UV4Plants

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Front cover illustrations: From the Light and Life conference in Barcelona (see page 30) and the workshop in Cork (see page 36).

Back cover illustration: UV-A induced fluorescence from lichens, mosses and herbs.
(Photo credit: P. J. Aphalo).

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Contents

From the editors' desk

We are at the end of 2019. This is the seventh issue of the Bulletin and the fifth year of publication. Having served as Editor-in-Chief for the whole of this period I will look back at what has been achieved and give my views on the future of our Bulletin.

I will start with some statistics, which to me look good (Table 1.1). The statistics are based on our OJS server, and ignore views and downloads previous to September 2017 due to statistics having been reset during a major update to the server software. In other words, they describe approximately 25 months of visits to the Bulletin site. These data do not include whole issue downloads. Of course, they also miss the views to copies deposited by authors in public repositories like ResearchGate.

Issue	Number of articles	Abstract views	PDF file downloads
2015:1	5	1195	304
2016:1	7	1429	550
2016:2	7	893	1174
2017:1	7	1895	938
2018:1	8	812	486
2018:2	9	1368	434
Total	43	7592	3886

Table 1.1: Number of views and downloads from the *UV4Plants Bulletin* OJS server between September 2017 and December 2019.

During the life of the Bulletin, 43 articles have been published. These "articles" are items that have been assigned a DOI. Editorials and letters from the president have been assigned DOIs only in the most recent issues.

I interpret the data in the table above as showing that the Bulletin has waken up the interest of readers not only within our Association but also outside it. It is also of interest to know how views and downloads relate to articles. Close to 7 600 abstract views and nearly 4 000 PDF downloads from only 43 articles published is encouraging.

If we look at the popularity of individual articles (Fig. 1.1) we can see that the distribution is skewed to the right (with a few very popular articles) and most frequently article PDFs being downloaded 25 times per year, and abstracts viewed more than 50 times per year. The abstract with most views had 822 views and the one with fewest had 51 views. The most popular PDF was downloaded 323 times and the least popular, 24 times. These numbers reinforce my belief that the Bulletin is relevant as a platform for communication of more than our associations' internal news. Significant, the most frequently downloaded article PDF and the most viewed abstract are for two articles describing methods.

What is happening outside of our server is difficult to assess. In the exceptional case of a book review that *has gone viral* (Aphalo 2018), reads continue to accumulate at a rate of approximately 1500 to 2000 per week, with an accumulated total of 267 134 *reads* as of today. This serves more as a warning about how to interpret altmetric indexes than as a demonstration of impact of this article published in the Bulletin. On the other hand this popularity shows that our copyright policy that allows authors to deposit in public and institutional repositories their articles can be highly beneficial both to authors and our Bulletin.

Now, let's look at the difficulties. We need both more manuscript submissions and a faster turn-around for reviewing and editorial decisions. One reason for the lack of submissions maybe the assumption that the Bulletin has very low visibility, which is refuted by the statistics above. Another reason may be the delay in publication of articles. This delay is

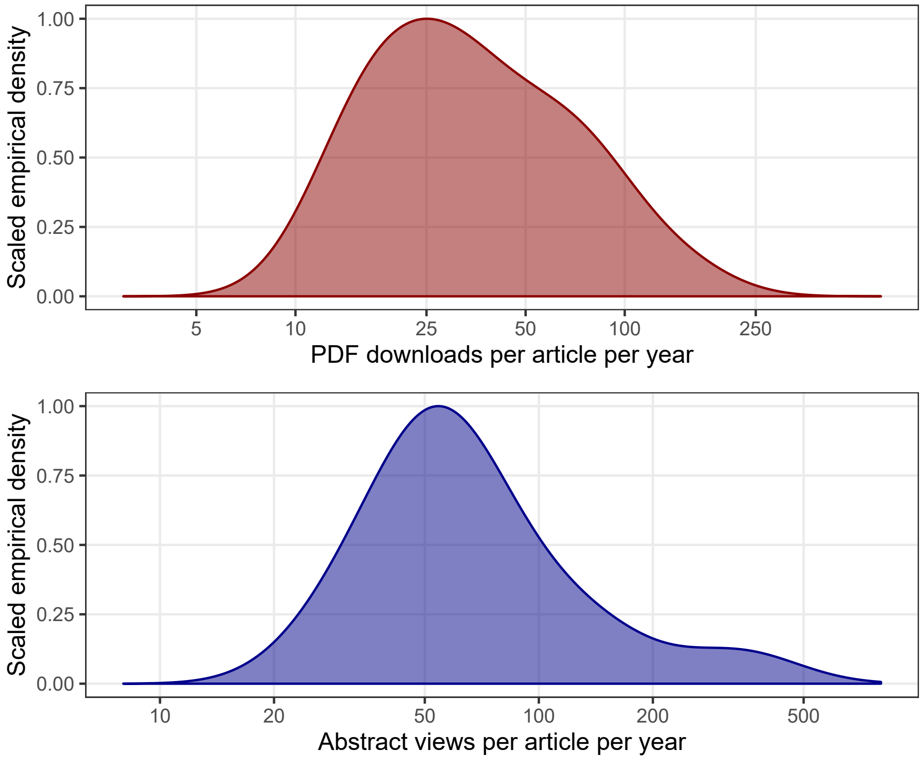

Figure 1.1: Popularity of individual articles. The y-axis shows the normalised frequency of articles having a given number of views or downloads per year. The distribution is skewed with a long right hand tail, even plotted using a logarithmic scale for the x-axis. Density computed from the number of views and downloads from the *UV4Plants Bulletin* OJS server between September 2017 and December 2019.

in part due to lack of articles preventing more frequent publication of issues and the technical difficulties we have encountered in implementing "early on-line publication". The slow turn-around and delays in decisions are related to editors' being busy with other duties and to how responsibilities have been assigned within the editorial board based on subject areas rather than on the steps in the editorial work-flow.

Looking forward to 2020, I will now focus on the future of the Bulletin and let our president discuss other matters in his letter. From the perspective of the OJS server software, new exciting features have been announced for the next major revision. The feature I find most relevant to the Bulletin is support for multiple article versions. Once publication takes place on-line, publication of separate errata makes little sense. The article can be corrected, and both the original and corrected version can be kept on line, with the corrected version displayed by default. The availability of versions for articles will also allow updates, for example, to tutorial articles in relation to suppliers and to track updates in the used software.

With respect to the management of editorial tasks I have started discussions with some members of the editorial board and we plan to produce a proposal for a new organization of our "virtual editorial office" before the next General Assembly meeting.

As promised by Marcel Jansen in the editorial to issue 2018:1, we have in the current issue new entries in the section "**Meet-**

a-Member", with *Paul W. Barnes* and *Line Nybakken* answering the "standard" set of questions. This section aims at bringing together our community of collaborating scientists and unrequested manuscripts with this same aim are warmly welcome.

Articles by *Frauke Pescheck* and *Marco Santin* report on the Photobiology Congress in Barcelona. *Marcel A. K. Jansen*, and *Arnold Rácz* and *Kristóf Csepregi* report on the work shop on *'UV-B and Climate Change; impacts on plants and vegetation'* held in Cork, from the organizers' and participants' perspective, respectively. An article by *Kaisa Lakkala* compiles abstracts from the *Annual Meeting of the Nordic Ozone and UV group, 2019* on presentations of interest to our readership.

My own article in the Methods section uses the example of neutral density filters to highlight that most pieces of equipment do not behave as the theory would require: actual neutral density and not really wavelength neutral. In practice, this is important when they are used to adjust irradiance or for shading in experiments. As discussed above, methods descriptions and tutorials have been popular and are important to keep interest in the Bulletin from the wider research community and in this way also advertise our association.

As usual we have a Letter from the president and a News section. Sadly, we also have an *obituary for Gaetano Zipoli*, a former member of UV4Plant who was a good friend to many of us.

Best wishes to you all,

Pedro J. Aphalo, Editor-in-Chief.
Helsinki, December 2019.

References

Aphalo, P. J. (2018). "Sense and nonsense of bibliometrics". In: *UV4Plants Bulletin* 2018.1, pp. 11–14. DOI: 10.19232/uv4pb.2018.1.10.

Letter from the President

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DOI: 10.19232/uv4pb.2019.1.02

First, I would like to take this opportunity to wish all our readers an enjoyable, healthy and productive 2020. I hope everyone feels ready for the opportunities and challenges that lie ahead as we enter a new year, indeed a new decade.

From a UV perspective, the last decade saw major advances: evidence that UVR8 is a photoreceptor was published in 2011 and the structural basis for its action was revealed a year later. Subsequently, more details of the cellular and molecular mechanisms of UVR8 action were reported, and the role of UVR8 in various UV responses in diverse species was demonstrated. Aside from UVR8, advances have been made across the broad spectrum of UV research during the last decade, not least in the ecological context and in the use of UV to enhance crop production. The perspective article published in Photochemical and Photobiological Sciences this year (DOI: 10.1039/c8pp00526e), which arose from discussions at the last UV4Plants Network Meeting, highlights both the progress that has been made and the opportunities that lie ahead.

It is difficult to know what the next decade will bring, but I think attention will increasingly focus on the major problems of global food security and climate change. UV research has relevance to both of these issues. With respect to food security, there is a need to increase production sustainably using essentially the same land area, so-called sustainable intensification. The application of UV lighting technology will be valuable in this context, as it has been shown to enhance both yield and quality of some crops in protected systems. Fundamental research on UV perception and response will enable us to understand the effects of UV treatments on particular crops so that UV lighting regimes can be optimised. With respect to the natural environment and climate change, it is important to understand how responses to UV are integrated with those to other factors, such as water availability and temperature, and again this requires fundamental research. We could gain new insights by extending the understanding gained from controlled laboratory experimentation to the more complex dynamics of the natural environment.

Finally, I hope everyone interested in UV research will attend the next Network Meeting of UV4Plants in Kiel from 1 to 3 April 2020 (see information at https://www.uv4plants.org). The programme has something to cater for all interests and we are indebted to Wolfgang Bilger and Frauke Pescheck for giving their time to organize the meeting. It will be a valuable opportunity to hear about new research, to plan ahead, to meet old friends and to make new ones. I look forward to seeing you all there.

Best wishes,

Gareth Jenkins, President UV4Plants.

News

UV4Plants Network Meeting”, Kiel 2020

Subject: Plant responses to UV radiation—Diversity in time and space.
Location: Kiel, Germany.
Dates: 1–3 April, 2020
Organizer: Wolfgang Bilger and Frauke Peschek.
Format: Talks, posters and discussion sessions.

Deadline for abstract submissions: 20 January 2020.

https://kiel2020.uv4plants.org/

Training school, Kiel 2020

https://kiel2020.uv4plants.org/

Location: Biology Center of Kiel University.
Dates: 29–31 March, 2020
Organizer: Wolfgang Bilger.

New Commercial Member of the UV4Plants association: Ceravision

Ceravision, a supplier of grow lamps based on the hot plasma technology has joined the UV4Plants Association. They supply both lamps emitting visible light and lamps emitting “UV” radiation ($280 < \lambda < 550$ nm). See: http://www.ceravision.com/

Linnaeus Medal awarded to Lars Olof Björn

The *Royal Physiographic Society of Lund* (see https://www.fysiografen.se/en/) presented an award to our honorary member Lars Olof Björn (Fig. 3.1). Lars Olof Björn was awarded the *Rosén Linnaeus Medal in Gold* for “[his] many years of investigating ozone holes in the atmosphere and their effect on the world’s plants, as well as his considerable commitment to popular science.”

Figure 3.1: Lars Olof Björn receiving the *Rosén Linnaeus Medal in Gold*

Methods

Practical hints and tips

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DOI: 10.19232/uv4pb.2019.1.30

Note: *The opinions given and recommendations of products are those of the author(s), and do not imply endorsement or not by the UV4Plants Association.*

The cost of UV LEDs continues to decrease

Finally, "high-power" UV-B LEDs are becoming affordable. They are not yet a commodity and are mostly available through specialized distributors like Roithner Lasertechnik although a few medium power LED types have appeared also in the catalogues of major electronic component distributors such as Mouser and Digikey. There are also a few (re)sellers in China, selling UV-B LEDs even cheaper. However, there are a few things to keep in mind when buying LEDs: 1) within a given part designation there are usually bins or sub-types available. These are not equivalent in performance, so a cheaper LED with the same designation, is likely to be one with a lower radiation output. Reliable sellers will provide the part designation in whole, rather than only the first part of it. 2) When LEDs are produced there is variation in the wavelength of the radiation emitted by individual LEDs. This means both that there are sometimes broad tolerances (e.g. ±5 nm or even ±10 nm) in the specifications, and that LEDs are also classified or binned by manufacturers based on wavelength of emission. Bins are usually also denoted by some digits or letters in the trailing part of the part code.

How much have prices changed? I will do the comparison based on UV radiation output, not on electrical power. Part of the reduction in cost is due to increased efficiency in the conversion of electrical power into optical radiation. This also reduces ancillary costs, and the improved life further reduces the effective cost of using UV-B LEDs. If we take LEDs available from Roithner Lasertechnik as example, in December 2014 I bought LEDs emitting 15 mW at 1180 € per piece, while this October 2019 I bought LEDs emitting 58 mW at 310 nm for 178 € per piece (current price 146 €). The cost per watt of emitted UV-B has decreased from 76 500 € down to 3070 €, or 25 times in 5 years! The LEDs I bought this year were expensive ones, incorporating a quartz lens. Cheapest available from a, reliable in my experience, Chinese supplier (`https://www.leds-global.com/`) emit 18 mW at 310 nm and cost 16.90 €, which makes their cost 940 € per watt, or 1.2% of what I paid in 2014!

UV flashlights

During the past few months I have been asked about UV-A flashlights and I have been using one of them for some time and recently acquired a second one. I also borrowed a third one for testing. I give here some hints on which flashlights are worthwhile buying and which ones are not. Good-quality UV-flashlights can be useful as radiation sources for photography and short term experiments

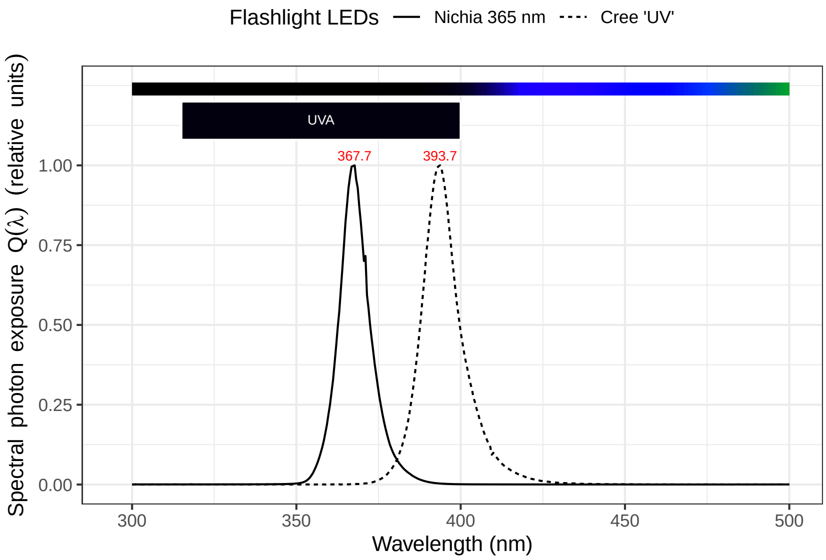

Figure 4.1: Comparison of two different "UV" flashlights. The output of both flashlights was normalized for this figure, in reality the radiation output of the flashlight with the Cree LED was only a fraction of that of the one with the Nichia LED. The flashlight with the Nichia LED had an unspecified UV-pass and VIS-blocking filter, while the one with the Cree LED had a clear glass. The spectrum for the Jaxman U1c flood is not shown as it overlaps the one for the Convoy 2+. (Emission spectra measured by the author. Data to be included in the next release of R package 'photobiologyLamps'.)

Figure 4.2: A Convoy 2+ flashlight next to a Jaxman U1c flood flashlight, both equipped with UV-pass/VIS-block filters.

Figure 4.3: The Convoy 2+ flashlight and the Jaxman U1c flood flashlight have similar bodies, and the same generic "remote cable switch" works with both.

but many of those being sold are unsuitable. These flashlights are rather widely available as they have various uses: checking the fluorescent safety threads and patterns in bank notes, identifying minerals in stones, looking for various types of contaminants both in households and commercial settings and even finding scorpions. Most if not all these flashlights use UV-A or violet LEDs, and almost all of them are sold with a clear glass window. First thing to be aware of is that many of these UV flashlights are based on LEDs with peak of emission at 385 to 410 nm. The ones that are useful as UV-A sources are those with LEDs with peak of emission at 365 nm as the others emit too much visible light (Fig. 4.1). Look for those using LEDs manufactured by the Japanese company Nichia,

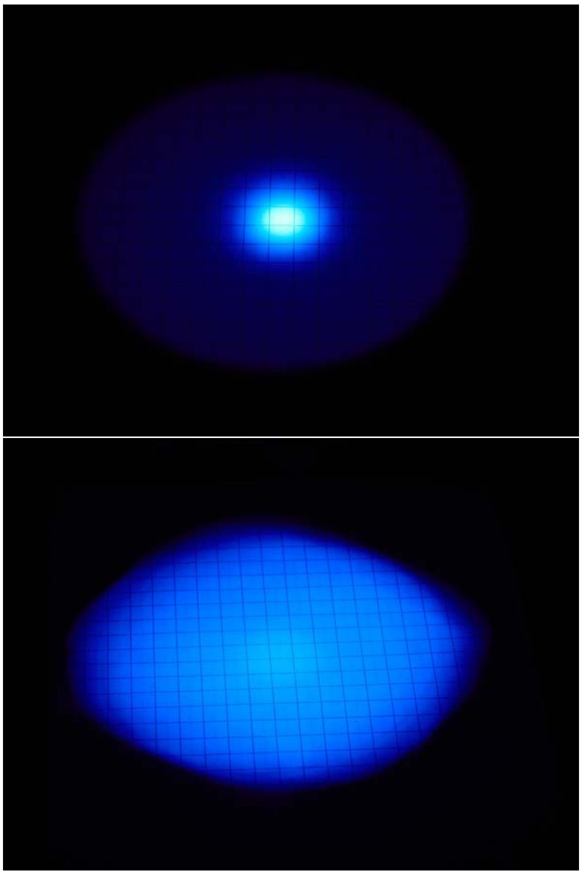

Figure 4.4: Light fields of a Convoy 2+ flashlight (top) and a Jaxman U1c flood flashlight. The photographs are of the UV-induced fluorescence of a white sheet of paper with rulings 10 mm apart.

Figure 4.5: A granite boulder at night. Top: illuminated with a white LED light source, exposure time 0.2 s; bottom illuminated with the Convoy 2+ flashlight by "light painting" and photographed through UV-blocking filters, exposure time 55 s. The yellow-fluorescing lichen on the boulder and the red fluorescence from the moss at the base of the stone are both clearly visible.

as these have strong output and less VIS contamination. In all cases the clear glass should be replaced with a good quality UV-pass VIS-blocking filter.

At this time, my recommendation is to buy a Convoy 2+ flashlight with a Nichia LED at 365 nm (ca. 25 €) or a Jaxman U1c flood flashlight, also with a Nichia LED at 365 nm (ca. 60 €) (Fig. 4.2, 4.3). As we will see below these flashlights are different and suitable for different purposes. Both are readily available through many different sellers in eBay and Aliexpress. As always there is a risk when buying from such on-line sellers, so it is important to check that the flashlight you have received matches the description and works as expected before the time for complaints and refunds is over. Buying filters is trickier than buying the flashlights unless you are willing to pay good money for them. Safest is to buy a filter made of Hoya glass already cut to size, buy this may cost you more than the flashlight. Filters 20.5 mm in diameter and 2 mm-thick, made from generic filter glass under the denomination ZWB2 can be good enough, but quality seems to vary a lot (they are sold for anything between 0.45 to 5 €). It is also important to consider both type, quality, and thickness of the glass filters in addition to their diameter. One eBay seller (uviroptics) sells these Convoy 2+ flashlights with a Hoya U-340 filter already installed at a price of ca. 90 € and the filter by itself for ca. 30 euro. The quality of the filters pre-installed by other sellers can vary greatly and will be type ZWB2 or inferior.

The Convoy 2+ Nichia 365 nm flashlights emit UV-A radiation in a concentrated beam, which can be a drawback for some applications. At close distance, at the centre of the beam UV-A irradiance is a few times more than in full sunlight at midday on a summer day (e.g. at 200 mm distance I have measured in the hot-spot of the UV-A illuminated field a photon irradiance of 1370 $\mu mol\,m^{-2}\,s^{-1}$). However, the area irradiated is mall and irradiance uneven (Fig. 4.4, top). The Convoy 2+ uses a LED rated at about 3 W of electrical power. The Convoy 2+ is good for spotting fluorescent object at night at distance. For photography of UV-A-induced visible fluorescence one usually needs to "paint" the area been photographed as is rarely possible to illuminate the whole area photographed simultaneously with such a narrow beam (Fig. 4.5).

Recently similar flashlights have appeared under a different brand name: Jaxman. These are readily available with pre-installed filters. Price and quality wise the Convoy 2+ is a good choice if one needs a concentrated UV-A radiation beam. Jaxman has a variant under the denomination of "U1C flood" which provides a much broader and even UV-A radiation field (Fig. 4.4, bottom). Even though the Jaxman is of the same small size as the Convoy, it has a LED rated at 6 W of electrical power. Still as the UV-A radiation is projected evenly over the illuminated area, the maximum irradiance is lower than for the Convoy 2+ (e.g. at 200 mm distance I have measured in the hot-spot of the UV-A illuminated field a photon irradiance of 117 $\mu mol\,m^{-2}\,s^{-1}$). I have used the Jaxman very little but spectral measurements indicate that both have an almost identical emission spectrum and leakage of VIS light. While the Convoy 2+ has only and on-off switch, the Jaxman, has low and high power settings. Although one could expect the Jaxman to heat up quickly because of the higher power rating, the metal body seems to dissipate heat well enough.

Both flashlights are externally very similar, with the bodies so similar as to be interchangeable. They measure 25 mm in diameter and 117 mm in length. The heads are different in the electronics, LED and optics. They both use one rechargeable Li-ion battery of type 18650. These batteries are fairly common, but not something you will get in the nearest supermarket. You need a charger or a battery with a USB charger circuit built in.

The Jaxman U1c flashlight comes in multiple versions, the "flood" version I have and a normal or non-flood version which I haven't tested. This version with normal optics can be expected to be similar to the Convoy 2+ in its 3W version, but I have no proof of this. This non-flood version at the moment sells for around 40 € for the 3 W version and 55 € for the 6 W version. They also have the two step power switch that the Convoy 2+ lacks, as well as the pre-installed UV-pass filter.

Although these flashlights emit in the UV-A, given the very strong and concentrated radiation output, it is advisable to use eye protection especially when using them in darkness or in weak visible light.

LEDs for horticulture and museums

Nichia (nichia.jp) has recently released LEDs chips designed for use in horticulture production. What is special about them? Primarily two features: very high energy conversion efficiency (About 2 or 2.5 times as efficient as Valoya B50 luminaires) and an emission spectrum unusual for grow lamps as it contains a good deal of radiation emission in the green range (Fig. 4.6 top). According to my tests photon irradiance can reach nearly 2 500 in a growth chamber (Aphalo and Belevich, unpublished).

Both Nichia and Toshiba/Seoul Semiconductor have released new series of LEDs

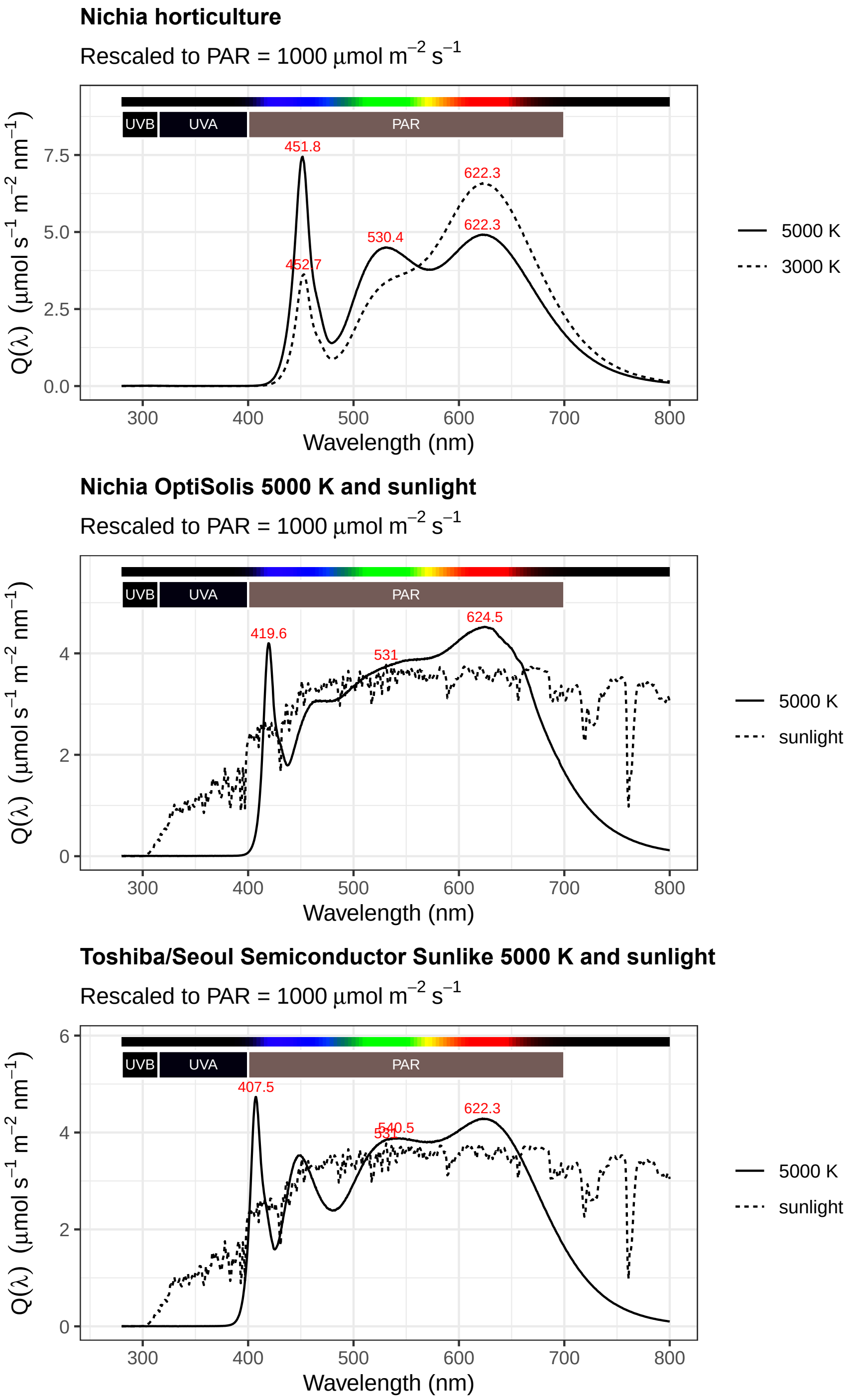

Figure 4.6: Emission spectra of white LEDs from Nichia and Seoul Semiconductor (LEDs' emission spectra measured by the author. Data to be included in the next release of R package 'photobiologyLEDs'.)

advertised as having an emission spectrum similar to that of sunlight (Fig. 4.6 middle). These LEDs are mainly aimed at achieving extremely good colour reproduction. Those from Nichia, sold under the name of *Optisolis*, do not emit UV and are advertised as ideal for use in museums. Those from Toshiba/Seoul Semiconductor are sold under the name *Sunlike* and emit to some extent at 390 nm (Fig. 4.6 bottom) (more information at https://www.nichia.co.jp/en/product/led_sp_optisolis.html and http://www.seoulsemicon.com/en/technology/SunLike/). Both series include versions emitting warmer and cooler white light. Energy conversion efficiency is slightly lower than that of the LEDs described in the previous paragraph. These LEDs emitting sun-like light would still need to be combined with UV-B, UV-A and far-red-emitting LEDs to achieve an spectrum that could considered a simulation of sunlight relevant to plants. Ready-assembled modules using these different LED chips are available from Lumitronix (https://www.leds.de).

In Memoriam
Gaetano Zipoli (1950–2019)

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Figure 5.1: Gaetano Zipoli (photo courtesy by Daniele Grifoni, CNR–IBIMET and LaMMA).

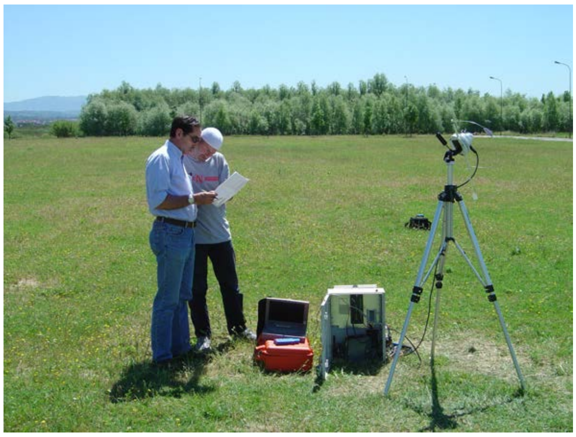

Figure 5.2: Gaetano at work (photo courtesy by Daniele Grifoni, CNR–IBIMET and LaMMA).

With great sadness we have to announce that our Italian colleague and friend Gaetano Zipoli passed away on 30th January, after a long illness. He was a member of the UV4Growth and UV4Plants communities from the beginning. His ambition to link understanding of climate with UV radiation left a mark on all of us. He will always be remembered for his vast knowledge of UV climatology, his good mood, his great sense of humor and his desire to walk (he was a tireless walker).

Born in Calenzano (Florence), he was married and had two children. He was educated at the Agricultural Science Faculty of University of Florence, where he got a degree in Agrometeorology in 1980. He completed his training at the Water Conservation Laboratory (USDA-ARS) in Phoenix (Arizona, USA). He became a researcher at the Italian National Research Council (CNR) in 1983, and was an invited lecturer at the University of Florence for many years. He contributed to the foundation of the Institute for Biometeorology (IBIMET, CNR) and the Laboratory for Meteorology and Environmental Modelling (LaMMA) in Tuscany, being Leader of Research Projects and finally Director of the LaMMA from its creation, and for several years. As an expert on the diverse topics of agrometeorology and agroclimatology, including radiation modelling, irrigation, remote sensing, crop energy balance and protection, climate change, etc., he strongly collaborated with different international organisms and projects. Gaetano was scientific coordinator of the World Meteorological Organization (WMO) Commission of Agricultural Meteorology, coordinator of FAO agrometeorological projects in Niger, member of the Board for the CEE Environment Projects on Applied Climatology and Natural Hazards, Project Leader of ENVISAT/ESA programs, etc. From the early 90's, Gaetano specialized in UV radiation, participating in several

Figure 5.3: Gaetano with Annamaria Ranieri and Tjasa Jug in a UV4Growth meeting at Pécs (Hungary) in January 2013 (photo courtesy by Marcel Jansen).

EU COST Actions on UV-B Forecasting, UV climatology, and finally in the COST Action UV4Growth (FA0906) on "UV-B radiation: a specific regulator of plant growth and food quality in a changing climate", where he developed fruitful scientific (and personal) relationships with colleagues from every corner of Europe and other continents. After his official retirement, he was appointed as environmental consultant in his hometown, and he still collaborated in many tasks and investigations. He was the author of more than 150 scientific publications, a number of them in collaboration with the UV4Growth and UV4Plants communities.

Some members of UV4Plants have expressed their impressions about Gaetano:

> "I did not know him personally, but he is remembered fondly by those who did and I wish I had met him. Also, he evidently made valuable contributions to the UV community" (*Gareth I. Jenkins, Glasgow, U.K., President of UV4Plants*).

> "Gaetano's been a great scientist and a gentle soul" (*Éva Hideg, Pecs, Hungary*).

> "I gratefully remember Gaetano's support in the early days of UV4Growth, as well as his great sense of humor. This is a big loss for the community" (*Marcel Jansen, Cork, Ireland*).

> "Gaetano was a good person and a great researcher" (*Annamaria Ranieri, Pisa, Italy*).

> "I remember him as a kind man, as well as an excellent researcher" (*Antonella Castagna, Pisa, Italy*).

> "I remember Gaetano's kind words and support for the ESR. I am grateful I had the chance to know him" (*Susanne Neugart, Grossbeeren, Germany*).

> "He was indeed an Italian cavaliere and a close person. With infinite patience he made and remade the radiation calculations for the Grapevine Ultraviolet Network investigations, paying attention to all our requests with quickness and wisdom" (*Encarnación Núñez-Olivera, Universidad de La Rioja, Spain*).

> "I hope he would not mind I make public one of his last mails, because it is a clear example of his humanity and personality. He said: <I want you to know that I consider myself a lucky man, despite the present occurrence, because I have a wonderful family that is helping me in this new challenge and a lot of

> friends. See you in La Rioja during my next Camino to Santiago. Get a bottle of wine ready>" (*Javier Martínez-Abaigar, Universidad de La Rioja, Spain*).

OUR CONDOLENCES FOR HIS FAMILY AND FRIENDS. GAETANO WILL FOREVER BE IN OUR HEARTS. REST IN PEACE CARO GAETANO, TERRA LEVIS.

The UV4Plants Managing Group and community.

Contents compiled by Javier Martínez-Abaigar, Universidad de La Rioja, Spain., ORCID: 0000-0002-9762-9862

Editorial-board-reviewed article.
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Meet-a-Member: Paul W. Barnes

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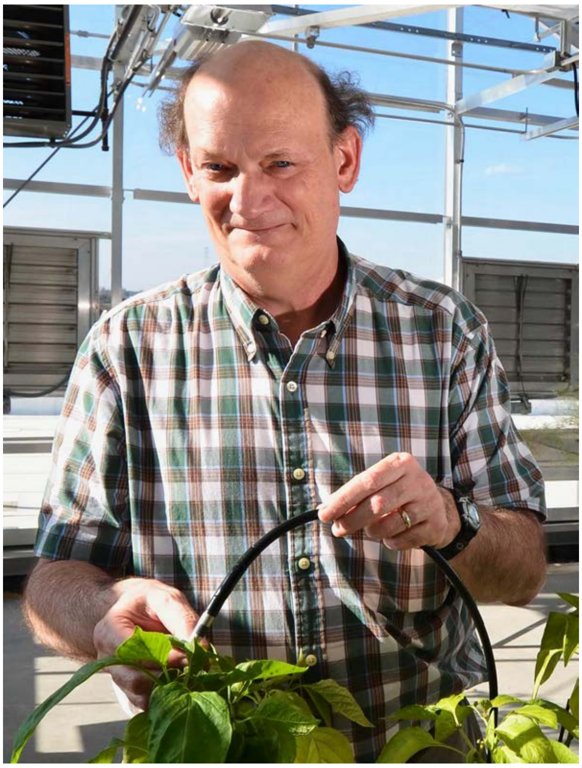

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Why did you choose to work on plant UV-effects? As a budding ecologist, I had little to no knowledge or interest in the effects of UV radiation on plants. In fact, my primary research interest (both as an undergraduate and then a graduate student) was understanding the ecological significance of variation in photosynthetic pathways (i.e., C3 vs. C4) in North American native prairie grasses. My first exposure to plant UV-effects research came as a postdoctoral researcher in Martyn Caldwell's lab at Utah State University. This research was aimed at understanding the effects of enhanced UV-B on plant competition and the work eventually lead to modelling light capture in multi-species canopies and exploring photomorphogenic effects of UV-B on plant morphology. All of this was happening in the mid-1980's before the discovery of the UV-B photoreceptor UVR8, and there was little recognition that UV-B could elicit non-damaging effects in plants. This research also had a sense of urgency as the Antarctic 'ozone-hole' had just been discovered and there was heightened concern over the potential ecological consequences of stratospheric ozone depletion. As a result of this experience, I came to enjoy conducting research that addressed intriguing fundamental questions about how plants respond to changes in their UV environment but which also had practical implications.

What is your research-specialisation? I am a plant physiological ecologist by training with interests in environmental UV photobiology, plant and ecosystem responses to global environmental change, mechanisms of plant-plant interactions, plant carbon, water and light relations, and grassland and savanna ecology. Presently, my research is focussed on addressing the following:

1. Understanding acclimation responses of plants to fluctuating UV conditions with particular interest in the mechanisms and physiological significance of rapid adjustments in UV sunscreen protection (e.g., flavonoids and related phenolics) in plants. This research is mostly conducted on cultivated plants using several species as model systems.

2. Further elucidating the role of UV radiation in driving the decomposition of leaf litter. This is largely field research that has been conducted in warm deserts where photodegradation has emerged as a potentially important driver of decomposition. Recent studies, however, have expanded to study photodegradation in coastal wetlands.

3. Determining the nature and ecological significance of positive (facilitation) and negative (competition) interactions between plants in grasslands and savannas. The overarching goal of this research is to better understand the causes and consequences of woody plant encroachment into dryland ecosystems, which is a world-wide phenomenon.

Of which UV-related accomplishment are you most proud, and why? My research has involved many students and collaborators over the years, so my accomplishments really reflect the collective contributions and support of these associates. Having said this, I think my proudest accomplishment is the discovery that plants can adjust their UV-shielding within a matter of minutes in response to changes in solar radiation. While others had alluded to this possibility, our research clearly demonstrated that this was a widespread phenomenon among higher plants and that it involved rapid changes in phenolic chemistry within leaves. We have yet to fully understand the functional significance of these changes, but I believe this research has changed how we view plant acclimation to UV radiation, particularly with respect to the time-scale in which plants can respond to rapid changes in UV radiation in their environment. I am also quite proud of the work I have done as a member of the UNEP Environmental Effects Assessment Panel, which, in support of Montreal Protocol, prepares scientific assessments on the environmental effects of ozone depletion and interactions with climate change.

Figure 6.1: Paul W. Barnes as a Ph.D. student measuring stomatal conductance of prairie grasses in the Nebraska Sandhills.

Can you tell a funny story relating to your work on UV-effects? Soon after I obtained a UV-A PAM, I began conducting field research in Hawaii. In my travels, I would always take this instrument with me on the airplane and as I passed through airport security there were invariably questions about what it was that I had in my possession. In one instance I was traveling with the UV-A PAM to New Zealand. As I moved through Customs in Auckland, one of the agents stopped me and, in a very serious tone, requested that I open the case for inspection. As he was looking inside the case he asked me what this device was. Not knowing what level of scientific expertise he possessed, I said something very general like “It’s a scientific instrument". For most security agents this was usually sufficient. In this instance, however, the young fellow persisted and wanted more detailed information. "What does it actually measure?" he asked. I told him it measured plant pigments—again a fairly general description. He pressed on and asked "What kind of pigments?" I couldn't tell if he was actually interested in knowing the answer or if he wasn't sure I was being truthful. So, I decided to be very specific in my next answer. I said "It measures UV screening pigments in leaves, non-invasively using chlorophyll fluorescence." He paused, then smiled, and said "Oh how interesting. I used a Walz mini-PAM to measure chlorophyll fluorescence on plants in my fourth-year research project for my diploma." So, with the tension eased, we both had a good chuckle and talked a bit about my research, his research and how he ended up as a Customs Agent and not a scientist as others behind me waited rather impatiently to file through Customs.

Have you got any hints, tips or other advice to share? I think it is prudent to be rather sceptical of findings that report large (and often detrimental) effects of UV radiation on plants. From my experience, I have come to appreciate that many plant responses to solar UV (especially UV-B) under realistic field conditions are subtle and difficult to detect. Thus, to avoid spurious results and conclusions, I think it is essential to pay attention to proper experimental design (e.g., high and independent replication), careful measurement of UV radiation, and accepted protocols and procedures for manipulating UV radiation, whether that involves UV filters or UV-emitting lamps. Having said this, be open to surprises and unanticipated findings in your research. In my own case, we discovered diurnal changes in UV-shielding because we just happened to be measuring plants at different times of day (e.g., dawn vs. midday). We assumed that time of day

Figure 6.2: Paul W. Barnes taking measurements with a UVA-PAM in the greenhouse at Loyola University New Orleans.

wouldn't matter for these measurements. Initially we thought the differences we observed were due to errors in measurement or instrument calibration. It took some time to convince ourselves that these changes were real, but we could have easily dismissed these results as "noise" in our data.

What made you join UV4Plants? I was invited to serve as an external evaluator for the COST Action UV4Growth program in 2014. I attended the final COST meeting in Bled, Slovenia that year, gave a presentation and have been a member ever since. I have to say it has been a most enjoyable and rewarding experience and I am most thankful to the managing members of UV4Growth/UV4Plants for the opportunity to be associated with this organization.

How would you like UV4Plants to develop in the future? I would like UV4Plants to grow in numbers and become more international in representation. I feel like this association has a lot to offer students and researchers around the world and can provide the critical support, collegiality and networking to maintain a strong and vibrant community for those interested in plant-UV science. I would also like to see the UV4Plants community initiate additional multi-investigator projects that cut across sub-disciplines (e.g., molecular to ecological) and/or conduct coordinated research projects at multiple field sites around the globe.

Who would you like to appear in a future "Meet-a-Member"? Pedro Aphalo

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Meet-a-Member:
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Why did you choose to work on plant UV-effects? I had been working on light stress in lichens for my master thesis and in a subsequent summer job for Wolfgang Bilger. After one year as a high school teacher in forestry I got an offer from Wolfgang that I could not refuse: PhD with field work in the French Alps, alpine Norway and at Svalbard. I used a prototype of the Xenon-PAM to measure UV-screening in plant species that grew at all three places along this natural UV-gradient.

What is your research-specialisation? Well, I may do too many different kinds of studies…but I would say that the ecology and physiology of chemical defences is the topic which has always been closest to my heart. I also have broad experience with outdoor experiments, which I consider more and more important to answer relevant ecophysiological research questions.

Of which UV-related accomplishment are you most proud, and why? I am proud of the pioneering work on UV-induction of defensive, screening compounds in lichens, done at my university. It all started when my colleagues Knut Asbjørn Solhaug and Yngvar Gauslaa found out that they could rinse out these pigments by using 100% acetone. After that, we have had a lot of fun! Another exciting result is the understanding of the role of UV-B in autumnal bud set in aspen, which was found in the studies of my PhD-student Christan Strømme.

Can you tell a funny story relating to your work on UV-effects? Hmm…it for sure was not very funny when it happened, but afterwards it became a good story! When I had arrived at the high altitude field station at Col du Lautaret for my first field campaign in the French Alps, I realized that the Xenon-PAM did not work. I called Wolfgang, who told me to go to Würtzburg (Germany) to get the instrument fixed by the technician who had built it. After a long day travelling by bus, plane and train I arrived in Würtzburg, where the instrument was fixed in just 20 minutes while I was having lunch…! I got a plane ticket for next morning, and spent the night at the university's guest room in the botanical garden. Surrounded by lush tropical vegetation, I found out that I had picked up food poisoning with my lunch, so the night was spent at the toilet in the cellar, trying to avoid the huge tropical cockroaches climbing on my legs. But the story had a happy ending: the day after I arrived safely back in the beautiful surroundings of Lautaret, and the Xenon-PAM has behaved well ever since that day.

Have you got any hints, tips or other advice to share? Working with UV is exciting, but difficult to do correctly! When you are planning an experiment, do not hesitate to ask for help, there are many experts in UV4Plants, and my experience is that people are always willing to help!

What made you join UV4Plants? In the COST action, I had developed research collaborations and friendships, it was just natural to join its continuation; the UV4Plants!

How would you like UV4Plants to develop in the future? I have enjoyed the discussion-intensive workshops, and I hope we will have more of those in the future!

Who would you like to appear in a future "Meet-a-Member"? Susanne Neugart!

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Participants' report

A Report on the ESP-IUPB 2019

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This year the European Society for Photobiology (ESP) and the International Union of Photobiology (IUP) for the first time held a joined World Congress on Photobiology under the motto "Light & Life". In the beginning, in the years 1954–1960 the IUP organized a conference every 3 years, from 1964–2004 every 4 years, and since 2009 every 5 years. The ESP holds a conference more often, with intervals of 1 year from 1986–1987, and since then every 2 years. Also, it was the first time that Barcelona hosted a photobiological conference of one of the two organisations bringing together scientist from many different disciplines of photobiology, like medicine, chemistry, physics, and biology.

It was impressive and very inspiring to meet such a lot of eminent researchers and listen to their ideas, results and questions. As an example, I can mention that I was fascinated by the talk of Dongping Zhong in the first keynote lecture. He explained vividly the newest results on the quantum yields of electron transfer processes within the UVR8 photoreceptor. Among many others the session on "Algal photobiology" also aroused my interest. The lecture by Patrick Neale about biological weighting functions in diverse microalgae explained the advantage of using polychromatic action spectra to estimate UV effects in an ecological context, and in interaction with elevated CO_2. Further, from the same session three presentations about UV protective substances in different classes of algae and their potential use as sunscreens in human sunlight caught my interest because the idea of an environmentally friendly sunscreen is very attractive to me. Within a session about climate change chaired by Janet Bornman the talk by Sharon Robinson discussed how ozone-driven climate change affects the ecosystems of the Southern Ocean in many ways, not only because of increased UV-B radiation.

On Wednesday during the session about plants' responses to UV-B, Gareth Jenkins drew attention towards the function of UVR8 in natural sunlight and under field conditions and discussed the possibility of another hitherto unknown UV photoreceptor. This was a perfect opening for Neha Rai to explain in her presentation on how UVR8 and the cryptochromes interact, in a redundant but also antagonistic way and co-regulate gene expression in *Arabidopsis thaliana*. Directly afterwards a short talk by Nicolas Tissot about cross-regulation of UV and visible radiation continued on the interaction of both photoreceptors and their common binding partners. Lastly, I want to mention a very interesting talk by John-Stephen Taylor who explained different energy transfer mechanisms with DNA molecules that can lead to photoproducts, either by direct absorption or by photosensitisation.

Definitely, I think, listening for 5 days to excellent presentations gave me strong motivation for my own research. Besides getting to know new people, I also noticed that, as a member of the UV4plants association, I

Figure 8.1: UV4Plant members at the conference

was feeling much less lonesome or lost in the crowd than can happen when joining such a big congress. Always someone from the community was around to spent time with and discuss the sessions. Therefore, for me the attendance at the EPS-IUPB has also increased my networking with the group of UV4plants members and through them the wider photobiology research community. Further, during the congress I met a collaborative partner of mine from Grenoble. For the first time we had the opportunity to discuss our project personally. This was a great chance and made me much more confident regarding the collaboration. During the poster session and on the following days I exchanged interesting thoughts about the prospects for my possible future research. Thanks to all discussion partners for their friendly comments!

I also would like to thankfully acknowledge Éva Hideg and the local organizers for the opportunity to put up an advertising poster for the upcoming Network Meeting of UV4plants next year in Kiel. Definitely, the time I have spent in Barcelona was an unforgettable positive experience. I enjoyed meeting colleagues, the city, and the food a lot!

Finally, I cordially want to thank the UV4plants association for awarding me with the travel bursary and for the relaxed and delicious dinner evening we had together as a society on Wednesday during the meetings!

Related readings

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■ Participants' report

An overview of the World Congress on Light and Life 2019

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Currently, I am a Post-Doc researcher at the Department of Agriculture, Food and Environment of the University of Pisa under the supervision of Prof. Annamaria Ranieri. My post-doctoral research work deals with studying the biochemical and molecular effects of UV-B exposure on many fruit and vegetable species, e.g. peach, apple, tomato, and lettuce. The research is mainly addressed at investigating how light quality and intensity might modulate nutraceutical value and both pre- and post-harvest quality and shelf-life of plant-based food. The treatments are mostly performed with UV-B narrowband lamps, but currently, our focus is to introduce UV-A/UV-B LEDs due to their undeniable advantages in terms of efficiency, electricity costs, durability and precision in the wavelengths emitted. Commercial implications of this research (e.g. increasing health-promoting natural compounds, improving resistance to pests and pathogens and extending shelf life of plant food) might be of potential interest for many companies and producers.

I presented my Post-doctoral research in the Congress on Light and Life, which took place in Barcelona (Spain) from the 25th to the 30th of August 2019. This was the first joint congress between the 17th Congress of the International Union of Photobiology and the 18th Congress of the European Society for Photobiology. It was organised in the luxury Hotel Crowne Plaza Barcelona Fira Centre, which provided six excellent meeting rooms where the parallel symposia were held.

The congress programme consisted of 7 keynote lectures, 2 plenary lectures and 12 symposia per day, with a total of 60 symposia. Two poster presentation areas were also set up, where the participants could go through sipping a coffee or tea and have a closer look at the presented work. The congress included multiple research areas: photomedicine and the photobiological sciences in all their aspects, e.g. chemistry, molecular biology, climatology, and environmental sciences, with a focus on how the ongoing climate change is affecting and will affect life on Earth. Particularly, I found the lecture "Molecular basis of plant responses to UV-B" by Prof. Gareth Jenkins (University of Glasgow) very interesting. The results presented in his talk showed how Arabidopsis plants acclimated to low UV-B irradiance responded differently from the non-acclimated plants when exposed to elevated UV-B irradiation. Results presented in a poster by Wei Liu showed that a photo-equilibrium is established between the UVR8 monomer and dimer forms in the UV-B-acclimated plants. However, when exposed to high UV-B, UVR8 monomerization was not enhanced, rather the binding with either COP1 or RUP1 was stimulated to increase the response to UV-B or to promote monomer re-dimerization, respectively, to maintain the photo-equilibrium. Although our group studies UV-B responses on different plant species, this fascinating work provides me many hints about how to in-

Figure 9.1: Rooms at the Hotel Crowne Plaza Barcelona Fira Centre where the parallel symposia took place. Plant Sciences symposia took place in (A) Verdi Room, (B) Rossini Room; environmental sciences symposia took place in (C) Coral + Crystal Room.

terpret some of our results and how to design the next experiments. The keynote lecture presented by Dr. Dongping Zhong, from The Ohio State University, also caught my attention. The talk was focused on deepening the mechanism of UV-B perception by the biologically active tryptophans within the UVR8 molecule. Innovative techniques such as time-resolved spectroscopy and extensive site-directed mutagenesis provided evidence that UV-B radiation triggers an energy flow network from the distal tryptophans to the epicentre tryptophans of the UVR8 photoreceptor. Dr. Zhong showed that mutations on only two epicentre tryptophans, W285 and W233, were critical for UV-B-induced UVR8 monomerization.

Considering the climate change and the increasing average global temperature, with an impact on patterns of precipitation and solar radiation, the studies on plant responses in their natural environment were of great impact. Particularly, Dr. Matthew Robson from the University of Helsinki presented a study on different Alpine plant species from the Station Alpine du Lautaret, where UV-A and UV-B irradiance is considerably high due to the high altitude. The plants were grown under different plastic filters that cut off specific portions of the solar spectrum: UV-B, UV-A and UV–B, blue and UV. The results indicated that the anthocyanin, which acts as a UV-screening compound, the level differed among the species and showed fluctuations during the daytime, indicating a fine regulation between shielding the high UV irradiance and maintaining the photosynthetic functions.

Figure 9.2: The exhibit area.

Figure 9.3: The Garden Room, during a coffee break.

Later, Prof. Åke Strid from Örebro University moved the attention to the applied research in the horticulture field, presenting the potential use of supplementary UV-B irradiation to improve the production of greenhouse cucumber. This is of great importance particularly in Northern countries, where most crops are cultivated in greenhouses that screen the UV portion of the solar spectrum. As per the literature, UV-B- and UV-A-treated cucumber seedlings showed a reduced height and mass, thicker leaves and stronger plants, with differences attributed to either UV-A or UV-B irradiation. However, no changes were observed in terms of fruit yield when compared to the control. Since transportation and transplantation of cucumber plants represent potentially detrimental stress for the plants, having stronger cucumber plants without affecting cucumber fruit production is exactly what the producers need. For this reason, Prof. Åke Strid underlined clearly that such kind of studies needs a constant and efficient communication between the researchers and the growers/companies, to address the work towards the right direction to match the producers' requirements.

Although the studies presented during the different sessions were very interesting, only a few researchers have focused their attention on the UV effects on crop plants and fruits. Transferring the knowledge of the UV perception mechanisms and responses to crop plants and fruits would be of great interest and importance from an application point of view and more useful for the general public.

In addition to the congress dinner, a separate dinner was arranged at the Ayre Hotel Gran Via by the UV4Plants association for its members. Considering the strict timetable of symposia and lectures of the congress, the dinner provided a great opportunity for the members to get together, discuss work and strengthen collaborations in a more informal setting. Although not members yet, Dr. Paula Casati and Prof. Janet Bornman were also present at the dinner and it was a great honour for us to have them there.

Overall, this first joint ESP-IUPB World Congress on Light and Life provided a valuable global forum for the dissemination of the latest discoveries and technologies in photobiology, exchanging ideas and establishing fruitful collaborations among researchers worldwide. Moreover, the city of Barcelona, with its warm weather and vibrant atmosphere, provided an ideal setting for this scientific event. I am very pleased to be able to participate in this congress and thankful to the UV4Plants Association for providing me a bursary. I believe that sharing scientific knowledge and establishing global networks among researchers worldwide through such scientific events is the true key to achieve the best results.

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Figure 9.4: The UV4Plants dinner during the Congress on Light and Life in Barcelona. An informal and relaxed atmosphere to strengthen collaborations and friendships among UV4Plants members. Such occasions are always precious not only to discuss about science, future works and careers, but also to make the UV4Plants association a great family.

Organizer's report

UV4Plants workshop in Cork, Ireland
'UV-B and Climate Change; impacts on plants and vegetation'

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The overarching aim of the Cork workshop was to explore the interactive effects of UV-B and climate change parameters on plants and vegetation.

A total of 28 researchers attended the workshop, which was organised under the auspices of the International Association for Plant UV-research (UV4Plants). The workshop was hosted by University College Cork (UCC) and generously sponsored by the Irish Environmental Protection Agency (EPA) and Science Foundation Ireland (SFI). Attendees came from Ireland, Norway, Finland, Sweden, Hungary, Czech Republic, Slovenia, Germany, Belgium, France, and Mexico, and the group displayed a good gender balance (13/15) and a mix of early career stage (11) and more established researchers (17). The meeting was organised by Marcel Jansen (School of Biological, Earth and Environmental Sciences, University College Cork, Ireland) with the help of a Scientific Committee comprised of Éva Hideg (Department of Plant Biology, Institute of Biology, University of Pécs, Hungary) and Otmar Urban (Laboratory of Ecological Plant Physiology, CzechGlobe, Brno, Czech Republic).

Attendees braved tough weather on Monday April 15 (54.6 mm rain; wind gusts of up to 45 knots, and a grand total of 0.0 h of sunshine), but inside the meeting room the talk was all about sunshine, heatwaves and drought. Matt Robson (Helsinki), presented some key points from the recent quadrennial report of the UNEP Environmental Effects Assessment Panel, and gave an introductory overview of anticipated changes in both UV-B and climate, emphasising the local character of many of the changes. Thus, climate change will be accompanied by decreasing UV levels in some places, but increasing levels in other places, especially those where tropospheric air quality is improving.

Phenology was central in the first session on Monday. Astrid Wingler (Cork) and Line Nybakken (Ås) discussed the complex effects of climate change on phenology, and whether UV exposure can impede the climate change induced delay in autumnal leaf shedding and/or bud set, thus impacting on the length of the growing season.

A range of studies focussed on the co-exposure with high UV, high CO_2, high temperatures, and drought. Otmar Urban (Brno) gave a detailed overview of the responses of various woody species exposed to combinations of UV and elevated CO_2. The message was that over the course of the growing season UV potentially diminishes the increases in photosynthesis caused by enhanced CO_2. Kristóf Csepregi (Pécs) reported on the interactions between UV and low temperatures, and how UV can induce cross-tolerance. Diana Sáenz de la O (Queretaro) and Louise Ryan (Cork) reported on interactive responses to UV and drought, and the scope to increase drought tolerance using UV. The role of Reactive Oxygen Species was further de-

Figure 10.1: Participants on April 15.

tailed by Éva Hideg (Pécs) and Arnold Rácz (Pécs). Anikó Mátai (Pécs) reported that β-aminobutyric acid can induce antioxidant defences, and potentially modify UV-responses. Flavonoids are important antioxidants and their protective potential was highlighted in several talks. Regulation of flavonoid accumulation was explored by Els Prinsen (Antwerpen) and Jakub Nezval (Ostrava). Frauke Peschek (Kiel) reported on UV-induced DNA damage in the context of the changing seasons. Barbro Winkler (München) reported on “deep phenotyping”, and emphasised the availability of European platform facilities that are available for plant impact studies.

To comprehend the interactive effects of multiple climate parameters on plant growth, Ivan Couée (Rennes) presented a conceptual model that identified integrative signalling hubs, convergence points, in the plant. A talk by Juergen Kreyling (Greifswald), with the fascinating title “To replicate or not to replicate – that is the question” focussed on development of advanced experimental design that is suitable for complex climate studies. A strong case was made for unreplicated, gradient design.

A special scenario in the climate change context is the increasing distribution of plants to higher altitudes where UV levels are high. Two studies reflected on the environmental parameters that determine plant growth at high altitudes. Tadeja Trošt (Ljubljana) reported how slope orientation (i.e. north, south, east, west) affects biochemical and anatomical characteristics of plants in the Slovenian Alps, while Gaia Crestani (Pisa & Cork) reported on the adaptive strategy of maca, a crop grown in the Peruvian Andes at altitudes above 4000 m.

Although the meeting was “plant-focussed”, two highly relevant non-plant studies were presented. Knut Solhaug (Ås) presented the case of low and high melanin accumulating lichens. While melanin offers protection against high light, this is accompanied by warming of the lichens. This will present a complex trade-off with increasing global warming. Finally, Gary Kett (Cork) presented the interesting case of cultured pacific oysters which are threatened by various pathogens in warmer summers. The case was presented that UV radiation contributes to the lowering of pathogen infection rates, a finding with potentially commercial relevance.

Discussions focussed on the direction of future research and were led by Matt Robson (Helsinki), Åke Strid (Örebro), Wolfgang Bilger (Kiel) and Marcel Jansen (Cork). In the first discussion session, the emphasis was on the “perceived gap” between laboratory and field experiments, and on how this void can be bridged. Overall, the delegates were positive concerning the integration of laboratory and field sciences as the climate conditions in growth chambers are gradually becoming more realistic, especially with the development of high output LEDs. It was recognised that one important reason to do laboratory research was to explore, in a more controlled environment, findings made under field conditions and/or hypotheses derived based on fieldwork. Conversely, it was argued that fieldwork should be inspired by advances in our understanding of fundamental plant responses, acquired in laboratory studies. Especially the use of characterised mutants in ecological studies should be encouraged as this can generate novel insights in plant responses. Furthermore, it was argued that “hybrid experiments” whereby plants are pre-grown in growth rooms prior to transfer to outdoor experiments, or alternatively, where plants are grown outdoors prior to exposure to UV or climate change under controlled lab conditions, can meaningfully contribute to bridging the knowledge gap between laboratory and field sciences. Overall, communication between disciplines was seen to be a factor of major importance, and this confirms the relevance of small discussion-intensive workshops such as this one, and others.

In the second discussion session, the focus

Figure 10.2: Participants on April 16.

was on the reason why so many of the "studies of interactive effects of climate change and UV" give such variable (or even unpredictable) responses. Various aspects were discussed, including the lack of consideration of leaf and or plant developmental age. In the workshop, several studies showed that depending on leaf/plant age and/or exposure time, different physiological outcomes do occur. The species specificity of plant responses has also been noted. Finally, the quality (or lack of) UV measurements was discussed. This is a longstanding problem, relating to available equipment and/or calibration. A major concern is that many experiments involve just one UV-dose and/or one climate change condition. Related to this, there is no reason to believe that UV (and climate parameter induced) responses will necessarily be linear, and it can be speculated that a mild increase in temperature together with a mild increase in UV cause cross-tolerance, but a higher increase in temperature together with a substantial increase in UV cause cross-sensitivity (i.e. aggravated stress). This relates to the point that for practical reasons many research groups are restrained to do small experiments, which do not necessarily capture the complexity (i.e. full dose response) of the interactions between climate change and altered UV. Therefore, the final session of the meeting focussed on the development of joint "phytometer" experiments whereby similar experiments are performed simultaneously in different countries. This positive engagement is an important outcome of the workshop, and practical benefits of the meeting will be reaped over the coming years. Mirroring this positive outlook, the meeting started in a howling rainstorm on April 15 (Figure 10.1), but ended up with much brighter weather on the 16th (Figure 10.2).

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Participants' report

UV4Plants workshop in Cork

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The latest workshop held under the auspices of the International Association for Plant UV Research (UV4Plants) took place in Cork, Ireland in April 2019. The conference was organized by Prof. Marcel Jansen and his group at University College Cork. The meeting brought together many researchers from all around the world to discuss and share ideas on recent advances in plant UV research. The two-day conference covered a broad range of research topics including molecular, biochemical and physiological aspects of UV-B responses, the interaction between UV-B and other environmental factors, ecology and evolutionary aspects. Altogether, there were 20 oral presentations discussing the latest research. In this article, we are summarizing some of the scientific (and non-scientific) highlights.

Arnold Rácz I am currently working on the effect of exogenous hydrogen peroxide on plant UV-B responses. The idea for this topic came from the recognition of the special role of this particular ROS in UV-B exposed plant leaves. The possibility of photo-cleavage of hydrogen peroxide into a hydroxyl radical was previously identified in my Department in Pécs. To take this further, my work is to explore similarities and differences between direct ROS (hydrogen peroxide) inducible and UV-B inducible changes in leaf metabolites, with an emphasis on POD and other antioxidant enzymes. An especially interesting part of this work is to explore whether leaves with metabolically or artificially increased hydrogen peroxide levels respond to UV-B in the same way. The meeting was a perfect place to get new ideas on my topic and look at my scientific problem from another angle. I have learned several new methods of ROS measurement during the lectures, some of which I will use in my future experiments. The two round-table discussions were very interesting for me. It was fascinating to listen to the different opinions and viewpoints about things that are commonplace, like plant growth parameters, because I had not realized how different such things can be from one research laboratory to another, and how they can affect the reproducibility. I was amazed during the closing roundtable discussion of the potential for many cross-border joint research projects, and I hope that more and more will be realized in the near future. In addition to gaining new knowledge and being able to present my results to the international community of plant biologists, participation in the meeting has given me the possibility of introducing myself to fellow PhD students and prominent researchers of the field. I am grateful for the UV4Plants bursary, which helped me to attend the meeting.

Kristóf Csepregi In the workshop I had a chance to talk about utilizing low dose supplemental UV radiation to prime bell pepper seedlings for environmental stresses. This

Figure 11.1: The Hungarian research group at University College Cork, from left to right, Kristóf Csepregi, Gyula Czégény, Arnold Rácz, Éva Hideg and Anikó Mátai.

is a new project and I decided to talk about preliminary, unpublished results rather than summarizing data from already published work. It was a good choice because I had valuable feedback from workshop participants. The short, 5 min talk format was perfect to give an outline of the experiment and just one set of results. I was able to share more ideas during small group discussions, which formed spontaneously during tea breaks and during the excursion. Unlike the larger conferences where one struggles to make contacts with lectures, the leisurely atmosphere of the workshop was very good for young scientists like me. My participation was sponsored by University of Pécs and the UV4Plants Association and I am grateful for these bursaries.

The city of Cork was captivating for both us. We got a taste of the Irish weather on the first day when we were hit by strong wind and rain at the airport. In the following days, however, we had a cloudless day, thanks to Marcel's excellent organization. University College Cork was breathtaking, with its beautiful old main building and a host of new outbuildings that make it make it easier and more enjoyable for students to study (we were a bit jealous of them). After admiring the sunny sights of the city, in the evening we had the opportunity to take a tour (thanks to our local tour guide) and catch a glimpse of the historic pubs of the city.

Figure 11.2: The authors adjusting to the local environmental conditions in a pub, named the "Sin é".

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Meeting report
Annual Meeting of the Nordic Ozone and UV group, 2019

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Introduction

The Nordic Ozone and UV group is a working group within the network of Nordic National Meteorological Services (NORDMET). The annual meeting 2019 was organized by Public Health England (PHE) in Chilton, U.K., 26–27 March.

The meeting provided opportunities to discuss the following areas: Ground based ozone measurements; Modelled ozone events and scenarios; Space-based ozone and UV products; Ground-based UV measurements; UV radiation and its effects on biosphere and on materials; Solar radiation and human health. The meeting is a good forum to share research ideas and results connecting UV/ozone studies and time series with research into the effect of UV.

Multidisciplinary research is much appreciated and the members of UV4Plants are invited to participate in the next meeting, to be held in Oslo, Norway, in April 2020. To give you an idea of the themes of the latest meeting, summaries of five presentations are presented here below. As before, colleagues from outside the Nordic countries are very welcome in the NOG meetings. In case you are interested to hear more about the next meeting or to be part of our mailing list, please send a message to `mailto:kaisa.lakkala@fmi.fi`.

Is exposure to UV radiation a viable choice for vitamin D production in the modern world?

Ann R. Webb, Richard C. Kift, Mark Farrar and Lesley E. Rhodes

University of Manchester, Manchester, UK

The measurement of UV radiation is often, at least partially, justified on the grounds of public health issues. Traditionally this was sunburn and skin cancer (risk), more recently vitamin D synthesis (benefit) has also gained support. Ability to balance UV benefit and risk depends on location (climate), skin type and behaviour, the latter determined by culture, employment and personal choice. Alternatively, vitamin D can be acquired by ingestion though modern diets are generally low in vitamin D and regular supplementation would be the most reliable way to achieve this. We showed how the risk/benefit balance for UV exposure can be achieved in the UK climate, whether different sections of the population come close to finding that balance, and how supplement use can be encouraged based on the climatology (Figure 12.1).

Daylight photodynamic therapy

Luke McLellan[1,3], Paul O'Mahoney[1,3], Stephanie Logan[1,2], Susan Yule[1,2], Carol Goodman[1,2], Andrea Lesar[2], Lynn Fullerton[2], Marina Khazova[4], Michael Higlett[4], Sally H.

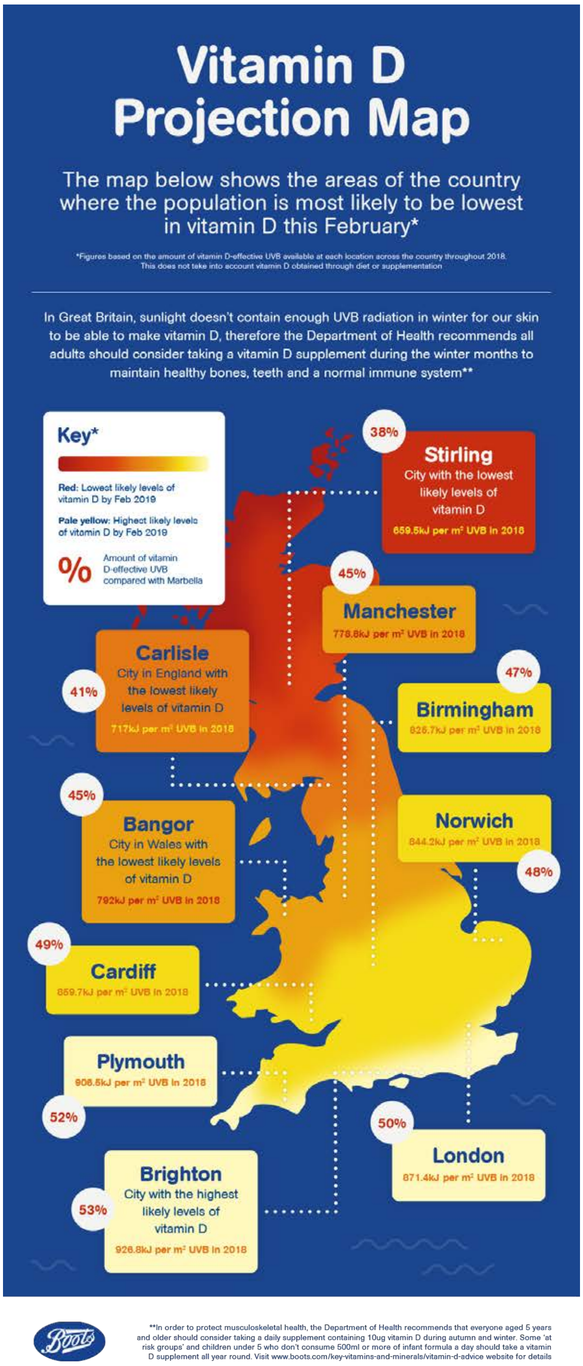

Figure 12.1: The vitamin D projection map shows the regions where the population are most at risk of wintertime vitamin D deficiency due to lack of solar vitamin D-effective UV radiation. The colour coded map is based on the total annual vitamin D-effective UV for 2018, calculated from satellite data input and verified against ground-based measurements.

Ibbotson[1,3] and Ewan Eadie[1,2]

[1]Scottish Photodynamic Therapy Centre, Dundee, [2]NHS Tayside, Photobiology Unit, Ninewells Hospital and Medical School, Dundee, [3]University of Dundee, Photobiology Unit, Ninewells Hospital and Medical School, Dundee, [4]Public Health England, Didcot, UK

Daylight photodynamic therapy (dPDT) is an effective treatment for type I and moderate type II actinic keratosis (AK). In combination with a light sensitising cream and molecular oxygen, it uses visible solar radiation to treat AK that are caused by over exposure to solar ultraviolet (UV) radiation. It is also a patient preferred treatment due to its high rates of clearance, convenience and low pain scores. This is important as AK is a chronic disease where treatment management and patient happiness is of high importance. An in-house patient survey was conducted at the Scottish Photodynamic Therapy Centre validating patient willingness to carry out home-based dPDT for their disease.

For a successful treatment, it is though that a minimum protoporphyrin-IX (PpIX)-weighted dose of 40 $\mathrm{kJ\,m^{-2}}$ is required. Lux meters are an inexpensive method of monitoring daylight exposure, and a conversion model was derived in order to convert illuminance (measured on a lux meter) into the clinically relevant PpIX-weighted dose. Applying this conversion model to historical data provided by Public Health England (PHE) gives an estimate for the expected PpIX dose year-round in the UK which may act as guidelines for clinicians and dPDT practitioners validated the model and demonstrated that successful dPDT can be applied year-round.

PHE also provided data on erythemally weighted UV and UV-A irradiance. As dPDT is a consequence of chronic UV exposure, historical trends in UV data help indicate, to an extent, prior patient exposure. This also depicts safer treatment times where UV dose is low whilst retaining a sufficient dPDT dose and omitting periods that fall below this. Similar trends for UV-A radiation were also shown.

This data highlights the need for photoprotection during dPDT particularly during the summer months around solar noon especially as patients have already accumulated chronic UV damage. However, approximately 40% of the dPDT dose absorption spectra lies within the UV-A, a region that is highly attenuated by modern day sunscreens. In our in vitro study, we demonstrated a reduction in the received PpIX-weighted dose of between 38% and 92% for a variety of sunscreens, highlighting the importance of sunscreen choice in dPDT.

Record-breaking 2018 and the increasing surface solar radiation over Sweden since the 1980s

Thomas Carlund

Swedish Meteorological & Hydrological Institute

During the period 1983–2018, for which good quality and homogenous radiation data has been recorded in Sweden, some clear features in the surface radiation climate show up (Figure 12.2). Significant positive linear trends in global radiation are found at all stations. Averaged over all stations, the trend until 2005 was about $+4\,\mathrm{W\,m^{-2}}$ per decade. From 2005 the increase is weaker but still positive. A major reason for the continued positive trend is the record sunny summer half year of 2018. The main reason for the increased surface solar radiation is a decrease in cloudiness leading to increased sunshine duration. Also UV irradiation was high in 2018. However, at the (single) measurement station in Norrköping record-breaking amounts were not experienced in 2018, despite normal to slightly lower total ozone amounts during the summer. One reason for the discrepancy in record years between global and UV irradiation measurements could be the relatively high uncertainty in the UV measurements.

Long-term Ozone Observation at the Swedish Institute of Space Physics in Kiruna

Uwe Raffalski

Institute of Space Physics, Kiruna, Sweden

The Institute of Space Physics (Institutet för rymdfysik, IRF) is a governmental research institute established in 1957 in order to conduct long-term observation of geophysical parameters in the first place. As Observatory it has started ozone monitoring in 2001, making use of its unique location north of the polar circle and, during wintertime, well inside the polar vortex most of the time. The Kiruna Millimeter wave Radiometer KIMRA measures the emission from the ozone line at 230 GHz ($\lambda \approx 1.3$ mm). Comparing our continuous measurements with satellite observations both data sets show very good agreement. The simultaneous observation of a CO emission line at ca. 231 GHz, close to the ozone line, enables to take dynamical processes into consideration when estimating the winter/spring ozone loss. Dynamical effects like down transport of relatively ozone rich air masses from the mesosphere where ozone is formed can mask the ongoing chemical ozone depletion further down in the atmosphere. Therefore it is important to eliminate dynamical effects by using CO as a tracer. A comparison between CO data from KIMRA and Aura/MLS satellite data shows very good agreement and provides confidence in such ground-based measurements of the upper stratosphere and mesosphere, a region of the atmosphere which is hard to probe in any other way than with the means of remote sensing.

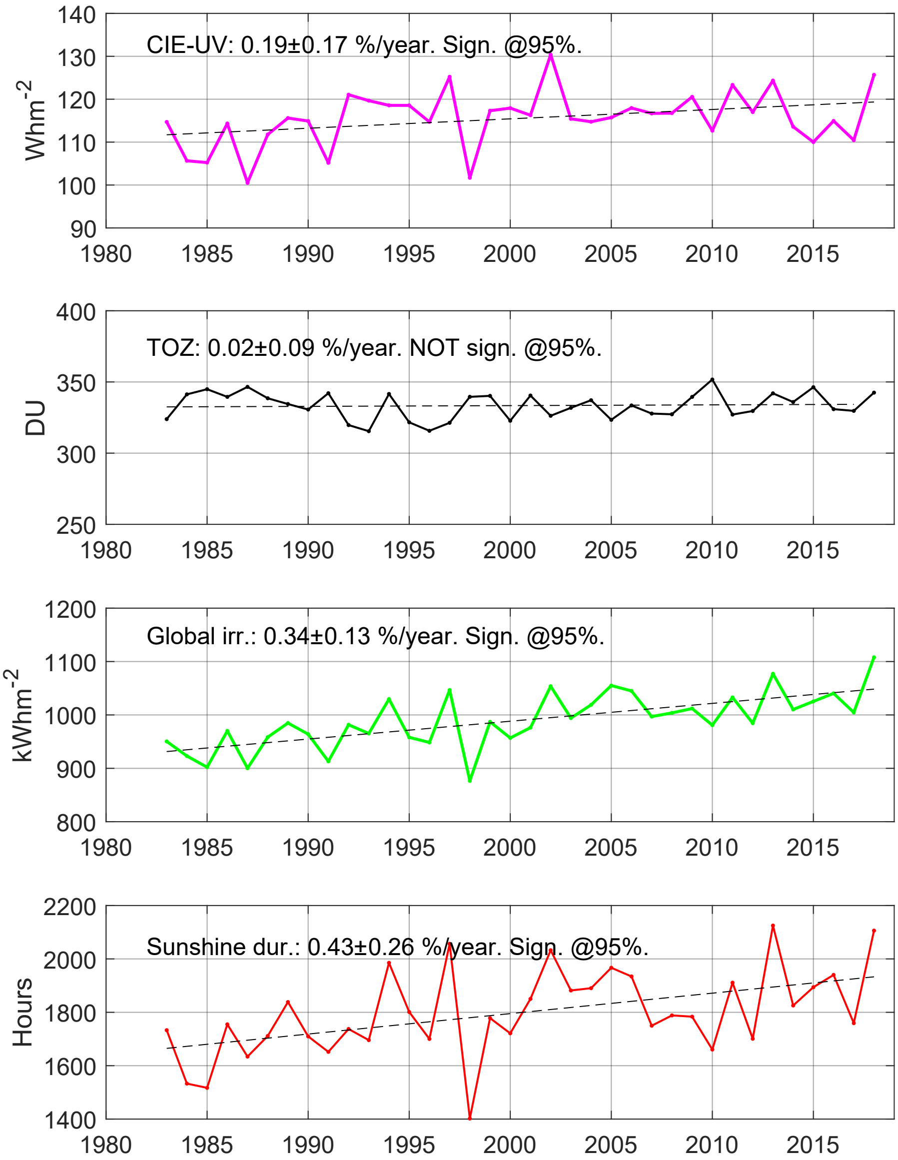

Figure 12.2: Time series of some solar radiation monitoring variables measured at the Swedish Meteorological and Hydrological Institute's station in Norrköping, Sweden. From top to bottom: Annual erythema-weighted UV irradiation, annual mean total ozone, annual global irradiation and annual sunshine duration.

Validation of AC SAF UV record product

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The EUMETSAT Satellite Application Facility on Atmospheric Composition Monitoring (AC SAF) UV Data Record R1 products (OUV RECO) were compared with ground based measurements from 30 sites for the period 2007–2017 (Figure 12.3) (Lakkala et al. 2019). The OUV RECO includes daily doses and maximum dose rates of UV-B and UV-A radiation together with values obtained by different biological weighting functions, solar noon UV index and quality control flags. The OUV RECO time series is processed using uniform algorithm throughout the 10-year period. For UV daily doses, the median of relative differences from ground based measurements was less or equal to 10% at 23 sites. The average of the medians of all stations, excluding two Antarctic sites, was -1.20%. For daily maximum dose rates, the relative difference was less or equal to 10% at 18 sites. The average of the medians was -5.4%, when excluding two Antarctic sites from the analysis. The stations of Syowa and McMurdo are located at the coast of the Antarctic, where high reflectivity from snow and ice together with changing sea ice conditions increase uncertainties in satellite retrievals. There still exist challenges in discrimination of snow and clouds for extreme conditions, like in spring at the high latitude site of Barrow.

Acknowledgement: The AC SAF team and operators of ground-based measurements are acknowledged.

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UV-dose data from an arctic station (Ny-Ålesund) applied to the study of UVB and UVA radiation effects on early life stages of zebrafish

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The Arctic sea-ice has undergone significant changes in recent years: decline in extent of summer ice, reduced ice thickness and younger ice pack (Wang et al. 2014). These changes have contributed to decreased surface albedo and increased transmission to the upper ocean, resulting in more energy deposited to the Arctic sea. Temperature increase and different exposure to visible light and UV have strong implications for the primary production of marine biomass, particularly photosynthesizing ice-algae and phytoplankton, serving as nutrient store for zooplankton (eg. *Calanus finmarchicus*), amphipodes, krill, fish larvae, etc. (Figure 12.4).

As part of the Norwegian UV-monitoring program, a GUV multiband filter radiometer

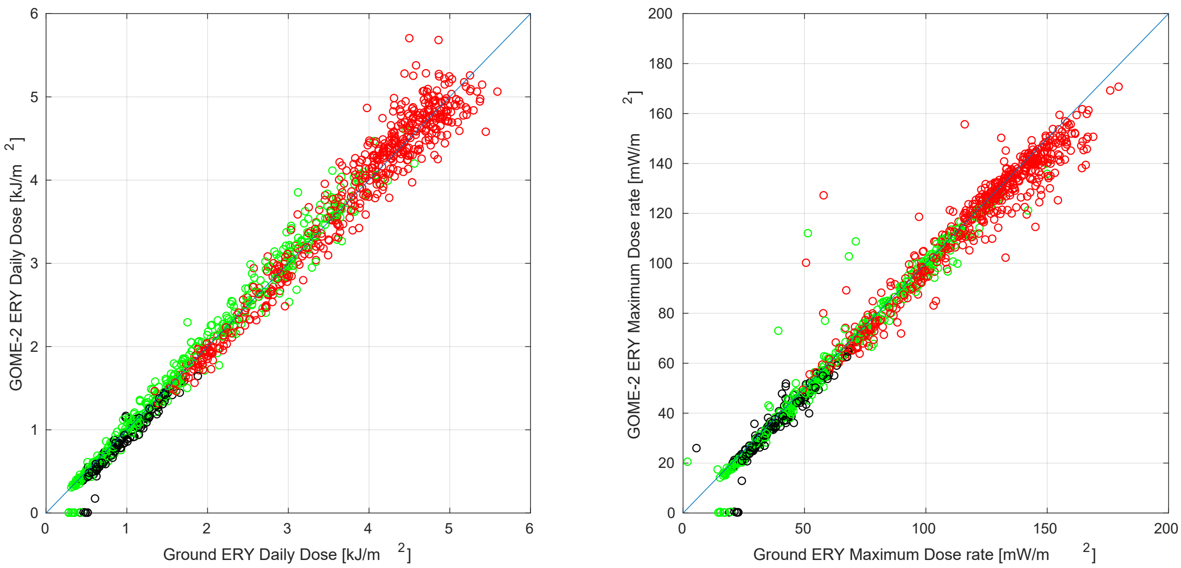

Figure 12.3: A) Erythemally weighted UV daily dose and b) erythemally weighted maximum UV dose rates measured by a spectroradiometer (Ground ERY) and the corresponding satellite product (GOME 2 ERY) at Summit 72°N. Data sets were divided into four seasons (December–February, blue), (March–May, green), (June–August, red) and (September–December, black). (Figure from Lakkala et al. 2019).

Table 12.1: Environmental doses at the surface or under an ice cover expressed as LD50 for zebrafish in UVA and UVB.

Conditions Surface, total regular mean dose	UVA Daily dose/ LD50: 2	UVB Daily dose/ LD50: 17
Number of extra LD50 going from:		
Normal to low Ozone	0.0	3.5
Clear to thick clouds (reduced dose)	-1.4	-11
High to low albedo	0.1	1.0
Thick to thin ice	0.28	1.9

located in Ny-Ålesund (78°N) has been operating since 1995, providing 23 year time series of UVB and UVA surface irradiances, as well as sky transmittance and surface albedo in the UVA part of the spectrum. The surface albedo represents the combined backscatter of open, and ice- and snow covered Kongsfjord area, land and ice caps, providing an indirect measure of inter-annual variations in snow and ice extent, and indicates the onset of snow melting. The melting period, starting in early May, ending in mid-July, occurs at a time of maximum solar elevation and natural variability in stratospheric ozone, where a shift in snowmelt period may result in significant variations in UV doses in the biologically active surface layer of the ocean. Combining high and low ozone values based on AURA-OMI overpass data, late and early onset of ice melt from long term GUV measurements, and clear sky and overcast conditions, we have estimated daily variations in surface UVB and UVA irradiances at the top of an ice layer. Furthermore, using ice transmittance data based on Belzile et al. (2000), daily variations in UVB and UVA irradiances in the ocean surface layer were estimated.

It is well known that waters around

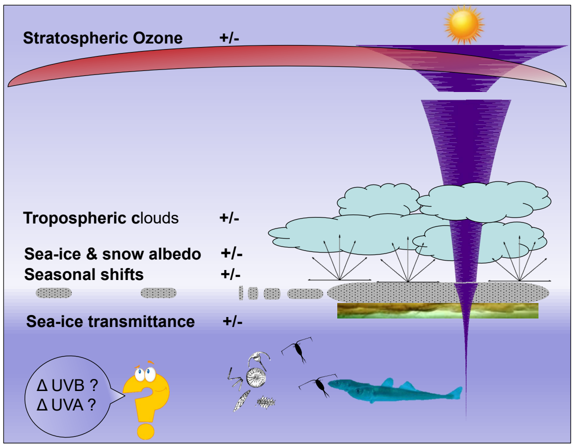

Figure 12.4: Schematic presentation of the main processes that contribute to climate related changes in UV-doses in an arctic marine environment.

Svalbard, Norway, are important spawning grounds for marine fish, which are of great economic importance for several countries. We have used an established fish model system to estimate to what degree the climate-induced changes in UV irradiance can influence survival, physiological factors and behaviour of fish larvae.

We exposed zebrafish (*Danio rerio*) embryos (4.5--5.5 hpf, hours post fertilization) to sub-lethal and environmentally relevant doses of UVA (94, 187, 377 $kJ\,m^{-2}$) and UVB radiation (0.13, 0.25, 0.76 $kJ\,m^{-2}$) from broad band fluorescent tubes for studies of behavioural and physiological effects. LD50, the dose killing 50% of the embryos, was estimated, and environmental exposures and experimental doses were expressed in terms of LD50. The doses used for studies of physiological and behavioural effects were all below the LD50 (range 0.13–0.68 times LD50) and caused no significant difference in survival, deformities, or hatching between exposed and control groups. Compared to controls, there were transient UVA and UVB exposure effects on heart rate. UVA exposure led to significant reductions in larval movement following exposure to the two highest doses of UVA, i.e. reduction in the time spent active and the total distance moved compared to control at 100 hpf, while no effect on the swimming speed was observed. The lowest dose of UVA had no effect on behaviour. In contrast, the highest dose of UVB led to a possible increase in the time spent active and a slower average swimming speed although these effects were not significant ($p = 0.07$). UV exposures also caused effects on ROS formation and lipid peroxidation. These results show that UV doses below LD50 levels are able to cause changes in the behaviour and physiological parameters of zebrafish larvae, as well as oxidative stress in the form of ROS formation and LPO. The changes in activity and swimming speed may be assumed to influence important functions as ability to migrate, search for food or avoid predators. Further testing is necessary to assess how this type of radiation and the effects observed could affect fish population dynamics.

We have presented climate related dose changes in Table 12.1. It can be assumed from the results obtained in zebrafish, that biological effects on naturally occurring fish embryos in the arctic sea may be induced by doses within the range of climate-driven variation.

Acknowledgement: This project was supported by Research Council of Norway through its Centres of Excellence funding scheme, CERAD project number 223268/F50.

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Figure 12.5: Group photo: Michael Higlett

Methods

Neutral density filters: theory vs. reality

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DOI: 10.19232/uv4pb.2019.1.15

Abstract

Neutral density filters in theory do not affect the shape of the spectrum of radiation that traverses through them. In practice, real neutral density filters are far from being truly neutral and do alter the spectrum of radiation. Not all neutral density filters alter the spectrum to the same extent or in the same way. Here I compare the spectral transmittance of seven readily available neutral density filters and consider how their effect on the light spectrum can have implications for their use in light sources used in scientific research and on camera lenses used for imaging.

What is a neutral density filter?

A neutral density (ND) filter is a "grey" filter, a filter that transmits equal fractions of the incident radiation at all wavelengths—e.g. constant 50% transmittance from the far UV to the far IR. A perfectly neutral filter over such a broad range of wavelengths is an idealized concept. Even over much narrower ranges of wavelengths it is very difficult to make filters that are perfectly neutral. There are different approaches to making filters approximating colour neutrality, and each approach has different advantages and disadvantages. A "cocktail" of pigments can be incorporated into the mass of a synthetic resin or optical glass, or applied as a coating to the surface of a plastic film, or sheet of synthetic resin or optical glass. A variation on this approach is the deposition of very thin layer of metal onto the surface of optical glass under vacuum. When pigment or metal coatings are used they can be protected from scratching and damage either by an additional coating with a hard material or by enclosing the coating in-between two sheets of optical glass or synthetic resin. I here compare the spectral transmittance of seven easy to obtain ND filters of different types and prices. These filters are used as examples of different types of filters, as many different suppliers exist (Fig. 13.1).

What are neutral density filters used for?

Neutral density filters can be used, in principle, whenever there is a need to decrease the flux of radiation. Before the advent of LEDs and LED-drivers allowing easy dimming, it was common to use ND filters to adjust PAR levels during gas exchange measurements (Sestak et al. 1971). In photobiology, they are frequently used to decrease irradiance from sources that cannot be easily dimmed, such as multi-metal discharge lamps, or lamps for which dimming causes a drastic change in the emission spectrum, such as incandescent lamps. In UV-B photobiology they are less frequently used as only special types of neutral-density filters transmit at wavelengths shorter than 350 nm (e.g. UV-VIS ND Filters from Edmund Optics described as spectrally flat from 250 to 700 nm).

The shade screens used in commercial greenhouses and frequently also in experiments studying the growth and development of plants under different irradiances, are thought of as providing “neutral shade”, although in most cases they absorb some wavelengths preferentially (as discussed in Kotilainen et al. 2018).

In photography, ND filters are used when it is desired to prolong exposure time (e.g. Cameron 2009). In scientific photography accuracy of colour reproduction is in most cases required (Blaker 1978). Is important for those using photography to document results from experiments to be aware of the possible effects of ND filters on the images captured.

Filters sold for use in photography are widely available in a variety of types, qualities and prices, making it easier to exemplify the problems one needs to be aware of when using ND filters in general.

How is the strength of ND filters indicated?

The strength of filters can be measured as absorbance, which is also called optical density (OD), or as transmittance, and one of these quantities should be used to describe ND filters in scientific work. Commercially, it is also frequent to describe filters by the denominator of the fractional transmittance (T) or by the reduction of exposure value (EV) or “number of [camera diaphragm] stops” (Table 13.1). A filter labelled ND16 transmits 1/16 or the incident radiation, and is equivalent to halving the flux 4 times in succession ($2^4 = 16$), which in photography we call 4 EVs or 4 f-stops, as illustrated in the table.

Table 13.1: Strength of neutral density filters. Numerical equivalents for quantities commonly used in the commercial and scientific description of neutral density filters: optical density (OD), transmittance (T) expressed as a fraction of one, ND*nn* naming convention, number of f-stops or exposure value (EV) change.

OD	0.3	0.6	0.9	1.2	1.8
T (%)	50	25	12.5	6.2	1.6
T	1/2	1/4	1/8	1/16	1/64
NDnn	ND2	ND4	ND8	ND16	ND64
Δ EV	-1	-2	-3	-4	-6

Methods and data sources

All the data used are available in R package ‘photobiologyFilters’ version 0.5.0 (Aphalo 2015). The data for the Schott filter is from the manufacturer, while all other filters were measured by the author with a diode array spectrometer with simultaneous use of deuterium and tungsten lamps (model 8453, Agilent, Santa Clara, CA, USA). Plots were produced with R packages ‘ggplot2’ version 3.3.1 (Wickham 2016) and ‘ggspectra’ version 0.3.4 (Aphalo 2015). Photon ratios were computed in R with functions from packages ‘photobiology’ version 0.9.28 and ‘photobiologyWavebands’ version 0.4.3 (Aphalo 2015).

The selection of filters used as examples was limited to the filters the author had available at the time of writing, and it is certainly biased with respect to brands, with two very popular brands, Hoya and Lee filters not represented. The Firecrest filter was bought directly from the manufacturer, Formatt-Hitech, at `https://www.formatt-hitech.com/` in 2018. The Hitech filter was also bought directly from Formatt-Hitech, but more than 10 years ago. The Zomei filters (`https://www.zomei.com/`) were bought in 2019 from an Aliexpress seller. For the Rosco filters (`https://emea.rosco.com/en`) I used samples from swatchbooks about 10 years old, stored in darkness at room temperature.

Figure 13.1: Some of the neutral density filters described in the article, supplied by Formatt Hitech, U.K, Zomei, China and KnightX, China.

How neutral are commercial ND filters?

Many ND filters are made using absorptive optical glass or plastic resin. Prices of these filters vary widely. Some very old filters could even be composed of a film of tinted gelating sandwiched between two sheets of optical glass for protection while the very fragile gelatin-film ND filters such as Kodak Wratten #96 are still available. Filters made using coloured pigments cannot be made with constant transmittance across a broad range of wavelengths. Some of the currently available high-end filters are in contrast made by deposition of a very thin metal layer on the surface of clear glass and can provide a much more uniform light attenuating effect across different wavelengths. Carbon can also be used as a broad band light absorber. When optical glass is used as a substrate UV-B radiation is almost completely absorbed.

The comparison presented in this article is not about brands, but about technologies. I first show a Firecrest ND filter from Formatt-Hitech (OD 1.2) made from optical glass with a thin metal layer (Figure 13.2). This type of filter has been earlier used only for scientific research due to their high cost. We can observe a rather flat curve, except for very low transmittance in the ultraviolet at wavelengths shorter than 290 nm. The low transmittance in this region is most likely due to low transmittance of the optical glass used as substrate. Only ND filters in which the substrate is fused silica or special UV-transmitting glass can be neutral in the UV region of the spectrum. This filter can be considered very good, but is far from perfect: the maximum and minimum transmittance in the range 350 nm to 900 nm are 0.076 and 0.051, while the rated OD 1.2 equals transmittance equal to 0.062.

As an example of a high-quality absorptive optical glass filter we use Schott NG3. We can see that the range of wavelengths for which the transmittance is close to the nominal value is much narrower (Figure 13.3). Photography filters of high quality are usually made from either Schott or Hoya optical glass. Absorptive glass can be combined with reflective coatings to reduce the “leak” of infrared-radiation as in the top-of-the-line ND filter from Zomei, a Chinese manufacturer of photography filters (Figure 13.4).

As a first example of absorptive “HD” resin filters we use a Zomei Pro ND8 filter (Figure 13.5). The spectrum of this filter is similar to that of the Schott glass but with higher transmission in the infra-red region and more variable transmittance within the visible region. In square sizes ND filters made from synthetic resin are still frequently used as they are

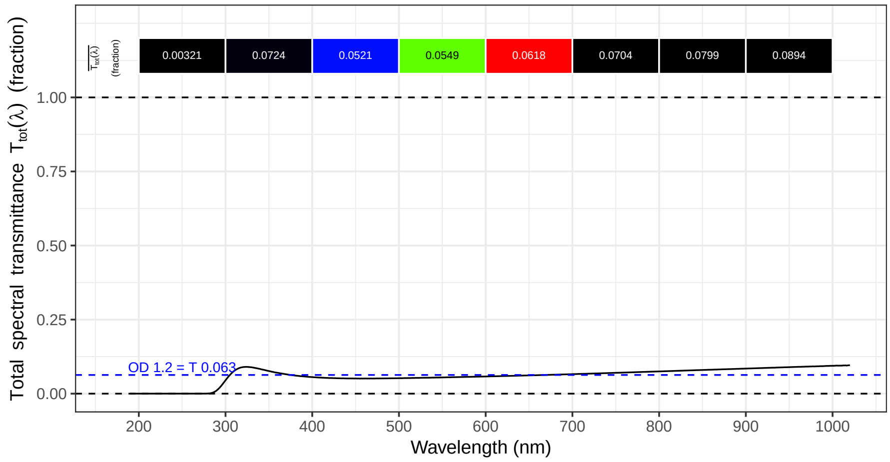

Figure 13.2: Metal deposition based neutral density filter. Transmittance spectrum of a Firecrest ND 1.2 photography filter.

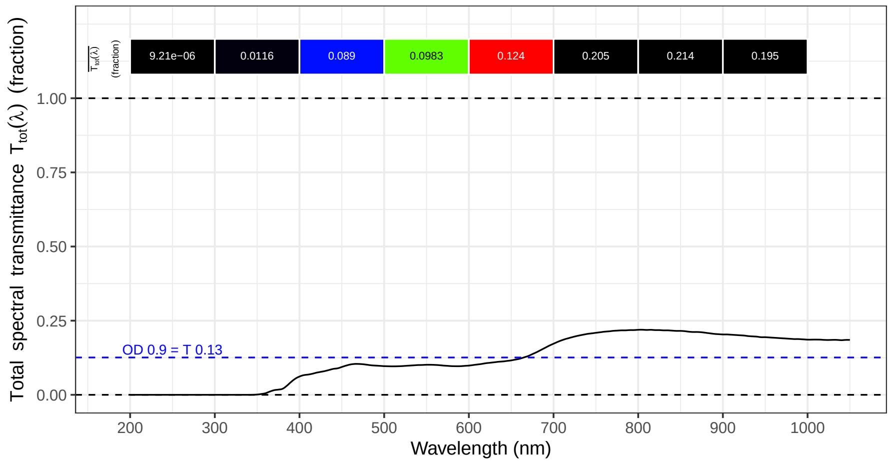

Figure 13.3: Absorptive optical glass neutral density filter. Transmittance spectrum of Schott NG3 glass at a thickness of 1 mm.

cheaper, although Firecrest filters with the same spectral transmittance as the one in Figure 13.2 are also available. As an example of a high quality filter of this type I use a Hitech filter rated at OD 0.9 (Figure 13.6). This filter has a rather flat absorptance within the visible, but very high transmittance in the infrared.

Finally we look at ND filters sold as films, usually called theatrical “gels”, which one might be tempted to use to attenuate sunlight when growing plants. We use as examples a Rosco E-Colour no. E209 ND filter (Figure 13.7) and a Rosco Cinegel no. 97 grey filter (Figure 13.8). These filters are not neutral when used in sunlight as they absorb UV-B much more than visible and far-red much less than visible, in fact they are very effective filters for decreasing the R:FR photon ratio.

Angle of incidence of the light beam

All data in the examples above are for a collimated radiation beam perpendicular to the filter surface. The effect of ND filters is in-

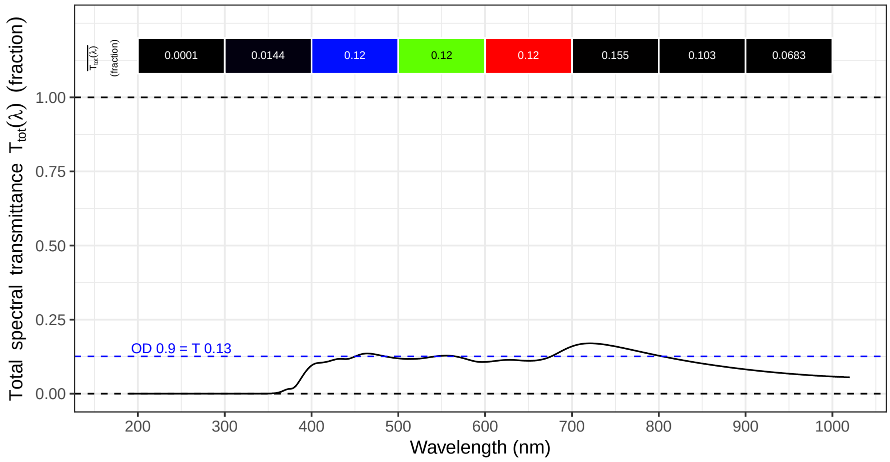

Figure 13.4: Absorptive optical glass multicoated neutral density filter. Transmittance spectrum of a Zomei Pro ND0.9 II MC filter.

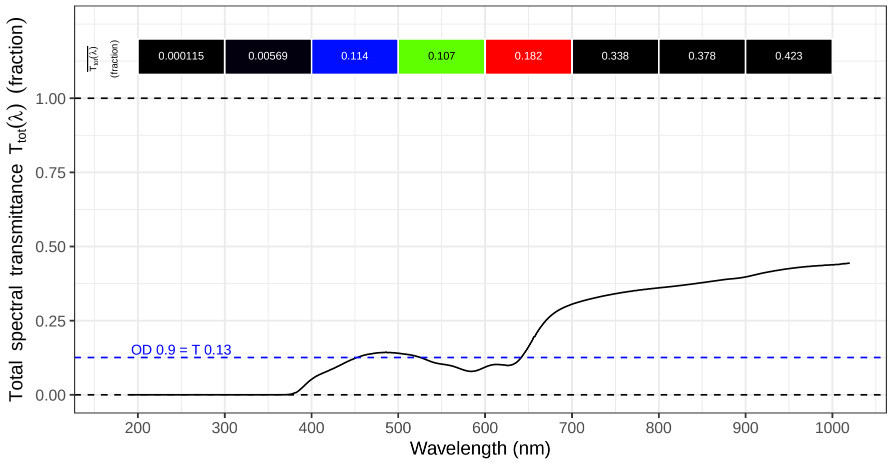

Figure 13.5: Absorptive optical resin neutral density filter. Transmittance spectrum of a Zomei Pro ND8 filter.

creased when the radiation beam's angle of incidence is shallower, as the length of the path through the absorbing medium increases. The strength of this effect depends on the type of filter, i.e. absorptive vs. reflective. It causes what in photography is called "vignetting", i.e. the darkening of the peripheral region of the image, which is most noticeable when using wide-angle objectives. When ND filters are used to attenuate irradiance, for example in radiation treatments to experimental plants, using light sources with a small emission area and a large incidence area we can get a similar effect on the edges of the light field. In cases when filters introduce colour shifts (Figures 13.2–13.8) or changes in photon ratios (Table 13.2), the magnitude of the colour shift or change in photon ratios also increase for shallower angles of incidence.

Filter aging and solarization

Exposure to strong light, both sunlight and from artificial sources, can degrade most types plastic films and sheets. Degradation usually appears as yellowing. By the time

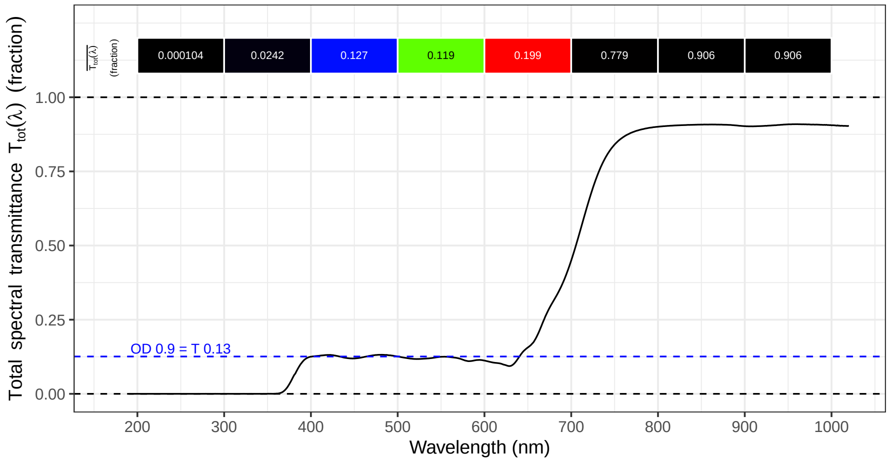

Figure 13.6: Absorptive optical resin neutral density filter. Transmittance spectrum of Hitech ND filter with OD 0.9.

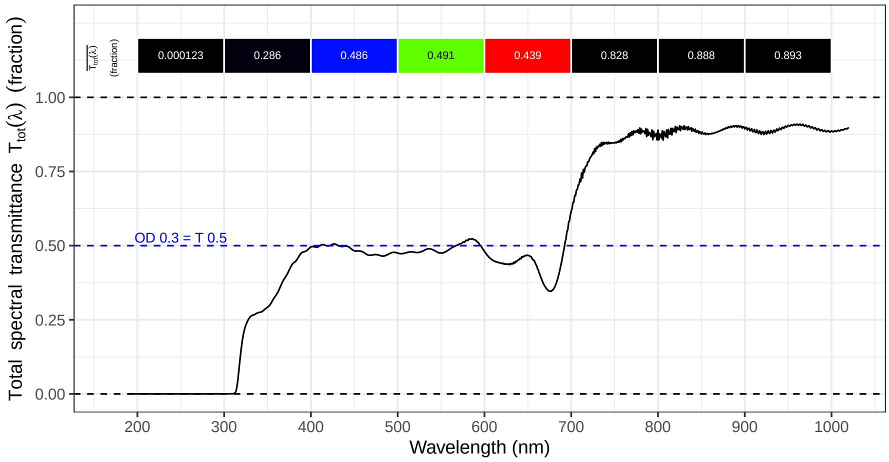

Figure 13.7: Theatrical neutral density gels. Transmittance spectrum of Rosco E-Colour no. E209 film.

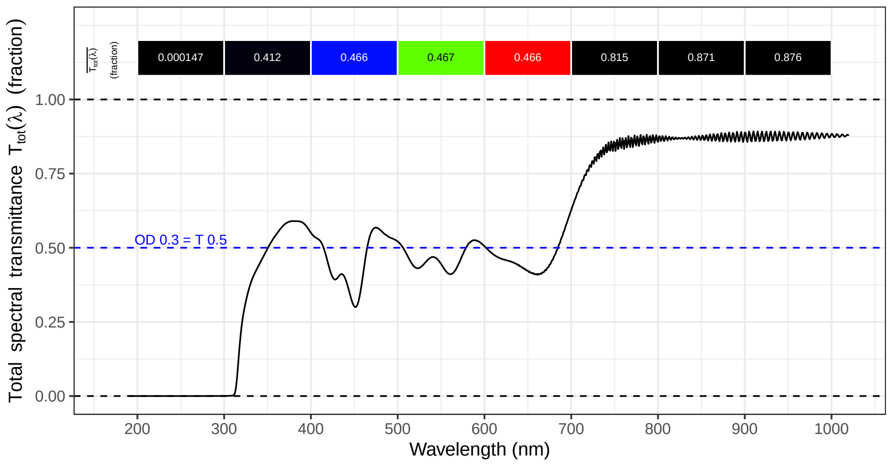

Figure 13.8: Theatrical grey gels. Transmittance spectrum of Rosco Cinegel no. 97 film.

Table 13.2: Effect of ND filters of different types on photon ratios considered important for plants. Wavelengths delimiting the different wavebands are: PAR, photosynthetically active radiation 400–700 nm; UVB, ultraviolet-B 280–315 nm; UVA, ultraviolet-A 315–400 nm; B, blue 420–490 nm; G, green 500–570 nm; R, red 655–665 nm, FR, far-red 725–735 nm. The solar spectrum used as example was simulated for 2010-06-22 near noon at Helsinki. Rows are ordered according to decreasing UVB:PAR photon ratio. The absorptance spectra of the filters are given in Figures 13.2–13.8.

Material	Filter	UVB:PAR × 1000	UVA:PAR	B:PAR	B:G	R:FR
Metal deposition	Firecrest ND1.2	2.588	0.118	0.193	0.819	1.155
—	**No filter**	**1.874**	**0.095**	**0.212**	**0.860**	**1.267**
Plastic film	Rosco Cinegel no. 97	0.065	0.105	0.203	0.853	0.646
Plastic film	Rosco E-Colour E209	0.024	0.074	0.217	0.858	0.654
Absorptive glass	Zomei ND0.9 Pro II MC	0.002	0.018	0.221	0.882	0.850
Optical resin	Zomei Pro ND8	0.001	0.006	0.195	0.923	0.813
Optical resin	Hitech OD 0.9	0.001	0.024	0.180	0.894	0.334
Absorptive glass	Schott NG3	0.000	0.016	0.191	0.825	0.773

these materials acquire a yellow tint, not only transmittance to UV radiation but also that to blue light has decreased. Although in general more stable than plastic polymers, glasses can also suffer changes in their spectral transmittance on exposure to UV and visible radiation. In the case of glasses traces of metals such as iron can determine how much their transparency changes. In the case of synthetic polymers ultraviolet radiation can break atomic bonds. In the specific case of coloured and grey plastics, the dyes used to tint the naturally clear synthetic resin may bleach when exposed to strong visible light or ultraviolet radiation.

Filters' cost and availability

Differences in price within and across different types of filters are large. I use a common size of round camera filters, 52 mm in diameter and OD of 8 to 16, or the closest value available, for the price comparison. A Firecrest filter costs 77 €, while a cheap resin one costs 4 € (spectrum not shown). Equivalent ND filters from Heliopan sell at 50 to 55 €. Zomei sells Pro ND filters made from light absorbing optical resin at 18 € for OD 8, labeled ND8 and the multicoated absorptive glass Pro II MC at 35 € . In the case of square filters, a common size is 100 × 100 mm (4 × 4 inches). The filters in this second comparison being larger, are also more expensive. A Firecrest filter costs 110 €. Edmund Scientific TECHSPEC® UV-VIS (250–700 nm) reflective neutral density filters in 50 mm diameter cost 165 €.

Optical glass ND filters are normally available in relatively small sizes of up to ca. 30 cm in diameter and 1 to 3 mm in thickness. Theatrical filter films are available in widths of up 0.6 m or 1.2 m, lengths of up to ca. 7 m, and a thickness of between 0.05 and 0.1 mm.

Implications for research in plant photobiology

As mentioned above, true ND filters are an abstraction and in practice no filter is perfectly neutral. Most commercially available ND filters have much higher transmittance in the far-red region than in the red region of the spectrum. *This means that most ND filters change both PAR irradiance and the R:FR ratio drastically.* With respect to shorter wavelengths, many ND filters will block all UV radiation or at least attenuate it to a different extent than PAR. To bring attention to these side-effects of ND filters I have computed UVB:PAR, UVA:PAR, B:G, and R:FR photon ratios in sunlight, and in sunlight filtered with ND filters (Table 13.2). One of these ND filters decreased the R:FR photon ratio to ca. 1/4 of its value in full sunlight—similarly to fairly deep vegetational shade—while all other filters decreased this ratio to smaller extents. At the short end of the spectrum, most filters strongly attenuated solar UVB radiation, with the exception of one filter that attenuated PAR more strongly than UVB (Figure 13.2) resulting in a 38% increase in the UVB:PAR photon ratio (top row in Table 13.2). The effect of the filters on the UVA:PAR photon ratio varied between a 24% increase and a 94% decrease. The filters had only a small effect on the B:G photon ratio. The unintended effects of ND filters on the photon ratios can be expected to induce strong responses in plants, which would then be confounded with those of irradiance attenuation and easily misinterpreted as an effect of a decrease in PAR. This is true at different scales, from the growth and development of plants during prolonged attenuation, to gene expression induced shortly after short-duration irradiation.

Unless objects under study are small or we intend to obtain images, shading does not need to be perfectly even in space or time. In fact shading in nature is highly variable in time and space. The easiest way of ensuring neutrality while keeping cost down is to use a material that completely blocks solar ration, but a fraction of its surface is covered by holes. Metal-wire meshes with small openings and black or silver/black scrims (e.g. Rosco E-Colour+ no. E275 or no. E270 and Lee no. 275 or no. 270) provide almost perfectly neutral shade. Black plastic shading mesh or cloth can be neutral, but its absorption outside the visible range may be different than in the visible. Finally, in the past white cotton gauze has been used for shading, but care should be taken as UV-absorbing blue-fluorescent pigments are added to most washing powders as optical whitening agents and white cloths also treated with such agents when manufactured. Depending on the distance to plants, and ventilation and or cooling or the air and lamps it may be worth considering whether the rejected radiation should be preferably absorbed or reflected. The black/-silver scrims set with the aluminium coated side facing upwards will reflect rather than absorb sunlight. In the case of all these materials light is either blocked by the wires, threads, black or metal-covered film, or transmitted through open holes, which ensures that they are spectrally close to neutral. In contrast, shading materials in which the “holes” are occluded by clear plastic films are in most cases far from being neutral (Kotilainen et al. 2018), and should be in general avoided when neutral shade is the intended treatment.

Implications for imaging

Using filters that are not neutral within the range of wavelengths a camera sensor or film is sensitive to, introduces a colour cast in the images obtained. In scientific photography and reproduction, colour casts introduce a bias in the information obtained—i.e. results in bad data. In everyday photography the colour casts result in artificially looking or unnatural images. To some extent colour casts can be corrected using custom colour profiles during image processing, but in most cases correction is only partial. Normal digital cameras are sensitive to wavelengths between approximately 380–410 nm to 680–720 nm, depending on brand and model. Based on the examples shown above, in most cases the main problem is a far-red or infrared “leak”, while non-neutral absorption in the range 400–600 nm is uncommon in high quality ND filters.

To avoid the introduction of colour casts when imaging in the visible, we can either use high quality ND filters like the Firecrest used as example, or stack or combine a filter that is neutral in the range 400–700 nm with an ultraviolet and IR blocking filter (Figure 13.9).

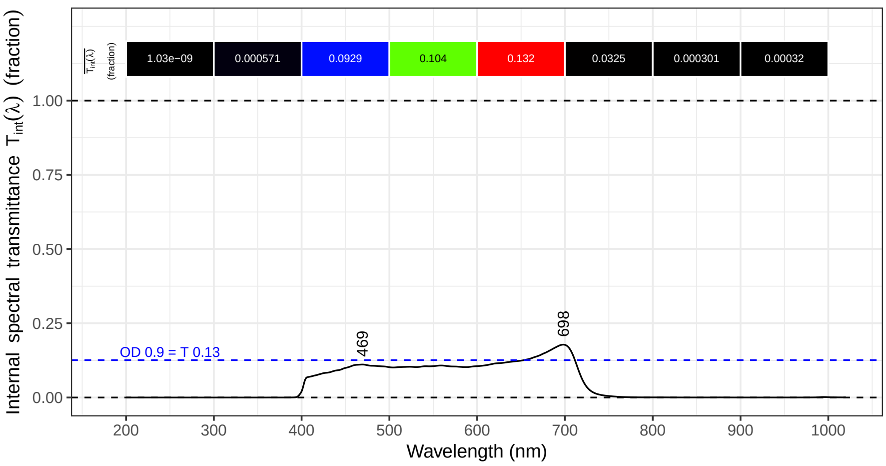

Figure 13.9: Filter "stack". Computed transmittance spectrum of Schott NG3 glass at a thickness of 1 mm stacked with a Fitrecrest UVIR Cut filter.

In photography, the second option has been the most commonly used as filters with low infra-red transmittance have been in the market for only a few years.

Conclusion

Although different in brand, thickness and manufacturer code, the filters you are likely to encounter when doing research will probably be made from similar materials and processes as those used in the examples given here, and consequently subject to similar pitfalls and limitations. When using filters in scientific research, never trust the verbal description given by manufacturers, they are usually based on the filters' function in a restricted use domain. Furthermore, when the name represents a theoretical ideal, as in the case of clear or neutral density filters, it is likely to be only an approximation to the actual characteristics of the filter. Never extrapolate from the published specifications: if behaviour at a wavelength of interest is not specified by the manufacturer, it may be different among production batches and unpredictable. Furthermore, most spectra published by filter manufacturers are described as typical and may differ from that for any given production batch. Some manufacturers will have tighter quality control than others. Filters may become mislabeled or mixed-up in our own labs and in sellers' storage. Filters from different brands, or different series or qualities within a brand, even if sold as equivalent, are frequently significantly different. Finally, the spectral transmittance of filters will frequently change in time through effect of exposure to radiation and/or to humid air and through surface oxidation. My recommendation is to measure the spectral transmittance of every filter you use in research both when new and at regular intervals afterwards, replacing as needed the degraded ones.

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Peer-reviewed article.

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Edited by: Titta K. Kotilainen.

2nd circular

The International Association of Plant UV Research announces the

3rd Network Meeting of the UV4Plants Association

April 1st – 3rd 2020 in Kiel, Germany

Dear colleagues,

We would like to invite you to register and submit abstracts for the next UV4Plants meeting from now on.

The meeting will be held under the motto

"Plant responses to UV radiation – Diversity in time and space"

which is also reflected in the topics of the sessions. You are kindly invited to contribute to one of the sessions, which are outlined below, together with keynote speakers:

- UV radiation in the physical environment (Gunther Seckmeyer)
- Sensing of UV radiation (Gareth Jenkins)
- Acclimation responses to UV radiation (Paul Barnes)
- Functional photoprotection (Martin Lohr)
- Analytical methods (Hans-Peter Mock)
- Application of knowledge (Titta Kotilainen)

The meeting will be preceded by a training school from March 29th (6 p.m.) until April 2nd (5 p.m.). Following the examples of former network meetings, a large weight will be put on time for exchange with colleagues. For this, we will have a scientific discussion in the schedule of the programme and welcome evenings offered for the training school on March 29th and for the conference on March 31st. Furthermore, after a short afternoon social programme on April 2nd we will have a conference dinner close to the Kiel Fjord providing ample of opportunities to network. The conference will conclude at lunchtime on April 3rd.

Venue

The conference will take place at the "Wissenschaftszentrum Kiel", Fraunhoferstraße 13, 24118 Kiel. The training school will be conducted at the Biology Center of Kiel University.

Registration and abstract submission

Registration for the meeting and the training school can be done from now on by email to: meeting2020@uv4plants.org. To this address should also be sent abstracts for contributions. Please, indicate if oral or poster presentation is desired. An abstract template can be downloaded from the website: https://www.uv4plants.org/meeting2020/.

- **Deadline for abstracts: January 20th**

Early registration (until January 20th)
Members 225 Euro
Non-members 280 Euro
Students 120 Euro

Late registration
Members 270 Euro
Non-members 350 Euro
Students 200 Euro

Training school (until January 10th)
Members 100 Euro
Non-members 150 Euro

The registration fee will include welcome mixer, lunches, tea/coffee, abstracts book and conference dinner.

Please transfer the conference fee to the following bank account:

Bank Name: Nordea
Account Name: UV4Plants
IBAN: FI56 1228 3500 0062 24, SWIF/BIC: NDEAFIHHXXX

Accommodation

We have three suggestions for accommodation for you. We have reserved limited contingents in 3 nearby hotels. Please indicate the key word "UV4Plants" when booking.

2 branches of the B&B Hotel (per room per night 63 EUR single bedroom, 73 EUR double bedroom, excl. breakfast):

B&B Hotel Wissenschaftspark (https://www.hotelbb.de/de/kiel-wissenschaftspark) Fraunhoferstraße 3, 24118 Kiel. Please reserve before February 21st by email kiel-wp@hotelbb.com or phone: +49 431 888 600 19.

B&B Hotel City (https://www.hotelbb.de/de/kiel-city) Kaistraße 70, 24114 Kiel. Please reserve before February 21st by email kiel-city@hotelbb.com or phone: +49 431 888 55727-0.

GHotel Kiel (per room per night 89 EUR single bedroom, 101 EUR double bedroom, incl. breakfast) (https://www.ghotel-group.de/en/hotels/kiel-en/): Eckernförder Straße 213-215, 24119 Kiel-Kronshagen. Please reserve before January 29th by email kiel@ghotel.de or phone: +49 431 3200 – 0.

Maritim Hotel Kiel (per room per night 89 EUR single bedroom, 116 EUR double room, incl. breakfast) (https://www.maritim.de/de/hotels/deutschland/hotel-bellevue-kiel): Bismarckallee 2, 24105 Kiel. Please reserve before February 29th by email reservierung.bki@maritim.de or phone: +49 (0) 431 3894-0.

Travel information

Kiel can be easily reached via train or airplane. From Hamburg Airport you can travel directly to Kiel using the "Kielius" bus line, which is leaving between terminal 1 and 2. Please have cash (return ticket 39 Euro = "Hin-und Rückfahrt") as no cards are accepted in the bus or buy the ticket online beforehand (https://www.bahn.de/autokraft/view/angebot/kielius_en/kielius-infos-eng.shtml). Departures from Hamburg Airport are every hour at 15 min past the full hour. Transfer time is around 1.5 h and arrival at Kiel is at the main station (select "Kiel Bahnhofsvorplatz" if you book online) where public buses to all directions can be taken (2.60 Euro, 1 direction). Alternatively, one can take "Kielius Exx", which is more costly, but also more comfortable with drop off at the desired address. For the return from Kiel to Hamburg airport the "Kielius" bus leaves also at 15 min past the full hour.

For the local organizing committee

Frauke Peschenck and *Wolfgang Bilger*

meeting2020@uv4plants.org

For UV4Plants Association

Prof. Gareth I. Jenkins, President

UV4Plants

The International Association for Plant UV Research

Key aims of the UV4Plants international association are to

- promote and foster research-excellence and good practice in plant UV research through the organisation of innovative events in research, public engagement and education
- provide channels for members to inform the plant UV research community about relevant activities or events of common interest
- enhance the usefulness of plant UV research by facilitating the transfer of knowledge from academia to stakeholders and the general public
- initiate and foster stakeholder contacts as part of an agenda of product development
- liaise with scientific funding bodies to influence their research agenda
- develop with its members the benefits of membership and the relevance of the Association

The Rules of the UV4Plants association, information on membership, management committee and up-to-date news are available at http//www.uv4plants.org.

A new association with a history The origin of UV4Plants was the very successful COST Action FA0906 'UV4Growth' which was active from 2009 to 2014. It brought together photobiologists, molecular biologists, ecologists, meteorologists and stakeholders from agriculture and industry. Many new collaborations were started and new ideas developed.

Three large conferences, and several workshops and training events were organized. Four special journal issues were produced: *Physiologia Plantarum* **145**, 4, *Emirates Journal of Food and Agriculture* **24**, 6, *Plant Physiology and Biochemistry* **93**, and *Plant, Cell & Environment* **38**, 5.

Most participants, the members of the managing committee and the external evaluator all agreed in that a way of continuing and furthering the achievements of 'UV4Growth' was needed.

Invitation to Join UV4Plants UV4Plants welcomes a whole spectrum of members from both academia and industry, applied and basic research. Membership fees for 2016 are EUR 25.00 for students and retired staff, EUR 50.00 for academic members, and EUR 250.00 for industry members. See http://www.uv4plants.org/news/invitation-to-join-our-association/ or contact mailto:secretary@uv4plants.org for details.

UV4Plants

Bulletin
2019: 1

In this issue

UV-A-induced visble fluorescence of lichens and mosses

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