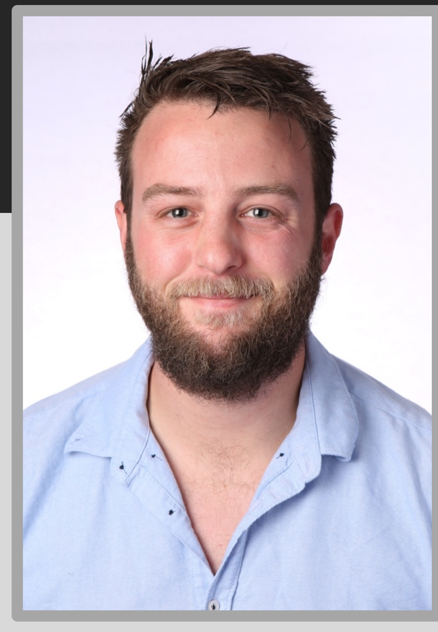
Solar UV enhances photosynthetic resilience to phosphorus stress in sunflower (*Helianthus annuus*)

THE UNIVERSITY OF SYDNEY



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Background

Global agricultural production is already limited by availability of phosphorus and this will likely worsen in the future. As population growth and global environmental change combine to reinforce ever-increasing demand for P, it is imperative that we understand mechanisms that enable plants to tolerate low phosphate conditions. Exposure to solar UV could help improve photosynthetic performance of plants and resilience to low P stress with no additional inputs.

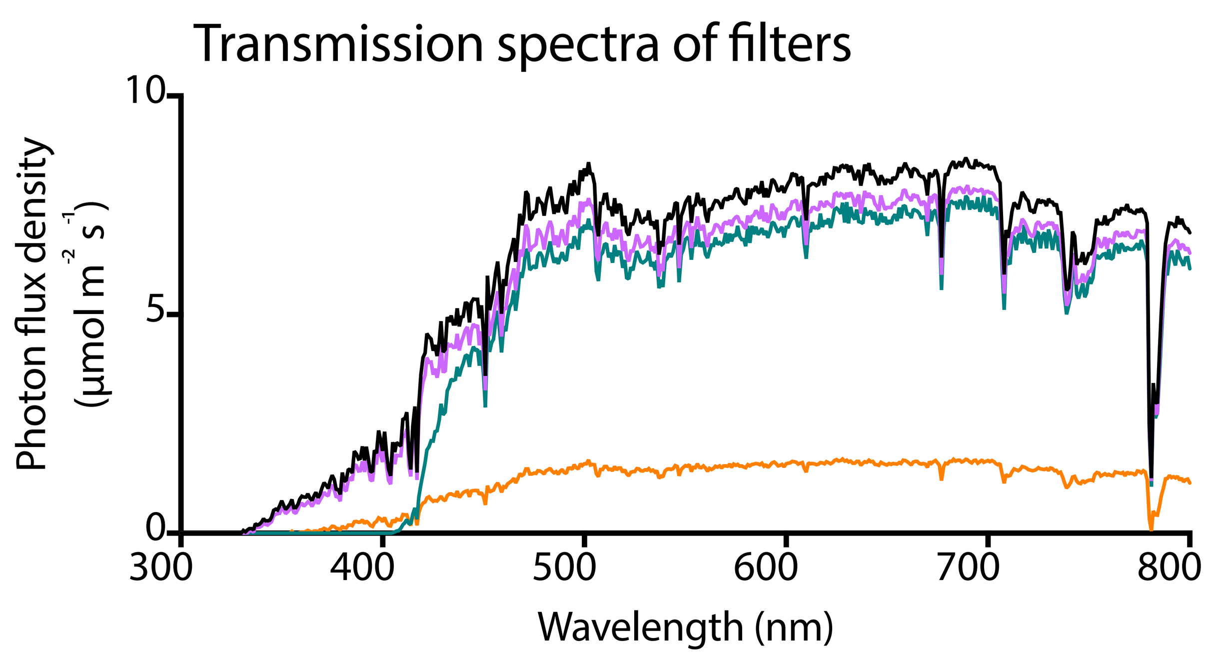
Aims of research

- To determine the extent to which sunflower (*Helianthus annuus*) grown under limited P_i supply would modify lipid biosynthesis to substitute phospholipids with non-P lipids, and liberate P_i for photosynthetic use.
- To find out whether exposure to solar UV would promote photoprotective mechanisms such that photosynthetic rates are less limited by reduced P availability than those grown under UV exclusion or shade.

Materials and methods

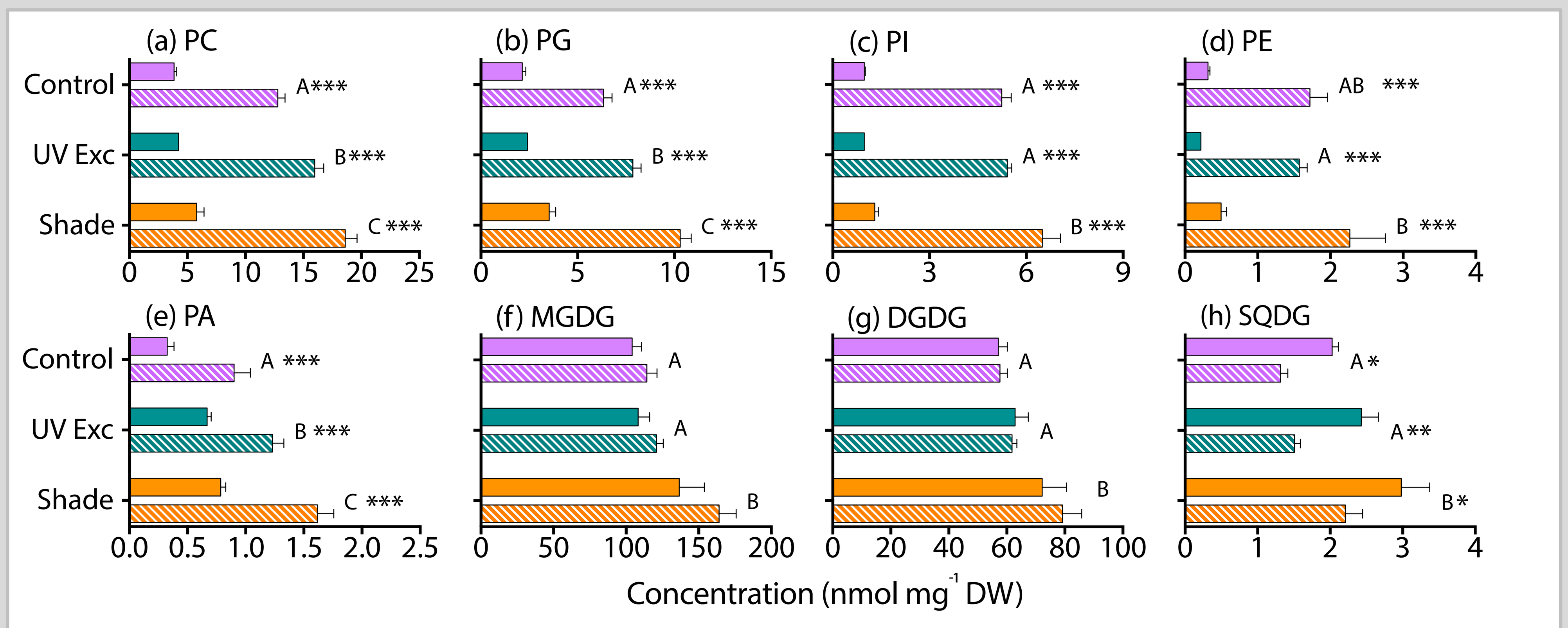
Sunflower (*Helianthus annuus* var. Dwarf Sunsation) was grown from seed outside. Fertiliser was applied three times weekly by hand. Measurements and samples were taken two weeks after germination on fully formed leaves.

- Two concentrations of P – High P (2 mM KH_2PO_4), Low P (0.33 mM KH_2PO_4).
- Three light treatments – UV-exclusion, Shade, Control.
- Measurements of:
  - Leaf gas exchange (A_{sat}, g_s, R_{day}, R_{dark} and A/C_i curves).
  - Leaf fluorescence emission and excitation spectra .
  - Leaf reflectance, absorbance and transmission spectra.
- Leaf samples collected for:
  - Phosphorus concentration.
  - Comprehensive lipid analysis.



Light treatment	Photon flux density (μmol m^{-2} s^{-1}) UV	Visible
Full sunlight	107	2224
Control	90	2043
UV exclusion	5	1910
Shade	13	434

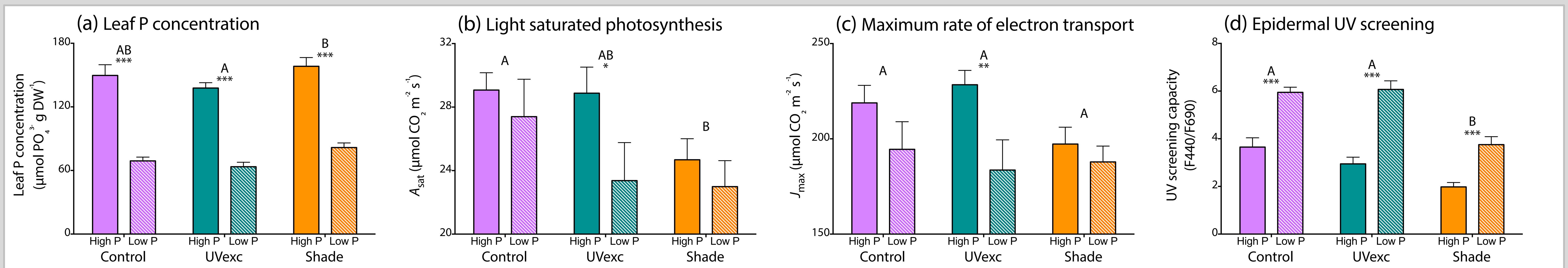
Transmission spectra of growth treatment filters; Full sunlight (**black**), Control (**violet**), UV exclusion (**teal**) and Shade (**orange**). Spectra measured on a clear day using a spectral radiometer. Values are total photon flux densities for the UV (λ 280 – 400 nm) and visible wavebands (λ 400 – 700 nm).



Leaf concentrations of **(a)** phosphatidylcholines (PC), **(b)** phosphatidylglycerols (PG), **(c)** phosphatidylinositols (PI), **(d)** phosphatidylethanolamines (PE), **(e)** phosphatidic acids (PA), **(f)** monogalactosyldiacylglycerols (MGDG), **(g)** digalactodiacylglycerols (DGDG), and **(h)** sulfoquinovosyl diacylglycerols (SQDG). Values are means ± SEM (n = 6). Asterisks indicate significantly different means (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$) between phosphorous treatments within light treatment; upper case letters denote significantly different means between light treatments identified by Fisher's LSD test ($P < 0.05$).

Results

- Foliar P concentrations were closely associated with P_i availability for all plants ($P < 0.001$).
- Reduced P_i availability slowed photosynthetic rates (A_{sat}) by 19% when UV was removed from the growth environment ($P < 0.05$). This corresponded with reduced maximum rates of electron transport (J_{max}) ($P < 0.05$). Photosynthetic rates of plants grown in full sunlight or under shade were unaffected by P_i availability ($P > 0.05$).
- Leaf phospholipid concentrations reflected P_i availability, with reductions in all major fractions under low P supply ($P < 0.001$). Sulfolipids increased in concentration under low P supply ($P < 0.05$).
- Concentrations of phospholipids were inherently lower in plants grown in full sunlight than those grown under UV-exclusion or shade ($P < 0.05$).
- Epidermal UV screening capacity increased two-fold under low P conditions ($P < 0.001$), but was unaffected by UV exposure ($P > 0.05$).



(a) Leaf phosphorus concentrations; **(b)** rates of light saturated photosynthesis; **(c)** maximum rates of photosynthetic electron transport; and **(d)** epidermal UV screening capacity (using the ratio of fluorescence emission at λ 440 nm to emission at λ 690 nm with an excitation of λ 380 nm). Values are means ± SEM (n = 8). Asterisks indicate significantly different means (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$) between phosphorous treatments within light treatment; upper case letters denote significantly different means between light treatments identified by Fisher's LSD test ($P < 0.05$).

Conclusions

The responses of sunflower to solar UV are promising with regard to future food production in this era of decreasing P supply. They suggest that modifying the spectral environment of horticultural crops could increase photosynthetic carbon gain and stress tolerance under low P conditions. Sunflowers grown under solar UV maintained faster photosynthetic rates regardless of P availability, due to inherently lower concentrations of phospholipids, freeing P_i for metabolic use. Considering benefits to photosynthetic capacity and increased photoprotection have been reported in crop species (for review see Wargent *et al.* 2013), our results add to the list of plant responses to UV that could be exploitable in the context of sustainable agriculture.

Acknowledgements

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References

Wargent, J. J. & Jordan, B. R. 2013. From ozone depletion to agriculture: understanding the role of UV radiation in sustainable crop production. *New Phytologist,* 197, 1058-1076.