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Rising CO_2 widens the transpiration-photosynthesis optimality space

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Stomatal conductance (g_s) and photosynthetic biochemistry, typically expressed by the temperature-adjusted maximum rates of carboxylation (V_{cmax}) and electron transport (J_{max}), are key traits in land ecosystem models. Contrary to the many approaches available for simulating g_s responses, the biochemical parameters V_{cmax} and J_{max} are often treated as static traits in ecosystem models. However, observational evidence indicates that V_{cmax} and J_{max} respond to persistent changes in atmospheric CO_2. Hence, ecosystem models may be improved by incorporating coordinated responses of photosynthetic biochemistry and g_s to atmospheric CO_2.

Recently, Prentice et al. (2014) proposed an optimality framework (referred to as the Prentice framework from here on) to predict relationships between V_{cmax} and g_s based on Fick's law, Rubisco-limited photosynthesis and the carbon costs of transpiration and photosynthesis. Here we show that this framework is, in principle, suited to predict CO_2-induced changes in the $V_{cmax} - g_s$ relationships. The framework predicts an increase in the V_{cmax}:g_s-ratio with higher atmospheric CO_2, whereby the slope of this relationship is determined by the carbon costs of transpiration and photosynthesis. For our empirical analyses we consider that the carbon cost of transpiration is positively related to the plant's Huber value (sapwood area/leaf area), while the carbon cost of photosynthesis is positively related to the maintenance cost of the photosynthetic proteins.

We empirically tested the predicted effect of CO_2 on the V_{cmax}:g_s-ratio in two genotypes of *Solanum dulcamara* (bittersweet) that were grown from seeds to maturity under 200, 400 and 800 ppm CO_2 in walk-in growth chambers with tight control on light, temperature and humidity. Seeds of the two *Solanum* genotypes were obtained from two distinct natural populations; one adapted to well-drained sandy soil (the 'dry' genotype) and one adapted to poorly-drained clayey soil (the 'wet' genotype). Measurements of g_s and V_{cmax} were obtained with a portable photosynthesis system.

Our empirical results support the prediction that the V_{cmax}:g_s-ratio increases with higher CO_2 in both *Solanum* genotypes. The 'dry' genotype revealed a significantly higher Huber value and lower V_{cmax} than the 'wet' genotype at each CO_2 growth level. Moreover, we found that the down-regulation of V_{cmax} under higher CO_2 was stronger in the 'dry' genotype than in the 'wet' genotype, whereas no change in the Huber value was observed between CO_2 levels. Consistent with the theoretical trade-off between the resulting costs of transpiration and photosynthesis, we found that the CO_2-induced increase in the V_{cmax}:g_s-ratio was stronger in the 'wet' genotype than in the 'dry' genotype. Given the divergence of V_{cmax}:g_s relationships observed, we conclude that rising atmospheric CO_2 may widen the $V_{cmax} - g_s$ optimality space available for plants to achieve an optimal trade-off between photosynthesis and transpiration.

References

Prentice, I. C., Dong, N., Gleason, S. M., Maire, V. and Wright, I. J.: Balancing the costs of carbon gain and water transport: testing a new theoretical framework for plant functional ecology, Ecol. Lett., 17(1), 82–91, 2014.