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Early responses of leaf level assimilation to elevated [CO_2] in a mature oak forest

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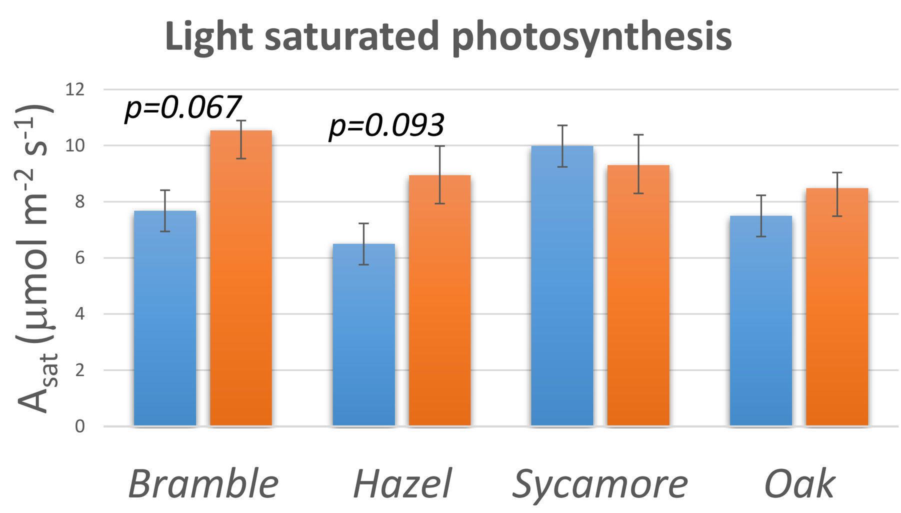
(1) Background

- Carbon dioxide (CO_2) from anthropogenic sources is the main greenhouse gas driving change in the Earth's climate [1].
- Increasing [CO_2] has stimulated plant C assimilation and growth and this 'CO_2-fertilisation' effect allowed terrestrial ecosystems to recapture 20-30% of all CO_2 released by human activity [2].
- It is unclear to what extent the CO_2-fertilisation effect can continue with further increase in [CO_2]. Lack of experimental data on mature forest ecosystems is a particular source of uncertainty [3,4].

(2) Research questions

- What is the short-term (3-4 months) effect of elevated [CO_2] on leaf level photosynthesis and stomatal conductance, the 'front end' of all ecosystem responses?
- Does elevated [CO_2] lead to downward acclimation of photosynthesis, e.g. decreases in maximum carboxylation rate (V_{cmax}) and maximum electron transport rate (J_{max}), the fundamental parameters used in many terrestrial ecosystem models (including the national UK model JULES)?
- How does the short-term effect of elevated [CO_2] on leaf level photosynthesis depend on species in different niches (overstorey versus understorey)?

(4) Results



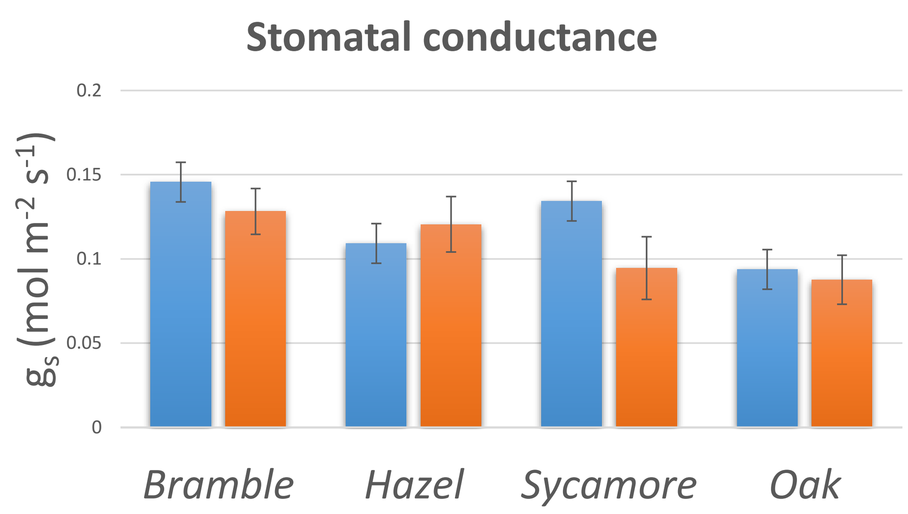


Figure 3: Light saturated net photosynthesis (A_{sat}) and stomatal conductance (g_s) measured at growth [CO_2] (blue columns: ambient [CO_2] plots, orange columns: elevated [CO_2] plots). Means and SE of n=3. P-values for differences between ambient and elevated [CO_2] plots reported where p<0.100.

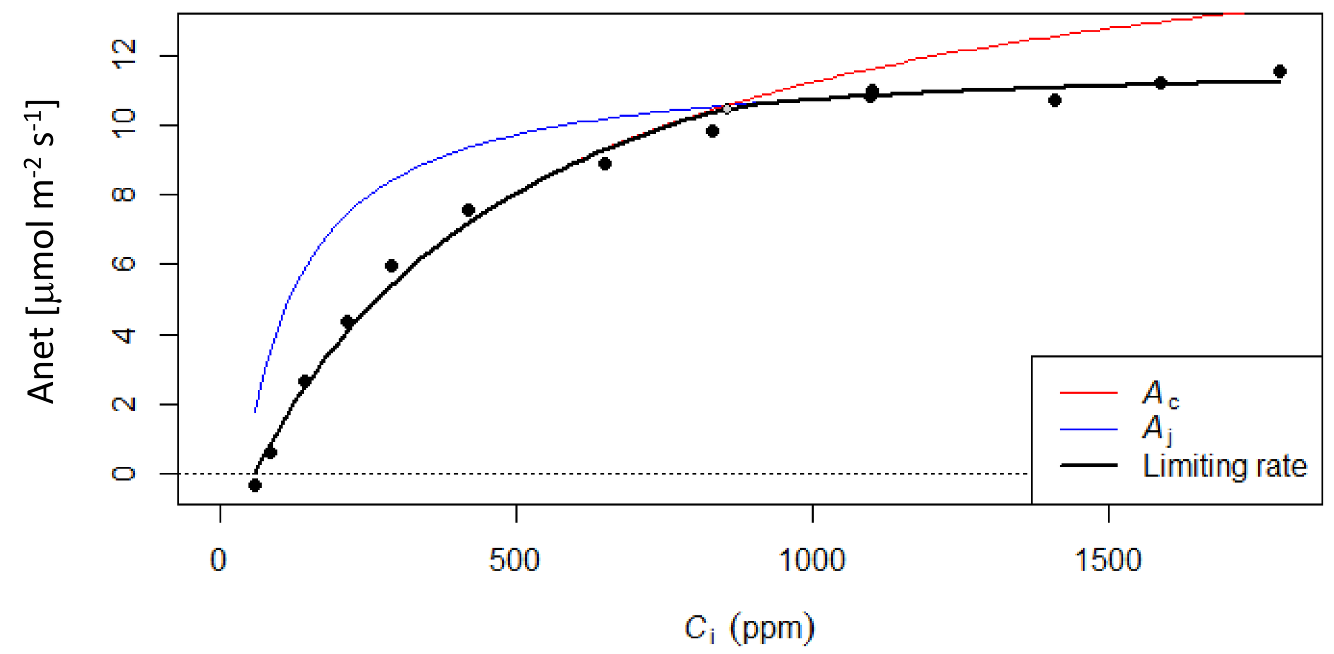
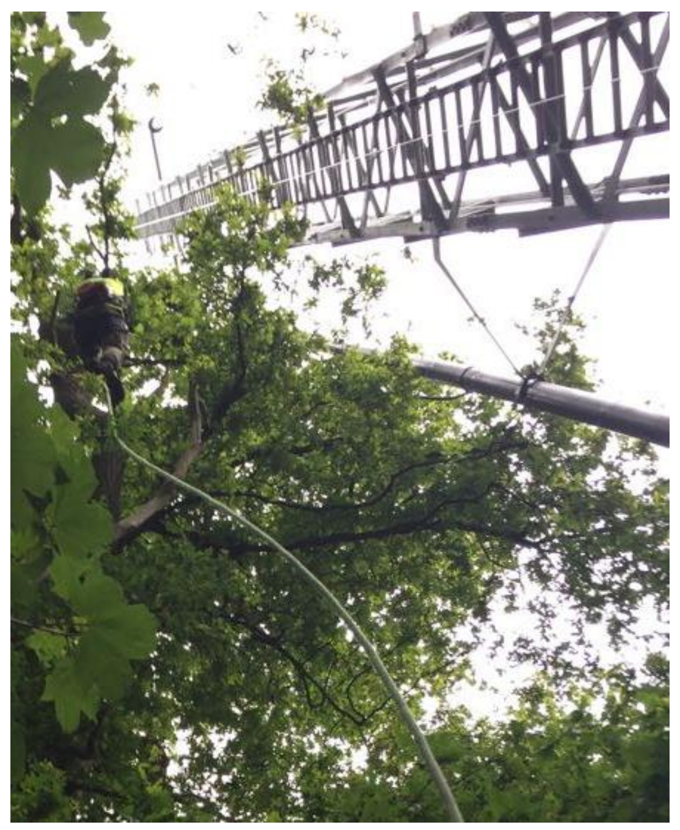


Figure 2: Example A-Ci curve measured on *Q. robur*, upper canopy. A_c is determined by the maximum carboxylation rate ($V_{cmax;}$ Table 1) and A_j by the maximum electron transport capacity ($J_{max;}$ Table 1). C_i leaf internal [CO_2] determined by outside [CO_2], photosynthetic rate and stomatal conductance, A_{net} net photosynthesis rate.

Table 1: Maximum carboxylation rate (V_{cmax}), maximum electron transport rate (J_{max}) and day respiration (R_{day}) from A-ci curves (Figure 2). Means and SEs of n=3 replicate plots in each. P-values for differences between ambient and elevated [CO_2] plots reported where p<0.100.

Species	[CO_2]	V_{cmax} [µmol m^{-2} s^{-1}]	J_{max} [µmol m^{-2} s^{-1}]	R_{day} [µmol m^{-2} s^{-1}]	J_{max}/V_{cmax}
Corylus avellana	ambient	39.4 ± 0.8	61.5 ± 2.5	1.0 ± 0.1	1.6 ± 0.1
(understorey)	elevated	44.7 ± 5.2	64.3 ± 4.8	0.9 ± 0.2	1.5 ± 0.1
Rubus sp.	ambient	45.2 ± 3.1	71.2 ± 8.5	0.9 ± 0.1	1.6 ± 0.1
(understorey)	elevated	50.5 ± 3.2	78.3 ± 4.7	0.9 ± 0.2	1.6 ± 0.1
Quercus robur	ambient	49.8 ± 6.2	108.0 ± 8.7 *p=0.053*	2.0 ± 0.4	2.2 ± 0.1
(upper canopy)	elevated	39.8 ± 2.7	78.8 ± 6.3	1.2 ± 0.2	2.0 ± 0.1
Acer pseudoplatanus	ambient	56.0 ± 2.3 *p=0.026*	112.6 ± 5.8	1.5 ± 0.1	2.0 ± 0.1
(mid-lower canopy)	elevated	42.5 ± 5.6	94.5 ± 20.3	1.7 ± 0.3	2.2 ± 0.2



Picture 1: Measuring photosynthesis with a LI-6400XT gas exchange system (left panel), cutting-down oak branches from the upper canopy for photosynthesis measurements (right panel)

(3) Material and Methods

Photosynthetic response curves (A-Ci curves) were measured at the Birmingham Institute of Forest Research Free Air CO_2 Enrichment (BIFoR-FACE) experiment [4] in Mill Haft, Staffordshire, during June 2017. CO_2-enrichment started beginning of April in 2017 (flush of *Quercus robur,* the dominant canopy tree). Four species were investigated: bramble (*Rubus fruticosus* agg., at 1 m above ground, understorey), hazel (*Corylus avellana*, 3 m, understorey), sycamore (*Acer pseudoplatanus*, 6 m, mid-understorey) and oak (*Quercus robur*, upper canopy).

Plants were grown either under current atmospheric [CO_2] (~407ppm) or elevated CO_2 (~150 ppm above the current [CO_2] concentration) in n = three replicate plots.

Measurements were conducted either on attached branches *in situ* (*Rubus, Corylus*) or on detached branches harvested by climbers (*Quercus*) or with pole pruners (*Acer*). A-Ci curves were recorded at saturating light (1000 PPFD) and close to ambient temperatures (20°C) with a portable open gas exchange system (LI-6400XT, LI-COR, Lincoln, NE, USA). Maximum carboxylation rate (V_{cmax}), maximum electron transport rate (J_{max}) and day respiration (R_{day}) were estimated from A-Ci curves (Figure 2) with the 'plantecophys' package of R [5].

(5) Preliminary conclusions

- Short-term stimulation of leaf level assimilation by elevated [CO_2] seemed more pronounced in understorey species bramble and hazel.
- Downward acclimation of photosynthesis may have moderated the [CO_2]-stimulation on assimilation of oak and particularly on sycamore.
- Effects on stomatal conductance were not significant for any species.
- Repeated measurement campaigns are needed to corroborate results and observe longer term changes.

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