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CO_2-induced photosynthetic and stoichiometric responses to phosphorus limitation

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Carbon fertilisation from rising atmospheric CO_2 concentrations increases the productivity of plants globally. Meanwhile, the global cycles of Nitrogen (N) and Phosphorus (P) are also altered due to anthropogenic emissions. In general, the additional supply of N is expected to exceed that of P, leading to an increase in P limitation in natural ecosystems. Although the direct carbon fertilisation effect and the interaction with available N is relatively well understood, it remains uncertain how carbon fertilisation is confounded by the availability of P. It is hypothesised that (i) the photosynthetic P-use efficiency increases at elevated CO_2 owing to a direct increase in photosynthesis and (ii) the photosynthetic maximum carboxylation rate (Vcmax) and electron transport rate (Jmax) are down-regulated in response to a combination of elevated CO_2 and P-limitation via a coordinated reduction of leaf N and P content per unit leaf area. In this study we examined the hypothesised effects of P limitation and CO_2 fertilisation on the photosynthetic and stoichiometric responses of three plant species: Holcus lanatus (C3 grass), Panicum miliaceum (C4 grass) and Solanum dulcamara (C3 herb). Individuals of these species were grown at sub-ambient (150 ppm), modern (450 ppm) and elevated CO_2 concentrations (800 ppm) and exposed to an N:P treatment consisting of either severe nitrogen limitation at an N:P ratio of 1:1, or severe P limitation at an N:P ratio of 45:1, with a similar supply rate of N. Our results show significant effects of growth CO_2 and P supply on Vcmax and Jmax, as well as the whole-plant biomass at the point of harvest. Interaction effects between growth CO_2 and P supply were observed for the light-saturated photosynthesis rate, stomatal conductance, leaf P content, and the N:P ratio of the leaf. No significant change in the leaf N content was observed across treatments. These results suggest that limited availability of P constrains the biochemical potential for plants to up-regulate Vcmax and Jmax. This effect is most prominently expressed at low CO_2 growth conditions, which induce strong up-regulation of Vcmax and Jmax when P is not limiting. Conversely, the down-regulation of Vcmax and Jmax at elevated CO_2 is more pronounced when P is limiting. Hence, the combined effects of rising CO_2 and additional P limitation may result in additional down-regulation of Vcmax and Jmax and a subsequent waning of the CO_2 fertilisation effect. These results highlight the need to consider P limitation in global vegetation models when studying carbon fertilisation effects.