Model enhanced phenotyping: Understanding photosynthetic traits in *Brassica rapa*

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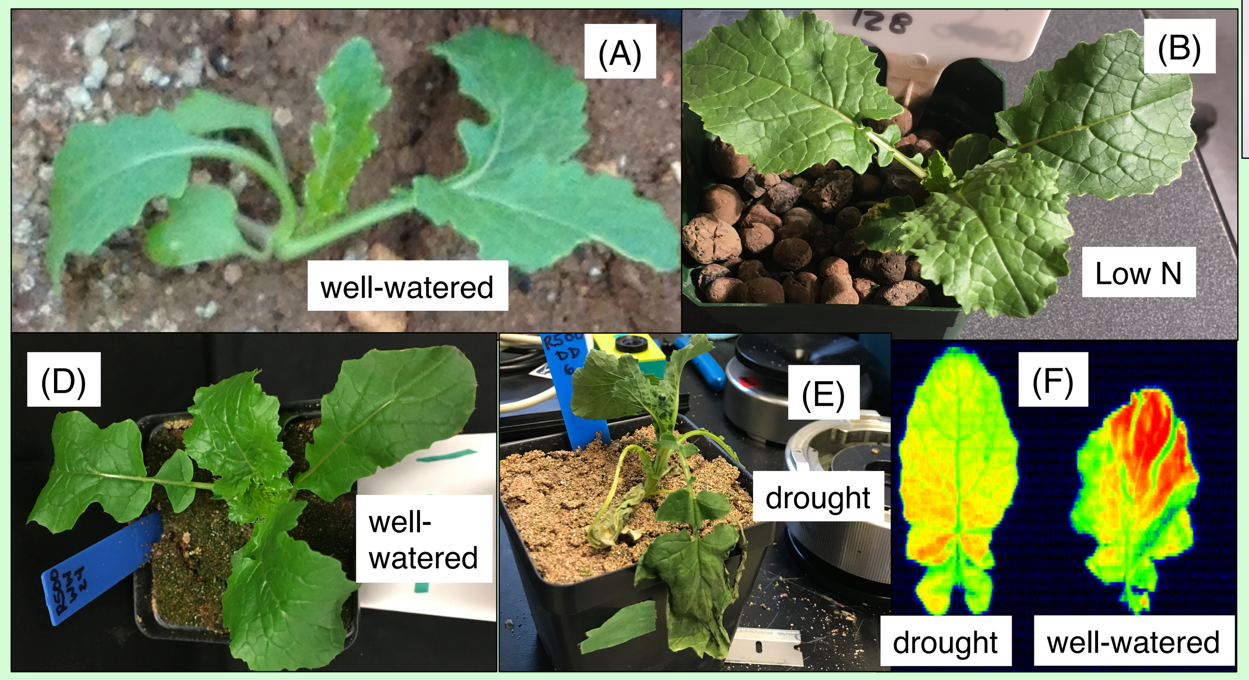
Experimental design

Experiments used four crop types *Pusa Kalyani* (*oil*), *Maiskaja* (*tur*), *Pekinensis* (*cab*), *Quarantina* (*bro*) as well as two parents R500 (*oil-type*) and IMB211 (Fast-Plant) of two recombinant inbred lines (*r46* and *r301*). These are evaluated under multiple growth conditions (Fig .1).



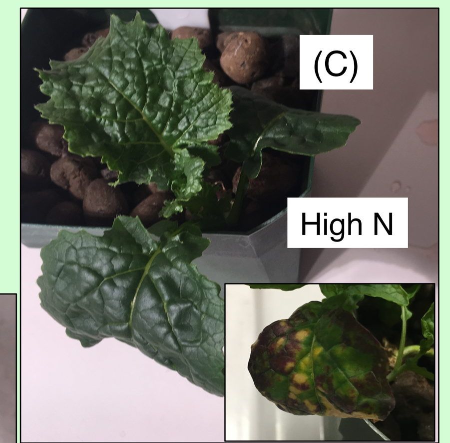


Fig1. *B. rapa* genotypes under varying conditions. Field-grown broccoletto (*bro*)(A); Hydroponic-grown *r301* low nitrogen(B); Hydroponic-grown *r301* high N (C) (toxicity inset); growth chamber R500 well watered (D); growth chamber R500 drought(E) and *r301* FluoCam image of Fv'/Fm in drought, well-watered (F).

Model and Prior development

I. Eight photosynthesis models developed in a Bayesian framework evaluating curves of assimilation vs. intercellular CO_2 availability (A/C_i) for six genotypes (*bro, cab, oil, tur, r46, r301*) grown under well-watered field conditions.
   I. Models pitted assumptions against one another in complexity analysis Fig. 2.
   II. Produced multiple posterior predictions for traits of interest, Fig 3.
   III. Species level trait posteriors used as prior for further analysis, Fig 3 & 4.

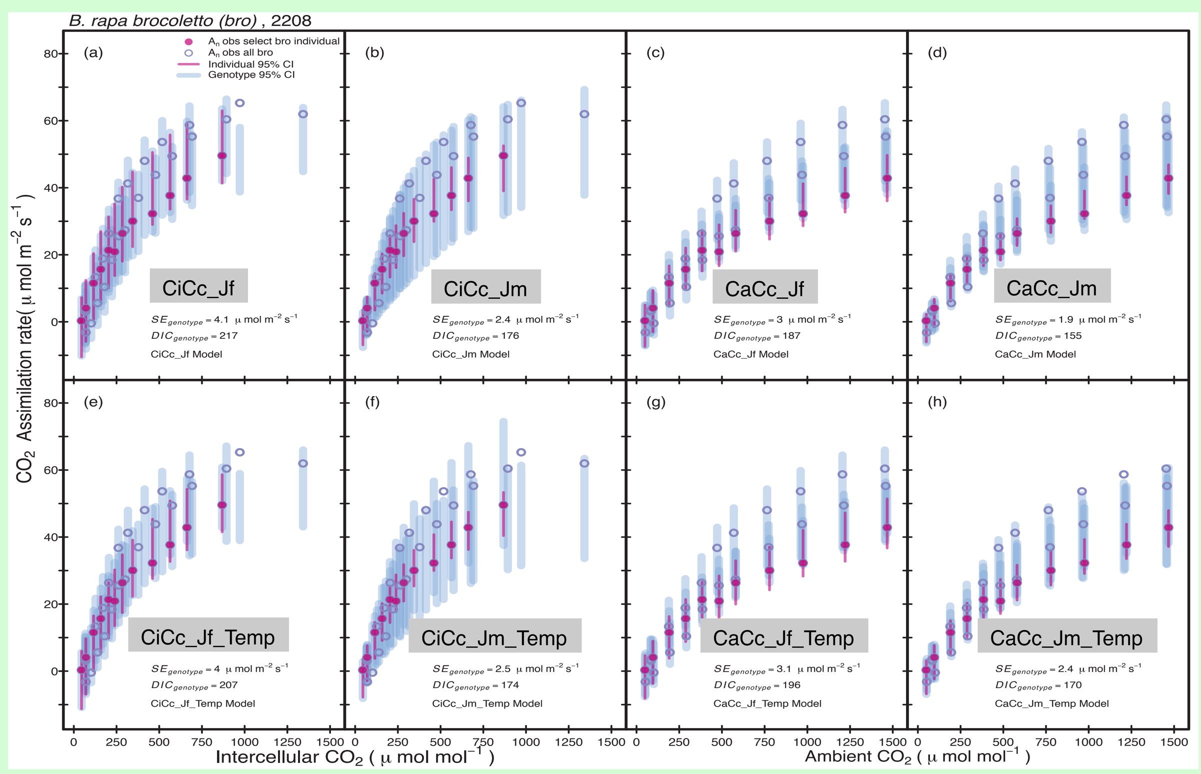


Fig 2. Comparison between observed assimilation (A_n) and estimated A_n for 8 photosynthesis models of *B. rapa*, var. *bro*. Each plot shows A_n for a select *bro* individual & A_n for all *bro* data. Bayesian 95% credible intervals are individual and genotypic. Models differ in 3 assumptions: (a,b,c,d) have no temp. constraint on parameters while (e,f,g,h) use an Arrhenius style temp, function. (a,c,e,g) estimate of electron transport rate (ETR) from chlorophyll fluorescence while in (b,d,f,h) ETR is derived based on estimates of quantum yield to CO_2 (ϕ_J) and maximum ETR (J_{max}). (a,b,e,f) predict mesophyll conductance limitations (g_m)vwhile (c,d,g,h) assume infinite $g_{m.}$

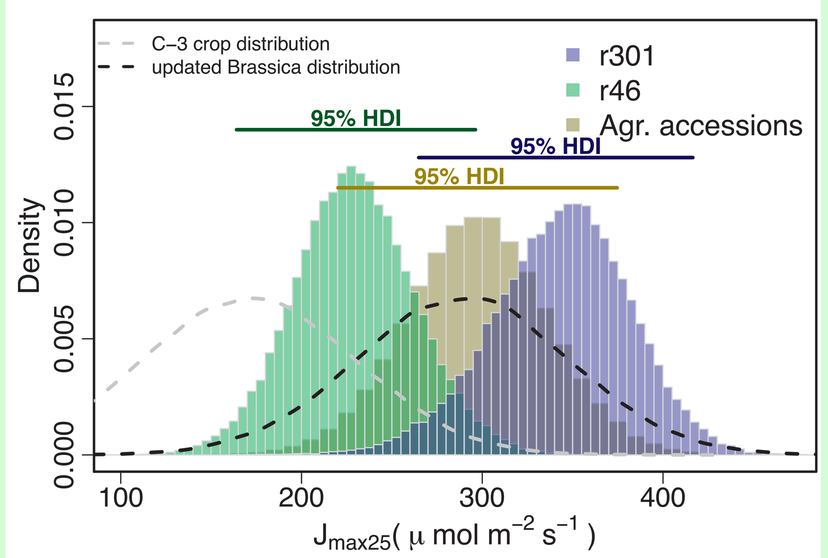


Fig. 3. Posterior trait distributions for maximum rate of electron transport (J_{max25}) for *r46, r301* and four agricultural accessions of *B. rapa* with 95% high density interval (HDI) for each, as well as original prior used for J_{max25} from Wullshleger et al. 1993 and updated distribution for full modeled set (--).

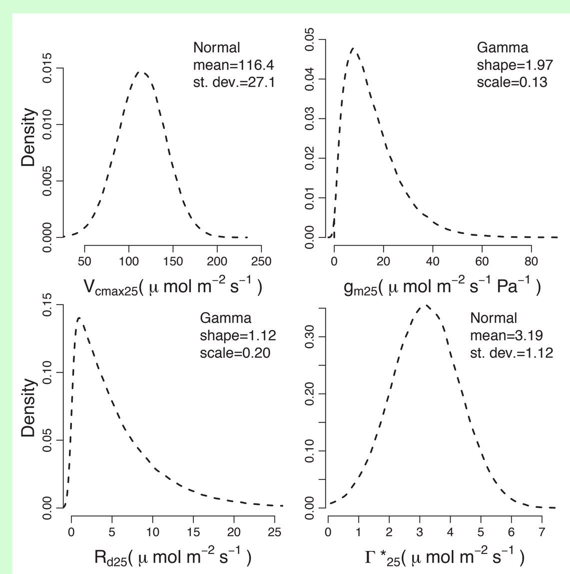
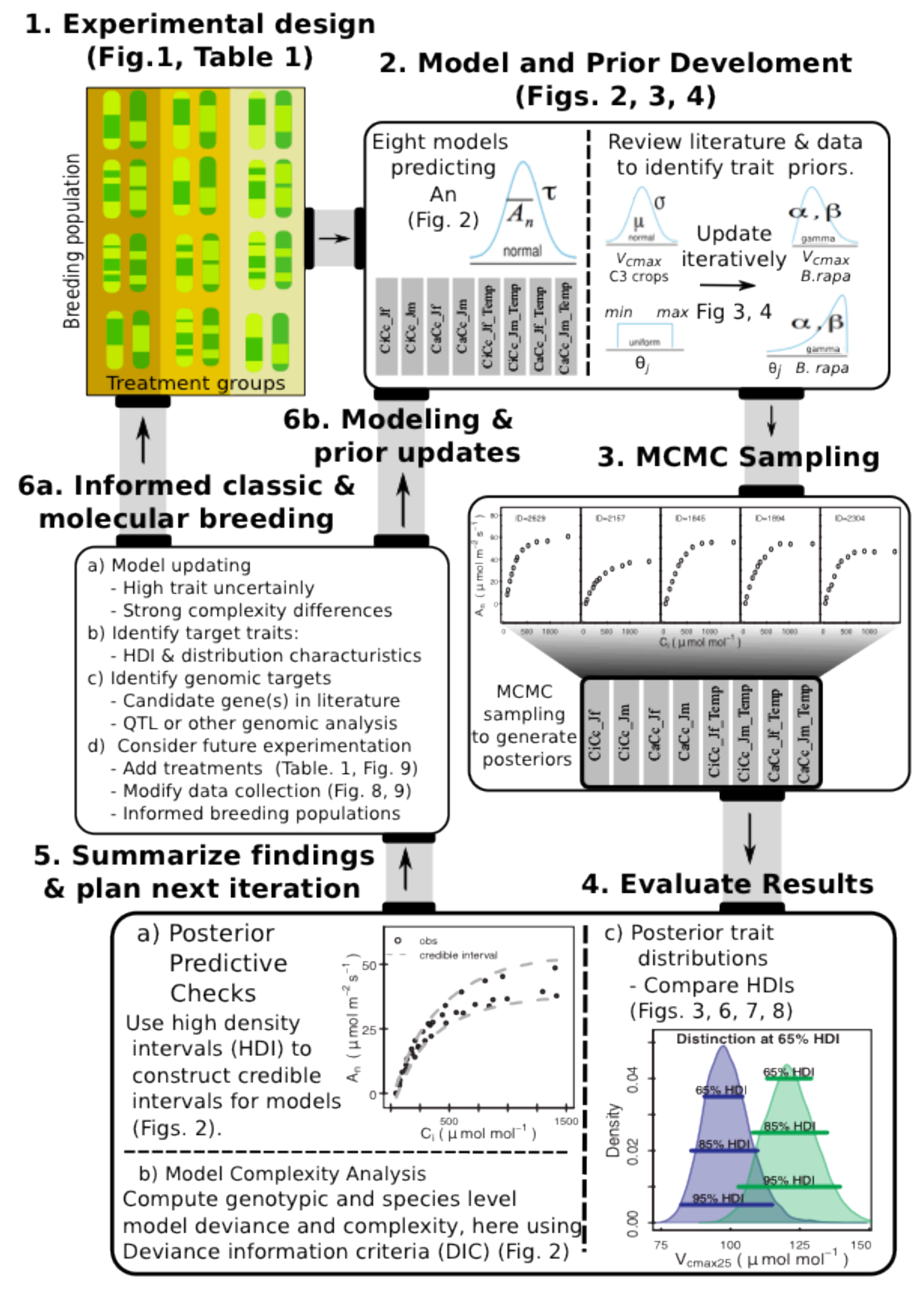


Fig. 4. Species-specific prior parameter distributions for four traits: Maximum rate carboxylation (V_{cmax25}), mesophyll conductance (g_{m25}), dark respiration (R_{d25}), and CO_2 compensation point in absence of respiration (Γ^*_{25}).

Iterative Model Enhanced Phenotyping

Challenge: Crop phenotyping must compare the impacts of genotype (G) & environment (E) on physiological performance. We propose an iterative modeling process for understanding this G X E interaction.



Acknowledgements and Citations

Acknowledgements

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Literature

Edwards et al. (2010). *Molecular Plant*. 5, 653-668. Farquhar et al. (1980). *Planta.* Wullschlegger et al. 1993. *JEB*. Guadagno, C.R..(2017). *Plant Physiology*. Kruschke J. (2010). *Doing Bayesian data analysis: A tutorial introduction with R.*

Evaluate Results

Experiment established to test model performance using updated priors from 1st iteration.

- Two genotypes (*r46, r301*)
- Flood and drain hydroponic system
- Two Nitrogen treatments (Table 1)
- Other macro and micro nutrients kept constant.
- Light level 300-500 μmol m-s s-1 PAR.

Table 1. Concentration in ppm of Nitrate and Ammonium

Nutrients (ppm)	Low	High
N(NO3-)	50	175
N(NH4+)	0.76	100

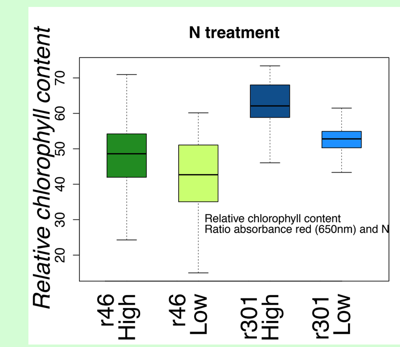

Fig 5 Relative Chlorophyll content of two genotypes (*r46, r301*) in two N treatments (high, low).

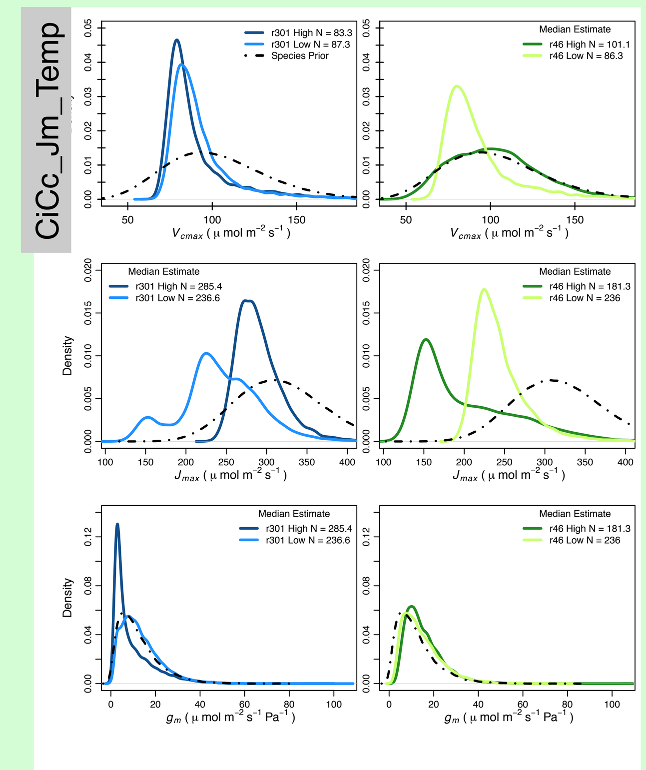

Fig 6. Posterior trait distributions of two *B.rapa* genotypes (*r46, r301*) for maximum rate of carboxylation (V_{cmax}), maximum rate of electron transport (J_{max}), and mesophyll conductance (g_m) under high and low nitrogen treatments.

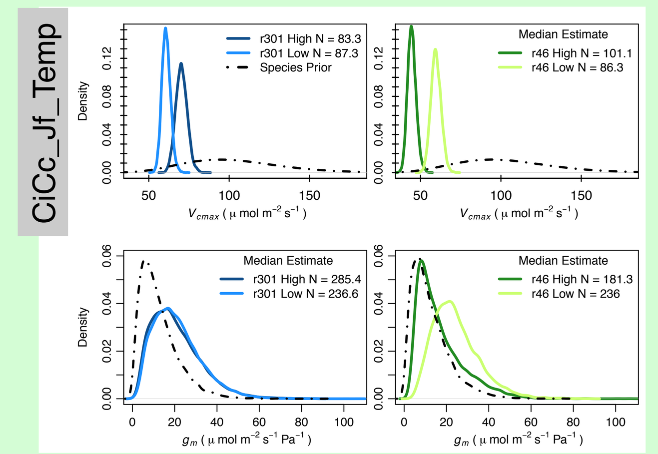

Fig 7. Posterior trait distributions of two *B.rapa* genotypes (*r46, r301*) for maximum rate of carboxylation (V_{cmax}) and mesophyll conductance (g_m) under high and low nitrogen treatments.

Conclusion

I. *B. rapa* displays diversity in photosynthetic traits including V_{cmax} and J_{max}
II. Updated priors provide a means of testing new experimental setups and potentially new populations.
III. Multimodel methods allow for comparing performance of model assumptions
IV. Improved integration of fluorometry is needed in models of assimilation.

Future data Integration

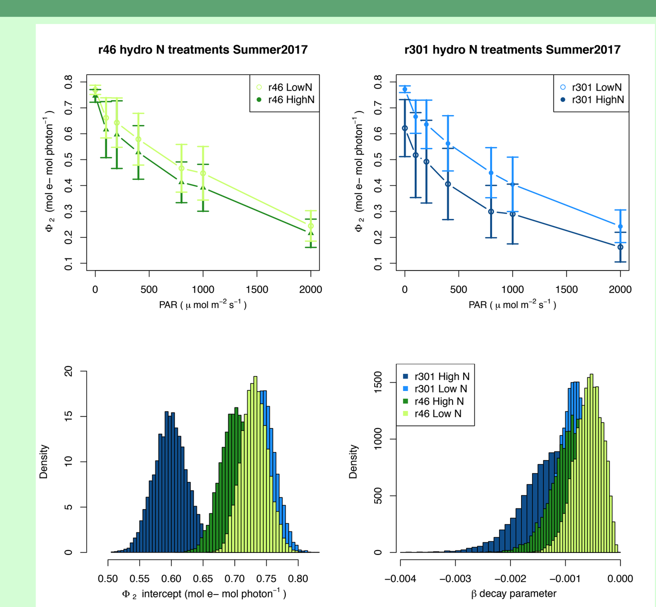

Fig 8. Photosystem II efficiency (ϕ_{II}) at PAR ranging between 0-2000 μmol m-s s-1 for r46 and *r301* in high and low N treatments (top panels). Relationship modeled using a decay function with an intercept (ϕ_{II} intercept) and decay rate (β). Posterior distributions of each shown (bottom panels).

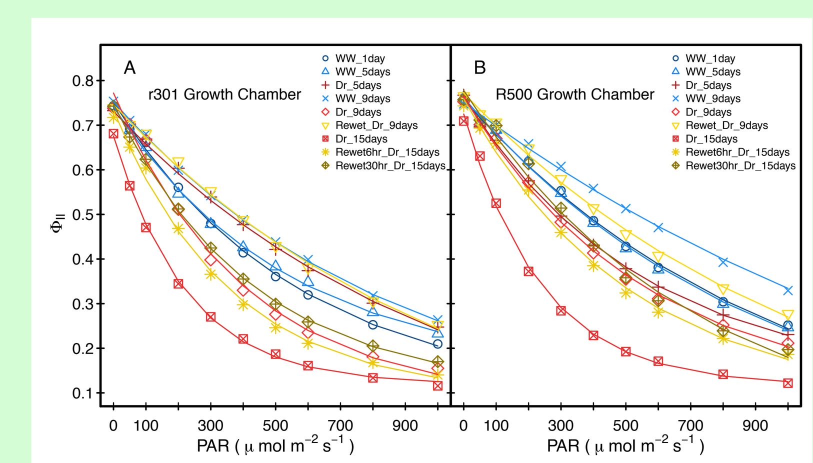

Fig 9. Photosystem II efficiency (ϕ_{II}) at PAR ranging between 0-1000 μmol m-s s-1 for r301 and R500 over a range of water regime from well water to increasing drought to re-watering.