Long-term growth of soybean at elevated $[CO_2]$ does not cause acclimation of stomatal conductance under fully open-air conditions.

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INTRODUCTION

•Accurately predicting plant function and global biogeochemical cycles later this century will be complicated if stomatal conductance (g_s) acclimates to growth at elevated $[CO_2]$. We define acclimation here as an effect of long-term growth at elevated $[CO_2]$ on the short-term response of g_s to A, H or $[CO_2]$.
•If acclimation to elevated $[CO_2]$ occurs, photosynthetic and stomatal models will require parameterization at each growth $[CO_2]$ of interest.
•Photosynthetic acclimation to growth at elevated $[CO_2]$ commonly occurs and is factored into models of terrestrial biosphere carbon fluxes.
•Acclimation of g_s has rarely been examined, even though stomatal density often changes with growth $[CO_2]$.
•The Ball, Woodrow & Berry (1987) model predicts g_s on the basis of a linear, empirical equation:

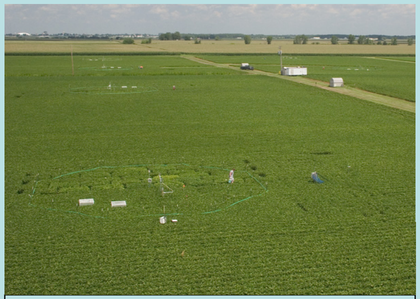
Eqn. 1 $$g_s = g_0 + m\frac{A\mathrm{H}}{[CO_2]}$$

A is the net rate of photosynthetic CO_2 assimilation,
H is the fractional atmospheric relative humidity,
$[CO_2]$ is the atmospheric $[CO_2]$ at the leaf surface,
g_0 is the y-axis intercept, and
m is the slope of the line.

AIM & METHODS

•AIM: To test if soybean grown at elevated $[CO_2]$ using Free-Air CO_2 Enrichment (FACE) undergoes stomatal acclimation, such that the Ball et al (1987) model parameters g_0 or m are changed, reflecting altered sensitivity of g_s to $[CO_2]$, H and/or A.

• Soybean was grown under field conditions at ambient $[CO_2]$ (378 µmol mol^{-1}) and elevated $[CO_2]$ (552 µmol mol^{-1}) using Free-Air $[CO_2]$ Enrichment (FACE) in Illinois, USA (www.soyface.uiuc.edu).
•Soybean is inbred and the field site provides relatively uniform growth conditions. This genetic and environmental uniformity increases the power to detect subtle $[CO_2]$ treatment effects.
•The soybean-corn agroecosystem is arguably the largest single ecosystem type in the USA, covering >60 million hectares of the contiguous states.
•The Ball et al (1987) model was parameterized and validated for the youngest fully expanded soybean leaves using LI-6400 gas exchange systems.



Plots of soybean grown with FACE fumigation at CO_2 concentrations predicted for 2050

RESULTS & DISCUSSION

Parameterization of the Ball, Woodrow & Berry (1987) model of g_s in the laboratory → Model validation in the field → Predicting variation in the CO_2 effect on g_s over time

Figure 1. Representative course of **(a)** incident photosynthetic photon flux density (PPFD), $[CO_2]$ and atmospheric saturation vapor pressure deficit (D) in the leaf chamber during gas exchange measurements of **(b)** steady-state net photosynthetic CO_2 assimilation (A) and stomatal conductance (g_s). Leaves were harvested pre-dawn, re-cut under water and measured in the laboratory. The response of gas exchange to variation in $[CO_2]$, PPFD and D was tested consecutively, while minimizing variation in the other variables. Steady-state gas exchange was attained after each stepwise change in conditions.

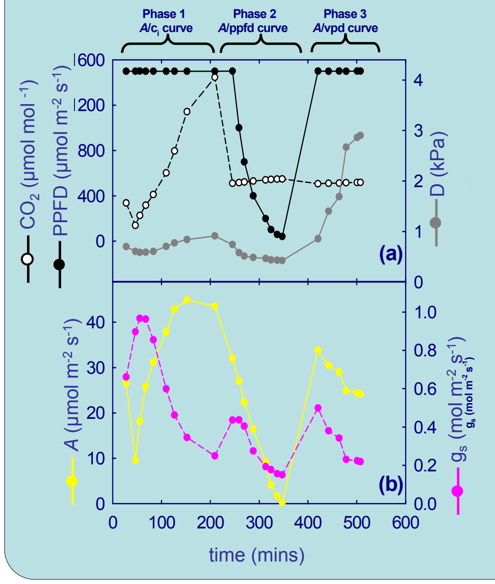
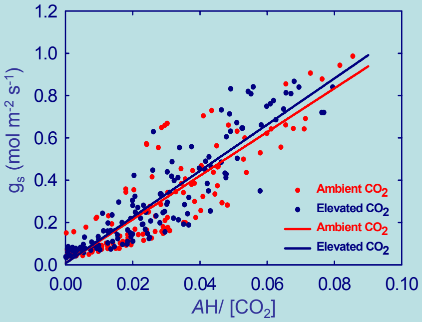


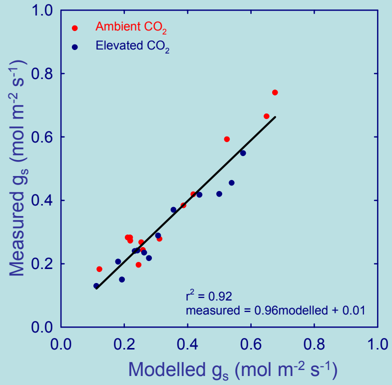
Figure 2. Relationship of measured stomatal conductance (g_s) with the product of net photosynthetic CO_2 assimilation (A) and fractional relative humidity (H) divided by the $[CO_2]$ measured in the laboratory. Individual points represent gas exchange measurements of a single leaf. Only data for which $[CO_2]$ > 150 µmol mol^{-1} were used. Regression lines for ambient and elevated $[CO_2]$ grown plants represent the treatment means (N = 4) of linear functions fitted to data from individual leaves.



Ambient $[CO_2]$: g_s = 10.6(AH/ $[CO_2]$)+0.008
Elevated $[CO_2]$: g_s = 10.9(AH/ $[CO_2]$)+0.007

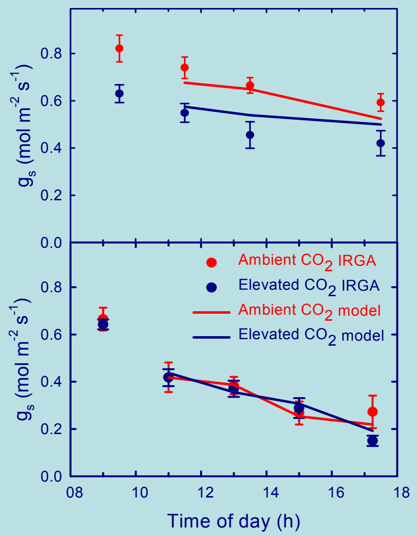
•There was no significant difference in g_0 and m under ambient and elevated $[CO_2]$
•The dependence of g_s on A, H and $[CO_2]$ at the leaf surface was unaltered by long-term growth at elevated $[CO_2]$

Figure 3. Relationship between stomatal conductance of the youngest fully expanded leaf measured over the diurnal period of 4 days in the field (measured g_s) and stomatal conductance predicted by the model parameterized from laboratory gas exchange measurements (modeled g_s).



•Modelled g_s corresponded very closely with g_s measured in the field under both ambient and elevated $[CO_2]$
•This suggests that (1) the commonly observed decrease in g_s under elevated $[CO_2]$ is due entirely to the direct instantaneous effect of $[CO_2]$ on g_s and (2) that there is no long-term acclimation of stomatal conductance independent of photosynthetic acclimation.

Figure 4. Diurnal course of stomatal conductance (g_s) measured *in situ* at SoyFACE (point values) and predicted by the model parameterized from laboratory gas exchange measurements (line values), on days of year 218 and 238. Measured data are mean values for 4 replicate plots ± 1SE. Modeled data are means of values modeled independently for each of the four plots per treatment.



•With inputs of *in situ* A, H and $[CO_2]$, the model successfully predicted variation in the effect of $[CO_2]$ on g_s over time

•The model accurately predicted g_s of field grown plants under ambient and elevated $[CO_2]$, when using statistically indistinguishable values for the parameters g_0 and m.
•This demonstrates that (1) there was no stomatal acclimation and (2) g_s under ambient and elevated $[CO_2]$ can be modeled without the need for parameterization at each growth $[CO_2]$.

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ADB Leakey, CJ Bernacchi, DR Ort & SP Long (2006) Long-term growth of soybean at elevated $[CO_2]$ does not cause acclimation of stomatal conductance under fully open-air conditions. *Plant, Cell & Environment* 29:1794-1800.