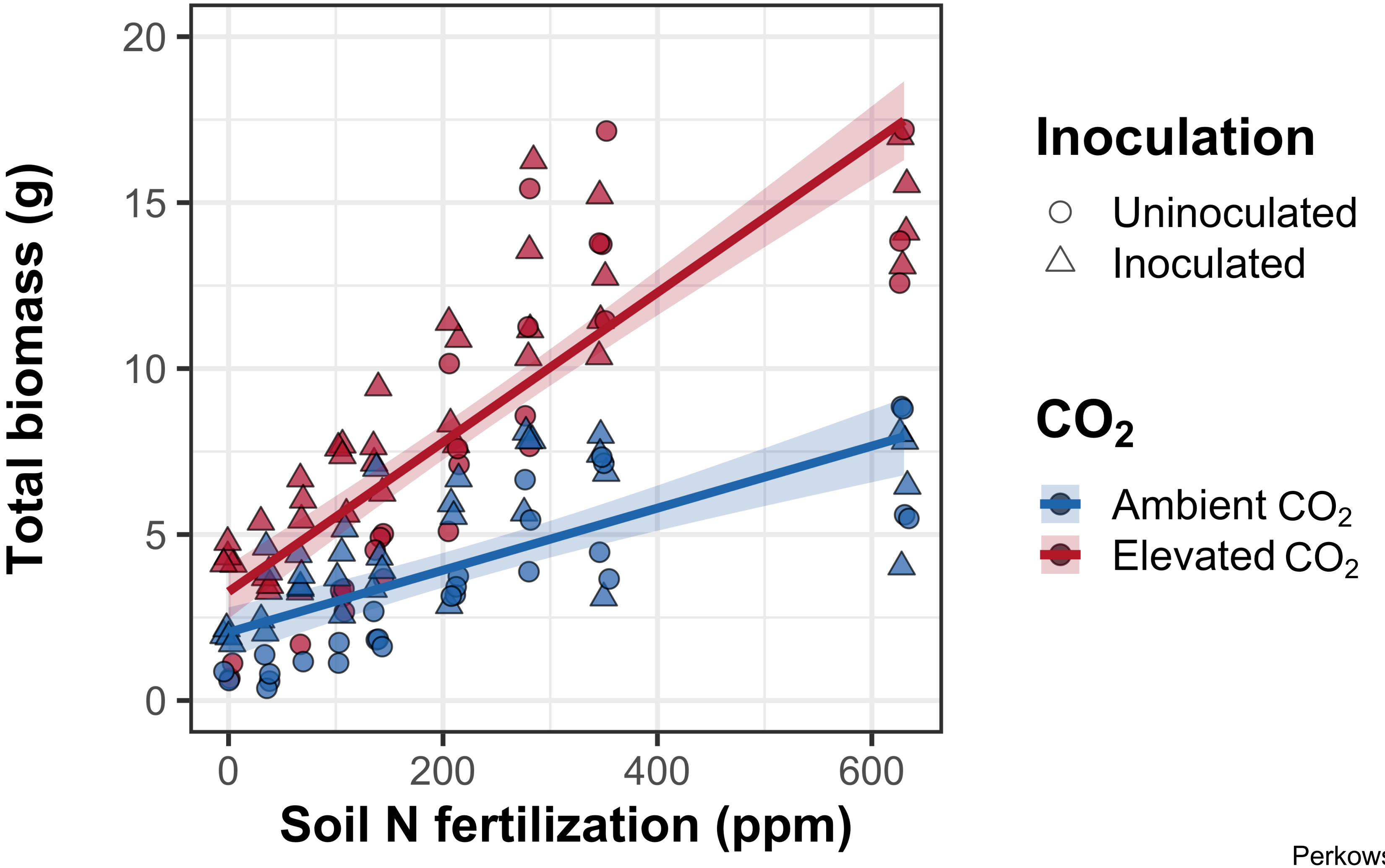


Increasing fertilization **increased** the **positive** effect of elevated CO_2 on whole-plant growth

CO_2: ***p*<0.001**
Fertilization (N): ***p*<0.001**
Inoculation (I): ***p*<0.001**
CO_2*N interaction: ***p*<0.001**



Perkowski et al. (in prep)

Inoculation did not modify the **positive** effect of eCO_2 on total biomass

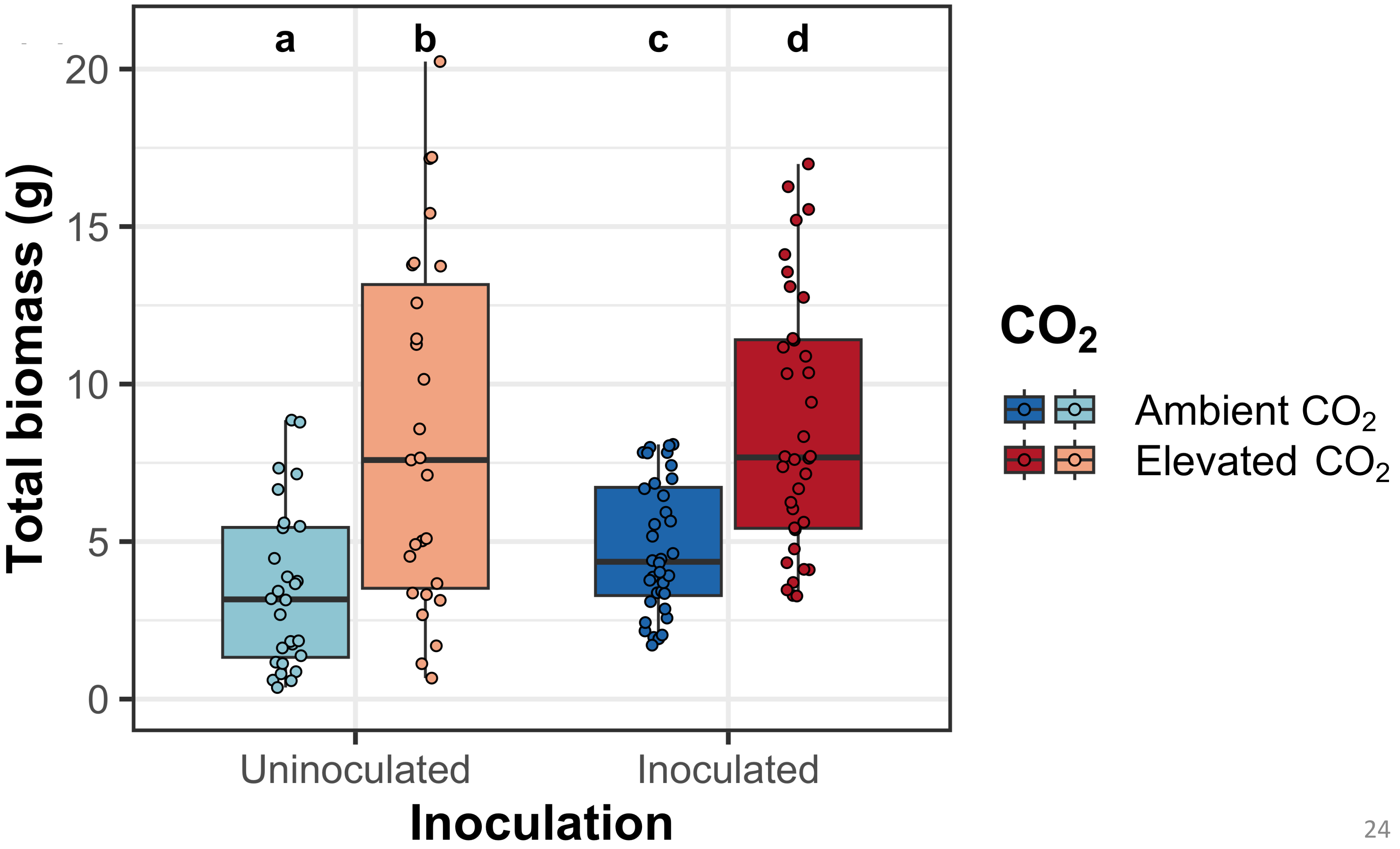
CO_2: ***p*<0.001**

Fertilization (N): ***p*<0.001**

Inoculation (I): ***p*<0.001**

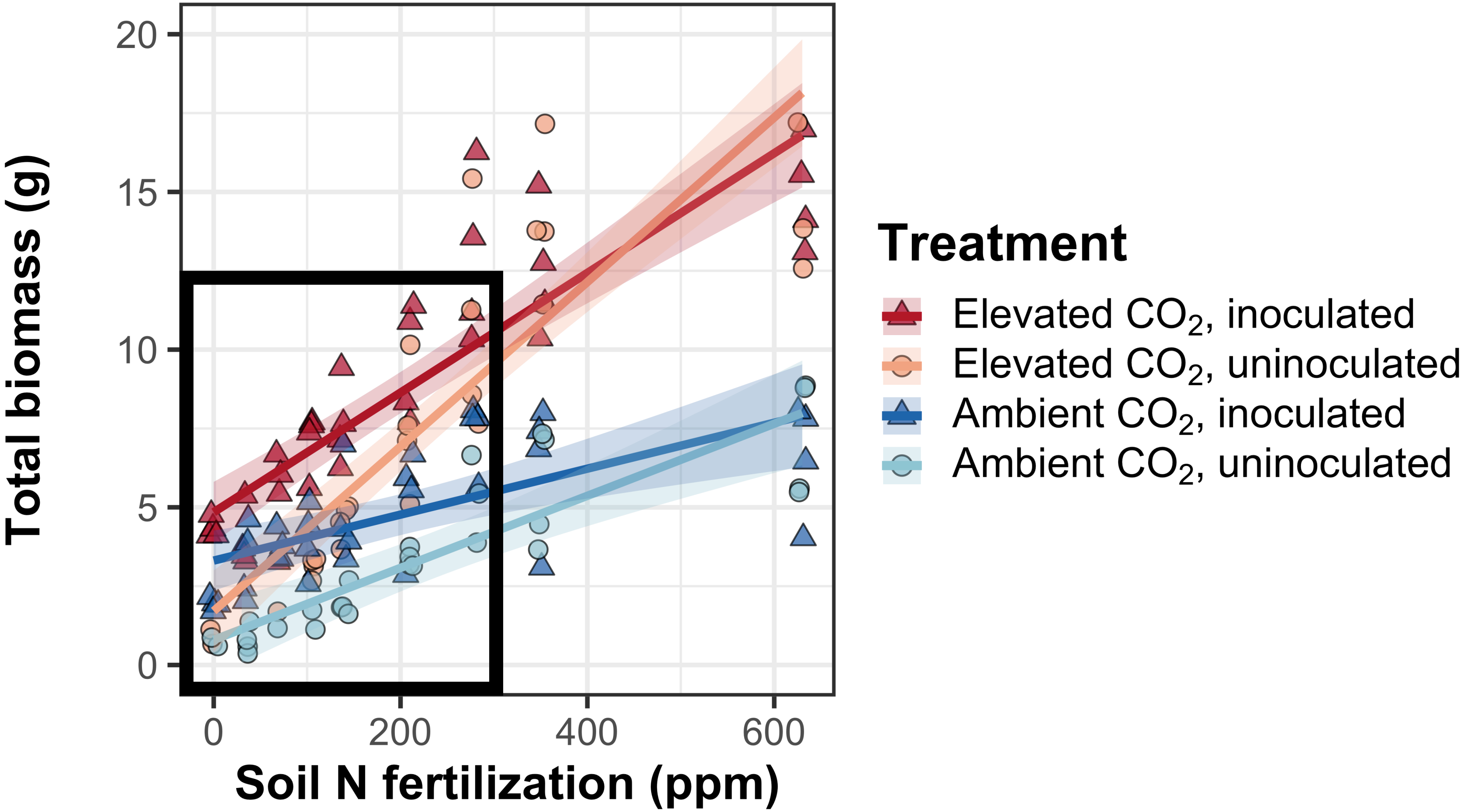
CO_2*N interaction: ***p*<0.001**

CO_2*I interaction: **NS**



However, inoculated plants had **greater** total biomass under low fertilization

CO_2:	***p*<0.001**
Fertilization (N):	***p*<0.001**
Inoculation (I):	***p*<0.001**
CO_2*N interaction:	***p*<0.001**
CO_2*I interaction:	**NS**



Perkowski et al. (in prep)

Increasing fertilization **decreased** the percent of leaf nitrogen content derived from the atmosphere

CO_2:	**NS**
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Inoculation (I):	***p*<0.001**
CO_2*N interaction:	**NS**
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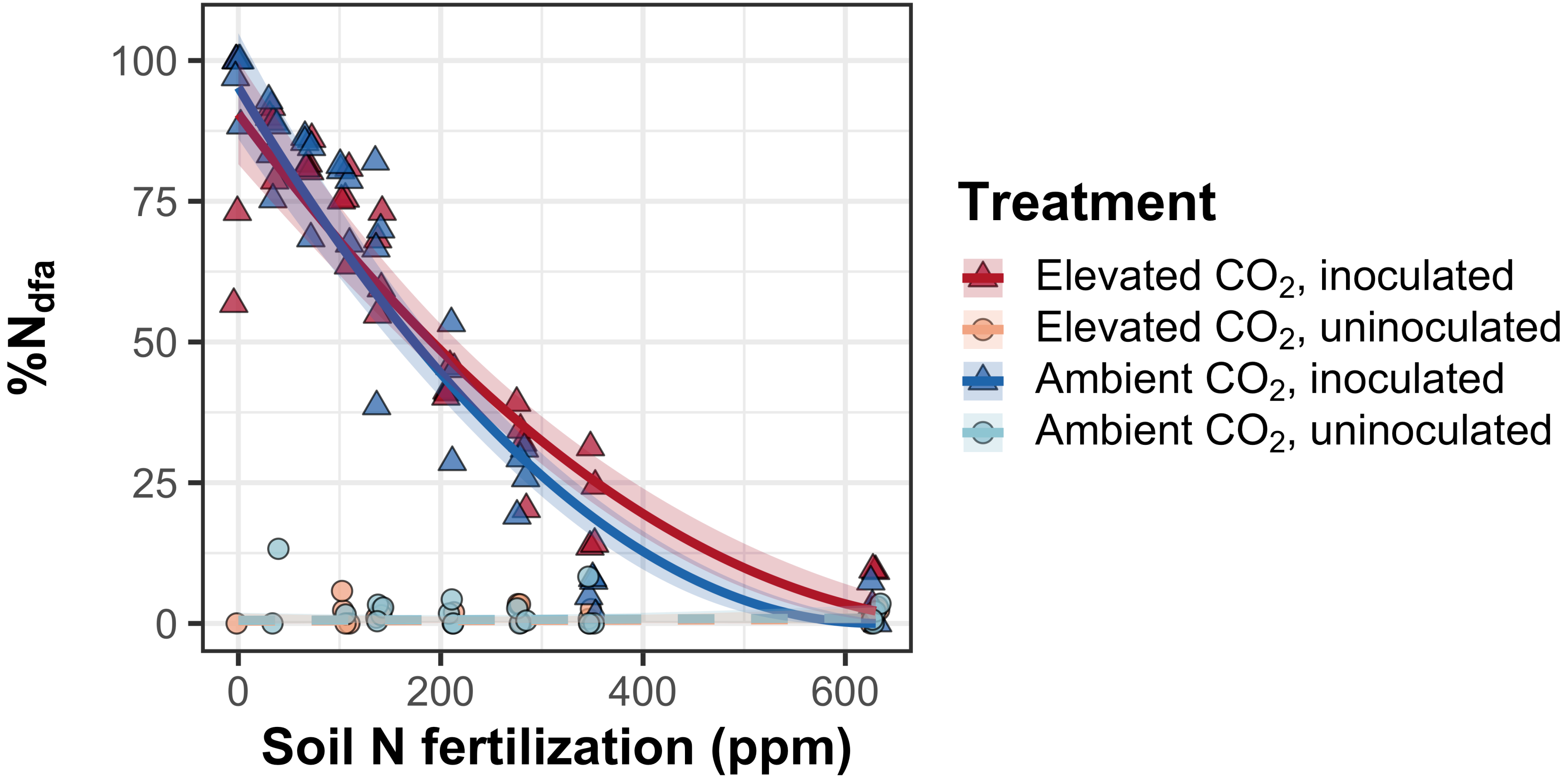
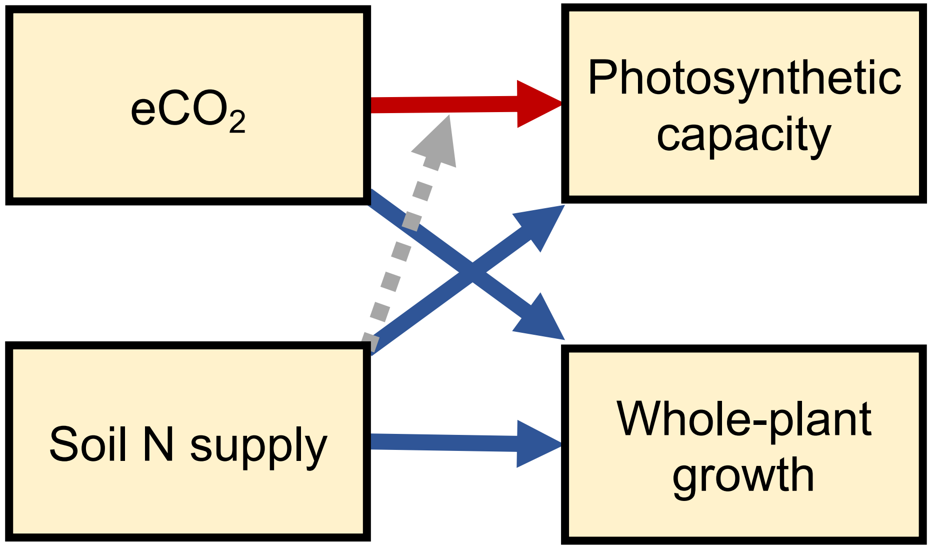
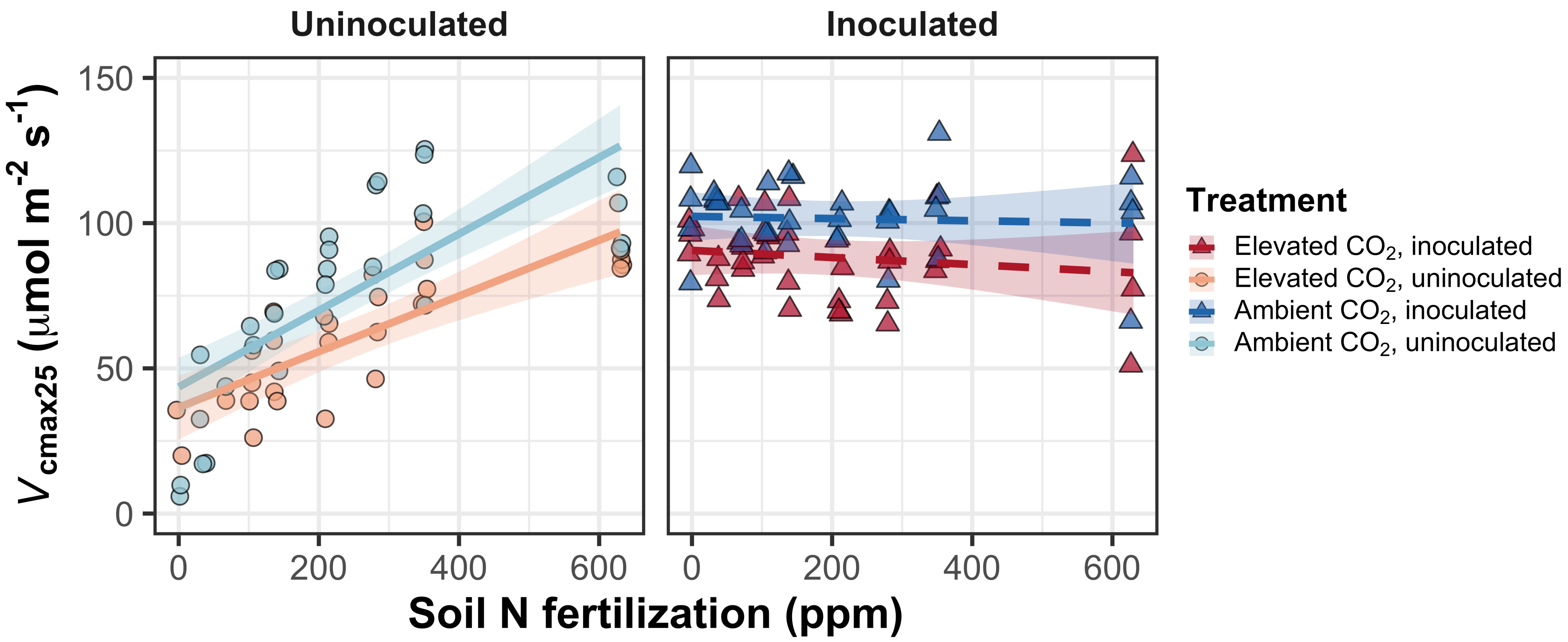


Conclusions

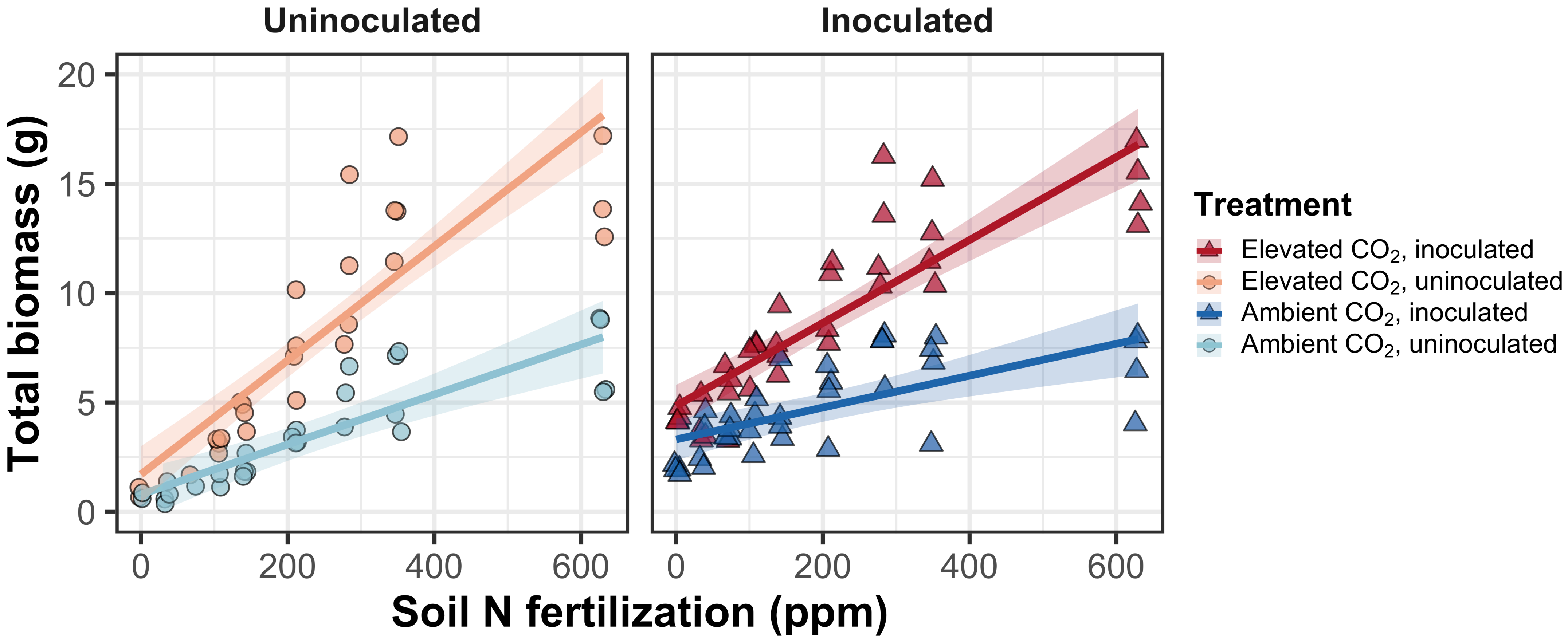
- N demand and supply control plant responses to eCO_2 at different scales
  - N supply → whole-plant response to eCO_2
  - N demand → leaf response to eCO_2



Increasing fertilization **increased** photosynthetic capacity, <u>but only in uninoculated plants</u>



Increasing fertilization **increased** total biomass **more strongly** in uninoculated plants



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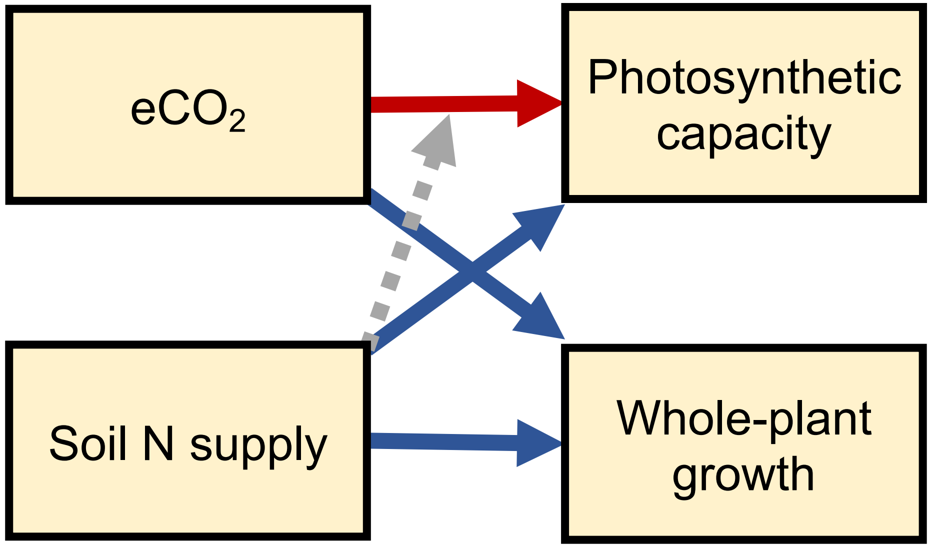
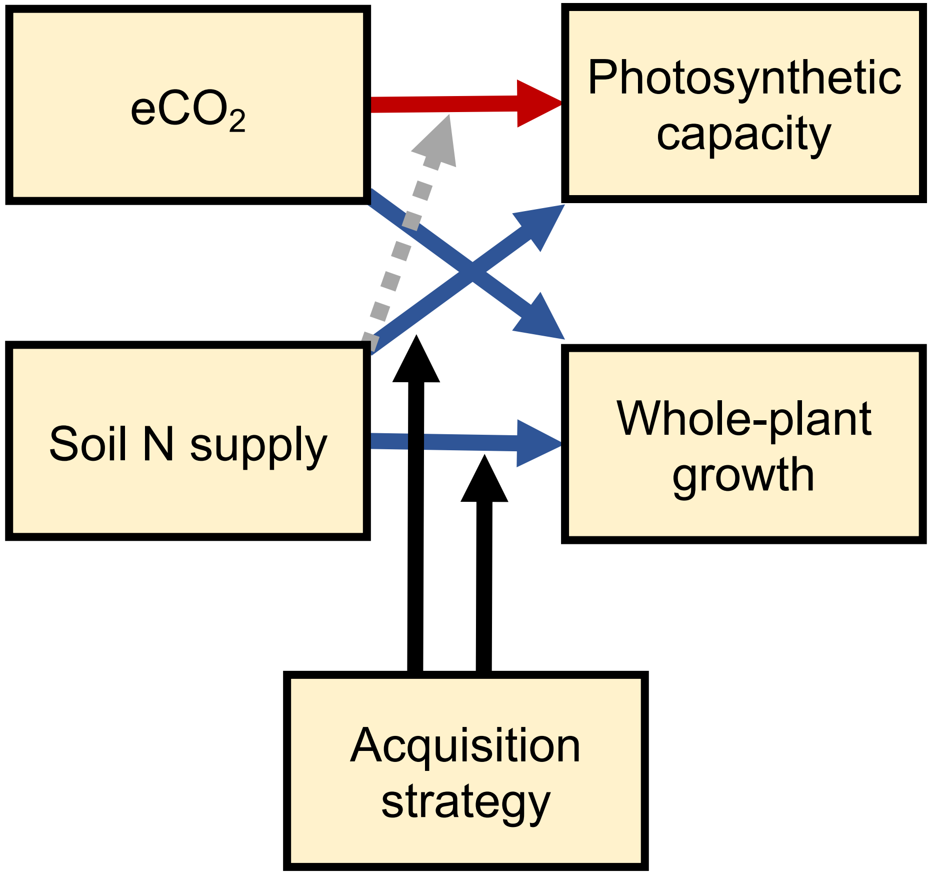


Conclusions

- N demand and supply control plant responses to eCO_2 at different scales
  - N supply → whole-plant response to eCO_2
  - N demand → leaf response to eCO_2
- Plant responses to fertilization are dependent on acquisition strategy



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Smith Lab MS student

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Smith Lab MS student

Snehanjana Chatterjee
Smith Lab PhD student

Hannah German
Smith Lab UG student

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Thank you!