PBIO-141
Sensory and Physiological Ecology of Plants

6: Responses to shading

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Outline

A new paradigm

Responses to (impending) shading

A new paradigm

A new paradigm is emerging

An exciting time to study plants!!

- Currently it is a very exciting time to study plants…
- …especially how their molecular biology, evolution and ecology are linked.
- We are in the middle of a paradigm shift…
- …for a long time we have disregarded/underestimated the central and complex role of plants' "senses".
- However, we should be open minded and use our imagination to understand plant life as it is…
- …rather than to project 'human' features and qualities onto plants.

Responses to (impending) shading

Shade avoidance vs. tolerance strategies: $\neq$ "goals"

These are two extreme strategies with putative roles:

- Shade avoidance $\rightarrow$ compete for access to strong light
- Shade tolerance $\rightarrow$ efficiently use weak light
- Acclimated phenotypes are very different!
- Sources of information used in some combination are many:
- Cues: R:FR photon ratio, B:G photon ratio, blue light irradiance, UV irradiance, wind, touch, ethylene (signal?), including their temporal dynamics.

Shade avoidance vs. tolerance 10 min

- How do you expect avoidance and tolerance to work in practice?
- Can you think about clear-cut and less clear-cut cases?
- In which environments tolerance is likely to be better for fitness than shade avoidance?

Leaf size and angle, petiole length, chlorophyll

End-of-day R or FR light (10 min/day), *Petunia axillaris*, (Casal et al. 1987)

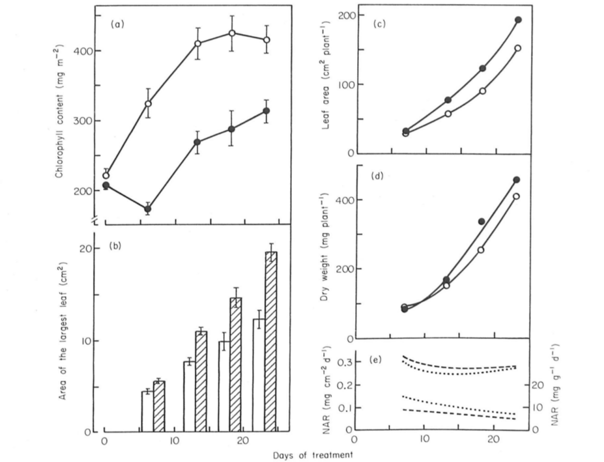
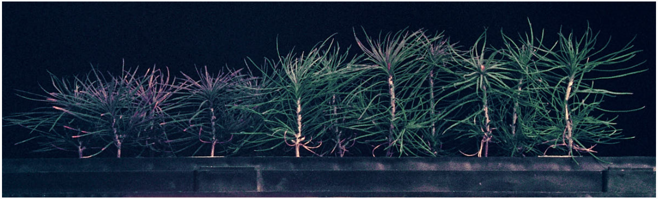


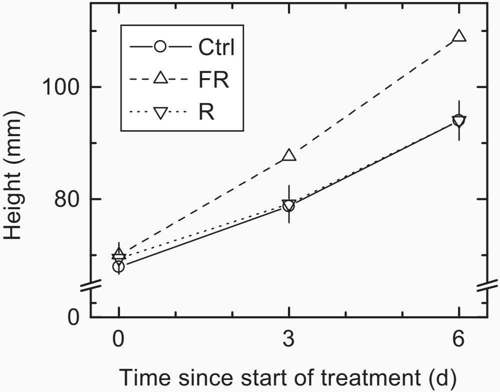
Figure 2. Effect of end-of-day R (○, □ or – – –) or FR (●, ▨ or . . .) irradiations on leaf chlorophyll content of the largest leaf (a), area of the largest leaf (b), leaf area per plant (c), total biomass per plant (d), and net assimilation rate (NAR) (e). Each point is the mean of 8 or 12 (last harvest) plants. Measurements were taken on different plants at each harvest except for Day 0 in (a). Data from Experiment A. Bars indicate ± SEM.

Stem elongation

- In sparse canopies ‘horizontal’ light flux is important for anticipated sensing of neighbours.
- Growing internodes are a key site of perception.



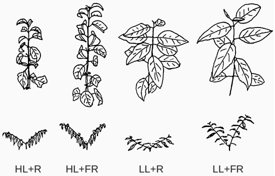
Stem elongation



Irradiation with red or far-red light from LEDs at the growing internode (whole photoperiod), *Betula pendula*. (from Aphalo and Rikala 2006).

Leaf size, thickness and photosynthesis

High (HL) and low (LL) PAR, *Fuchsia magellanica* (Aphalo et al. 1991).



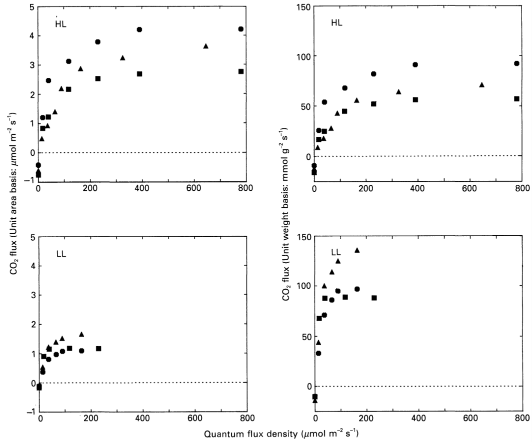
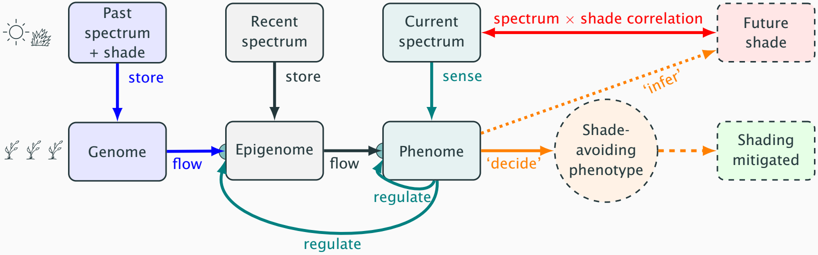


Figure 4. Responses of CO_2 flux per unit projected leaf area (left) and CO_2 flux per unit leaf dry weight (right), to quantum flux density in plants grown under white light. HL = 350 μmol m^{-2} s^{-1} and LL = 25 μmol m^{-2} s^{-1}, equal to 12·6 and 0·9 mol m^{-2} d^{-1}. Measured between 134 and 150 d after the start of treatment, each replicate is from a different plant; data shown with the same symbols were measured on consecutive days.

Stems position and length, apical dominance

Sunlight, full and minus blue, *Medicago truncatula* Rai, Yan and Aphalo, unpublished.

Preemptive acclimation: shade



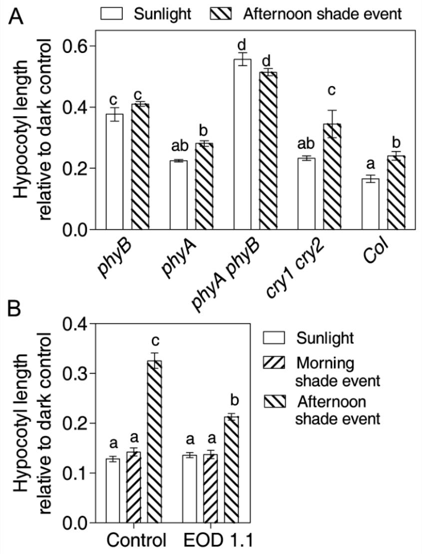
Flow of information in preemptive acclimation to shade by perception of radiation changes. Arrows represent flows of information: **blue** = retrieved from genome (stored during earlier generations), **black** = acquired and/or 'memorized' during an individual's or its progenitor's lifetime, **teal** = regulation of gene expression by phenome or downward causation, **red** = lagged correlation between early changes in spectral irradiance and future low PAR irradiance, **orange** = outcome of information processing: a 'decision', based on an 'implicit forecast of impending shade', leading to developmental adjustments that would increase the probability of higher fitness in the presence of neighbours in comparison with phenotypes lacking preemptive acclimation. **green** = 'Shading mitigated' compared, in probabilistic terms, to no acclimation. Dashed boxes and arrows represent the likely or forecasted future.

Preemptive acclimation: What is the evidence?

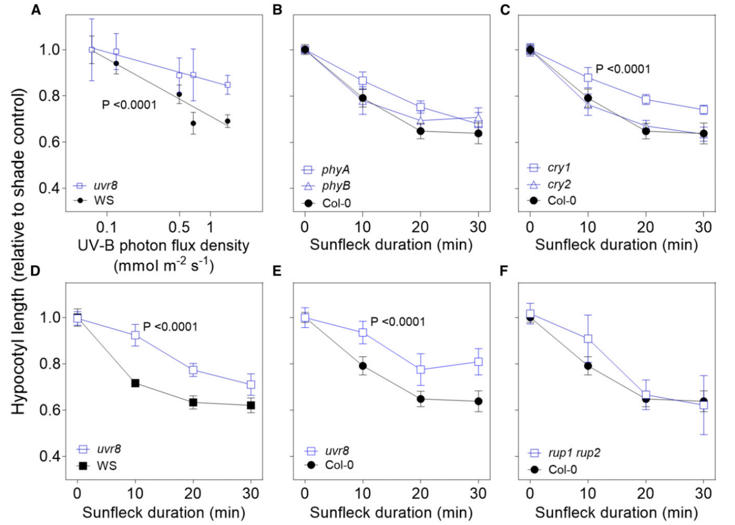
- Several plant responses can be only explained from the evolutive/fitness point of view as being a ‘preparation’ to tolerate or escape future stress events or take advantage of future favourable conditions.
- Preemptive shade avoidance as a response to reflected far-red light from neighbouring plants.
- Winter hardening and dehardening, timing of bud burst, timing of flowering, etc.
- *Anticipatory responses* and *future perception* are terms also used in this context.

Timing of shade

Arabidopsis seedlings (**Sellaro2012**).



Arabidopsis seedlings (from Moriconi et al. 2018). In A $\mathrm{mmol\,m^{-2}\,s^{-1}}$ should read $\mathrm{\mu mol\,m^{-2}\,s^{-1}}$.



Acclimation vs. rapid/reversible responses 5 min

(from Casal 2013). What about the balance between light reactions and carbon reactions of photosynthesis?

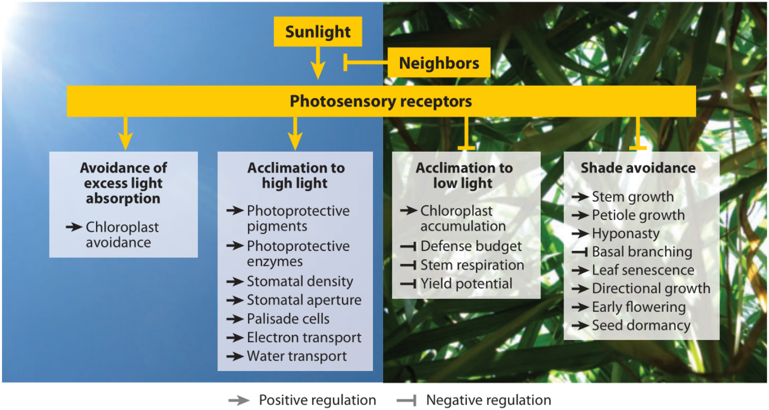
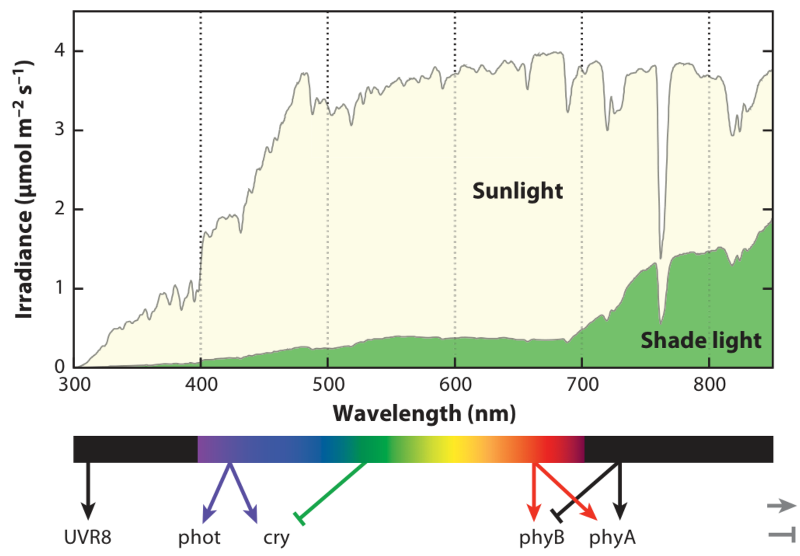


Figure 3

Plant responses to either sunlight (*left*) or shade light (*right*) perceived by photosensory receptors.

Role of photoreceptors in responses to shade

(from Casal 2013).



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Environmental correlations and forecasting

Can plants 'predict' the arrival of the cold season?
What sources of information do they use?

Environmental correlations and forecasting

Can plants 'predict' the arrival of the spring?
What sources of information do they use?

Can plants emit 'signals' for their benefit?
What are the signals used to attract pollinators?

Can plants emit 'signals' for their benefit?
What are the signals used to enlist "helpers" for seed dispersal?

Can plants emit signals to deceive other organisms?
How does mimicry work?

Environmental correlations and forecasting

Can plants ‘generate’ environmental correlations for their benefit?
How does release of organic volatile compounds create a correlation?

Symbioses: ectomycorrhizas

Do symbioses involve communication?