evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Review alert

Marcel Jansen

Tato akce se koná v rámci projektu:
Vybudování vědeckého týmu environmentální metabolomiky a ekofyziologie a jeho zapojení do mezinárodních sítí (ENVIMET; r.č. **CZ.1.07/2.3.00/20.0246**) realizovaného v rámci Operačního programu Vzdělávání pro konkurenceschopnost.

Review Alert!

Recent reviews of plant UV–B biology

On the history of phyto-photo UV science

Björn, Lars Olof. "On the history of phyto-photo UV science (not to be left in skoto toto and silence)." *Plant Physiology and Biochemistry* (2014).

Topics:

- The early history of ultraviolet photobiology; DNA and Photosystem II as major targets, photoreactivation and photolyases.

- The stratospheric ozone layer and the Montreal treaty.

- Changing emphasis towards "positive" effects of UV-B radiation; regulation rather than damage and inhibition.

- Overview UVR8, regulation, signaling, and exploitation of UV effects.

On the history of phyto-photo UV science;

What is “hot”?

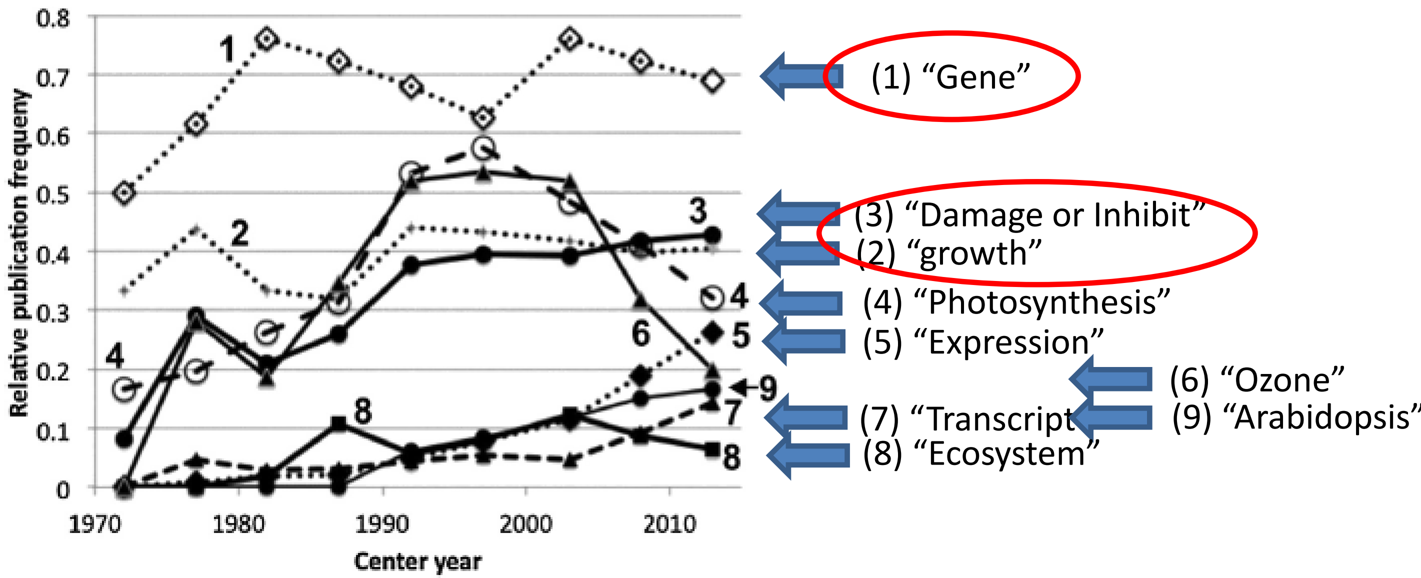


Fig. 6. The number of publications for different searches in combination with “UV-B* AND plant*”, divided by the total for the search “UV-B* AND plant*”. In order to see clearly the long-term changes, the values were binned over 5 years, and plotted *vs* the center year of the bin (i.e., 1972 represents the period 1970–1974, 1977 represents 1975–1979 etc. The various curves stand for the following searches within “UV-B* AND plant*”: 1 “gene*”; 2 “growth*”; 3 “damage OR inhibit*”; 4 “photosynth*”; 5 “expression”; 6 “ozone*”; 7 “transcript*”; 8 “ecosyst*”; 9 “Arabidopsis*”. The topic “photosynth*” was searched without the specification “plant*”, so in principle it includes also photosynthesis in algae and bacteria. It can be seen that while the proportion of “growth*” stays fairly constant, “photosynth**” and “ozone*” are maximal during the period 1995–1999, while the molecular-biology related “expression”, “transcript*” and “Arabidopsis*” increase their proportions with time. The maximum for “ecosyst*” in the period 1985–1989 is due to a single NATO workshop report published in 1986.

Search within “UV-B AND Plant”

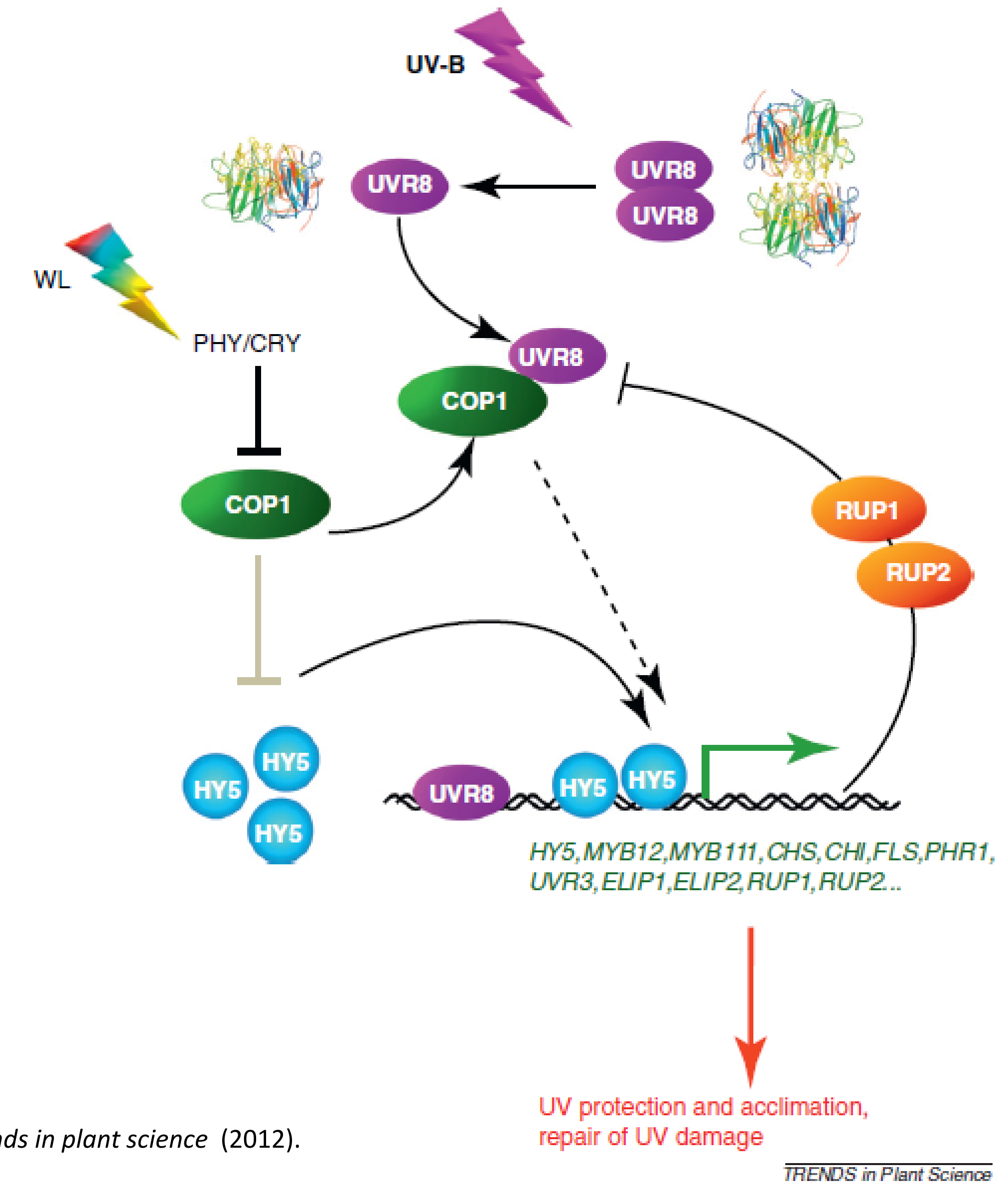
UV-B photoreceptor-mediated signalling in plants

Heijde, Marc, and Roman Ulm. "UV-B photoreceptor-mediated signalling in plants." *Trends in plant science* 17.4 (2012): 230-237.

Topics:

- Ultraviolet-B radiation (UV-B) is a key environmental signal
- The UVR8 photoreceptor; location, molecular structure, the tryptophane chromophore
- The UVR8 mediated pathway and early signalling components and physiological responses (COP1, HY5, RUP1 and RUP2).
- Commonalities and differences in UV-B and visible light signalling

UV-B photoreceptor-mediated signalling in plants



Heijde and Ulm. *Trends in plant science* (2012).

How plants see the invisible

Gardner, Kevin H., and Fernando Correa. "How plants see the invisible." *Science* 335.6075 (2012): 1451-1452.

Topics:

- Plants are able to sense UV-B through the UV-B photoreceptor UVR8.

Structure and function of the UV-B photoreceptor UVR8

Jenkins, Gareth I. "Structure and function of the UV-B photoreceptor UVR8." *Current opinion in structural biology* 29 (2014): 52-57.

Topics:

- UVR8 is a UV-B photoreceptor that employs specific tryptophans in its primary sequence as chromophores in photoreception.
- UV-B absorption causes dissociation of the dimeric photoreceptor by neutralizing interactions between monomers.
- The monomeric form initiates signalling through interaction with the COP1 protein, leading to transcriptional responses.

How do plants sense and respond to UV-B radiation?

Ulm, Roman, and Gareth I. Jenkins. "Q&A: How do plants sense and respond to UV-B radiation?." *BMC biology* 13.1 (2015): 45.

Topics:

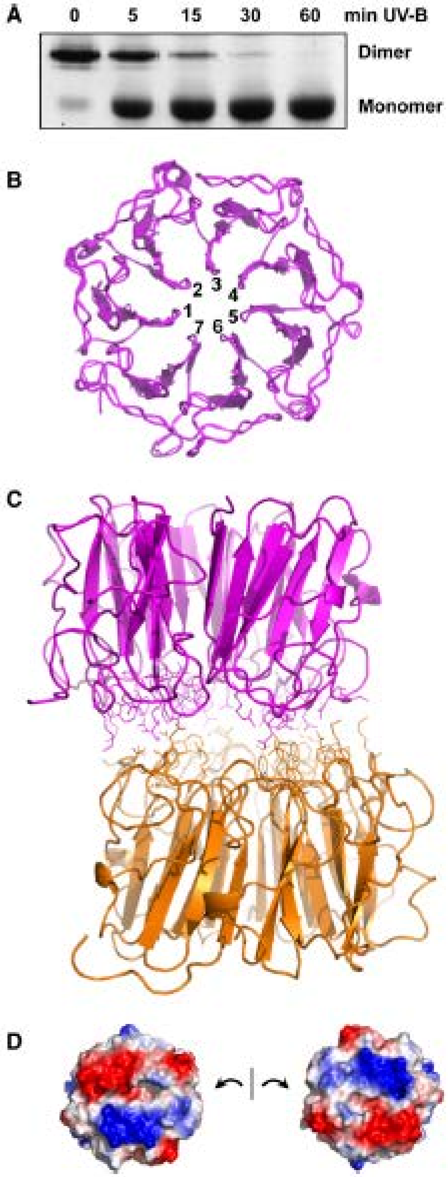
- Plants are able to sense UV-B through the UV-B photoreceptor UVR8.

The UV-B photoreceptor UVR8: from structure to physiology

Jenkins, Gareth I. "The UV-B photoreceptor UVR8: from structure to physiology." *The Plant Cell* 26 (2014): 21-37.

Topics:

- Low doses of UV-B elicit photomorphogenic responses in plants that modify biochemical composition, photosynthetic competence, morphogenesis, and defense.
- UVR8 mediates responses to UV-B by regulating transcription of a set of target genes.
- UVR8 uses specific Trp amino acids instead of a prosthetic chromophore for light absorption.
- Absorption of UV-B dissociates the UVR8 dimer into monomers, initiating signal transduction through interaction with CONSTITUTIVELY PHOTOMORPHOGENIC1 (COP1).



Jenkins. "The UV-B photoreceptor UVR8: from structure to physiology." *The Plant Cell* 26 (2014)

Figure 1. UVR8 Dimer Structure and Monomerization.

(A) UV-B induces monomerization of UVR8. Coomassie blue–stained SDS-PAGE gel of purified UVR8 exposed for the times shown to 1.5 μmol m^{-2} s^{-1} narrowband UV-B (λmax 311 nm). Samples were prepared for electrophoresis without boiling. The UVR8 dimer and monomer are indicated.

(B) Seven-bladed β-propeller structure of the UVR8 monomer. The structure is shown for amino acids 14 to 380.

(C) Structure of the UVR8 dimer showing residues at the dimer interaction surface.

(D) The dimer interaction surfaces of two UVR8 monomers displayed to show patches of complementary electrostatic potential. Basic (blue) and acidic (red) amino acids contribute positive and negative charges, respectively.

Images in **(B)** to **(D)** were produced using PyMOL. (*All panels produced from data presented by Christie et al. [2012].*)

“State of the field” molecular UV-B biology

- Regular supply of updated reviews
- Rapid progress identification downstream signalling components
- Rapid progress understanding other signalling pathways (e.g. phytochrome and cryptochrome)
- (Relatively poor understanding “downstream” physiological and environmental relevance)

UV-B and plant morphology

ROBSON, T., et al. "Re-interpreting plant morphological responses to UV-B radiation." *Plant, cell & environment* 38 (2015): 856-866.

Topics:

- Morphological responses at cell level (cell division, elongation and/or differentiation)
- Morphological responses at organismal level (thicker leaves, shorter petioles, shorter stems, increased axillary branching and altered root:shoot ratios).
- Underlying mechanism (UVR8 and/or stress?).
- Function in UV protection and consequences for fitness (decreased UV-B and photosynthetic light capture and plant-competitive abilities)?.

UV-B and plant morphology

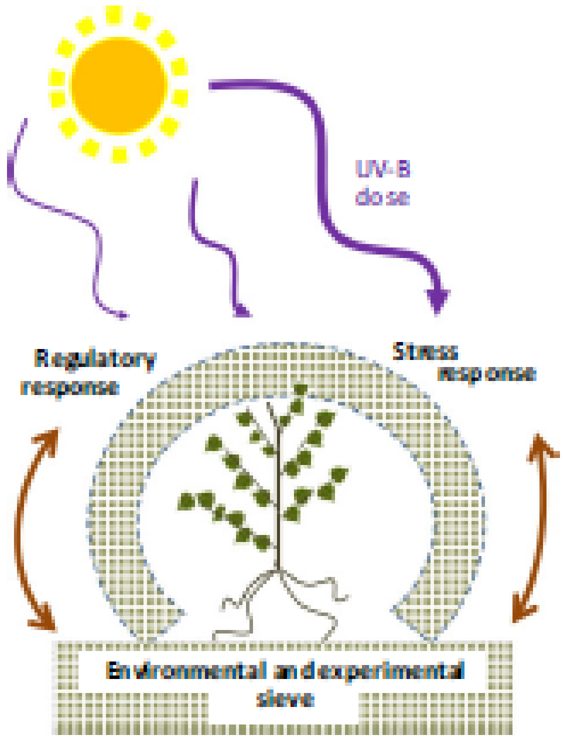


Figure 3. Schematic overview indicating that different strengths of UV dose produce a response mediated by interacting regulatory pathways and stress-induced pathways. The relative importance of these responses is UV dose dependent and is further modulated through an environmental filter.

ROBSON, T., et al. "Re-interpreting plant morphological responses to UV-B radiation." *Plant, cell & environment* 38 (2015): 856-866.

Integration UV-B effects across organisational levels

Suchar, Vasile Alexandru, and Ronald Robberecht. "Integration and scaling of UV-B radiation effects on plants: from DNA to leaf." *Ecology and Evolution* (2014).

Topics:

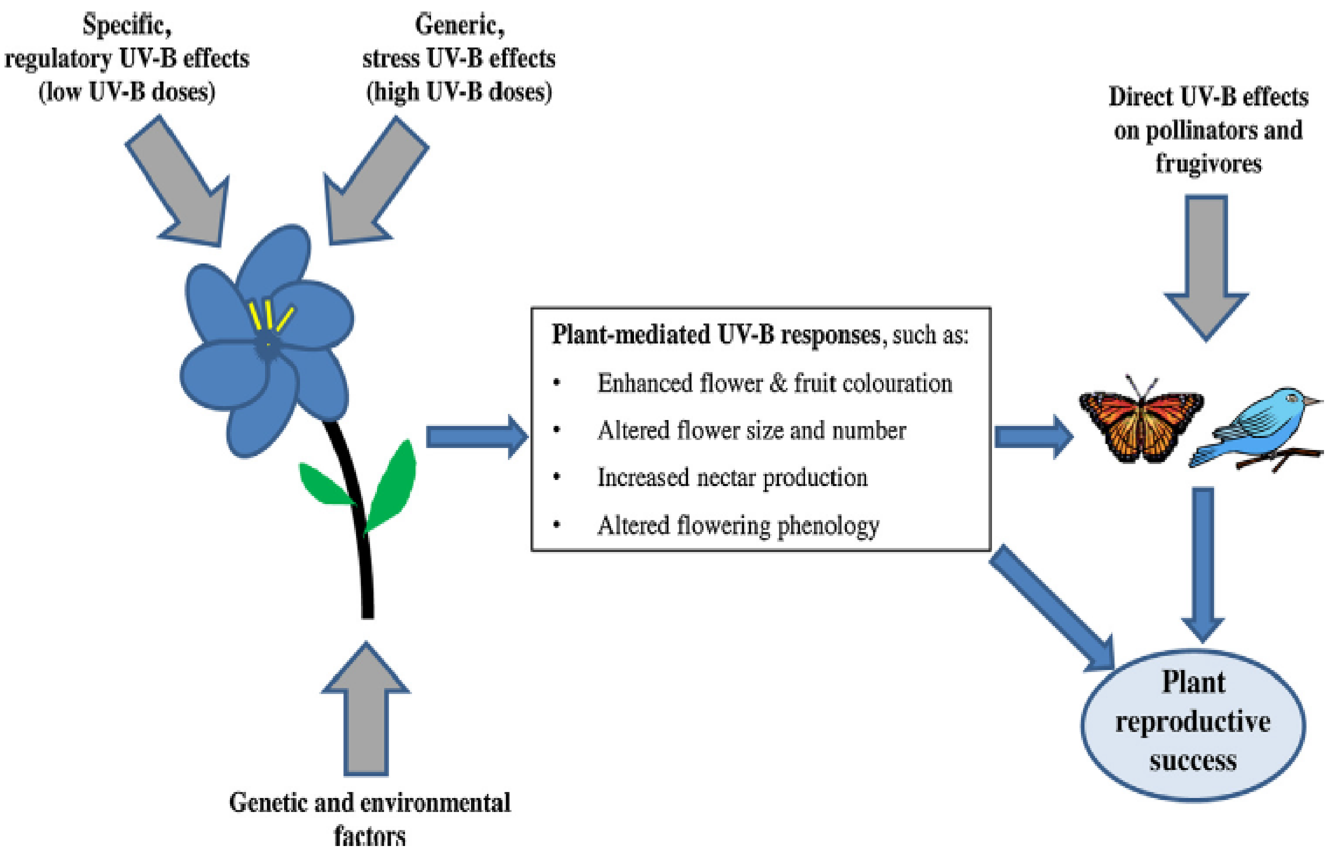
- A process-based model integrating the effects of UV-B radiation through epidermis, cellular DNA, and its consequences to leaf expansion
- UV-B radiation-induced DNA damage significantly delayed cell division, resulting in significant reductions in leaf growth and development.
- Leaf expansion highly dependent on the number of pyrimidine cyclobutane dimers.
- Formation of pyrimidine-pyrimidone (6-4) photoproducts (6-4PP) has no effect on the leaf expansion.

UV-B and plant sexual reproduction

Llorens, Laura, et al. "The role of UV-B radiation in plant sexual reproduction." *Perspectives in Plant Ecology, Evolution and Systematics* 17.3 (2015): 243-254.

Topics:

- UV-B can affect pollinators directly or through UV-B mediated changes in plants.
- Most floral parts are effectively UV-B protected through UV-absorbing compounds.
- Pollen is the most susceptible stage to suffer UV-B stress.
- UV-B can increase the development of flower and fruit colouration (attractants!).
- As UV-B doses increase, annuals delay flowering and decrease seed & fruit production.
- Dose–responses are complex emphasizing the need to use multiple UV-B doses in future studies of UV-B-mediated flowering responses.


Specific,
regulatory UV-B effects
(low UV-B doses)
Generic,
stress UV-B effects
(high UV-B doses)
Direct UV-B effects
on pollinators and
frugivores
Plant-mediated UV-B responses, such as:
• Enhanced flower & fruit colouration
• Altered flower size and number
• Increased nectar production
• Altered flowering phenology
Plant
reproductive
success
Genetic and environmental
factors

UV-B and nutritional value

Schreiner, M., et al. "UV-B-induced secondary plant metabolites-potential benefits for plant and human health." *Critical Reviews in Plant Sciences* 31.3 (2012): 229-240.

Topics:

- Epidemiological studies have revealed inverse associations between consumption of fruit & vegetables, and the risk of cancer and cardiovascular disease.

- This protective effect is mostly due to secondary metabolites present in plant tissues.

- Low UV-B levels trigger distinct changes in the accumulation of, among others, phenolic compounds, carotenoids and glucosinolates.

- Thus, targeted low dosage UV-B radiation treatments may be used to generate fruit & vegetables, enriched with secondary plant metabolites resulting in increased ingestion of these health-promoting substances by human consumers.

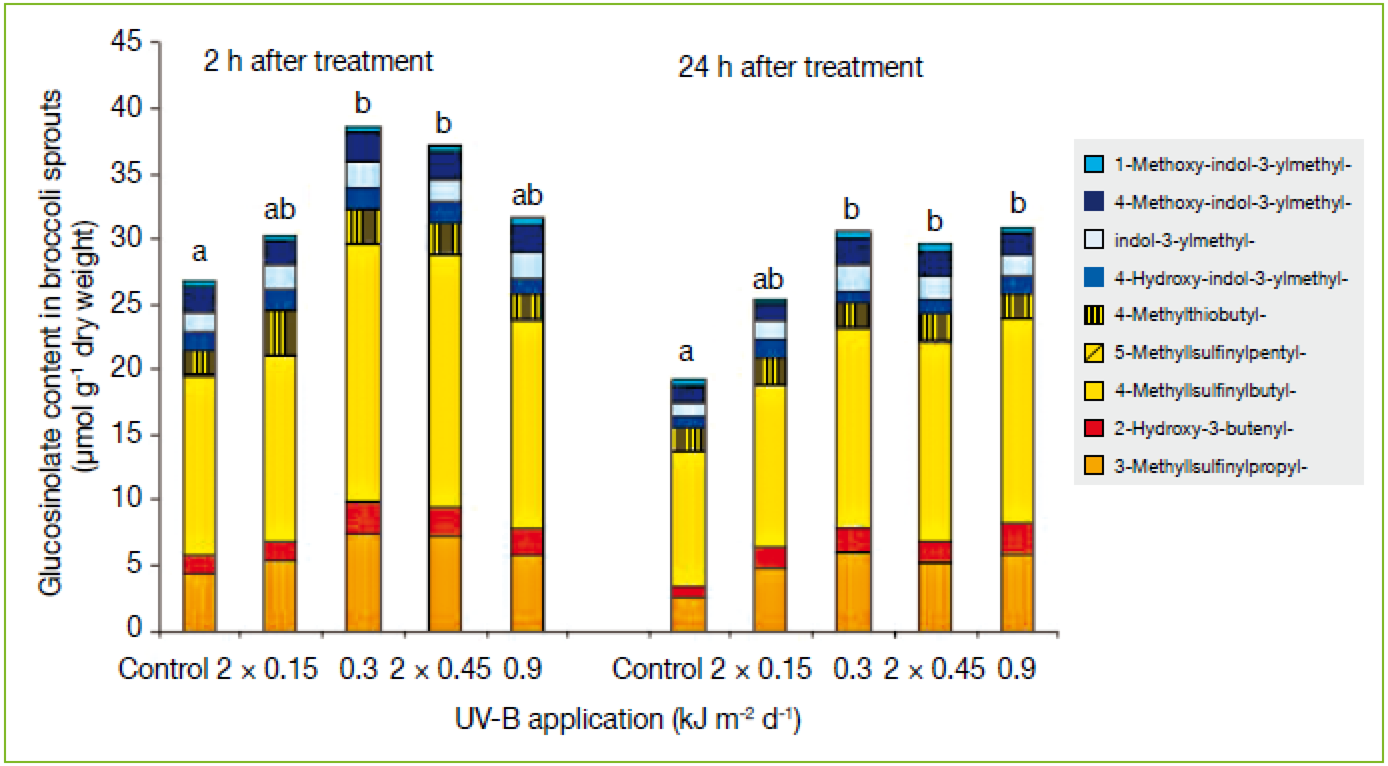


Fig. 3 Glucosinolate contents of broccoli sprouts after single and double exposure to different UV-B doses. In the double treatments with two UV-B applications, the first application was done 24 h before harvest, followed by a second application 2 h before harvest, resulting in equivalent levels to single treatments. Sprouts were 13 days old. Different letters indicate significant differences among treatments at the two different harvest times, Tukey's HSD test $p \leq 0.05$.

Schreiner, Monika, et al. "UV-B Induced Secondary Plant Metabolites." *Optik & Photonik* 9.2 (2014): 34-37.

Light signaling and plant responses to blue and UV—Perspectives for horticulture

Huché-Thélier, Lydie, et al. "Light signaling and plant responses to blue and UV radiations—Perspectives for applications in horticulture." *Environmental and Experimental Botany* (2015).

Topics:

- Blue light and UV-radiation modulate both photomorphogenesis and photosynthesis.
- Several plant photoreceptors perceive UV and blue wavelengths.
- Plant develops protective responses to UV and high fluence blue radiations.
- UV and blue wavelengths interact on processes involved in plant quality.
- LEDs are tools to adapt light spectrum to plant needs.

State of the field of physiological and organismal UV-B biology

- Plant morphology & modelling of morphology (*no major new developments*?)
- Nutritional value, and use of UV-B in horticulture (*several new reviews*)
- Reproduction (*no major new developments*?)

- *UV-A review in progress (Dolores Verdaguer)*

UV-B, ROS and Stress

Hideg, Éva, Marcel AK Jansen, and Åke Strid. "UV-B exposure, ROS, and stress: inseparable companions or loosely linked associates?." *Trends in plant science* 18.2 (2013): 107-115.

Topics:

- Discovery of UVR8; is UV-stress and UV-B-induced reactive oxygen species (ROS) still a relevant concept?
- Measurements of antioxidants and of antioxidant genes show that both low and high UV-B doses alter ROS metabolism.
- Under low UV-B, expression of antioxidant genes is linked to the UVR8 pathway.
- There is no evidence that ROS control gene expression under low UV-B.
- Low UV-B doses cause ‘eustress’ (good stress) which pre-disposes plants to a state of low alert that includes activation of antioxidant defenses.

Solar UV and ozone depletion-driven climate change

Bornman, Janet F., et al. "Solar ultraviolet radiation and ozone depletion-driven climate change: effects on terrestrial ecosystems." *Photochemical & Photobiological Sciences* 14.1 (2015): 88-107.

Topics:

- Interaction UV-B radiation with other climate change factors, and the influence terrestrial organisms and ecosystems (cross-tolerance –stress).

- recognition regulatory role UV-B , and beneficial consequences for plant productivity and quality

- UV-B as driver of decomposition of plant litter

- UV radiation as contributor to climate change via its stimulation of volatile organic compounds from plants, plant litter and soils,

Solar UV and ozone depletion-driven climate change

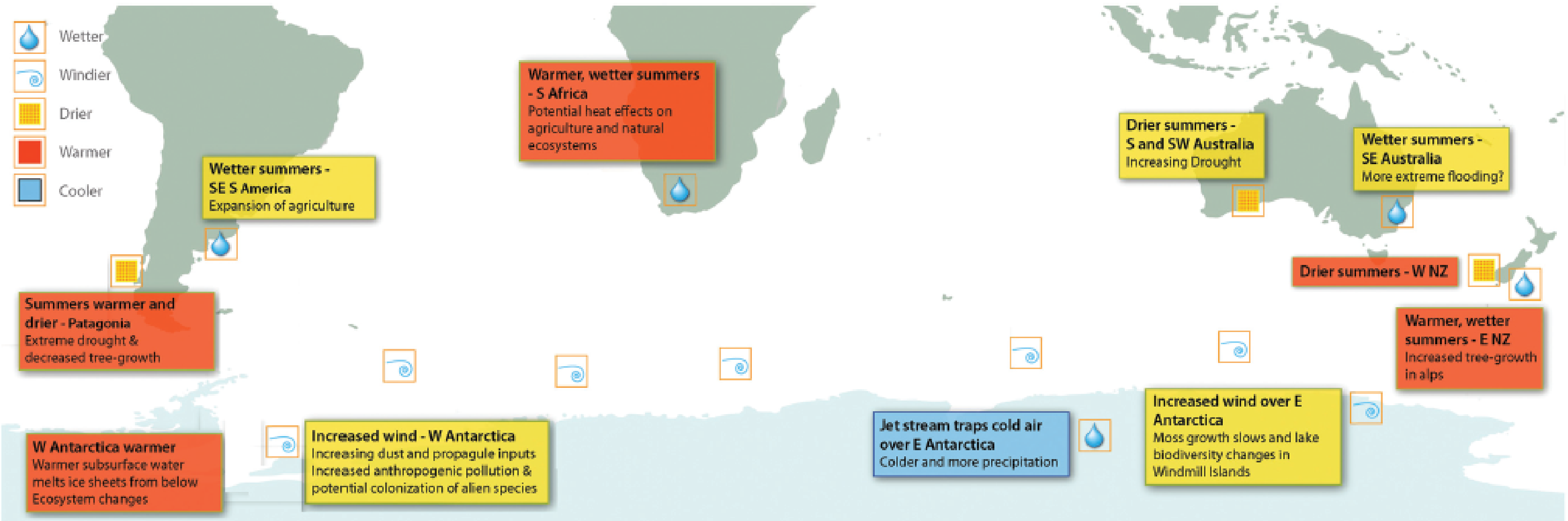


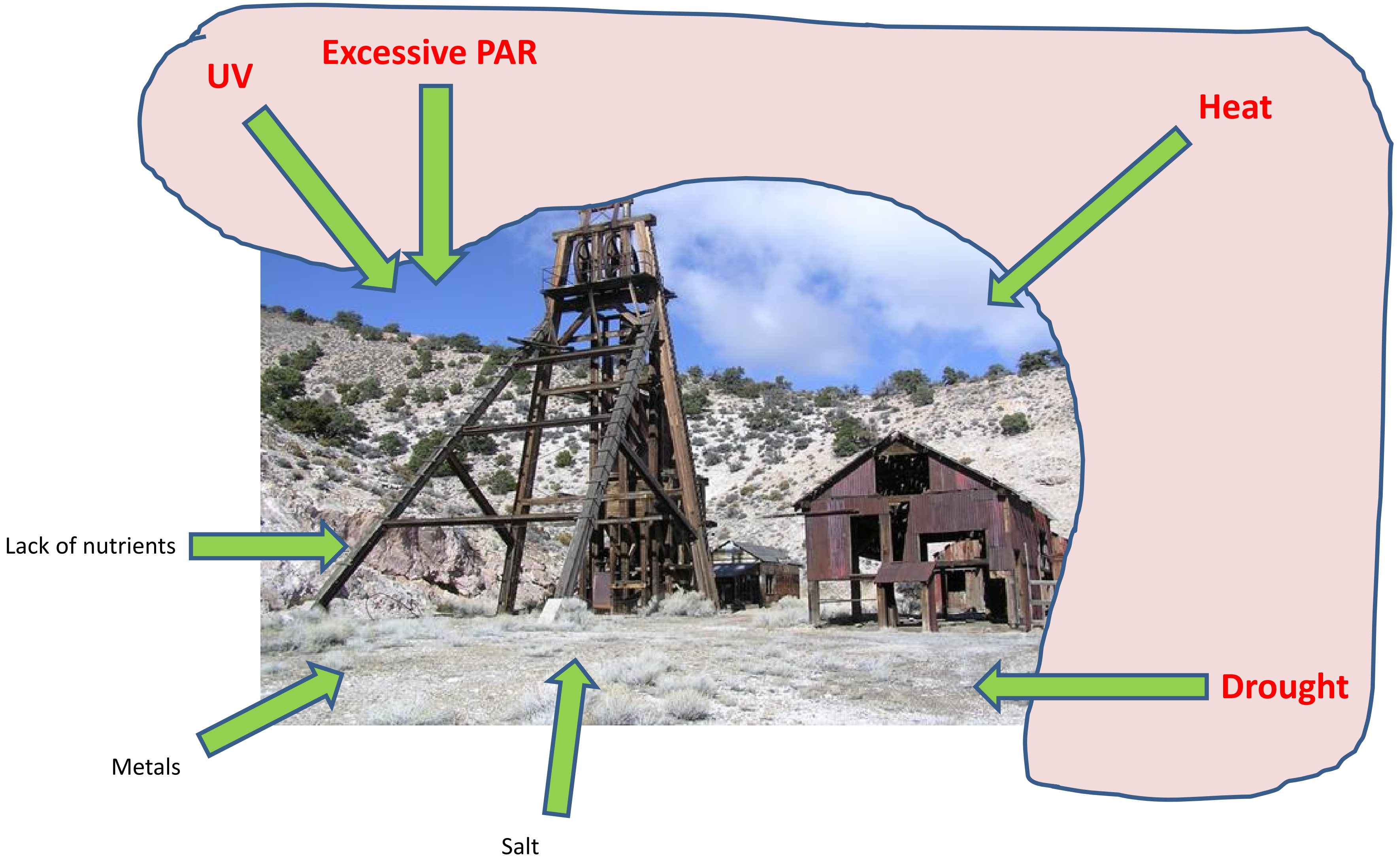
Fig. 2 The Southern Hemisphere showing the impacts of the positive phase of the Southern Annular Mode (SAM) on atmospheric circulation, wind patterns and precipitation, as well as oceanic currents and temperatures. The associated effects of these climate changes on terrestrial ecosystems are shown where available. Over the past century, increasing greenhouse gases and then ozone depletion over Antarctica have both pushed the SAM towards a more positive phase and the SAM index is now at its highest level for at least 1000 years.[67] During the summer months the positive phase of the SAM is strongly associated with ozone depletion. NZ, New Zealand. The figure, produced by Andrew Netherwood, has been modified from Robinson *et al.*[7]

ological Sciences

State of the field “UV-B and stress”

- UV-B and climate change are linked
- Substantial numbers of individual studies on cross-tolerance
- Fewer studies on aggravated stress
- Contradictions between published studies
- No (or one?) recent reviews

Multiple stressors



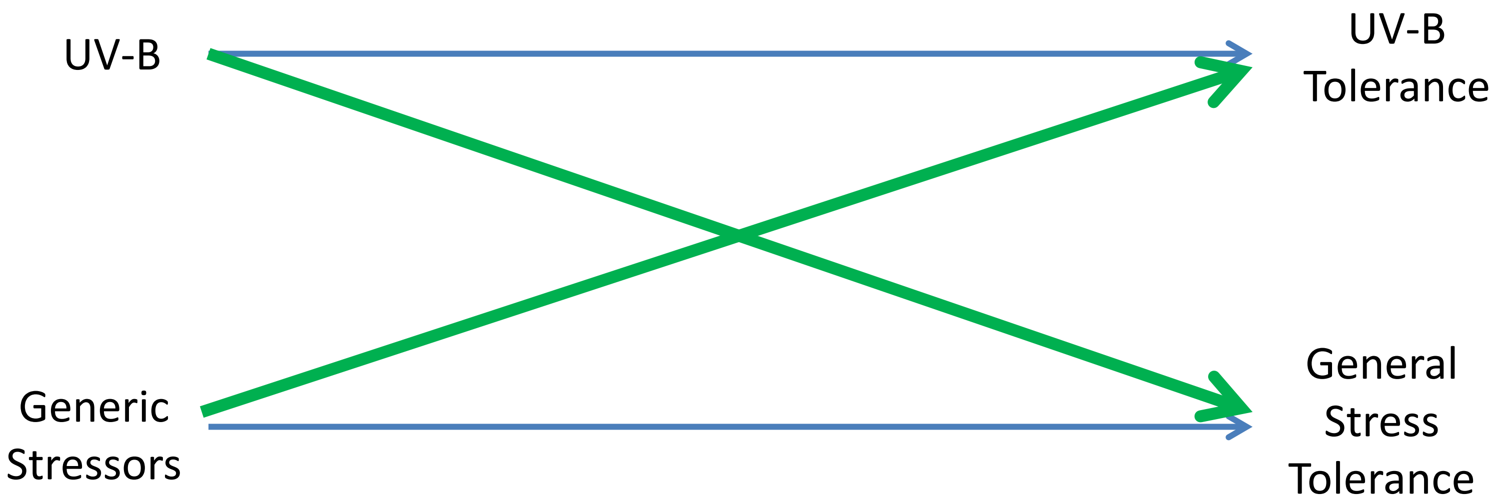
UV-B and stress

UV-B $\longrightarrow$ UV-B Tolerance

Generic Stressors $\longrightarrow$ General Stress Tolerance

UV-B and stress

Cross-tolerances



- Based on generic stress defences, such as;
  - ROS-scavenging capacity
  - Morphological adjustments
  - Stomatal responses
  - And others

UV-B and stress

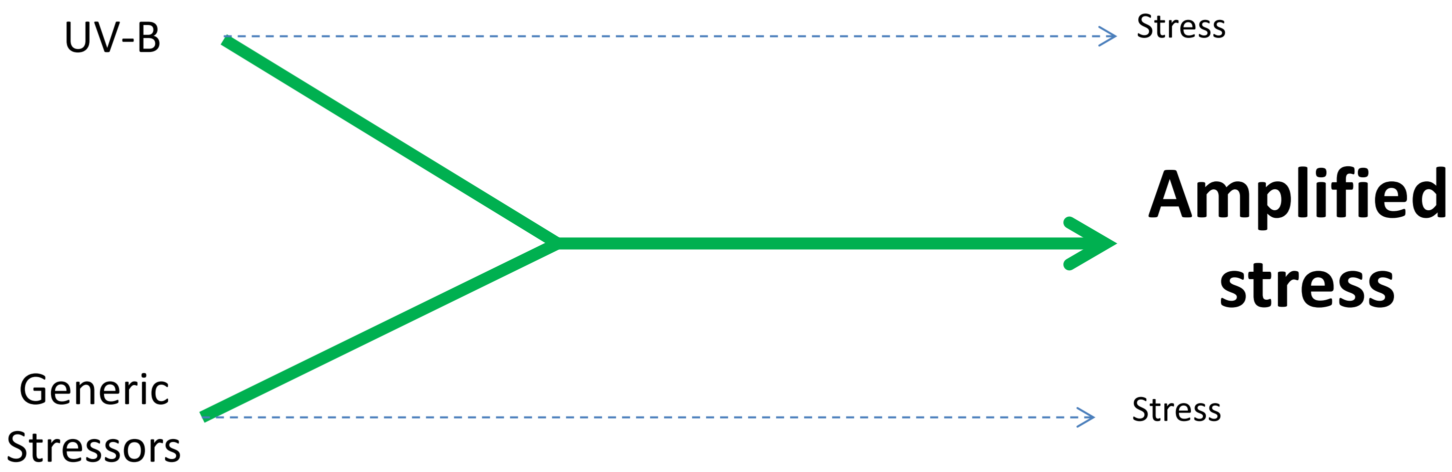
Amplified stress

UV-B $\dashrightarrow$ Stress

Generic Stressors $\dashrightarrow$ Stress

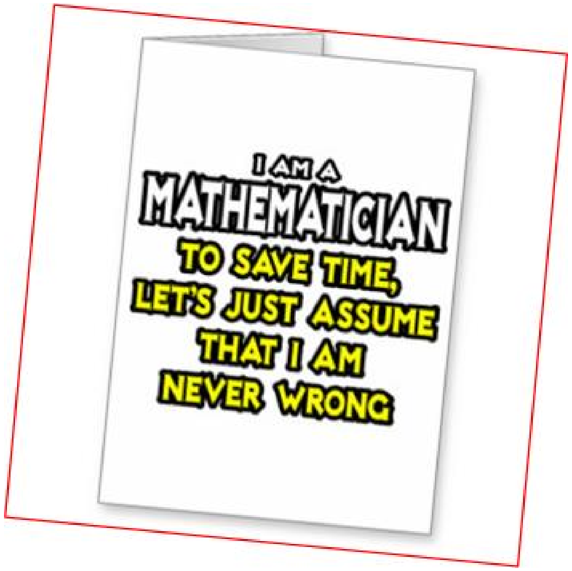
UV-B and stress

Amplified stress



- Simultaneous application of two stressors may result in severe stress
- UV-B “only” triggers stress in plants already subjected to another stress????

The enigma….



$1 + 1 = 0$ → Cross-tolerance

or

$1 + 1 = 3$ → Amplified stress

The enigma....

$1 + 1 = 0$ → Cross-tolerance

or ←

Depends on????

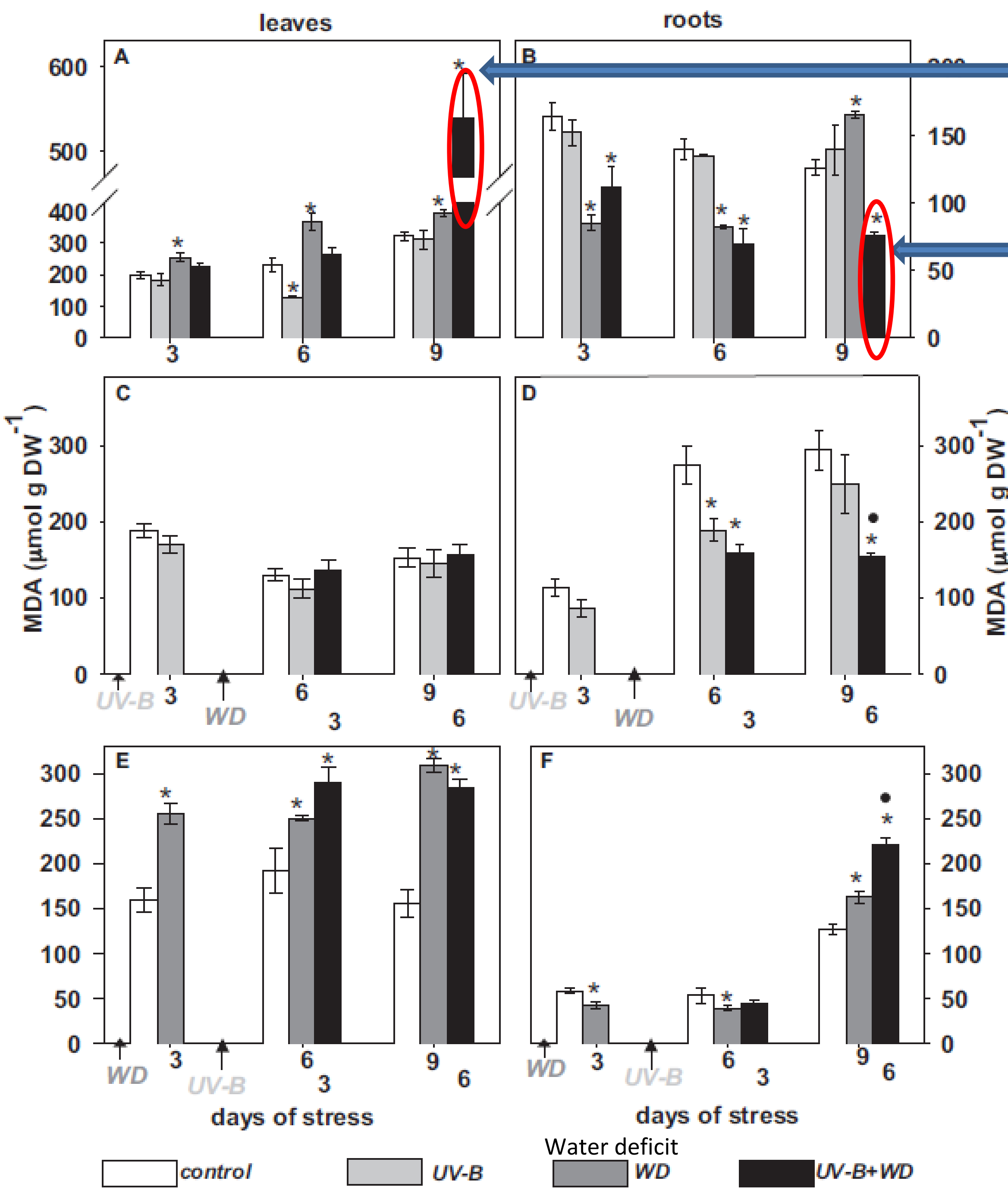
- Exposure consecutive or simultaneous
- Severity of each stress
- Genetic and environmental factors

$1 + 1 = 3$ → Amplified stress

Separate and combined responses to water deficit and UV-B radiation

Bandurska, Hanna, Justyna Niedziela, and Tamara Chadzinikolau. "Separate and combined responses to water deficit and UV-B radiation." *Plant science* 213 (2013): 98-105.

- Common metabolic responses to water deficit and UV-B are observed.
- Combined action of stresses may alleviate or increase damages.
- UV-B may enhance resistance to Water Deficit (WD) and vice versa.
- H_2O_2, NO, ABA, jasmonic acid, salicylic acid and ethylene participate in cross-talk.



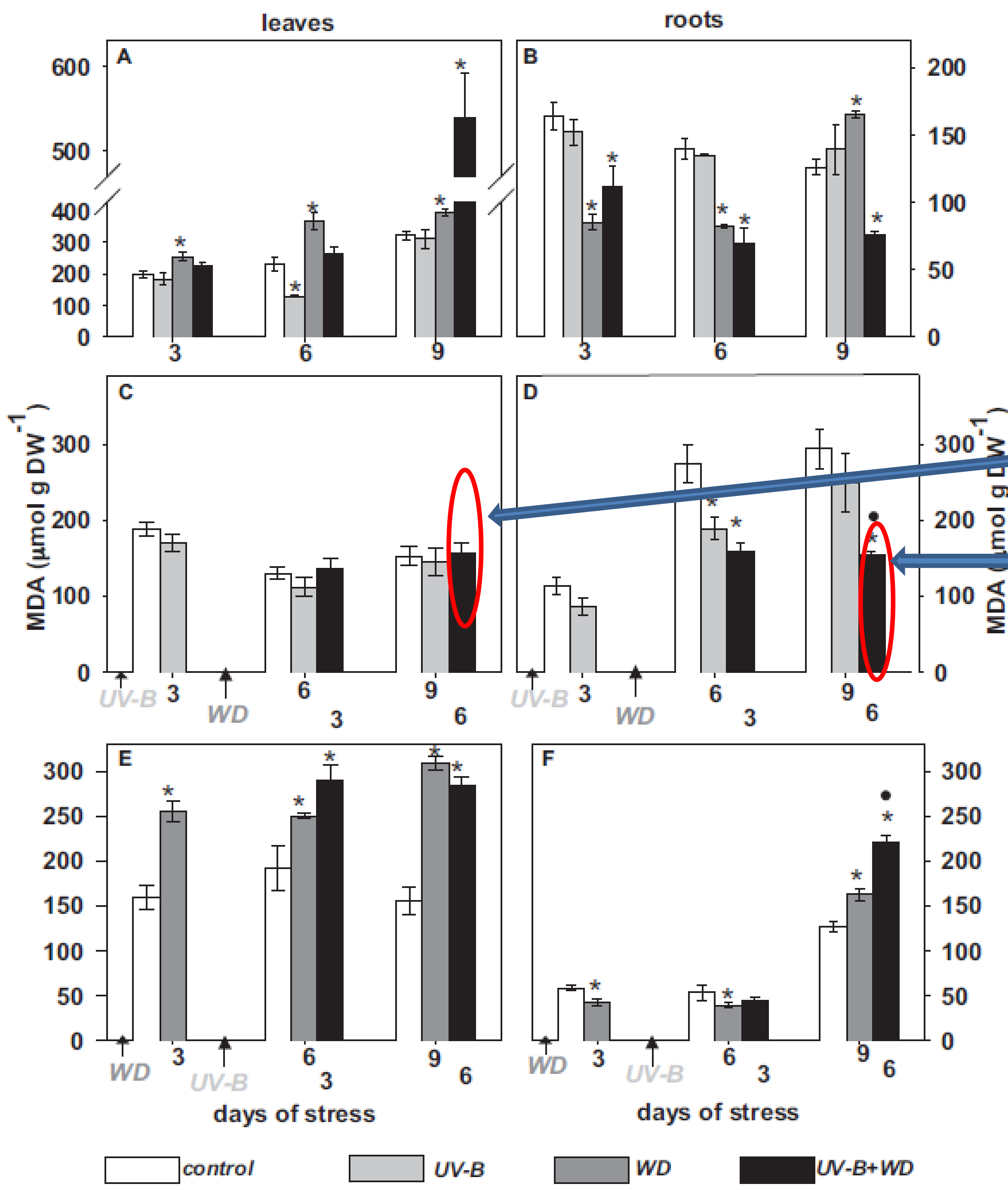
Aggravated stress

Simultaneous stress exposure

Cross-tolerance

Barley-exps

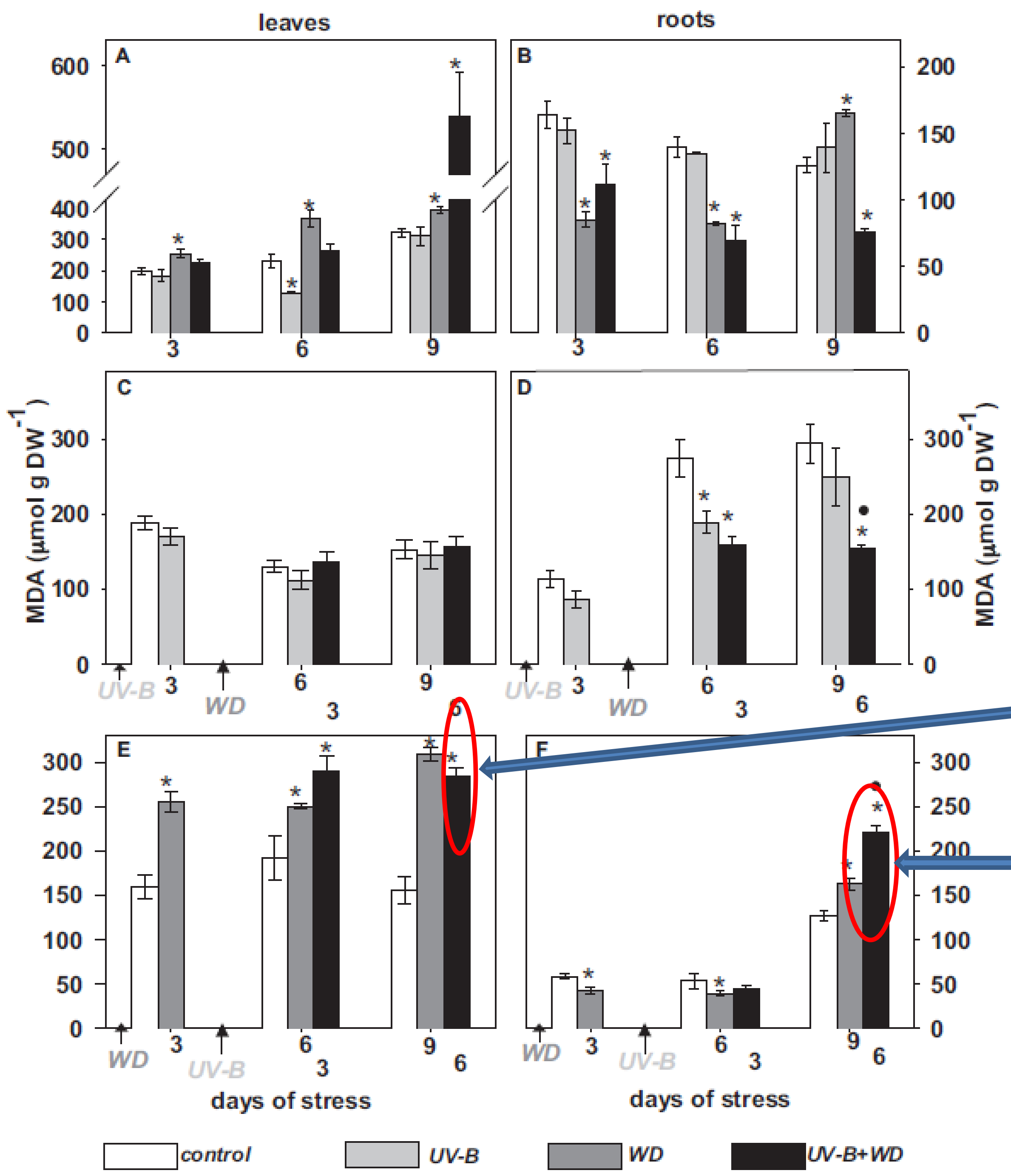
Bandurska and Cieślak. *Environmental and Experimental Botany* 94 (2013): 9-18.



No aggravated stress

Cross-tolerance

Sequential stress exposure



Sequential stress exposure

No aggravated stress

No cross-tolerance

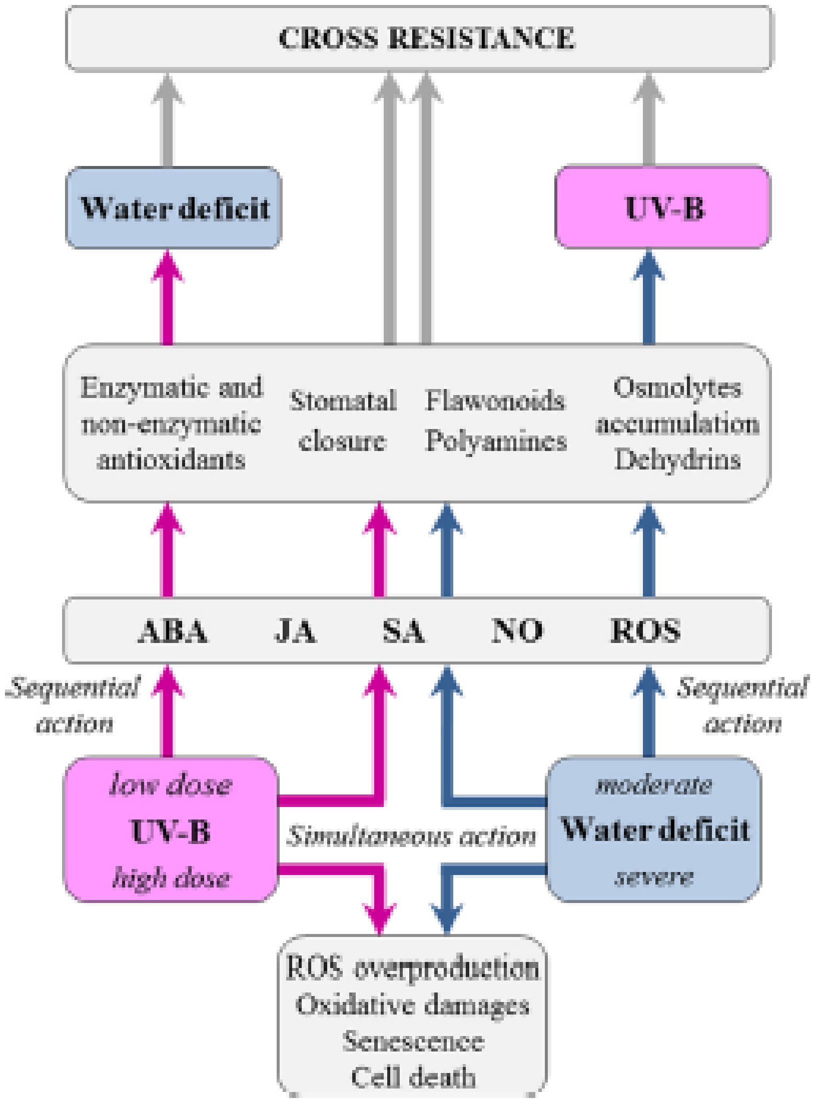


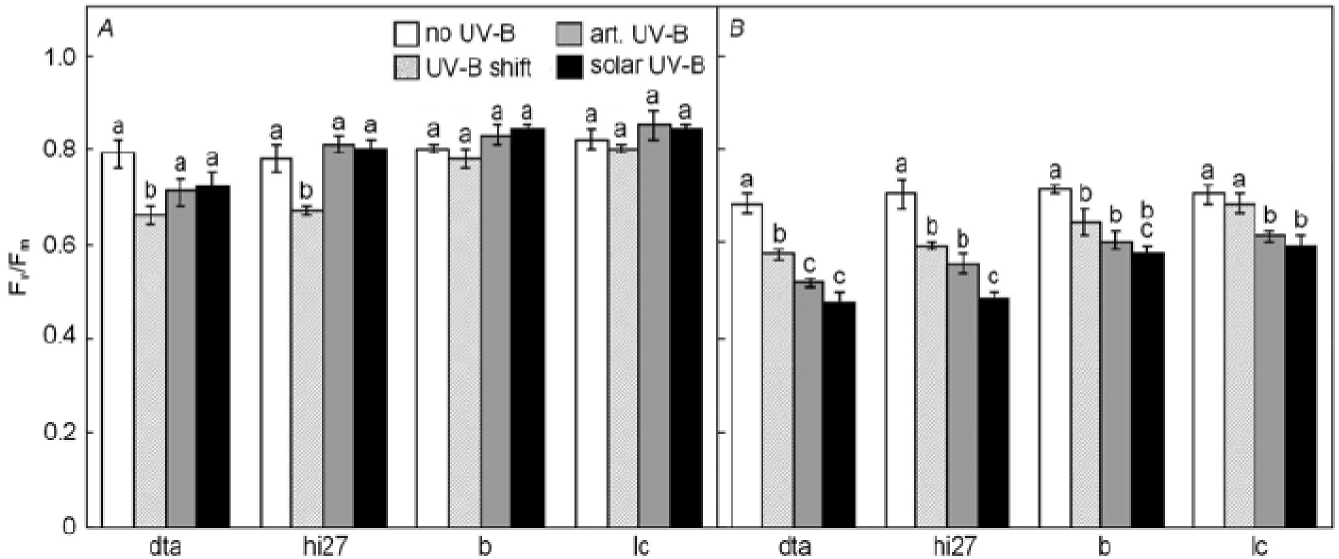
Fig. 3. A proposed model of cross-talk in plant responses to combined action of water deficit and UV-B radiation. Abbreviations: ABA, abscisic acid; Et, ethylene; JA, jasmonic acid; SA, salicylic acid, ROS, reactive oxygen species, NO, nitric oxide.

Two crosstalk scenario's

Bandurska, Hanna, Justyna Niedziela, and Tamara Chadzinikolau. "**Separate and combined responses to water deficit and UV-B radiation**." *Plant science* 213 (2013): 98-105.

Aggravated stress

Well fertilised | Nutrient deficient



Maize-lines

Fig. 3. Measurements of F_v/F_m for the four isogenic maize grown with sufficient (*A*) or deficient (*B*) nutrients, and exposed to four radiation regimes. Means ± SE (*n* = 4–7 plants per treatment) are shown. Column colors and statistical ANOVA test are described in the legend for Fig. 2.

Lau, T. S. L., et al. "Ambient levels of UV-B in Hawaii combined with nutrient deficiency decrease photosynthesis in near-isogenic maize lines varying in leaf flavonoids: Flavonoids decrease photoinhibition in plants exposed to UV-B." *Photosynthetica* 44.3 (2006): 394-403.

Aggravated stress

Brassica exps

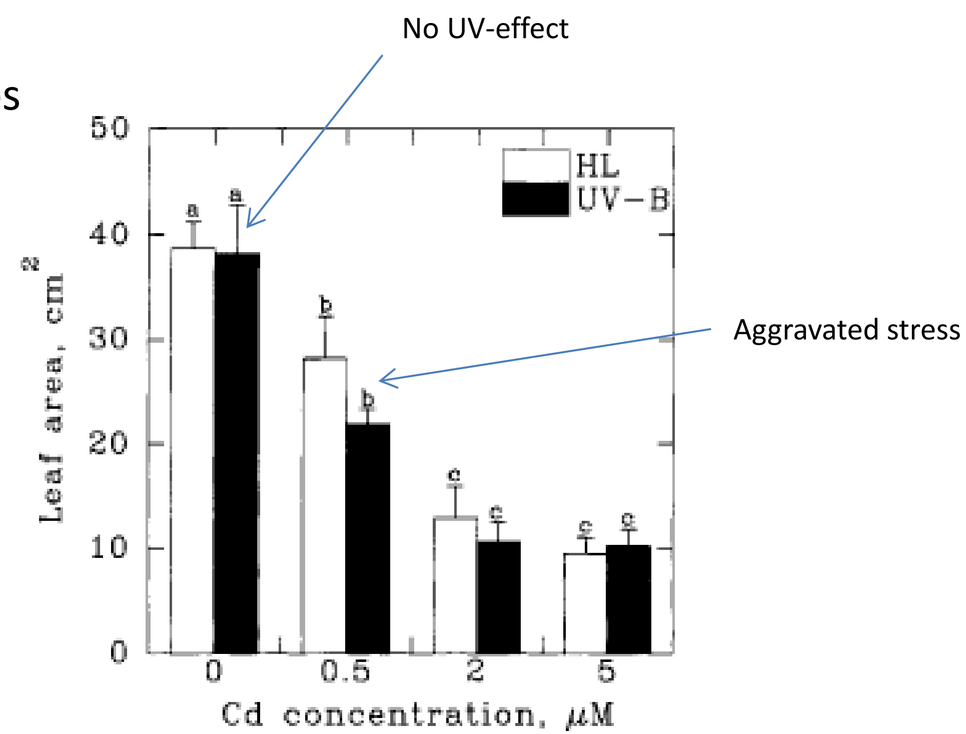
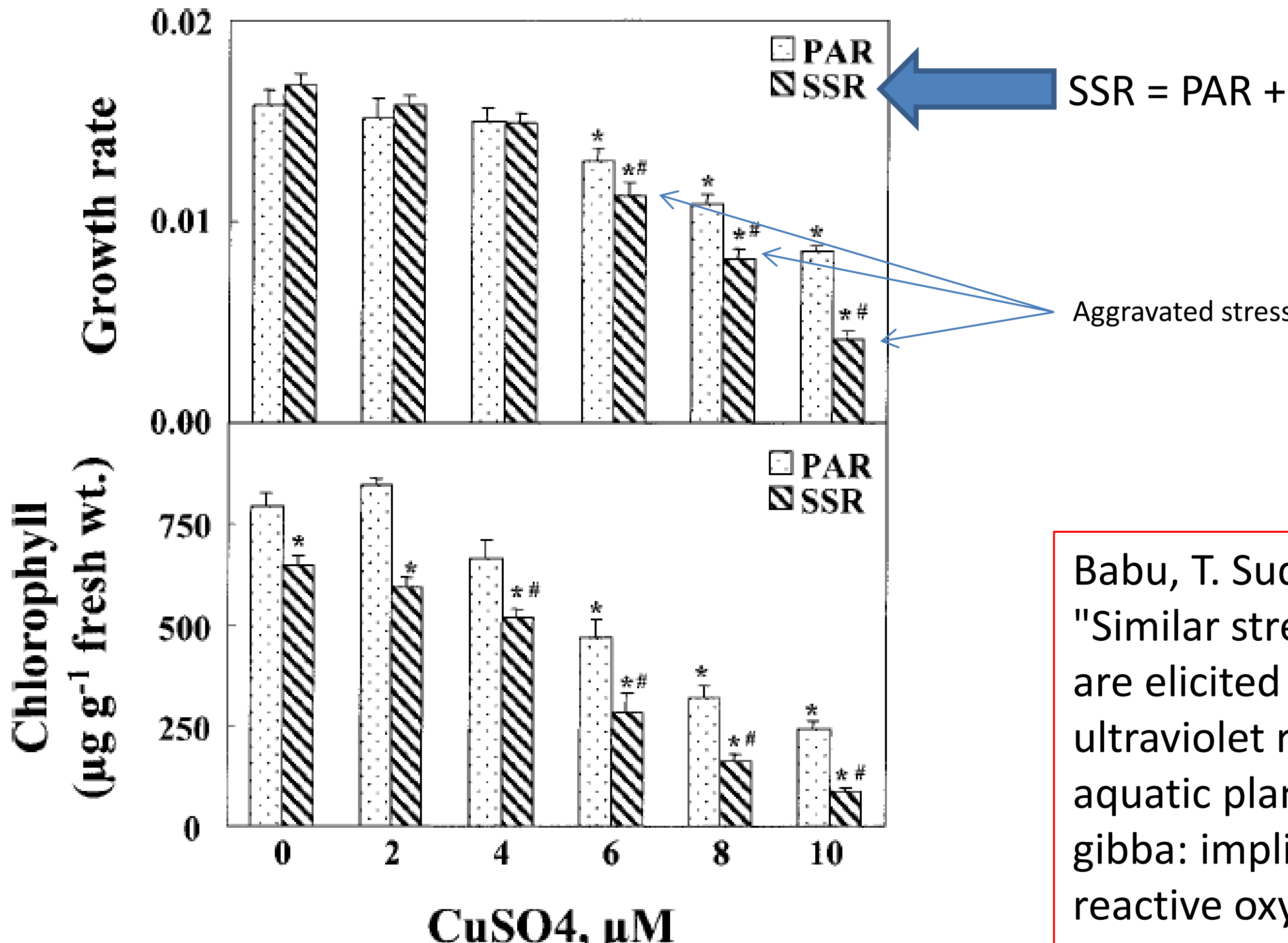


Fig. 1. Leaf area after 14 d of treatment with different Cd concentrations ± UV-B. Error bars represent SE of the mean, $n = 5$, $P < 0.05$.

Larsson, E. Helene, Janet F. Bornman, and Hakån Asp. "Influence of UV-B radiation and Cd2+ on chlorophyll fluorescence, growth and nutrient content in Brassica napus." *Journal of Experimental Botany* 49.323 (1998): 1031-1039.

Aggravated stress



SSR = PAR + UV-A + UV-B

Babu, T. Sudhakar, et al. "Similar stress responses are elicited by copper and ultraviolet radiation in the aquatic plant Lemna gibba: implication of reactive oxygen species as common signals." *Plant and Cell Physiology* 44.12 (2003): 1320-1329.

Co-tolerance following sequential exposure?

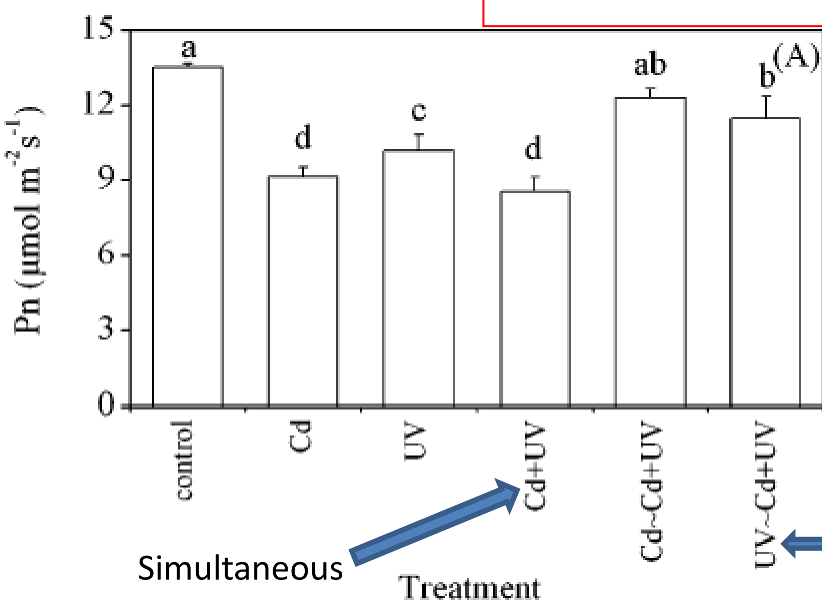
Plant Soil (2012) 352:377–387
DOI 10.1007/s11104-011-1003-8

REGULAR ARTICLE

Changes in photosynthesis, antioxidant enzymes and lipid peroxidation in soybean seedlings exposed to UV-B radiation and/or Cd

Xuemei Li · Lihong Zhang · Yueying Li ·
Lianju Ma · Ning Bu · Chunyan Ma

Soybean exps



Simultaneous

Pre-treatment with UV or Cd shows co-tolerance

Fig. 3 Effects of UV-B and/or Cd on net photosynthetic rate

UV-B field studies

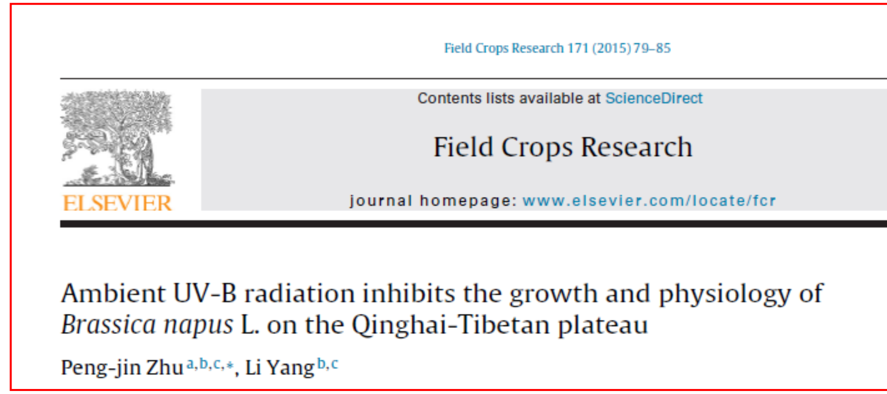
Why do some authors report co-tolerance, while others measure aggravated stress?

Co-tolerance OR aggravated stress?

Co-tolerance OR aggravated stress?

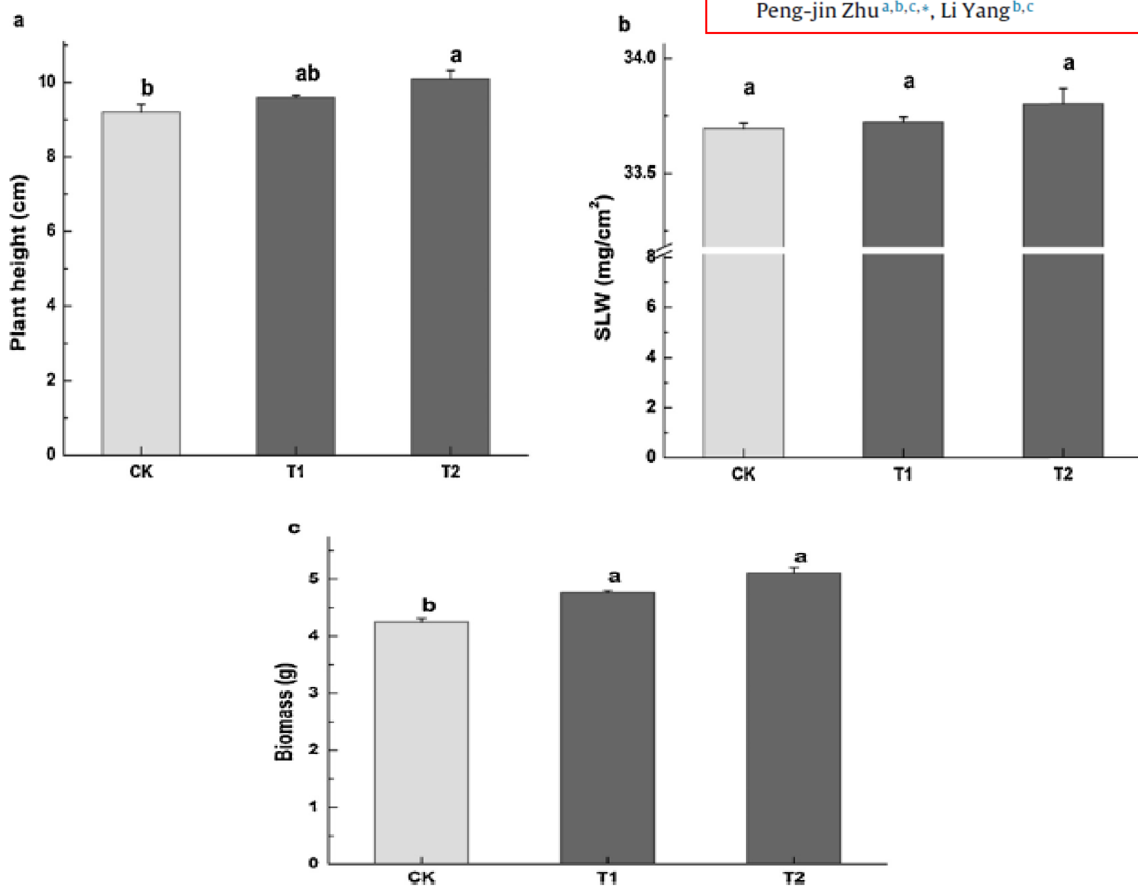
- **Can the direction of the response be predicted?**
- **Can we propose better experiments?**
- **Can we advise on better reporting?**

Aggravated stress?


Field Crops Research 171 (2015) 79–85
Contents lists available at ScienceDirect
Field Crops Research
journal homepage: www.elsevier.com/locate/fcr

Ambient UV-B radiation inhibits the growth and physiology of *Brassica napus* L. on the Qinghai-Tibetan plateau

Peng-jin Zhu[a,b,c,*], Li Yang[b,c]



100% 75% 30% of solar UV

Brassica napus grown at 2300m in Tibet

Aggravated stress

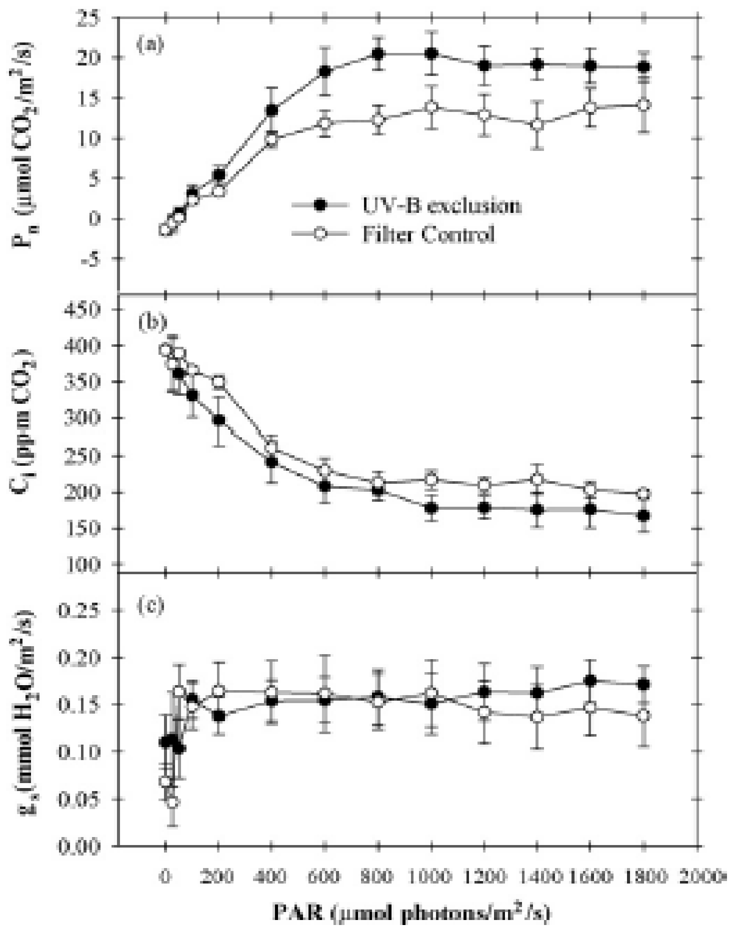


Fig. 2. Light response curves at 400 ppm CO_2 in the 'fixed angle site'. (a) Net photosynthesis (P_n), (b) Intercellular CO_2 concentration (C_i) and (c) Stomatal conductance (g_s) are depicted as mean ± standard error ($n = 20$). Open symbols are ambient UV-B (filter control, F) and closed symbols are reduced UV-B treatment (Mylar, UV-B). Net photosynthesis was significantly lower in ambient UV-B ($p = 0.0002$), the intercellular CO_2 was higher in ambient UV-B ($p = 0.0002$) and no effect was seen on stomatal conductance ($p = 0.8541$).

Albert, Kristian R., et al. "Ambient UV-B radiation reduces PSII performance and net photosynthesis in high Arctic Salix arctica." *Environmental and experimental botany* 72 (2011): 439-447.