The interrelationship of $p$CO$_2$, soil moisture content, and biomass fertilization expressed in the $\delta^{13}$C value of C$_3$ plant tissue

A. Hope Jahren$^1$ and Brian A. Schubert$^2$

$^1$Centre for Earth Evolution and Dynamics, University of Oslo, N-0315, Oslo, Norway; $^2$School of Geosciences, University of Louisiana at Lafayette, Lafayette, LA 70504

Hundreds of chamber and field experiments have shown an increase in C$_3$ plant biomass in response to elevated atmospheric carbon dioxide ($p$CO$_2$); however, secondary water and nutrient deficits are thought to limit this response. Some have hypothesized that secondary limitation might be self-alleviating under elevated $p$CO$_2$ as greater root biomass imparts enhanced access to water and nutrients. Here we present results of growth chamber experiments designed to test this hypothesis: we grew 206 *Arabidopsis thaliana* plants within 5 growth chambers, each set at a different level of $p$CO$_2$: 390, 685, 1075, 1585, and 2175 ppmv. Within each growth chamber, soil moisture content ($\theta_m$) was maintained across a spectrum: 1.50, 0.83, 0.44, and 0.38 g g$^{-1}$. After 3 weeks of total growth, tissues were analyzed for both biomass and net carbon isotope discrimination ($\Delta^{13}$C) value. From these values, we calculated $\Delta_{\text{residual}}$, which represents the residual effect of water stress after subtraction of the effect of $p$CO$_2$ due to photorespiration. Across the full range of moisture content, $\Delta_{\text{residual}}$ displayed a significant $\sim$2.5‰ increase with increasing $p$CO$_2$. This further implies a $\sim$0.1 unit increase in $c_i/c_a$, consistent with decreased water stress at elevated $p$CO$_2$. The influence of CO$_2$ fertilization on the alleviation of water stress was further evidenced in a positive correlation between percent biomass change and $\Delta_{\text{residual}}$, such that a doubling of plant biomass yielded a 1.85‰ increase in carbon isotope discrimination. In addition to providing new insight into water uptake in plants growing under elevated carbon dioxide, these data underscore the importance of separating the effects of increased $p$CO$_2$ (*via* photorespiration) and altered $c_i/c_a$ (*via* stomatal conductance) when considering changes in the $\Delta^{13}$C value of C$_3$ land plants during the Anthropocene, or across any geological period that includes a marked change in global carbon cycling.