**Summary paragraph for "**Optimal resource investment to photosynthetic capacity controls leaf acclimation responses to elevated CO2**"**

Plants respond to elevated CO2 concentrations by reducing leaf nitrogen allocation and photosynthetic capacity, an acclimation response that coincides with increased growth rates and total leaf area over short time scales that dampen with time1,2. Progressive nitrogen limitation has been hypothesized to be the primary mechanism driving leaf and whole plant responses to elevated CO2, as nitrogen availability limits net primary productivity globally3,4 due to high nitrogen requirements to build and maintain photosynthetic enzymes5,6. Recent work calls 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 hypotheses7–9, studies that quantify leaf and whole plant responses to elevated CO2 generally assess such responses using meta-analytic techniques2,10, and studies that examine leaf and whole plant responses concurrently are rare. Here, we show that reductions in photosynthetic capacity under elevated CO2 were independent of soil 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 were enhanced with increasing fertilization and inoculation, a pattern that was associated with increased plant nitrogen uptake rates with increasing fertilization and inoculation. Results from this experiment resolve discrepancies between optimal resource allocation and progressive nitrogen limitation, showing that optimal resource allocation to photosynthetic capacity drives leaf acclimation responses to elevated CO2, while patterns expected from progressive nitrogen limitation in turn drive whole plant responses to elevated CO2. The differential role of soil nitrogen availability on leaf and whole plant responses to elevated CO2 build on previous work suggesting that land surface models may improve their simulation of photosynthetic processes under future novel environments by adopting frameworks that include optimality principles7,11,12.

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