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University College Cork, Ireland
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■ Organizers' report

Workshop "Modulation of plant UV-responses by environmental factors"

Marcel A. K. Jansen, ORCID: 0000-0003-2014-5859
School of Biological, Earth and Environmental Sciences, UCC, Cork, Ireland

Otmar Urban, ORCID: 0000-0000-0000-000
Czech Globe, Brno, Czech Republic

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A group of 21 plant UV-researchers came together on June 27 and 28, 2017 for a discussion-intensive workshop at CzechGlobe in the south Moravian town of Brno in the Czech Republic. The workshop was organised by Drs. Otmar Urban (CzechGlobe—Global Change Research Institute, Czech Republic) and Marcel Jansen (University College Cork, Ireland) under the auspices of UV4Plants, with sponsorship by the Czech Ministry of Education (grants LO1415 and CZ.02.1.01/0.0/0.0/16_013/0001608) and Science Foundation Ireland (grant 11/RFP.1/EOB/3303). The workshop brought together a very nice mix of "young" and "not-so-young" researchers from 10 countries, and included some familiar faces, as well as researchers new to the UV community. Brno was a very appropriate host-town, being the place where Gregor Mendel did most of his pioneering research on pea genetics. Indeed, in the evening of the 27th of June we visited Mendel's old monastery for a guided tour learning, among others, about the great man's poor track record in passing exams, as well as his lesser known research on plant taxonomy, meteorology (tornados and their geometry) and honey-bee crossbreeding (Figure 4.1), and his banking activities arising from his position as abbot of Augustinian monastery. It was also good to see Mendel's original glasses, so well-known from the portraits.

Figure 4.1: Building where Gregor Mendel used to keep his bee hives. Old Augustinian Monastery, Brno. Photo: Pedro J. Aphalo.

The objective of the workshop was to bring together plant scientists with an interest in cross-talk between UV-B and other environmental drivers. Over the last two decades, extensive data have been generated on plant responses to UV-radiation. Experimental set-ups vary, but in general plants are kept under near-optimal conditions, in the field, glasshouse or growth room, where they are exposed to supplemental UV radiation. However, a more environmentally realistic situation is where plants are simultan-

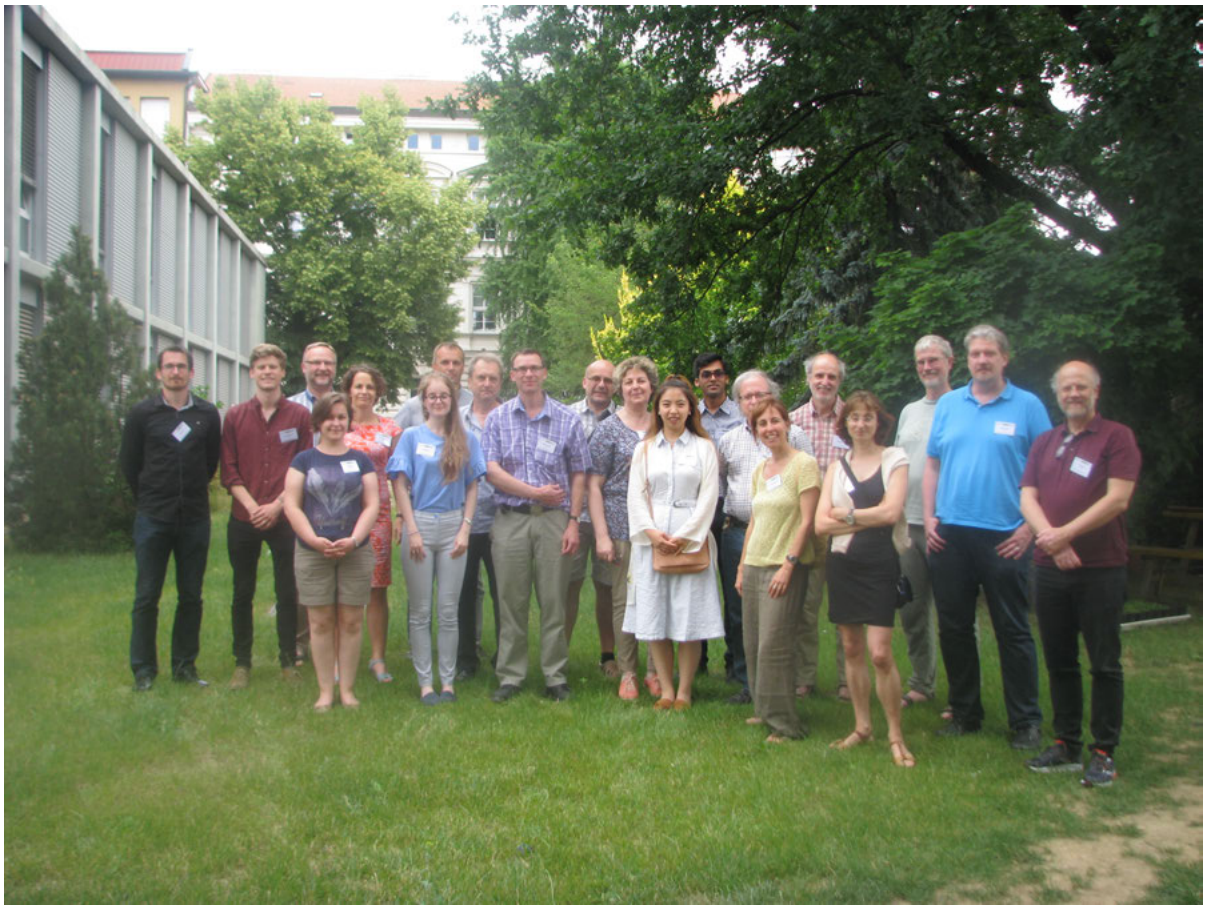

Figure 4.2: Workshop participants at the grounds of the Old Augustinian Monastery, Brno.

eously exposed to multiple environmental signals and/or stressors. In nature high levels of UV-B radiation are commonly accompanied by high levels of photosynthetic radiation (i.e. risk photoinhibition), while heat and drought are also likely to be relevant under such conditions. Appropriately, several presentations focused on the interaction between UV-B and drought. Presentations by Laura Llorens (Girona) and Anikó Mátai (Pécs) demonstrated interactive effects of UV and drought on plant morphology, carotenoids, flavonoids, total antioxidant activity, and photosynthetic energy dissipation. Regulation of flavonoid accumulation, in particular, seems to be a target of interactive effects of UV-B and other environmental factors. Dirk Schenke (Kiel) revealed some of the highly complex interactions between UV-B and pathogens, with pathogens suppressing the UV-induced accumulation of flavonoids, while a role for flavonoids in pathogen suppression is being explored. Karel Klem (Brno) showed that flavonoid levels are associated with tissue C:N ratios, and thus ultimately soil conditions. Wolfgang Bilger (Kiel) emphasised the role of low temperatures in controlling flavonoid-mediated UV-screening by epidermal cells. In agreement, Marcel Jansen (Cork) showed that accumulation of flavonoids in *Arabidopsis* grown outdoors peaks under low winter temperatures, with no discernible solar UV-effect noted. Line Nybakken (Ås) showed that higher temperatures were associated with lower concentrations of phenolic compounds. Furthermore, these studies also showed the full complexity of interactions between temperature

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Figure 4.3: Craig Brelsford (Helsinki) giving his presentation to an attentive audience.

and UV-B with consequent effects on secondary metabolites, plant growth and phenology. Thus, although the induced accumulation of flavonoids is one of the "classic" plant UV-B responses, several presentations revealed how interactions with "other" environmental factors can moderate, or completely mask, UV-induced flavonoid accumulation.

Interactions between UV-B and other parts of the solar spectrum were discussed by several authors, including Ashutosh Sharma (Bristol) who reported on the role of UV-B and UVR8 in shade avoidance, i.e. interactions with the red / far-red sensing phytochrome system. Craig Brelsford (Helsinki) had studied plant responses to blue and UV-A radiation in the dynamic light environment of forest understories, and revealed that the UVR8 mediated induction of phenolic acid derivatives can be driven by UV-A. Yan Yan (Helsinki) showed flavonoid accumulation in the epidermis induced by short UV and blue light. Jakub Nezval (Ostrava) showed that UV-A (and to a lesser extent UV-B) shielding can be induced by blue light in combination with high intensity of photosynthetically active radiation (PAR). These studies clearly show the interactions between the different spectral regions in controlling biosynthesis of plant flavonoids. Knut Solhaug (Ås) emphasised the complex accumulation patterns of secondary metabolites, and showed that some of these UV-induced compounds don't apparently contribute to UV-protection, but rather to protection against high PAR intensities.

Perhaps one of the most important reasons to explore interactions between plant response to UV-and other environmental factors is the increasing reality of climate change. Otmar Urban (Brno) reported on the interactive effects of elevated CO_2 and UV-B on photosynthetic performance of beech saplings. UV reduces the positive effects of elevated CO_2 on photosynthesis, and this would have substantial impacts on predictions of plant productivity in future climate scenario's.

A plenary lecture by Jacques Roy (Montpellier) addressed some of the limitations of our current approaches in studying interactions between multiple environmental factors. The "reproducibility crisis" and the "local truth" refer to over-standardised approaches that do not take in consideration the complexities of the natural environment. To resolve this, Roy emphasised the importance of shared international infrastructures, and large, collaborative experiments. The examples of the Montpellier Ecotron and the European infrastructure AnaEE (Analysis and Experimentation on Ecosystems) were presented and enabled us to start interconnecting UV4Plants and AnaEE research communities.

Presentations were accompanied by discussion sessions that focussed on many of the aspects presented in the talks. One major issue concerned the terminology to describe and discuss data (stress, acclimation, adaptation and especially cross-talk and cross-tolerance). Cross-talk was considered a mechanistic concept that refers to reciprocal interactions whereby two streams of information (signalling pathways) influence each other. Cross-tolerance is an outcome, whereby a cell or organism that has gained protection against one environmental factor is also more tolerant towards another factor. The assembled group aims to draft a dis-

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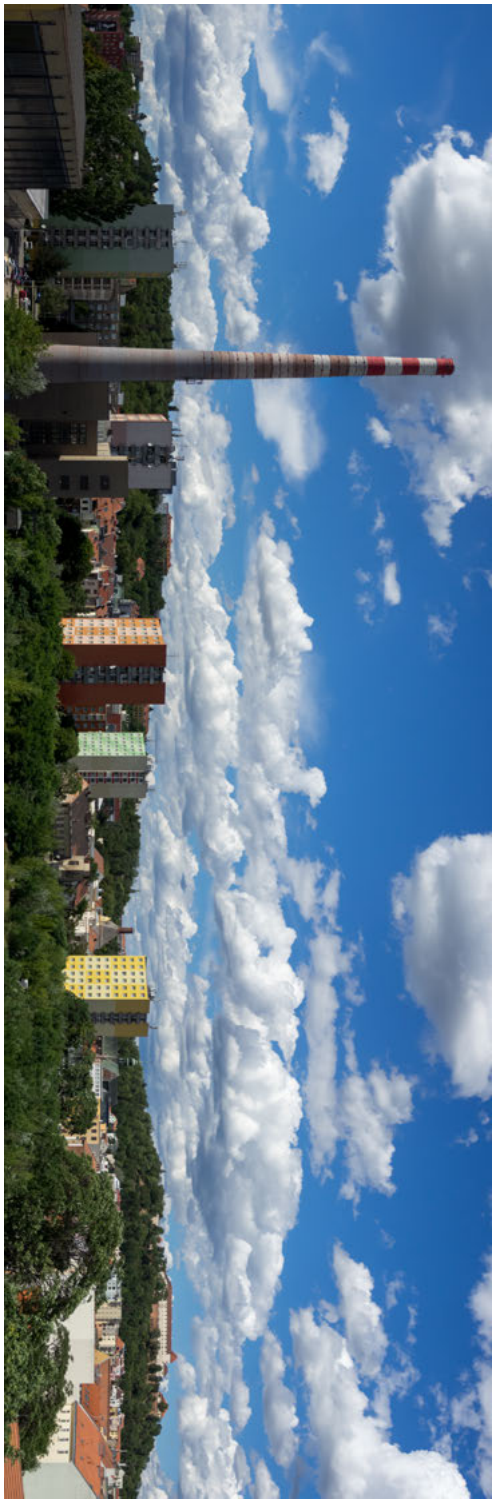

Figure 4.4: Panoramic view of Brno and its castle from the roof of Czech Globe. Photo: Pedro J. Aphalo.

cussion paper detailing the issues and putting forward appropriate terminology. It is intended to publish this discussion paper as part of a special issue of the journal Plant Physiology and Biochemistry, focussed on the theme of "Modulation of plant UV-responses by environmental factors". UV-researchers interested in contributing a paper please contact Marcel Jansen on mailto:brno17.papers@uv4plants.org.

A central question in the discussion was whether the UV-sensing capability of plants is simply about UV-B protection, or underpins a more comprehensive priming of plant protective responses. It was agreed that UVR8-mediated signalling / changes to gene-expression should guide us when discussing the ecological role of UV-B / UVR8. Although there are no direct answers to this question (yet!), several contributors emphasised the regulatory role of UV-B and the commonly reported lack of UV-stress. Pedro Aphalo (Helsinki) introduced the concept of "pre-emptive cross-acclimation" to, among others, restricted water supply, and argued that a main role of UV perception by plants is to acquire advance information about changes in the environment that are correlated to UV-doses. In fact, presentations at the workshop showed that a broad range of plant environment responses (among others to drought, spectral-composition, nitrogen, temperature, carbon dioxide, and bacterial pathogens) is moderated by UV-B, and vice versa. In conclusion, it was argued by several contributors that UV-B has a ubiquitous, modulating effect on all plant-environment responses. This sweeping generalisation has not (yet) been proven, but triggers important and novel questions about the ecological function of plant UV-B sensing.

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