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Plant photosynthetic and stoichiometric responses to rising CO_2 under phosphorus limitation

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Introduction

As plants require CO_2 for their photosynthesis, the anthropogenic rise in atmospheric CO_2 concentrations increases the productivity of plants (termed 'carbon fertilization'). At the same, the global cycles of the key plant nutrients Phosphorus (P) and Nitrogen (N) are altered, predominantly due emissions from intensive agriculture. Particular the ratio of N:P available to plants is rising, which may lead to natural ecosystems to become more P limited. However, it remains uncertain how the carbon fertilization effect is confounded by changes in the N:P ratio of available nutrients.

Photosynthesis can be limited by the maximum rate of carboxylation (V_{cmax}) or the maximum rate of electron transport (J_{max}) where generally a shift towards J_{max} limitation takes place with increasing CO_2 level. Furthermore the stomatal conductance (g_s) can be affected. Regarding the physiology of the plant, changes in the biomass and leaf morphology, like the specific leaf area (SLA), are expected when different nutrient and CO_2 inputs are applied. Acclimation of leaf nutrient concentrations is also expected and may correlate to changes in photosynthetic parameters. In this researched we investigated how the above mentioned variables are affected by both CO_2 level as P availability.

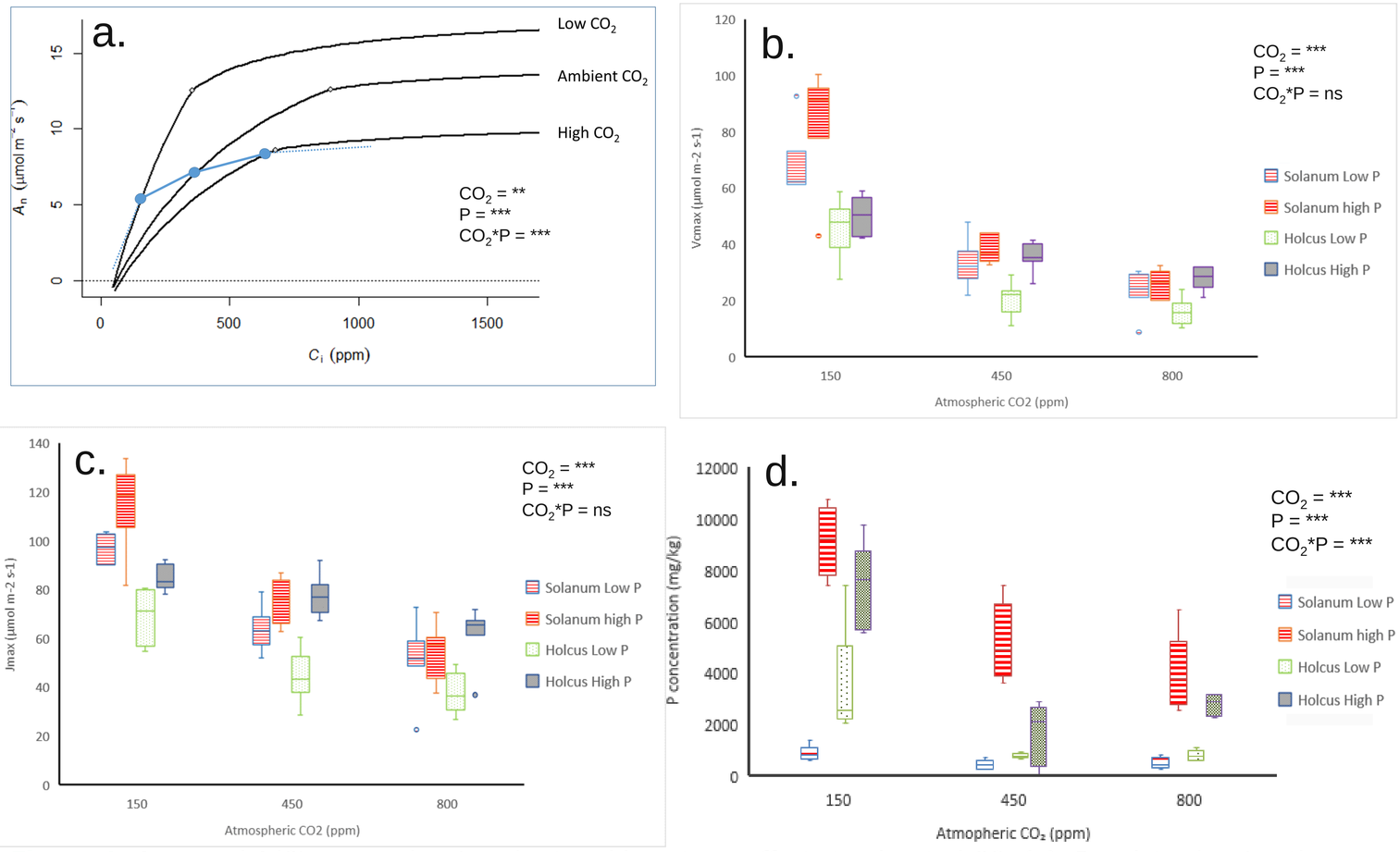


Figure 1: Averaged A/Ci curves showing short and long term effects to elevated CO_2 (a). Boxplots showing the response of V_{cmax} (b) J_{max} (c) and leaf P (d) to the CO_2 and P treatments for *Holcus lanatus* and *Solanum dulcamara*. ns = not significant + = $P \leq 0{,}10$ * = $P \leq 0{,}05$ ** = $P \leq 0{,}01$ *** = $P \leq 0{,}001$

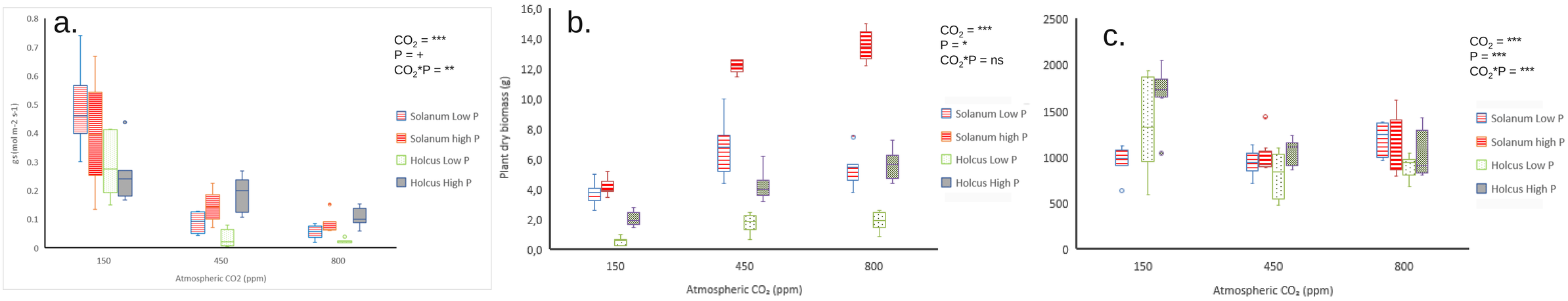
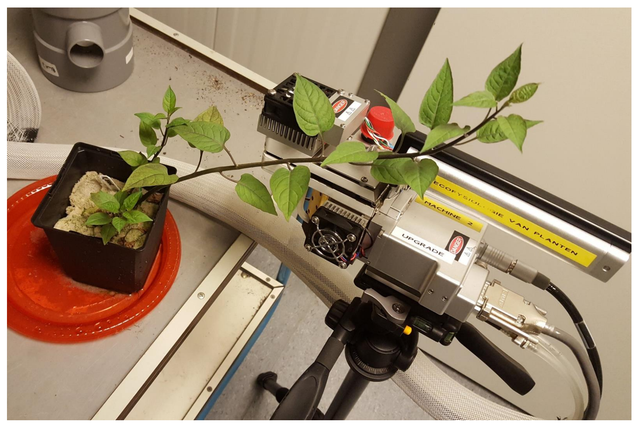


Figure 2: Boxplots showing the response from the left to the right of g_s (a), total biomass (b) and SLA (c) to the CO_2 and P treatments for *Holcus lanatus* and *Solanum dulcamara*. ns = not significant + = $P \leq 0{,}10$ * = $P \leq 0{,}05$ ** = $P \leq 0{,}01$ *** = $P \leq 0{,}001$

Table 1: Materials and methods

Methodology	
Plant material and growth conditions	• Controlled growth chamber experiment • C_3 grass and vine species *Holcus lanatus* and *Solanum dulcamara* • Plants grown in sand treated with nutrient solutions • No water stress and saturated light
Treatments	• CO_2 growth conditions: 150, 450, 800 ppm • Nutrient treatments: N:P ratio of 1:1, 45:1
Measurments	• Photosynthetic measurements and A/Ci curves measusured using with a portable photosynthesis system (Licor LI-6400XT) • Leaf traits and biomass measurements • Analysis of P and N content in the leaves
Analysis	Determining photosynthetic parameters (g_s, V_{cmax} and J_{max}) and physiological variables (SLA, dry biomass, N and P leaf content) and how they are affected by CO_2 and P level



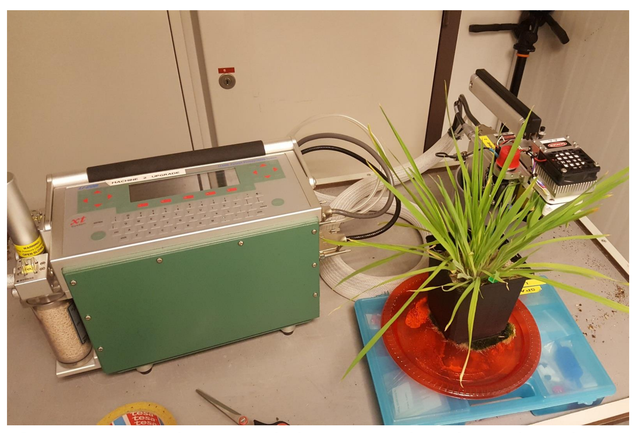


Figure 3: *Solanum dulcamara* (top) and *Holcus lanatus* (bottom) during photosynthesis measurements

Results

- Decrease in photosynthetic capacity, but increase of photosynthetic rate with elevated CO_2 as a result of downregulation of g_s, V_{cmax} and J_{max}
- Elevated CO_2 has a positive effect on the total biomass and SLA
- Leaf P content is lower under P limitation and decreases with increasing CO_2 cocentration
- Limitation of photosynthesis and plant growth by P limitation

Conclusions and discussion

- Increased photosynthetic efficiency with elevated CO_2
- Decreased photosynthetic efficiency under P limitation
- Increase in plant biomass, but can be limited by P limitation
- Changes more profound from 150 to 450 ppm
- Difference between species