

# Effects of CO<sub>2</sub> and drought on N<sub>2</sub> fixation in field-grown soybean plants

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## INTRODUCTION

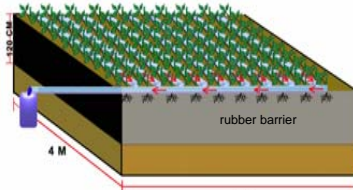
The effects of elevated concentrations of atmospheric CO<sub>2</sub> on plant productivity are of great concern in agricultural systems. In soybean, increased concentrations of CO<sub>2</sub> have been shown to increase photosynthesis and carbon allocation to developing organs, including roots. Increased carbon transport may increase crop production by stimulating symbiotic N<sub>2</sub> fixation in legumes. Conversely, drought has been shown to reduce N<sub>2</sub> fixation in soybean. Climate models combining elevated CO<sub>2</sub> with regional weather conditions suggest that some soybean growing areas will experience increased drought along with higher CO<sub>2</sub> concentrations, thus drought may counteract beneficial aspects of increased CO<sub>2</sub>.

## OBJECTIVES

- To quantify the effects of elevated CO<sub>2</sub> and increased drought, alone and in combination, on nodulation and N<sub>2</sub> fixation by soybean.
- To determine if, and by how much, CO<sub>2</sub> will counteract the effects of drought.

## METHODS

- This study took place in a soybean (*Glycine max*) agroecosystem at the University of Illinois Soybean Free Air CO<sub>2</sub> Enrichment (SOYFACE) experiment.
- SOYFACE is set up with a full factorial combination of CO<sub>2</sub> and drought treatments.
- Atmospheric levels of CO<sub>2</sub> were increased to 550 ppm, ~180 ppm above ambient conditions
- Drought treatments used gutters, placed between crop rows, to intercept rainfall. Gutters covered 40% of the subplot area. Soil moisture in the rooting layer was reduced by up to 15%

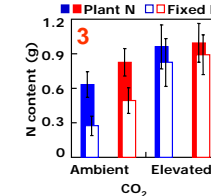
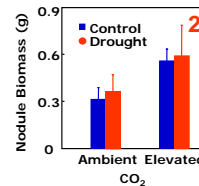
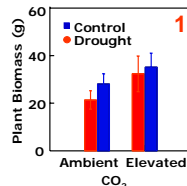
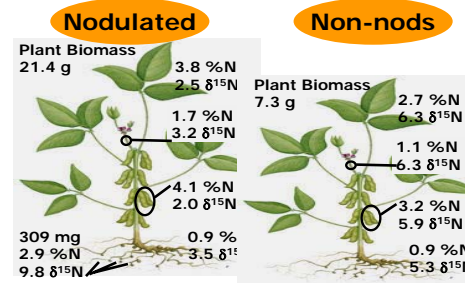


- Whole soybean plants were harvested at peak plant biomass in early September 2003. After harvest, plants were divided by tissue, dried, weighed, and ground for elemental and isotopic analysis.
- $\delta^{15}\text{N}$  was analyzed using an infrared mass spec with an elemental analyzer.
- Fixation was determined using natural abundance of  $^{15}\text{N}$  and a non-nodulating isolate of soybean as a reference.
- N from fixation has lower  $\delta^{15}\text{N}$  than soil sources (fertilizer).

## RESULTS

- Non-nodulating plants showed clear differences in  $\delta^{15}\text{N}$ , indicating the absence of fixation. The lack of N<sub>2</sub> fixation had a distinct effect on plant size.

- Elevated CO<sub>2</sub> increased tissue (36%) mass, nodule mass (70%), and N content compared to ambient levels. (1, 2, 3) Drought effects were not significant.



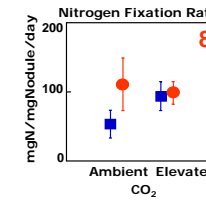
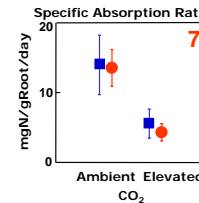
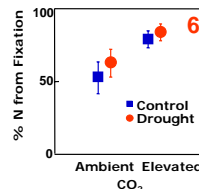
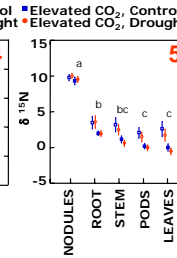
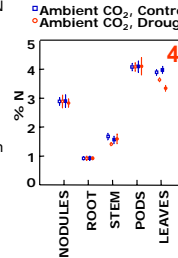
- Differences in allocation of N among tissues were clear. 4. The amount of fixed N generally increased from the top down in the plant, especially at high CO<sub>2</sub> 5.

- Elevated CO<sub>2</sub> increased the amount of fixed N in each tissue type and on a whole plant basis (125%). Drought had little effect. 4 & 5

- The ratio of fixed to total N in CO<sub>2</sub>-grown plants was 62% greater than in ambient plants. 6

- There were no overall differences in %N among treatments 4, as plants with less fixation absorbed more N from the soil. 7

- N<sub>2</sub> fixation rates did not differ among treatments. 8



## DISCUSSION

- The results from the first year of this study track results from greenhouse experiments that suggest elevated CO<sub>2</sub> will mitigate the deleterious effects of drought on N<sub>2</sub> fixation in soybean (Table 1). However, field conditions result in high seasonal and interannual variability in weather patterns which will influence the strength of response to drought and the ability of elevated CO<sub>2</sub> to counteract drought effects.

Table 1: Results from other studies assessing the effects of drought and elevated CO<sub>2</sub> together. Arrows indicate the strength and direction of response, compared to the ambient condition. Different numbers of arrows within a column indicate significant differences among treatments. Colored rows roughly correspond to drought treatments from our experiments.

Treatment (ppm CO <sub>2</sub> )	Plant Biomass	Specific Nodule Activity	Nodule mass & Ureide content number
Serraj 2003, Serraj et al. 1999, 1998			
360, wet		Ambient condition	
360, dry	↓↓	↓↓	↑↑
700, wet	↓	N.S.	N.S.
700, dry	↓↓↓	↓	↑
Yu et al. 2002			
350, amb °C & H <sub>2</sub> O	Ambient condition		
700, amb °C & H <sub>2</sub> O	↑↑	↑↑	
350, +2°C	↓↓	↓	
700, +2°C	N.S.	N.S.	
350, +10% H <sub>2</sub> O	↑↑	↑↑	
700, +10% H <sub>2</sub> O	↑↑↑	↑↑↑	
350, +2°, +10%	↓	↓	
700, +2°, +10%	↑↑	↑↑	

Drought decreases fixation and nodulation, elevated CO<sub>2</sub> reduces the drought effect.

Increased water supply increases plant biomass. Increased temperature, presumably decreasing soil moisture, reduces biomass. Elevated CO<sub>2</sub> reverses the effects of temperature and adds to effects of watering.

- Elevated carbon dioxide increases the amount of nitrogen fixation in soybean which leads to greater plant biomass and higher nitrogen contents. Increases in N<sub>2</sub> fixation are brought about by increases in nodule biomass, not by increased fixation rates.

- These results from the first year of this study confirm the positive effects that elevated CO<sub>2</sub> has on nodulation. Drought effects were less distinct. The experiment is ongoing, and subsequent years results will allow for a more complete interpretation of seasonal and annual variability of drought effects on field-grown soybean.