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Atmospheric CO_2 level affects plants' carbon use efficiency: insights from a ^{13}C labeling experiment on sunflower stands

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The increase of atmospheric CO_2 concentration has been shown to stimulate plant photosynthesis and (to a lesser extent) growth, thereby acting as a possible sink for the additional atmospheric CO_2. However, this effect is dependent on the efficiency with which plants convert atmospheric carbon into biomass carbon, since a considerable proportion of assimilated carbon is returned to the atmosphere via plant respiration. As a core parameter for carbon cycling, carbon use efficiency of plants (CUE, the ratio of net primary production to gross primary production) quantifies the proportion of assimilated carbon that is incorporated into plant biomass. CUE has rarely been assessed based on measurements of complete carbon balance, due to methodological difficulties in measuring respiration rate of plants in light. Moreover, foliar respiration is known to be inhibited in light, thus foliar respiration rate is generally lower in light than in dark. However, this phenomenon, termed as inhibition of respiration in light (IRL), has rarely been assessed at the stand-scale and been incorporated into the calculation of CUE. Therefore, how CUE responses to atmospheric CO_2 levels is still not clear. We studied CUE of sunflower stands grown at sub-ambient CO_2 level (200 μmol mol-1) and elevated CO_2 level (1000 μmol mol-1) using mesocosm-scale gas exchange facilities which enabled continuous measurements of $^{13}CO_2$/$^{12}CO_2$ exchange. Appling steady-state ^{13}C labeling, fluxes of respiration and photosynthesis in light were separated, and tracer kinetic in respiration was analyzed. This study provides the first data on CUE at a mesocosm-level including respiration in light in different CO_2 environments. We found that CUE of sunflower was lower at an elevated CO_2 level than at a sub-ambient CO_2 level; and the ignorance of IRL lead to erroneous estimations of CUE. Variation in CUE at atmospheric CO_2 levels was attributed to several mechanisms. In this study, CO_2 enrichment i) affected the size of respiratory substrate pools and the relative contribution of temporary storage pools and current assimilation pools; ii) affected the extent of inhibition of stands' respiration in light, which was related to leaf-level re-fixation of respired CO_2; and iii) influenced the ratio of leaf mass to total plant mass. Our study highlights the necessity of integrating measurement of respiration in light in assessing carbon cycling. If the decrease of CUE by CO_2 enrichment is a general response of terrestrial ecosystems, the buffering effect of plants C acquisition to the rise of atmospheric CO_2 is lower than estimated so far.