Is photosynthetic enhancement sustained in *Q. robur* after three years of eCO_2?

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(1) Introduction

- Anthropogenic carbon dioxide (**CO_2**) is the main greenhouse gas driving change in the earth's climate [1].
- Rising CO_2 is expected to stimulate photosynthesis, at least in the short-term, but limited studies have been conducted in **mature forests** [2].
- There is evidence to suggest that photosynthesis acclimates to eCO_2 over a longer time period, known as **photosynthetic down-regulation**. Yet, results have been mixed [3].
- There are still many unanswered questions, particularly in mature forests, in regards to photosynthetic **enhancement**, **capacity** and the presence/absence of **down-regulation** in response to projected **CO_2 emissions** [4].

(2) Research Objectives

1. To quantify the photosynthetic response to eCO_2 for mature *Q. robur* and how environmental conditions influences this response.
2. To determine whether photosynthetic downregulation with eCO_2 occurred in *Q. robur*.
3. To establish the relationship between leaf N and photosynthetic capacity, and whether this is changed with eCO_2.

(3) Methods and Materials

This experiment is based at the Birmingham Institute of Forest Research Free Air CO_2 Enrichment (**BIFoR-FACE**) experiment in Staffordshire, UK.

Six (30m diameter) plots of mature woodland are paired into two treatments (n=3):
- elevated CO_2 (**eCO_2**)(~550ppm) and
- ambient CO_2 (**aCO_2**)(~407ppm).

Leaf gas exchange measurements and biochemical parameters (Vc_{max} and J_{max}) have been conducted in **the pre-treatment**, **1st and 3rd year** of CO_2 fumigation (2015,2017 and 2019), from **June to September.**

Diurnal *in situ* measurements have been conducted in the **upper oak** (*Quercus robur L.*) **canopy,** of one tree per plot, using a portable gas exchange system (**Li-6800**, LICOR).

***A/C*$_i$ curves** were taken to assess photosynthetic capacity (Vc_{max} and J_{max}). Curves were analysed using the 'ecophys' package in R.

Elemental analysis was conducted on upper canopy oak leaves, in 2015, 2018 and 2019, to obtain **leaf C, N** and **isotopic** data.

All statistical analysis were performed using R software ('LME' package).

(4) Results and Discussion

Light saturated **photosynthesis** (A_{sat}) **significantly increased** under eCO_2 treatment (+34%). This effect was sustained across the three sampling years ($p < 0.01$) (Fig.1).
= Photosynthetic enhancement slightly less than expected (37%) for this site following Nowak et al. (2004).

We observed no significant effect of **eCO_2** for both **Vc_{max}** or **J_{max}** (Fig 2.) Additionally, there no significant effects of **eCO_2** in foliar nitrogen (**N_{area}** or **N_{mass}**).
= Suggests there is no evidence towards the presence of photosynthetic down-regulation after three years in *Q. robur*

This study found no changes to the **J_{max}: Vc_{max} ratio**.
Suggesting co-ordination of photosynthetic processes with exposure to eCO_2.
= No re-allocation of nitrogen occurring in *Q. robur.*
→ Suggests N is not limiting in the system.

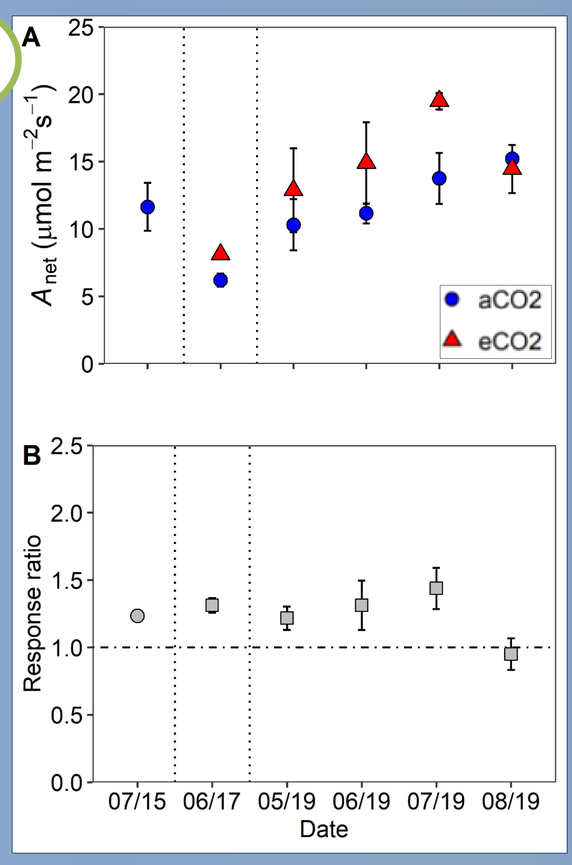
Figure 1. (**A**) Light-saturated net assimilation (A_{net}) and (**B**) the response ratio with eCO_2.

Figure 2. Maximum rates of (**A**) carboxylation (V_{cmax}) and (**B**) electron transport (J_{max}), in addition to (**C**) area based (N_a) and (**D**) mass based (N_m) leaf nitrogen.

Figure 3. Linear relationship between J_{max} and V_{cmax}.

Means (±SE) of whole-plot averages (n=3) for ambient (blue circles) and elevated (red triangles) CO_2 treatments. Data includes: pre-treatment ('07/15'); 1st Year ('06/17'); and the 3rd year ('05/19' - '08/19') of CO_2 fumigation.

1)



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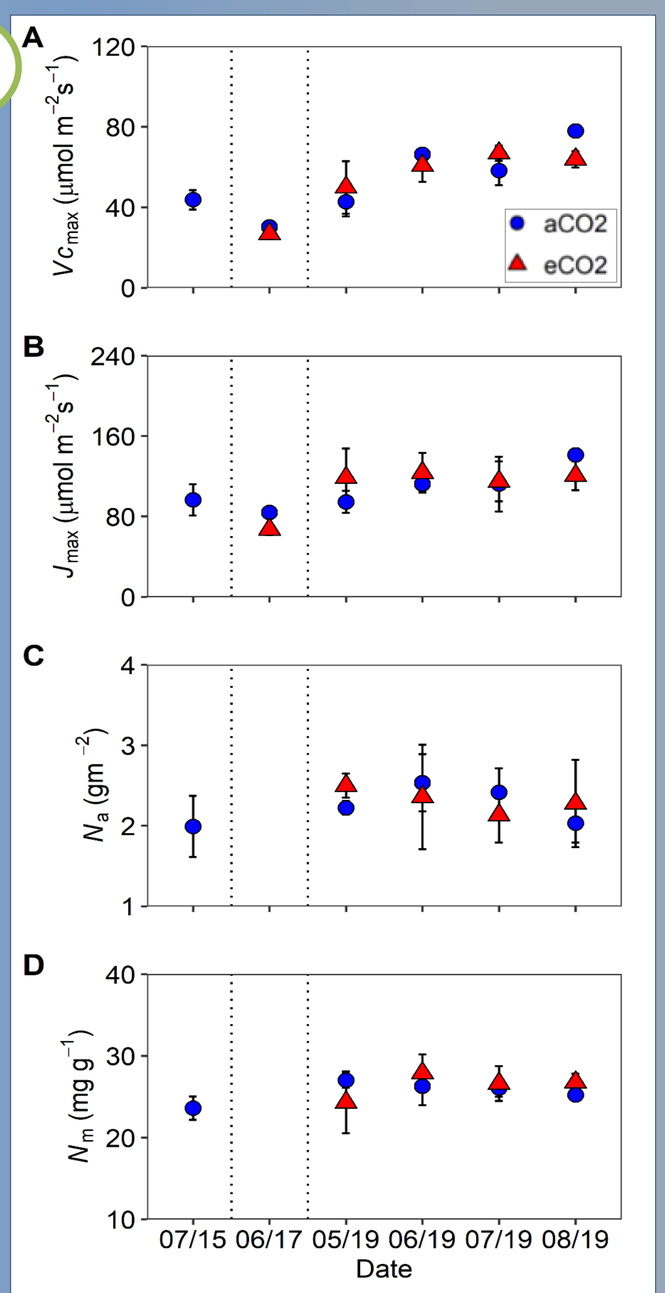

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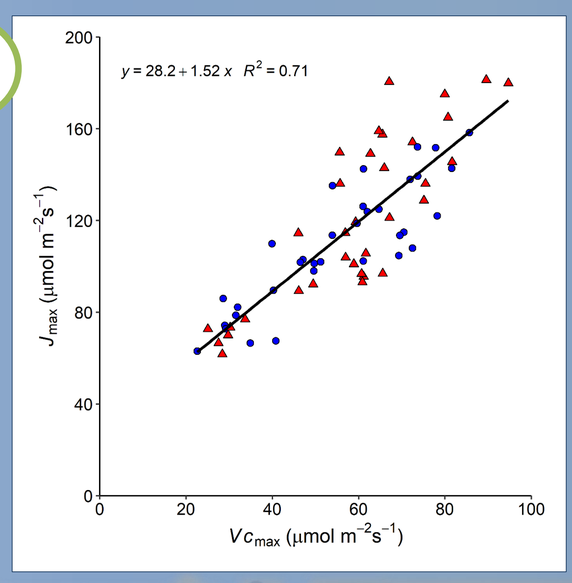

(5) Conclusion

- **A_{net} significantly increased** under eCO_2 **(~33%).**
→ Slightly lower than expected enhancement (37%) and other FACE, but higher than EucFACE (19%).
- No evidence for photosynthetic **down-regulation** in mature *Q. robur.*
→ Instead, **sustained photosynthetic enhancement**, implications for modelling.
→ Longer-term data required.
- Photosynthesis is likely not limited by soil nutrients.
→ **Re-assess** after further eCO_2 **for long-term** photosynthetic capacity.

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References: **[1]** Stocker TF *et al.* 2013. Climate Change 2013. Cambridge University Press. **[2]** Le QuéréC *et al.* 2016. Earth Syst. Sci. Data 8, 605–649. **[3]** Medlyn *et al.* 2011. Global change biology. 17, 2134–2144. **[4]** Norby.R *et al.* 2016. New Phytologist.209, 17–28.