**Target Journals:** *Nature*, *Nature Ecology & Evolution*

**Title**:Optimal coordination and progressive nitrogen limitation control plant responses to elevated CO2 at different scales

**Running Head:** Resolving *G. max* leaf and whole-plant responses to elevated CO2

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**Main**

**Plants respond to elevated atmospheric CO2 concentrations by reducing leaf nitrogen content and photosynthetic capacity, acclimation responses that coincide with increased growth rates and total leaf area over short time scales that dampen with time**1,2**. Progressive nitrogen limitation has been hypothesized to be the primary mechanism driving these responses, as nitrogen availability limits net primary productivity globally**3,4**. Recent work calls aspects of this hypothesis into question, suggesting that leaf responses to elevated CO2 are independent of nitrogen availability and are instead the result of optimal resource investment to photosynthetic capacity. Despite empirical support for both hypotheses**5–7**, studies that examine leaf and whole plant responses to elevated CO2 concurrently are rare. Here, we show that reductions in photosynthetic capacity under elevated CO2 are independent of nitrogen fertilization or nitrogen-fixing bacteria inoculation status in *Glycine max*. We also show that increased whole-plant growth and total leaf area under elevated CO2 are enhanced with increasing fertilization and inoculation, a pattern associated with increased plant nitrogen uptake. Results from this experiment show that optimal resource allocation to photosynthetic capacity drives leaf acclimation responses to elevated CO2, while patterns expected from progressive nitrogen limitation drive whole-plant responses to elevated CO2. The differential role of soil nitrogen availability on leaf and whole-plant responses to elevated CO2 suggest that land surface models may improve their simulation of photosynthetic processes under future novel environments by adopting frameworks that include optimality principles**5,8,9**.**

**Introduction**

Land surface model simulations of the future land carbon sink are particularly sensitive to the representation of photosynthetic processes and their response and acclimation to increasing CO2 concentration10. Models that include photosynthetic acclimation to elevated CO2 simulate a downregulation in leaf nitrogen content and photosynthetic capacity that results from progressive soil nitrogen limitation4,11, an effect that reduces the future terrestrial carbon sink compared to models that do not simulate this downregulation12,13. While true that soil nitrogen availability limits net primary productivity3, alternative h

**Results and Discussion**

**References**

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