Does Phloem Loading Strategy Impact Photosynthetic Response To Rising [CO_2]?

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Introduction

Plants have evolved different mechanisms for loading sucrose into the phloem for transport to heterotrophic tissues. Apoplastic loaders actively load sucrose into the phloem companion cells using sucrose transporters (Fig 1). Other species are thought to passively load sucrose into the phloem[1]. This work tested the hypothesis that passive phloem loaders, adapted to high mesophyll sugar concentrations, would avoid sugar-mediated down-regulation of photosynthetic capacity at elevated [CO_2].

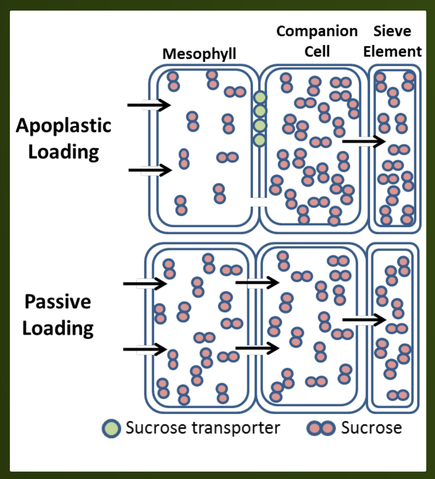

Figure 1. Different strategies of phloem loading in plants. Beet and pea use apoplastic loading, while peony and strawberry use a passive strategy to load sucrose into companion cells and sieve elements. Adapted from Rennie & Turgeon (2009).[1]

Hypotheses

1. Species with passive phloem loading will have greater photosynthetic responses to elevated [CO_2] compared to apoplastic loading species.
2. Passively loading species, adapted to high mesophyll sugar content, will avoid down-regulation of Rubisco activity at elevated [CO_2].

Methods

- Three 12′ x 12 ′ square Free Air CO_2 Enrichment plots (600 ppm) and three ambient CO2 plots (400 ppm) were established at the SoyFACE experimental facility. Each plot contained two passive phloem loading species: *Paeonia lactiflora* (peony) and *Fragaria x ananassa* (strawberry) and two apoplastic loading species: *Pisum sativum* (pea) and *Beta vulgaris* (beet).[1]
- Measurements of photosynthesis and samples for diurnal carbohydrates were taken May 29-30 & June 19-21, 2013 and May 30-June 1 & June 17-19, 2014.
- Diurnal measurements of photosynthesis were taken every 2-3 hrs during the day and photosynthetic capacity (maximum Rubisco carboxylation and electron transport capacity) was estimated from A/c_i curves fit with the Farquhar et al.[2] model of C_3 photosynthesis.

Results

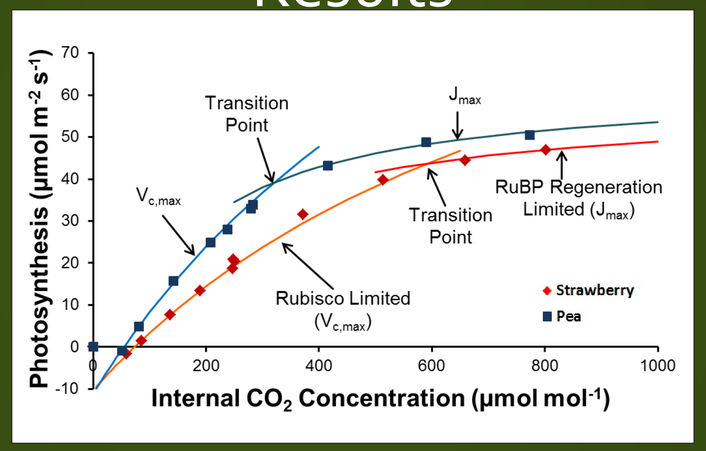

Figure 2. Example A/c_i curves for strawberry and pea. The transition point between Rubisco-limited ($V_{c,max}$) photosynthesis and electron transport-limited (J_{max}) was higher in passive loading species than apoplastic loading species.

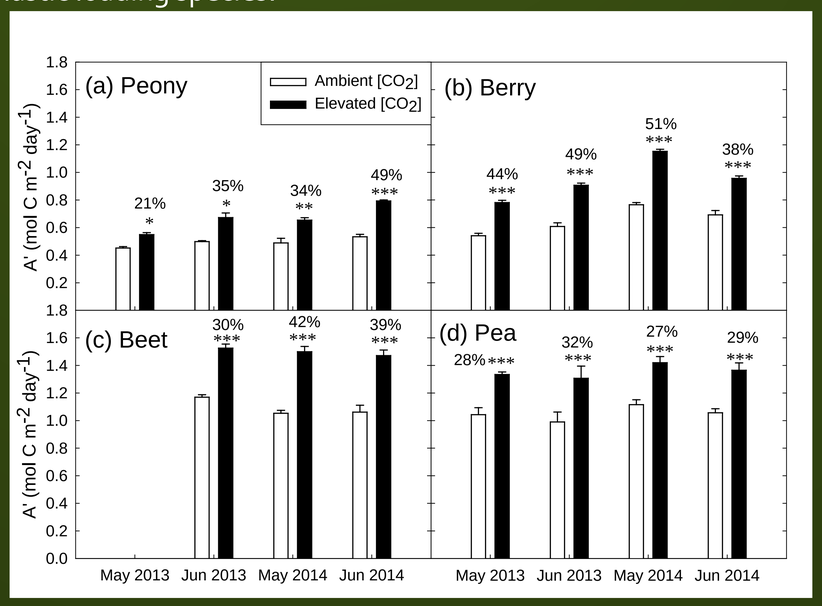

Figure 3. Diurnal photosynthesis significantly increased in all species at elevated [CO_2], and there was no consistent species x CO_2 interaction.

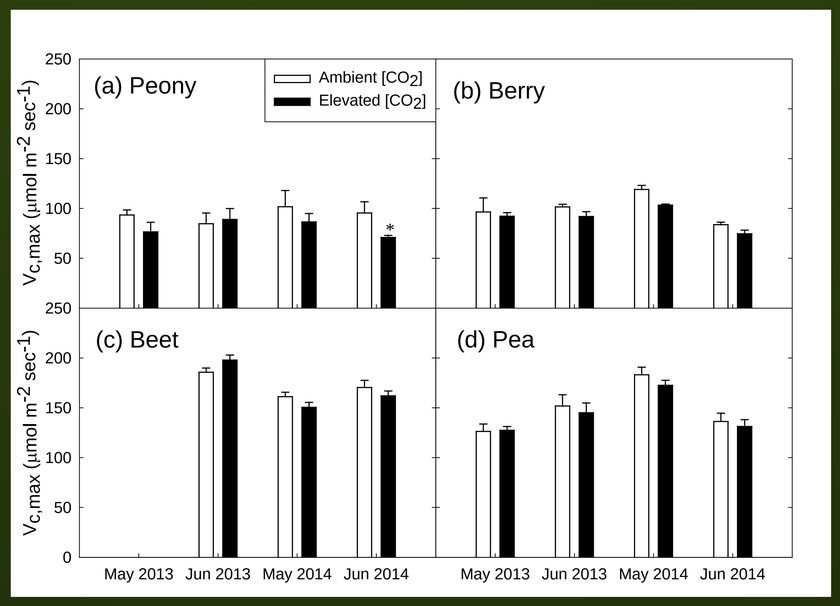

Figure 4. Maximum Rubisco carboxylation capacity ($V_{c,max}$) measured in 2013 and 2014. Growth at elevated [CO_2] had a significant, but small effect on $V_{c,max}$ in 2014, but not 2013. However, pairwise comparisons within timepoints and species revealed that only peony showed a significant decrease in $V_{c,max}$ in June 2014.

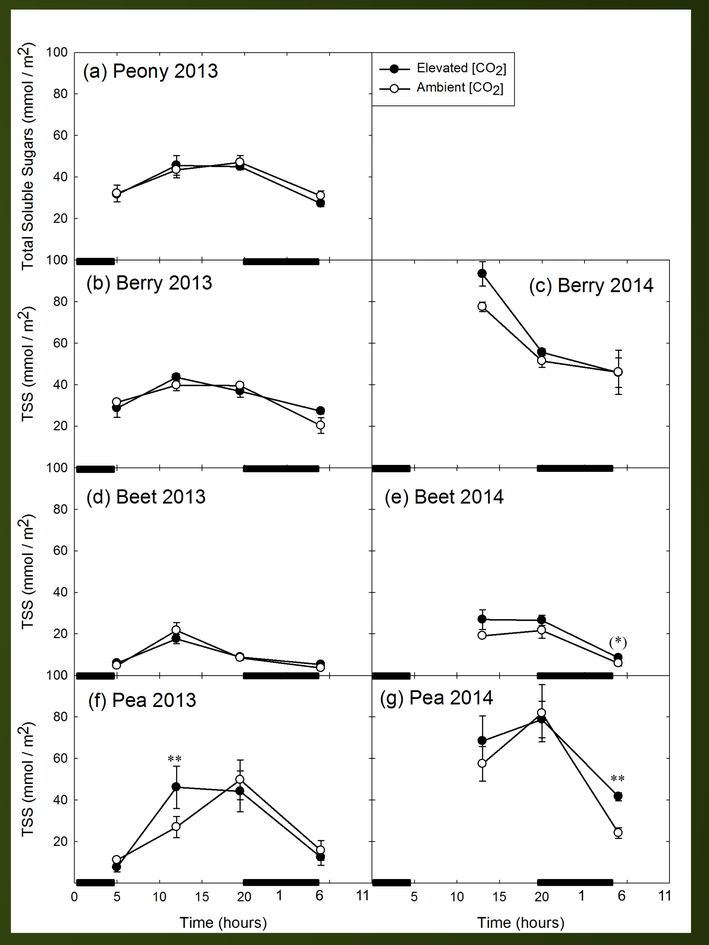

Figure 5. Diurnal measurements of soluble sugars (glucose, fructose and sucrose) in 2013 and 2014. There were no consistent effects of elevated [CO_2] on leaf sugar content in any of the species.

Conclusions

- In contrast to our hypothesis, there were no significant differences in photosynthetic response to elevated [CO_2] among species with different phloem loading strategies in the field experiment.
- All species showed enhanced daily C gain when grown at elevated [CO_2], and little evidence for down-regulation of photosynthetic capacity.
- Future work is surveying all published literature of known passive and apoplastic loaders to further test these hypotheses.

Acknowledgements

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References

[1]Rennie EA and Turgeon R (2009). A comprehensive picture of phloem loading strategies. Proc Natl Acad Sci **106**: 14162-14167.

[2]Farquhar GD, von Caemmerer S, Berry JA (1980) A biochemical model of photosynthetic assimilation in C3 species. Planta 149: 78-90.