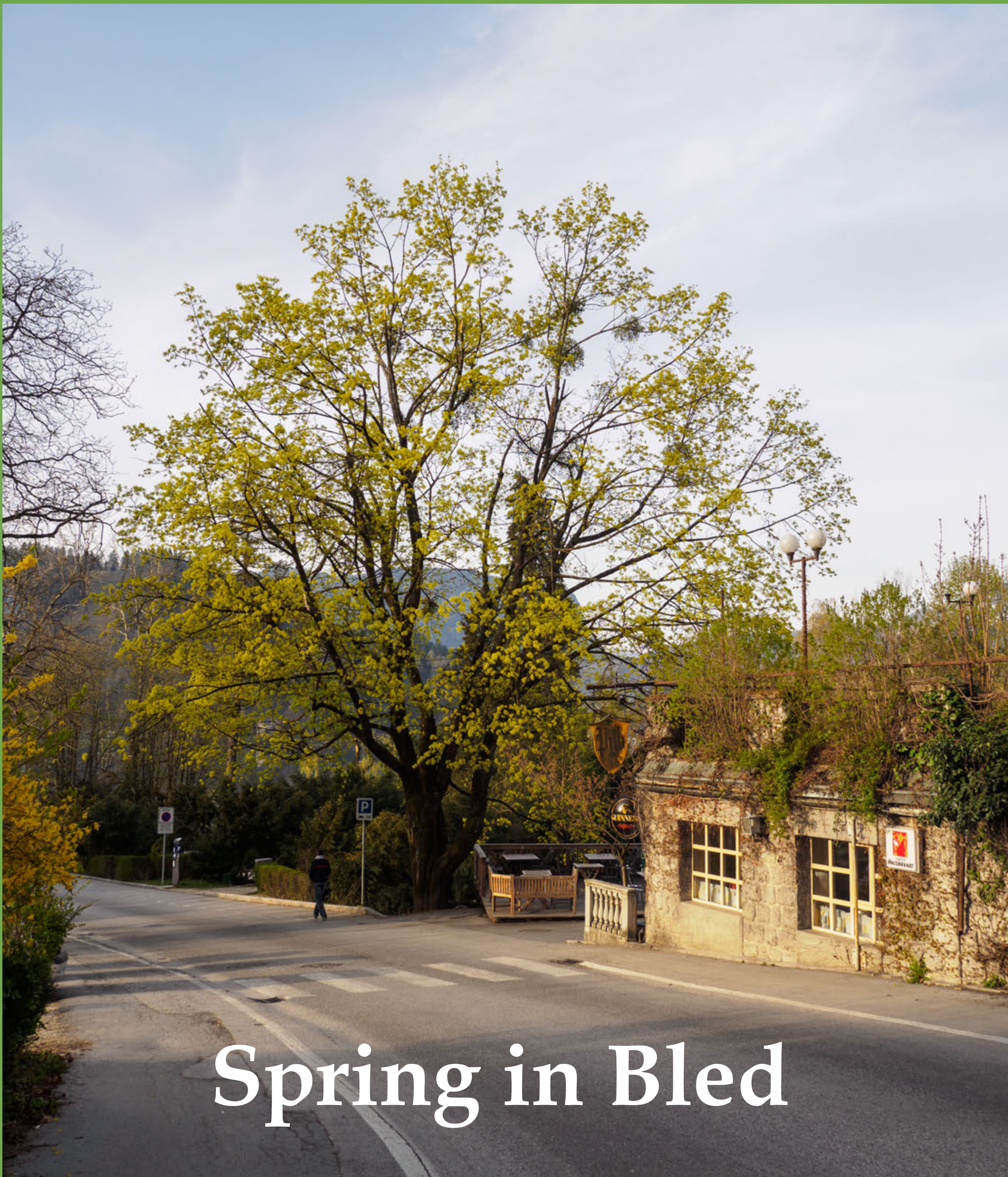
UV4Plants Bulletin

2018: 1



Spring in Bled

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Cover illustration
View of a street in Bled, April 2014 (Image: P. J. Aphalo).

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Contents

From the editors' desk

From Puerto Rico to Pisa and Bled

In this issue we have two PhD thesis summaries. I found this a great way to get informed about latest work done by research groups in our community! Laura Díaz Guerra, supervised by Dolors Verdaguer and Laura Llorens, has studied plant and soil responses to UV radiation and water availability, including perturbation in the form of aerial plant biomass removal and fire. The larger context of the work is related to climate change and alterations in cloud cover and consequently irradiance conditions and precipitation in Mediterranean ecosystems. Min Wu's research, supervised by Åke Strid, aims to improve our understanding on how UV-B radiation actually does the trick, so to say. This was achieved with molecular dynamic methods that were used to study the mechanisms of UV-B-induced signalling pathways in plants.

Pedro J Aphalo shares his knowledge about LEDs, the status of the technological development, and especially of course our prospects for using UV-LEDs in our experiments. Do you know the difference between the two main ways to dim the LEDs, constant current and pulse width modulation, or how to build your own radiation source with LEDs? All this and more is explained, with illustrations.

In another article, Pedro J Aphalo shares his experience about the objective measures of research impact; what after all lies behind his notification that according to ResearchGate he recently became the most read author from Finland! The measurement of the impact of publications and the possible misleading use of impact statistics sounds quite familiar regarding what is going on more general in politics, how opinions rather than facts and using information to suit one's own agenda can lead to unforeseeable consequences. As Pedro puts it, "…we need to be aware of which factors unrelated to the quality of our work affect the data used to asses us". Or one can even quote Homer Simpson here, "Facts are meaningless. You can use facts to prove anything that's even remotely true. Facts, schmacts."

UV4Plants organized two sessions at the 17th congress of the European Society for Photobiology (ESP) that took place in autumn 2017 in Pisa, Italy. Gareth Jenkins, Éva Hideg, Antonella Castagna and Annamaria Ranieri summarise the event and the topics covered. Further, PhD students Yan Yan, Neha Rai and Sari Siipola share their experience from that same congress. Their reflections took me immediately down memory lane. The first conference that I attended during my PhD work, was the 33rd congress of the American Society for Photobiology. The venue was a fancy resort in Rio Grande, Puerto Rico. That in itself was already exotic enough, the hot and humid air and the tropical thunderstorms were quite an experience! Me, giving my first ever scientific presentation was of course exciting and to make it perfect and so apt regarding the topic, we went on a kayaking trip one evening to a bioluminescent bay. Surrounded by the dinoflagellates producing the mesmerizing light was a moment when I actually pinched myself to make sure I was not dreaming!

So enjoy this spring issue of the UV4Plants Bulletin and let us continue gathering more great memories from congresses and meetings, starting in Bled at the UV4Plants network meeting!

Titta K. Kotilainen (editor)

Helsinki, April 2018.

Letter from the President

Gareth I. Jenkins, ORCID: 0000-0002-1855-4875

Institute of Molecular, Cell and Systems Biology, University of Glasgow, Glasgow, UK.

Spring in Bled

As I write this in late March there are signs that Glasgow is taking its first tentative steps towards spring. Only a couple of weeks ago snow and sub-zero temperatures closed our University for several days and we all hid inside our houses, venturing outside only when necessary. In the UK we do not have serious snow very often and do not have the infrastructure to deal with it, so everything comes to a halt. Our Scandinavian friends must laugh at us! But now temperatures are rising, the sun is trying to shine, and a few spring flowers have bravely emerged. To quote the famous Scottish poet Robert Burns:

> *The smiling Spring comes in rejoicing,*
> *And surly Winter grimly flies;*
> *Now crystal clear are the falling waters,*
> *And bonie blue are the sunny skies.*

From: *My Bonie Bell* (1791)

But although the Scottish spring has much to commend it, I am really looking forward to experiencing spring in Bled. Apart from the warmer climate, we can enjoy the local scenery, Slovenian hospitality and, of course UV4Plants 2nd Network Meeting! We have assembled an excellent programme and Alenka Gaberščik and her team will ensure that everything runs smoothly. Planning for the Meeting started in January 2017 when we invited applications to host the event and the decision to hold it in Bled was made just over a year ago. Since that time a lot of effort has gone into organising the conference and we are very grateful to Alenka and the members of the local organizing committee for all the time they have devoted to this project. It is never easy organising a conference but now we can appreciate the results of the hard work. We look forward to hearing about new progress in UV-B research, both through presentations and posters. Hopefully the new information and ideas we share will have a lasting influence on our research. Importantly we will get the chance both to meet old friends and to make new ones, and to discuss opportunities to work together. Our early career researchers will benefit from making contacts with other labs and will see how their work fits into the broader context of UV research. We have designed the Meeting to facilitate networking. We deliberately included long coffee/tea breaks in the programme to promote interaction and to keep everyone fresh. There will be dedicated poster and discussion sessions and, in addition, we will hear a presentation from Dr Lars Olof Björn, who has made major contributions to UV-B research over many years.

I doubt if Robert Burns would have had the slightest interest in plant responses to UV-B, but I'm sure he would have appreciated the beautiful scenery of Lake Bled, with its Castle and island in the middle. He might even have tried a trip in a Pletna boat. There is certainly much to look forward to and I sincerely hope everyone enjoys and benefits from the meeting.

Best wishes,

Gareth Jenkins
(President UV4Plants)

Figure 2.1: Spring in Bled, 2014-04-01. Photo: Pedro J. Aphalo.

News

The second UV4Plants conference starts in a few days time

The *2018 UV4Plants Conference*, will be held in Bled, Slovenia. Dates: 15–18 April, 2018. To be preceded by a Training Workshop. Local organiser: Alenka Gaberščik. In the next issue you will find reports on the conference.

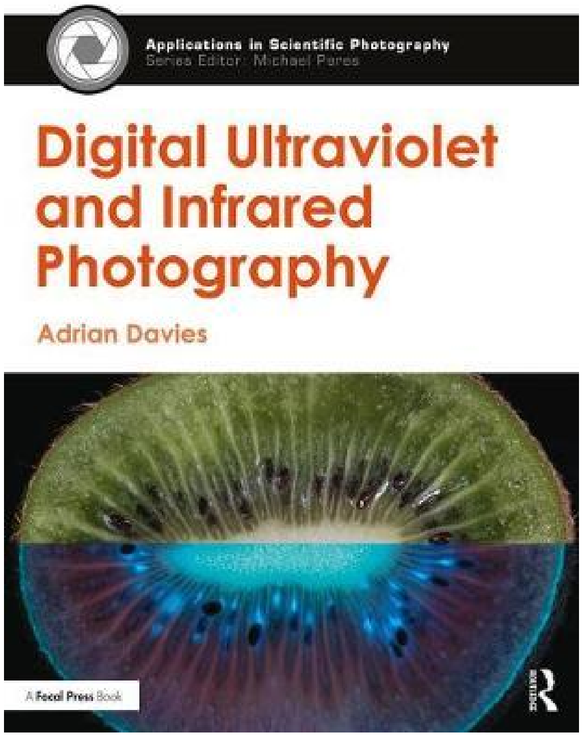
2019 ESP-IUPB World Congress "Light and Life Barcelona"

LIGHT & LIFE 2019 BARCELONA

The 18th ESP Congress will be held jointly with the 17th International Congress of Photobiology on 25–30 August 2019 in Barcelona (https://www.photobiology2019.org/).

Not less than 60 symposia are programmed together with plenary and keynote lectures plus commercial exhibitions and other events and activities.

New book: Digital Ultraviolet and Infrared Photography



Organisers' report
UV4Plants at ESP Congress

Gareth I. Jenkins[1], ORCID: 0000-0002-1855-4875
Éva Hideg[2], ORCID: 0000-0002-1486-4278
Antonella Castagna[3], ORCID: 0000-0001-6481-4570
Annamaria Ranieri[3], ORCID: 0000-0002-5939-656X

[1]Institute of Molecular, Cell and Systems Biology, University of Glasgow, Glasgow, UK.
[2]Department of Plant Biology, University of Pécs, Hungary.
[3]Department of Agriculture, Food and Environment, University of Pisa, Italy

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UV4Plants organized two sessions at the European Society for Photobiology (ESP) Congress in September 2017, which was held in the charming city of Pisa. ESP congresses are intended to span the whole spectrum of photobiology and therefore include a very broad range of mini-symposia, covering aspects from medical photobiology to bacterial photosynthesis, and from molecular processes to environmental photobiology. Plant photobiology is always represented in several sessions and in Pisa there were mini-symposia on photosynthesis and cryptochrome photoreceptors. In addition, ESP agreed to have two sessions focused on plant UV photobiology, jointly organised by UV4Plants, which was a very welcome development. We hope this will become a feature of future ESP congresses because we wish to provide opportunities for UV4Plants members to meet and develop collaborations in the years between our main biennial networking meetings. ESP congresses provide an excellent opportunity to do this because they are also held every two years and interdigitate with our meetings. A welcome feature of our involvement with ESP was that they managed all aspects of registration and poster submission and our members could attend the two UV sessions, which were conveniently held on consecutive days, with low registration fees. Furthermore, UV4Plants student members had reduced registration fees for the whole Congress, enabling them to attend a range of other sessions. We hope to continue our involvement with ESP at their next congress, which will be held in Barcelona in late August 2019.

One of the UV-B sessions in Pisa—UV-B Stimulated Plant Protection—was organized by Gareth Jenkins (University of Glasgow, UK) and Éva Hideg (University of Pécs, Hungary). This mini-symposium focused on the ability of UV-B exposure to stimulate protection of plants against abiotic and biotic factors. This session had four invited speakers, the two organisers together with Monika Schreiner (Leibniz Institute of Vegetable and Ornamental Crops, Germany) and Jason Wargent (Massey University, New Zealand), and there were several contributions selected from submitted abstracts. Éva Hideg started the session with a summary of how photosynthetically active radiation, UV-B and UV-A light can generate different types of reactive oxygen species in plants. Different light qualities also stimulate gene expression and biosynthesis, particularly of phenolic compounds, that ameliorate oxidative stress. Hence acclimation underpins protection. The importance of secondary metabolites, not only in plant protection but also as beneficial factors in human nutrition was highlighted by Monika Schreiner. Since UV-B is a key factor in stimulating secondary metabolite accumulation, manipulation of UV-B in the light environment will facilitate production of fruit and vegetables for a healthy diet. Gareth Jenkins summarized how both UVR8-dependent and UVR8-independent signaling pathways regulate gene expression responses that contribute to different aspects of protection against abiotic and biotic factors. Unfortunately, Jason Wargent was unable to attend in person, but sent a prerecorded video presentation, which was very effective. The video emphasised the positive regulatory impacts of UV-B on traits that are important in crops. In particular, the acclimatory role of UV-B, detected by UVR8, on photosynthetic performance was highlighted. Further information on this point was provided by Rixta Sievers (also from Massey) in her short presentation, which showed how gene regulation by UVR8 contributed to enhanced photosynthetic activity in Arabidopsis. Ashutosh Sharma (University of Bristol, UK) reported how UV-B, perceived by UVR8, inhibits plant shade avoidance and thermomorphogenesis (developmental responses to elevated temperature), in particular through the regulation of PIF transcription factors, whereas Matthew Robson (University of Helsinki, Finland) showed how a combination of low temperature, UV and blue light regulates flavonoid accumulation. This response appears to involve complex functional relationships between different photoreceptors. Finally, Piotr Zglobicki (Jagiellonian University, Krakow, Poland) outlined how sugars reduce DNA damage caused by UV-B radiation by stimulating the production of UV-absorbing compounds.

The second UV-B session was organized by Annamaria Ranieri, who is a Professor at the University of Pisa, and was held in the Department of Agriculture, Food and Environment. This session was entitled 'Turning photobiology into commercial reality: exploiting UV radiation for sustainable and innovative food'. As the title states, this session focused on the potential applications of UV technology in production of food from plants, which is a very important aspect of current UV-B research. Several presentations explained how UV-B exposure of crops or harvested products influenced production. Javier Martínez-Abaigar (University of La Rioja, Spain) explained how UV-B exposure of grapevines affects aspects of crop physiology, including secondary metabolite production and susceptibility to pathogens, and hence the quality of grapes and wine, and showed the importance of factors such as timing, method of application and variety. In addition, Marco Santin (University of Pisa, Italy) used metabolomics profiling to show how direct exposure of peach fruits to UV-B affects biosynthetic activity. In particular, phenolic compounds were produced through stimulation of expression of the relevant biosynthetic genes. Further speakers described effects of UV-B on other crops, including brassica vegetable crops. There were also presentations on the use of LEDs for UV-B exposure, which is an important current topic, given the need to provide specific, non-damaging UV-B treatments in a cost effective manner for growers. Timo Bongartz described the LED systems being developed by Osram for this purpose and Melanie Weisner-Reinhold (Leibniz Institute of Vegetable and Ornamental Crops, Germany) showed how UV-B LEDs affect the production of secondary metabolites in several leafy vegetable crop species. Different effects were observed for specific metabolites and qualitative and quantitative differences were observed between genotypes. Spectral quality in the growing environment can be manipulated using combinations of light sources and filter materials, but it is important to characterize the light environments so that they can be optimized for specific pur-

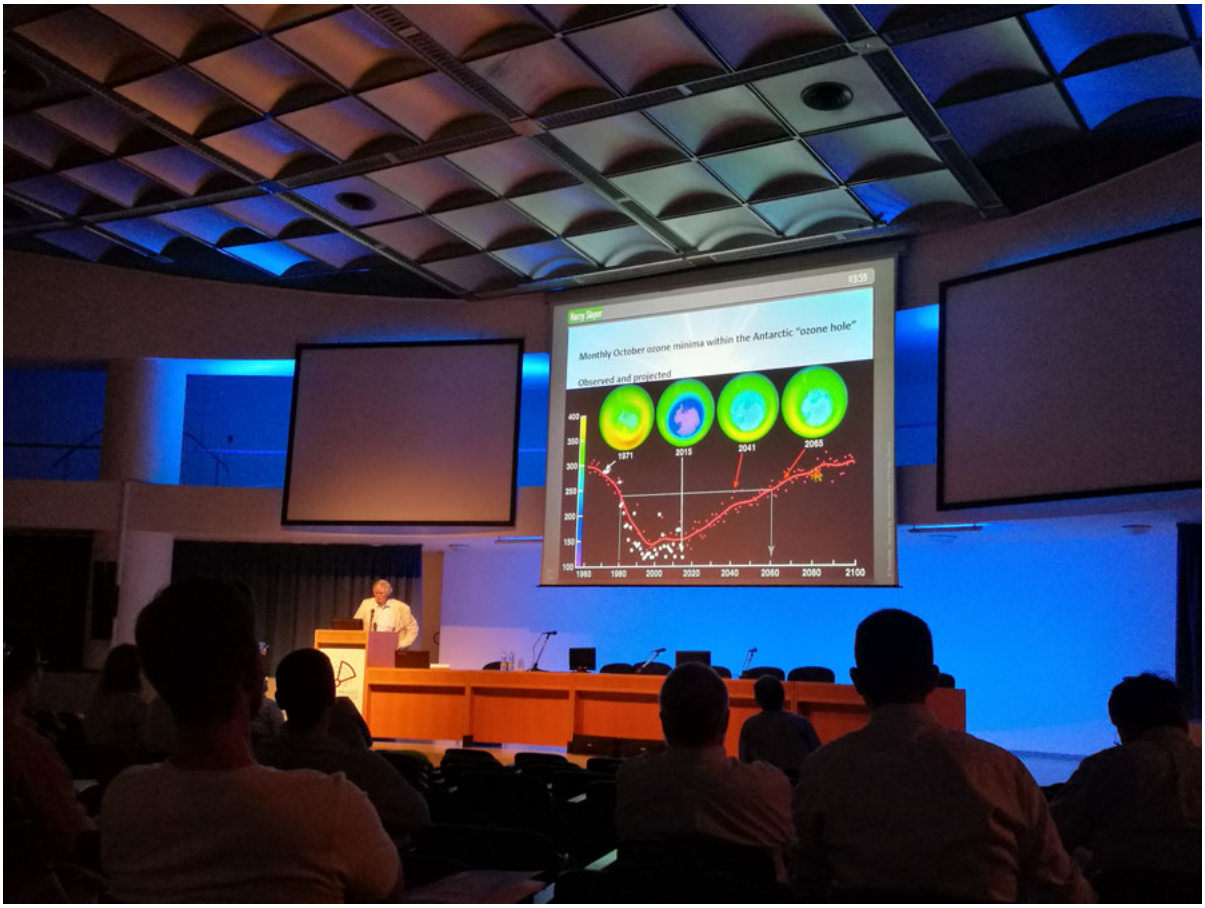

Figure 4.1: From one of the sessions at the European Society for Photobiology (ESP) Congress in September 2017. Photo: Neha Rai.

poses. Titta Kotilainen (University of Helsinki, Finland) described methods to measure and model light environments in horticultural settings and discussed how this information could be used by growers to predict the effects of particular light environments on different crops.

Both sessions were regarded as very successful and two aspects were particularly pleasing. First, the science presented was of a high standard, the topics were interesting and demonstrated the importance of UV-B research both in advancing understanding of plant responses to their environment and in helping to produce sustainable, healthy food production. Second, each session was attended by well over 60 people, and there was good discussion and interaction among those attending, including at the posters. The strong attendance was noted by the organisers of the ESP Congress, and will provide a good basis for future UV4Plants sessions, hopefully in Barcelona in 2019. So, thanks to all who contributed to the success of the meetings.

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Commentary
Sense and nonsense of bibliometrics

Pedro J. Aphalo, ORCID: 0000-0003-3385-972X
ViPS, Organismal and Evolutionary Biology, University of Helsinki, Helsinki, Finland
DOI: 10.19232/uv4pb.2018.1.10

The facts

Several times during recent months, according to ResearchGate statistics I was the most read author from Finland, with dramatically increasing numbers of reads per week for one specific article. The article in question is approaching 100 000 reads in its life time of less than two years. This number of reads is 89% of the reads over their full lifetime accumulated by the 118 research items of my authorship tracked by ResearchGate since I created my profile several years ago. Because of this I had some time ago the exciting message shown in Figure 5.1 waiting for me when I visited the ResearchGate web site. The first of these messages alerted me on something unusual happening in my profile, and since then I have been receiving long strings of unlikely ResearchGate achievements week after week (Figure 5.2). Some of these apparent achievements reveal that fields of research are assigned relying on users' profiles—in the example lead astray by matching my expertise in "Mineral Nutrition" to an achievement in "Nutrition and Dietetics" .

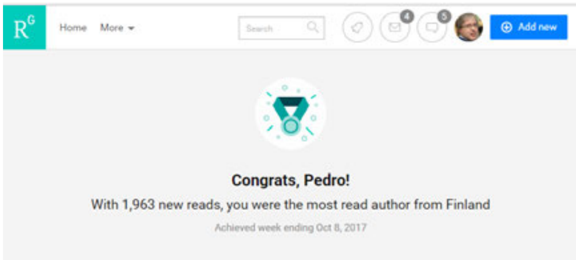

Figure 5.1: An exciting message from ResearchGate.

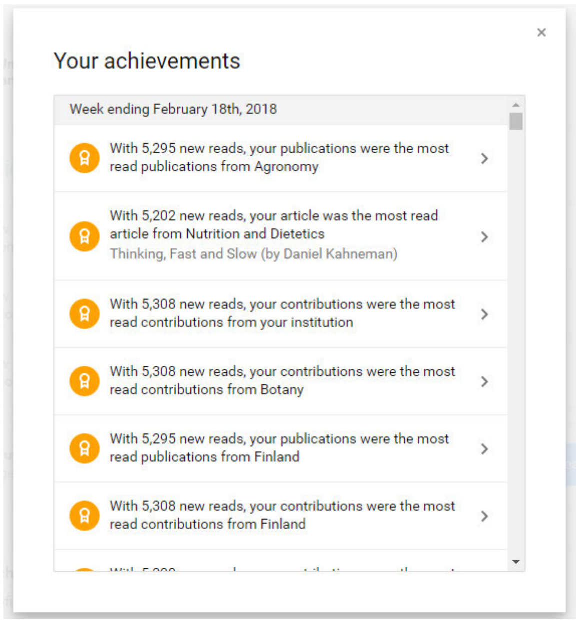

Figure 5.2: The top of my list of ResearchGate "achievements" for a recent week.

Which of my publications could be so popular? and where could it have been published? A publication that is taking my bibliometric statistics to heights seen never before during my whole career! By further navigating the ResearchGate web site I found the answer: the article in question is a book review published in 2016 in this same *UV4Plants Bulletin* (Aphalo 2016)!

By plotting reads-per-month on a log scale as a function of time we see that growth in the number of reads has been nearly exponential for a whole year (Figure 5.3). The initial lag was in part due the delay between

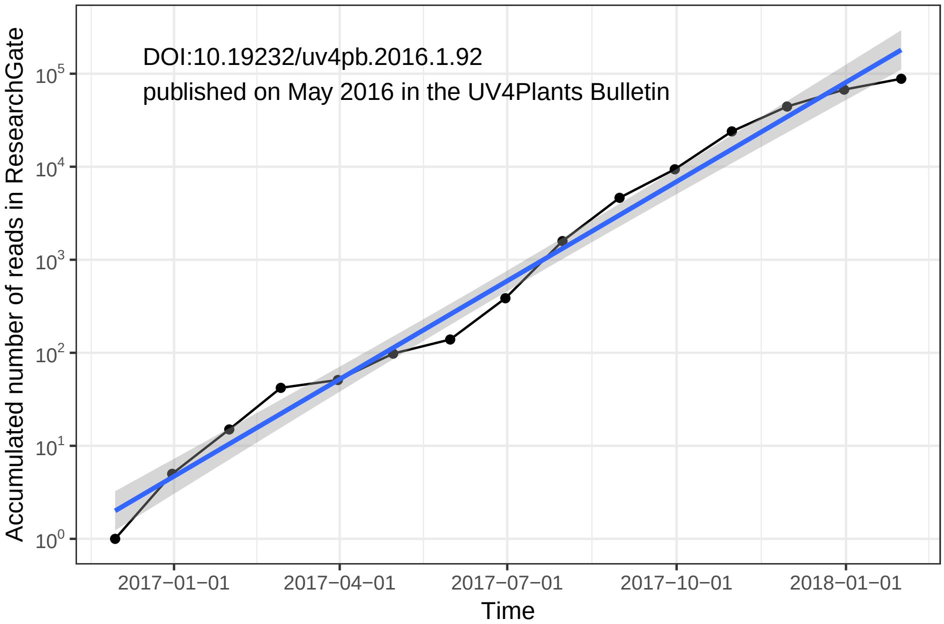

Figure 5.3: The exponential growth in ResearchGate reads of my book-review articlemy book-review article.

publication in the Bulletin and upload of the offprint file to ResearchGate. An important question is: what kind of "snowball" process could be driving this unexpected pattern of growth in "interest" in a publication of minor significance? In the next section I discuss the possible causes of exponential growth in reads and the implications of the event described in relation to the use of "objective measures of research impact" in academic evaluations.

Pondering on the vagaries of bibliometrics

I think this event tells us a lot about the measurement of the impact of publications and research and the problems of using them for assessing performance. First of all it tells us, that a simple book review with no original research component can bias indexes in an extreme way. In particular, I suspect that "reads", as opposed to citations, depend a lot more on the choice of title and keywords than on the content of articles.

When searching with Google and similar "engines" the ordering of search results we see is not random. There are two factors at play: payment of a fee by web site owners and the application of complex mathematical algorithms to guess which search results most closely match the expectations of the user who has submitted the search request. Those results "floated to the top" as a result of a fee paid to Google are discreetly labelled as "ad". For other results Google uses the previous search history of the user submitting the current search and also the overall popularity of pages. Popularity of pages is inferred from number links to them in other pages and from how frequently they have been visited when they have been shown in earlier search results. A further source of information used is the popularity of keywords and similar content including words in titles. In other words, algorithms used by on-line search engines determine to a significant extent what internet content becomes popular or "goes viral".

What web site developers call SEO, or

search-engine-optimization, is the manipulation of the contents of a web page to improve its positioning/ranking in the output from on-line search engines. Optimization ranges from careful selection of web page titles and URL texts, to embedding in pages hidden content unrelated to the visible content of a page to "trick" search engines. Numerous free resources on SEO are available in the internet (e.g. the guide at https://moz.com/beginners-guide-to-seo).

From the point of view of the UV4Plants Bulletin, events like this, increase visibility and may improve our Bulletin's SEO through their impact on search results. From a practical point of view, it also shows that uploading all off-prints and pre-prints that copyright allows us to, to a site like ResearchGate can boost our "numbers". An improvement in apparent impact, even though possibly accidental in origin, can affect how our performance is assessed. It will also affect how many users visit our profile, find our other publications, and follow our project descriptions and then this may in turn affect the *real* impact of our work. As the current trend is for our work performance to be assessed by administrators, and even by peers, based on various impact statistics instead of by direct evaluation of our publications, we need to be aware of which factors unrelated to the quality of our work affect the data used in performance assessments.

I encourage every author and co-author of articles in our Bulletin to upload the reprints or even better make available links to their publications in our web site using DOI-based links as displayed in the Bulletin's web site (http://bulletin.uv4plants.org/) through ResearchGate and similar sites. In addition, time and effort spent in "optimizing" publication titles and keywords for both human readers and search engines is very likely to pay back by making our work more visible in searches and improving ranking in performance evaluations.

Even less controversial measures of impact like number of citations are not reliable measures of the value of scientific performance (reviewed by Bornmann 2016) and if used require very careful consideration of the context of the research being assessed. In my opinion impact statistics should be used only as a complement to actual expert evaluation of the scientific production of researchers and never by themselves in an automated manner. Based on the read statistics described above one could create the advertisement shown in Figure 5.4 relying on *actual hard numbers*; however, few readers would take it seriously. In contrast, a similar advert but with the name of a *big* journal, would be credible! The lesson is, that even *hard numbers* when taken out of context can drive us pitifully astray. Meanwhile, "blind" use of publication-impact- and similar indexes in performance assessments is too frequent to be ignored by those being evaluated. This suggests that well-guided *search engine optimization* or *SEO* of publications' titles, keywords and contents could be a useful and morally acceptable tool for achieving success in academia.

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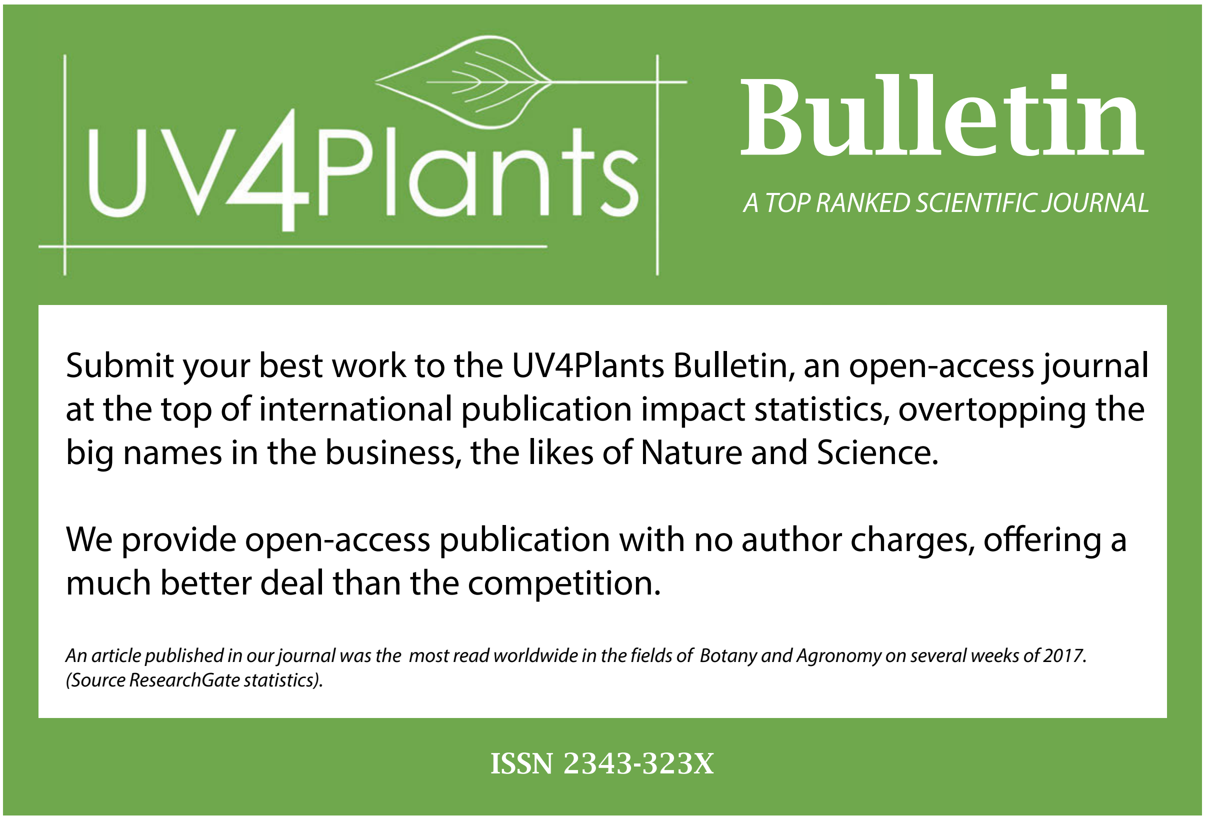

Figure 5.4: A fake advertisement for the Bulletin, which could have been real, had we not known the context of the readership statistics.

Methods

Using LEDs: drivers and dimming

Pedro J. Aphalo, ORCID: 0000-0003-3385-972X
ViPS, Organismal and Evolutionary Biology, University of Helsinki, Helsinki, Finland
DOI: 10.19232/uv4pb.2018.1.12

Light emiting diodes (LEDs)

In this article I describe how currently available LED drivers and computer interfaces make it extremely easy to build custom light sources. In particular light sources useful for photobiological experiments. Currently in electronics "functional building blocks" have become very common for high power devices as in the 1970's logic and low-power analogue integrated circuits. Logic integrated circuits made it feasible to build the first personal computers. Some of the current solid state LED drivers make it possible to assemble custom circuits for driving power LEDs using very few parts. However, before one can take full advantage of these LED drivers some understanding of how LEDs work and the methods commonly used for adjusting their radiation output is needed.

LEDs are diodes, devices with two electrodes and polarity. Electrons move through a diode only in one direction, and need to be always driven by direct current. Under typical use within the recommended current range the amount of light emitted by LEDs is approximately proportional to the current flowing through them, although conversion efficiency slightly decreases when LEDs are driven their *maximum current* specification.

LEDs are available as components, as bulbs and as whole lamp fixtures. Bulbs and light fixtures have built-in drivers and can be connected directly to the mains power line. As the driver is built-in, in general bulbs and fixtures allow only limited control of light output and are available only for certain spectral characteristics (e.g. "warm white" or 2700 K to 3000 K, "cool white" or 4000 K and more rarely "daylight" or 5000 K to 6000 K) and emission geometries (e.g. with reflectors:"spot" or 20–30 degrees, "flood" or 60–65 degrees, or a nearly spherical shape). The variety of LEDs available as electronic components is enormous, both in specifications and type of "encapsulation"—meaning the "enclosure" they are permanently encased in. High power LEDs tend to be arrays assembled from multiple lower-power dies or chips—meaning the actual semiconductor devices (See Table 6.2 for definitions of electronics-related terminology) . Currently single-die LEDs of up 4 W are available. Dies can be densely packed onto a small carrier board, or chip-on-board (COB) packages. Latest state-of-the-art types can be so densely packed as to reach very high emittances (for example white COB LEDs of type NVEWJ048z-V1 from NICHIA pack 168 W of LED power on a board 24 mm × 24 mm, with an output of more than 10 000 lm). Such extreme concentration of heat production requires special handling to avoid the destruction of the devices. More conventional arrays are less densely arranged within the packages or they can be arrays of individually packaged LED dies soldered onto a carrier board—usually with a metal core that ensures good heat conduction into a heatsink for its dissipation by radiation and convection (Figure 6.1).

The technology for making LEDs emitting

Figure 6.1: Light emitting diodes. a) The first UV LED sold commercially (top view). The LED die can be seen at the center below the flat window (type NSHU550E, Nichia, Japan), b) A custom assembled array with 50 1 W LED dies. This array has five channels, each one with different dies. One of the channels emits at 365 nm. (Shenzhen Weili, Shenzhen, China) c) A 4 W high power LED at 365 nm mounted on a star-board (type LZ1-00UV00 LED Engin, USA).

in the ultraviolet region of the spectrum has remained behind that of LEDs emitting visible and infra-red radiation. LEDs emitting at different wavelengths are based on different crystalline chemical substances. The principle by which all LEDs emit radiation is the same, but it is not equally easy to make LEDs emitting at all wavelengths, in particular efficiencies vary widely depending on the materials used. In recent years UV-A and violet LEDs with peaks of emission between 365 nm and 410 nm have become available with conversion efficiencies comparable or in some cases even better than that of blue and other visible LEDs. Prices for these types of LEDs are also comparable to the now very low cost of visible LEDs.

At shorter wavelengths the situation is not that favourable, yet. The company pioneering short UV LED technology was SETi (Sensor Electronic Technology Inc., Columbia, SC, USA). It was acquired by its competitor in UV LED technology, (Seoul Viosys, Gyeonggi-do, Republic of Korea) which is now the main supplier of short-UV LED chips. For some years LEDs emitting at shorter and shorter wavelengths have been developed—with 255 nm LEDs commercially available at the time of writing—, but most of these LEDs were of so low power as not to be useful for plant photobiology, or so expensive for higher optical power ones as to be of limited use except under laboratory conditions. High power UV-B LEDs, like those from SETi, had very high electrical power consumption but very low UV-B radiation output. While the best commercially available UVA LEDs at 365 nm can convert more than half of the electrical power into radiation, the most efficient UVB LEDs at 310 nm available commercially until two years ago had a conversion efficiency of the order of 0.1%. Furthermore, these LEDs had an output that decreases significantly with use and a rather short rated life of only about 2000 h and prices in thousands of euro. In the last couple of years more efficient and cheaper LEDs emitting at wavelengths shorter than 365 nm have become available making their use in plant photobiology research feasible.

Marktech's new 340 nm LEDs with an electrical power of 2 W and emitting 55 mW of radiation—an efficiency of 1.5%—are available for less than 50 € (type MTSM340UV-F5120S, Marktech Optoelectronics, Latham, NY, USA). The same company sells 310 nm LEDs with electrical power of 0.21 W emitting 2 mW of radiation—an efficiency close to

1%—also for close to 50 € (type MTSM310UV-F1120S). A different company, RayVio, has announced 280 nm and 310 nm LEDs with electrical power of 6.4 W emitting 50 mW of radiation—an efficiency of 0.85%—(types RVXP4-280-SB and RVXP4-310-SB, RayVio Corporation, Hayward, CA, USA). The 280 nm type is already available at 170 €, while the 310 nm type is not yet available. In contrast to most other types of LEDs, the radiation output of RayVio's UVB LEDs decreases drastically with increasing temperature. In the case of these new devices the expected life is not yet provided and technical specifications are still labeled as "preliminary". Seoul Viosys together with SETi offer also newer types of 310 nm LEDs, such as type CUD1AF4C with an electrical power of 0.48 W emits up to 8 mW of radiation—an efficiency close to 1.7%—and type CUD1AF4D, four times as much. Furthermore, type CUD1AFMA, a 310 nm LED chip-on-board package with 64 chips, has an radiation output of 80 mW, and type CUD1TFMA with 256 LED chips has an output close to 0.5 W of UVB radiation.

Dimming of LEDs

Depending on the power source used, the radiation output from LEDs may vary in time at a relatively high frequency. Both mains supply frequency and the approach used for adjusting the radiation output or *dimming* may cause variation in output in most cases invisible to the human eye. Use of LEDs is becoming pervasive in buildings and gradually increasing for commercial plant cultivation. They are also becoming common in controlled environments used in plant research. Dimmers are frequently used to adjust the light level in households, offices, commercial spaces, and currently also in growth chambers and growth rooms. Even special LED lamps sold for studio and on location video and photography are in most cases dimmable.

There are two main approaches to dimming: constant current (CC) and pulse width modulation (PWM). The later approach is more frequently used, as achieving high efficiency in a CC driver requires a more complex and expensive electronic circuit than PWM. There is third approach in use, based on the use of phase shift dimmers, and useful when "retrofiting" LEDs as replacements for incandescent lamps. Phase shift dimming is similar in PWM, but instead of using square pulses, they "chop" part of each sinusoidal half cycle of the mains AC supply. As rarely used for new installations, I will only discuss the first two LED-specific dimming approaches. Driving LEDs at constant voltage is in general to be avoided as current flow through LEDs tends to increase exponentially with the increase in voltage. In addition as current at a given voltage increases when the LED gets warmer, this can lead to feed forward and the destruction of the device. For very low power LEDs in most cases resistors connected in series with LEDs function as current limiters.

When LEDs are driven at constant current a circuit adjusts voltage in such a way that current flow through the LED remains at a constant value. As the output of LEDs is approximately proportional to the current flowing through them, by decreasing the current (the flow of electrons) we can decrease the light output (the flow of emitted photons). Good quality LEDs drivers can regulate the current to a tolerance better than $\pm 1\%$, giving extremely steady illumination (Figure 6.2).

Pulse width modulation, in everyday words means that the LEDs are very rapidly switched on and off. Light output alternates between maximum output and no output (Figure 6.2). The combined duration of a pair of light plus dark periods remains constant, but their relative duration is adjusted to achieve dimming. When we plot the light output as a function of time it is a train nearly of square pulses. The average photon irradiance depends on the ratio between the light

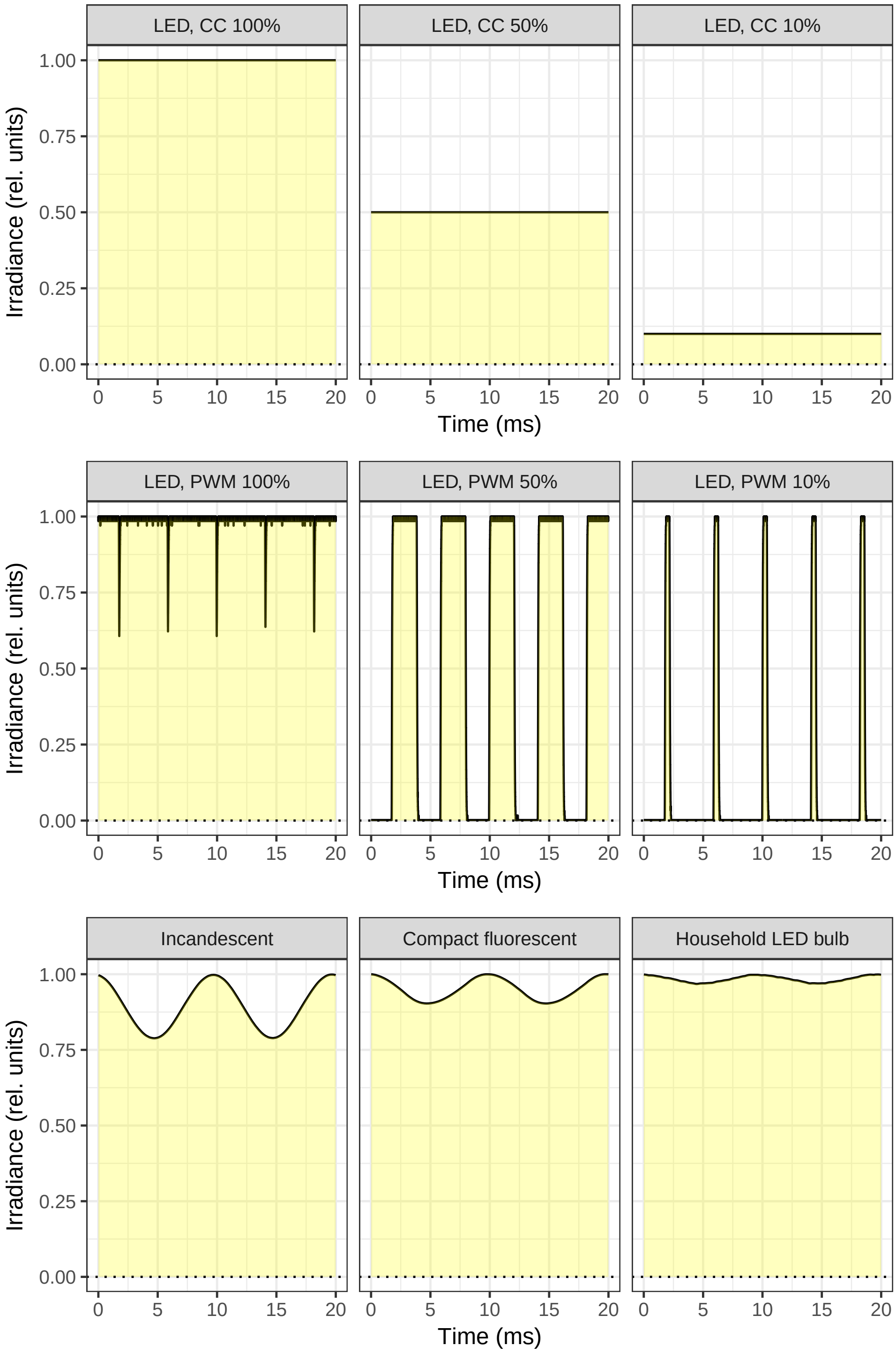

Figure 6.2: LED dimming. Top) Continuous current dimming. Middle) Pulse width modulation dimming. The relative light output from LEDs at 100% output, and dimmed to 50% and 10%. Bottom) Light output from three types of common household bulbs, not dimmed. The time scale of 20 ms is equivalent to one cycle of 50 Hz mains power as used in Europe. Measured with a TSL251R (or TSL252R, for high frequency) light-to-voltage sensor connected to an oscilloscope (Picoscope 2204A, Pico Technology).

periods and the whole cycle period—i.e. the frequency remains constant, what changes is the width of the "square-wave" shaped peaks. Hence, pulse width modulation. The frequency used can vary very widely, from close to 100 Hz (10 ms per cycle), the minimum that humans will not perceive as flicker, to much higher frequencies of the order of 10 to 100 kHz.

While for human vision 100 Hz is fast enough, for light sources used in photography this is not enough to avoid uneven exposure. An example of use of PWM at high frequency is the Amaran AL-H9 LED light source (Aputure Imaging Industries, Bao'an, Shenzhen, China), which uses a frequency of 40 kHz (0.025 ms per cycle). This is unlikely to cause uneven exposure because a shutter speed of 1/10 000 s is enough to ensure that a single exposure encompasses four pulses of light.

LED lamps sold as substitutes for incandescent and compact fluorescent lamps, as well as these older types of bulbs they replace tend to have a light output that to variable extent changes cyclically in time. As mains power is alternating current (AC), in each cycle there are two half cycles, one negative and one positive. Both half cycles drive the emission of light, but twice in a cycle voltage becomes zero, resulting in light output pulsing at twice the frequency of the mains power (Figure 6.2).

Although we do not see high frequency flickering, a digital or film camera can see it at some shutter speeds (Figure 6.3). Focal-plane camera shutters use a moving slit for short exposure times, in other words, the whole frame is not captured at the same time. I have earlier discussed dimming of LEDs and line-frequency oscillations in artificial illumination in relation to photography (Aphalo 2017a,b).

In the case of plants, CC is closer to sunlight than PWM. Within canopies sunflecks con be of short duration but the alternation is between two irradiances, none of which is close to zero. With PWM dimmed LEDs, the alternation is between light and darkness, which does not occur in plant canopies. Effects of pulsed illumination on plants has been studied in relation to sunflecks, but the results from these studies do not necessarily apply to PWM given the broad range of frequencies in use and the presence of dark periods. This is a problem that needs to be studied, and that can be studied using the circuits described later in this article.

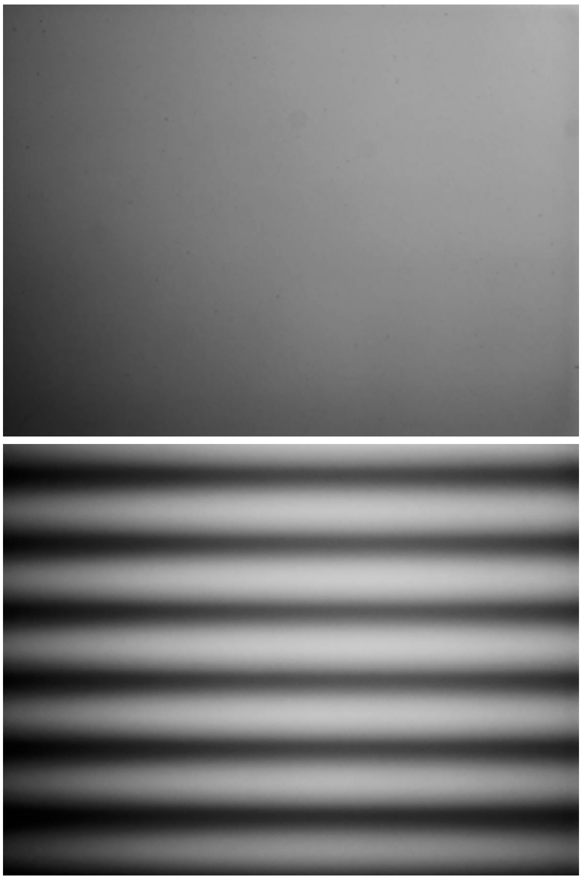

Figure 6.3: Photograph of a plain white wall illuminated with a LED dimmed using pulse width modulation. When taking this photographs to my eyes the wall was evenly illuminated; top) Shutter speed 1/10 s, bottom) shutter speed 1/1250 s. The two photographs have been identically edited so as to increase their contrast.

Building an UV, VIS or IR radiation source using LEDs

We will present two similar circuits, the first one is suitable for manually controlled dimming using the constant current (CC) approach. The second circuit allows dimming using both approaches, even simultaneously, CC and PWM. Dimming in this case can be controlled locally using a computer or microcontroller connected via USB, or remotely through the internet to any device with a web browser. Both circuits can run on batteries or with a mains powered DC source. No wiring is needed on the mains power side of the circuit allowing assembly by users not officially qualified to do electrical installations in countries like Finland where strict legal regulations are in place. Many variations are possible when using DC/DC LED drivers to control multiple LEDs (see RECOM 2017).

The example circuits use a driver that limits maximum current to 0.7 A, the maximum allowed current limit for the types of LEDs used here. As a safeguard I prefer to use drivers that have a "hard-wired" maximum current limit at a value that will not destroy the LEDs being used. Variants within the same series of drivers are available with different values for this limit (In the case of RECOM's RCD-48 series, 0.35 A, 0.50 A, 0.70 A, 1.00 A, and 1.20 A), and using these variants does not require any changes to the circuits described here (see RECOM 2016). It is possible to use drivers with a higher maximum current rating than what is allowed for the LED being driven, but then *the user should remember* not to ever use a *soft* current setting higher than what the driven LEDs tolerate.

The DC LED drivers used here do not require external components to function, but they do required an external signal to control dimming. For manual control a potentiometer (variable resistor) is needed for adjustment of constant current dimming, while PWM dimming is not possible without a separate source of pulses. The potentiometer

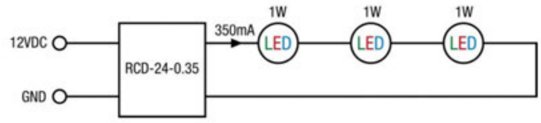

Figure 6.4: Dimming circuit based on an RCD series DC/DC LED driver with a variable number of LEDs connected in series. Reproduced from RCD white paper.

used in the example allows exactly repeatable settings. However, if repeatability of settings is not a requirement, it can be substituted by a cheaper potentiometer of the same resistance value. For permanent installations using a printed circuit board or a prototyping perforated board and soldering all components is best. For semi-permanent assembly the use of quick connectors as shown in these examples is adequate while making assembly very easy, reducing the soldering of wires to what is required for connecting the LED itself.

The chosen LED drivers can regulate the voltage output to the LED(s) between 2 V and 56 V while keeping the current flow at the set value. This makes it possible to drive with the same circuit anything from a single LED to more than 20 LEDs connected in series, and also LED arrays specified to require up to 56 V (Figure 6.4). The DC input voltage supplied determines the maximum achievable output voltage and it must be within 9 V and 60 V. Within this range, the input voltage needs to be at least 4 V higher than the output voltage required to drive the LED at maximum rated current. All component specifications are subject to tolerances, i.e. values are given as ranges of possible values, and for this reason it is usually wise to slightly "over-specify" components when designing a circuit.

LEDs, even modern very high efficiency types, have an efficiency of at most 60%. In the case of LEDs emitting at wavelengths shorter than 365 nm typical efficiencies are 2% at most. The power that is not emitted as visible or UV radiation becomes thermal en-


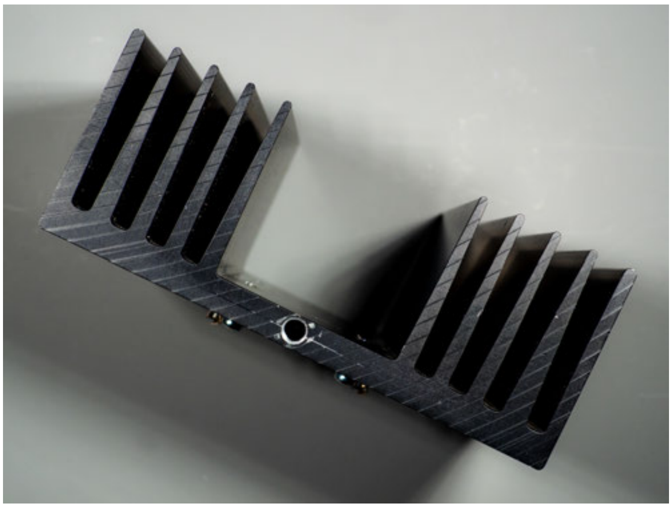

Figure 6.5: Heat sinks. left) A heat sink for medium power LEDs mounted on star boards—this type is nice as it can be easily fastened with M5 screws taking avantage of the split holes at the tip of the fins. right) A generic heat sink for high power devices.

ergy that heats up the LED chip. LED chips get destroyed if their temperature raises above 100 to 125 °C, and because of this reason power LEDs require cooling. The simplest type of cooling devices are passive heat sinks. Heat sinks are usually made of aluminium, which has high thermal conductivity, and are anodized black to enhance emissivity. The shape of heat sinks varies a lot, but all of them have fins to increase their surface, as both thermal radiation emission and convective cooling depend on the surface area through which energy is exchanged (Figure 6.5). In contrast, the RECOM RCD-48 driver has very high efficiency of up to 96% both when dimming through PWM and CC, and consequently does not require a heat sink for its cooling.

The LED drivers in the RCD-48 series come not only in different maximum current variants, but also in different packages (Figure 6.7). Most of the available packages are plastic, but differ in whether they have pins suitable for installation in a printed circuit board or insulated wires suitable for direct wiring. For prototyping, the first type can also be used in a "breadboard". Within this series, the type with the highest current rating is encapsulated in a metal package as metal conducts heat better than plastic.

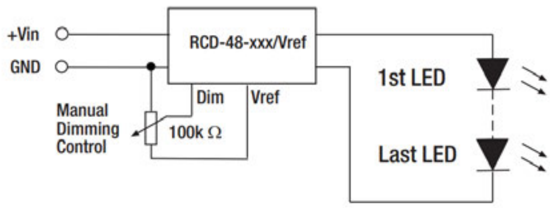

Figure 6.6: Analogue dimming circuit based on an RCD-48 DC/DC LED driver. Reproduced from data sheet.

Constant current dimming with manual control

We need only three electronic components in addition to the LED(s): a) a DC power supply or battery, b) a DC/DC LED driver and c) a potentiometer (variable resistor with three terminals). Which power supply to use will depend on the number and type of LEDs to be powered. I have used 12V DC power banks, and AC mains to 9 V DC, 12 V DC and 36 V DC power supplies, with current ratings between 1 A and 4 A. As DC/DC drivers, those in the RECOM RCD-48 family are very versat-

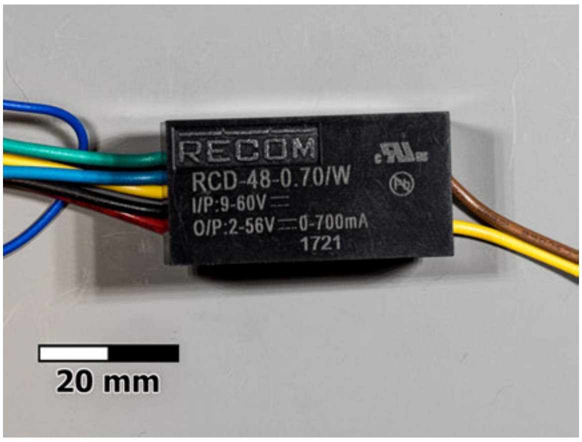

Figure 6.7: A direct current to direct current high precision LED driver from RECOM.

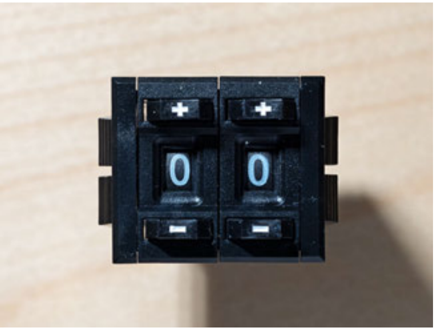

Figure 6.8: A 100 KΩ precision potentiometer that is set by means of two push-buttons per digit.

ile and the same type will be used in all examples: RECOM RCD-48-0.70-W which has a maximum current rating of 700 mA and has wire leads instead of the more usual pins for installation in printed circuit boards (Figure 6.7). Most potentiometers with a resistance of 100 kΩ could do the job in these case. I chose a 2-digit type with push-buttons which allows 100 different repeatable settings, which I find convenient (Figure 6.8).

The heart of the circuit is the LED driver. This integrated module has seven wires, two for DC input, red (+) and black (−), to be connected to the power supply, and two for regulated DC output (brown (−) and yellow beside brown (+) to be connected to the LED(s). The three remaining wires are used for control. The blue (+) one is a digital input which allows PWM dimming and/or ON/OFF switching of the current fed to the LED. The green (+) is an analogue input, accepting a voltage between 0 V and 5 V which allows constant current dimming. The yellow wire in-between the black and blue wires is a reference output at 5.1 V, which can be used to control analogue dimming with passive components like resistors and potentiometers.

Dimming controlled with computer, tablet or phone via USB

For this type of control there are many options, as what we need is to generate a voltage between 0–5 V for constant-current dimming, or a train of square wave pulses for PWM. I have chosen two very small but high quality modules from Yoctopuce for maximum flexibility (Figures 6.9 and 6.10). The module called Yocto-PWM-Tx generates pulses at a frequency and duty cycle that can be easily set using a web browser. The range of achievable frequencies is very broad. The module called Yocto-0-10V-Tx generates a tightly regulated DC voltage of any value between 0 and 10 V, and can also be easily set using a web browser (Figure 6.11). Each of these Yoctopuce modules has two independent channels, and consequently is able to control two independent groups of LED drivers. Tens of LED drivers to be dimmed simultaneously can be connected to each channel of the modules. Both modules are powered through their USB connections to the device used as controller but the “two sides” of the interface modules, one connected to the USB port, and the other to the LED driver are electrically isolated. Isolation in the Yoctopuce modules ensures that the host computer will not be perturbed or damaged if the LED driver circuit fails or is wrongly connected. Although I describe here control through a web browser, the modules can be also accessed through user-written computer programs that “talk” to libraries provided by Yoctopuce.

This same circuit when used with a com-

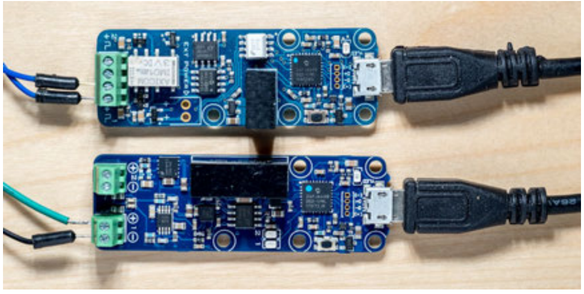

Figure 6.9: A Yocto-0-10V-Tx module and a Yocto-PWM-Tx module.

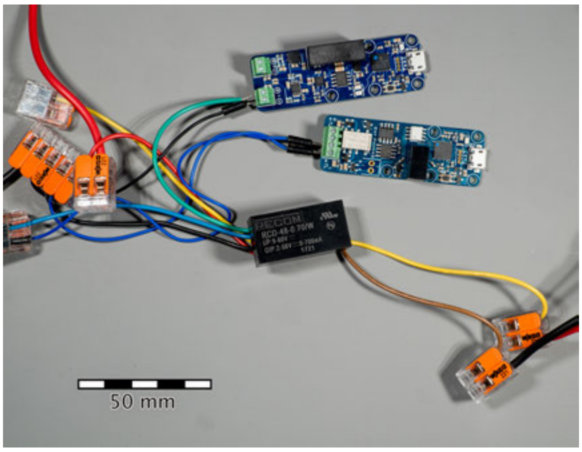

Figure 6.10: Assembled control circuit, using Wago wire connectors for easy of assembly. The components are the same as shown in Figures 6.7 and 6.9. The micro-USB cables are not plugged in.

puter (any computer, including microcontroller boards like Raspberry Pie and Beaglebone) can achieve more elaborate types of control by addition of sensors and writing of suitable software. It is needed, however, to approach this type device development keeping in mind reliability. Any computer system that crashes even once in a few months, is unsuitable for any device that needs to reliably function without interruption for months if not years.

Dimming controlled with computer, tablet or phone via LAN or Internet

The same modules, instead of being connected via USB to a computer, can be connected to a Yocto-hub and this connected via ethernet, Wifi or GSM to a LAN or a router (Figure 6.12). With appropriate firewall settings everything works as described in the previous section. However, if ports cannot be opened in a firewall, other methods of remote access to the modules are available. The Yoctopuce modules use high quality industrial grade electronic components in most cases rated for operation under -40 C to +80 C. Administration, including firmware updates can be done remotely. Access can be password protected.

Suppliers

I have bought most parts from large electronics parts distributors, except for the YoctoPuce modules, which I bought directly from the manufacturer. I list in Table 6.1 the manufacturers and distributors of the parts used.

Further reading

The book *Applied Electronics for Bioengineers: an introduction* (Karplus 2017) is a good place to start if you want to learn about electronics with a focus on instrumentation and simples device used in biological research.

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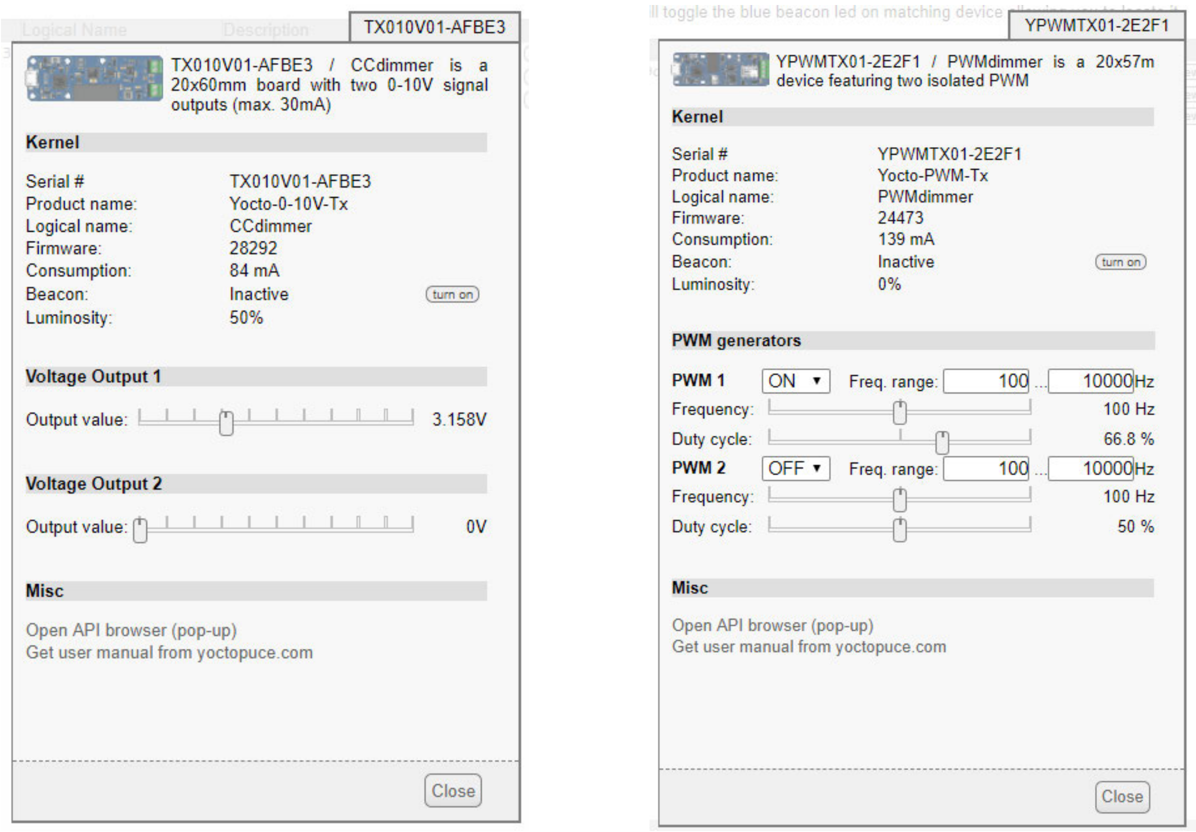

Figure 6.11: The control interfaces of a Yocto-0-10V-Tx module and of a Yocto-PWM-Tx module as they are displayed on a web browser. The interface is identical whether the modules are connected locally via USB to the computer or through an ethernet, Wifi or GSM YoctoHub accessed remotely through the internet (WAN) or a local area network (LAN).

Table 6.1: Suppliers of electronic components and UV LEDs.

Supplier	URL	components
Bourns	http://www.bourns.com/	high precision potentiometers
Digi-Key electronics	https://www.digikey.com/	elec. comp. distributor
LED Engin	http://www.ledengin.com/	UVA and VIS LEDs
Marktech optoelectronics	http://www.marktechopto.com/	UVB and UVA LEDs
MEAN WELL	http://www.meanwell.com/	LED drivers and power supplies
Mouser electronics	https://eu.mouser.com/	elec. comp. distributor
NICHIA	http://www.nichia.co.jp/en/	UVA and VIS LEDs
OHMITE	http://www.ohmite.com/	heat sinks for star board
RayVio	http://www.rayvio.com	UVB and UVA LEDs
RECOM Power	https://www.recom-power.com/	LED drivers and power supplies
Roithner laser	http://www.roithner-laser.com/	LED and laser distributor
Seoul Optosys	http://www.seoulviosys.com/en/	UVC, UVB and UVA LEDs
t-Global technology	http://www.tglobaltechnology.com/	pre-cut heat-transfer pads
Wakefield-Vette	http://www.wakefield-vette.com/	heat sinks
Yoctopuce	https://www.yoctopuce.com/	USB interfaces and sensors

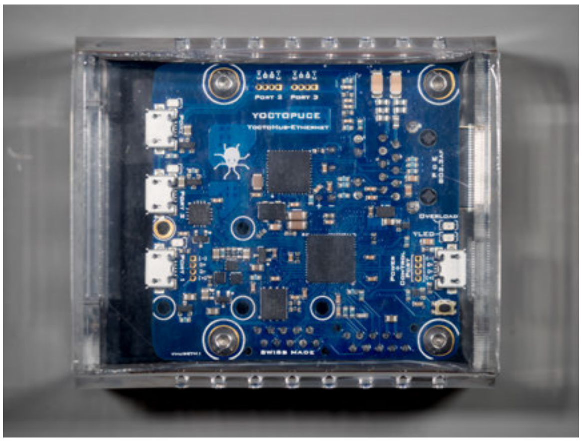

Figure 6.12: A Yoctopuce ethernet hub.

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Table 6.2: Glossary of terms frequently used in electronics.

Term	Meaning
LED die	The actual piece of specially processed semiconductor substance that emits photons when electrons flow through it.
LED chip	see LED die.
Semiconductor	Substance at the boundary between metals and non-metals. Electrical conductivity depends on “impurities” in the crystals.
Dimming	Method used to decreasing the radiation output from a lamp or LED by adjustment of the average rate of flow of electrons through the lamp or LED.
Data sheet	The document published by a manufacturer describing the technical specifications of an electronic device, sometimes including very simple examples of their use.
Application note	A document published by a manufacturer describing in detail examples of the use of an electronic device.
Software driver	A program in a computer that provides a way for controlling an electronic device through another computer program which provides a user interface.
Breadboard	A board in which electronic components and wires can be plugged in to assemble a circuit. In general used for temporary assembly during testing of a design.
Perfboard	A perfboard or prototype board is a generic printed circuit with rows of holes connected be electrically conductive copper strips or lanes layered on top of an insulating material. Assembly requires soldering and breaking/cutting some of copper strips. Usually used for permanent assembly of simple one-of-kind circuits or prototypes.
Printed circuit	A circuit board where the copper lanes and locations and sizes of perforations or attachment pads have been designed for a given circuit and usually photo-etched from a board of insulating material fully covered with a copper layer. Assembly is by soldering of components. Used in different variations all the way from one-of-kind circuits to series of millions of identical electronic devices.

■ Participants' report

Experience from 17th Congress of the European Society for Photobiology (ESP): sharing knowledge and insights

Yan Yan, ORCID: 0000-0003-0520-1621
Neha Rai, ORCID: 0000-0002-4972-9332
Sari Siipola, ORCID: 0000-0003-1411-3121

ViPS and DPPS, Organismal and Evolutionary Biology, Faculty of Biological and Environmental Sciences, University of Helsinki, Finland

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Our research group, led by Pedro J. Aphalo, has long been studying light as a regulatory signal that guides plants' growth and development: on morphological, physiological and molecular levels. Corresponding experiments have been performed either in the field with natural light or in controlled environments with artificial light. In both cases, we attempt to maintain as realistic light conditions as we can for the plants. Since, in the natural environment, prolonged exposure to UV radiation is often followed by drought stress, our research interests also include assessing the interaction between the responses regulated by these two environmental factors. We use a varied variety of plant species ranging from model species such as *Arabidopsis thaliana* and *Medicago truncatula* to horticultural species such as *Vicia faba*, *Pisum sativum*, *Solanum lycopersicum* and *Lactuca sativa*. In the past experiments, we have also used boreal tree species *Betula pendula* and *Betula pubescens*. High throughput Next-generation sequencing have been recently used to identify whole range of transcriptional response regulated by UV and drought. Therefore, the congress of the European Society for Photobiology was really a must-go for our group.

The congress of the European Society for Photobiology covered all aspects of photobiology at different levels of organization. It is an essential forum to promote new research and technological breakthroughs in photobiology. The congress also offers great opportunities for researchers to have effective discussions, exchange insights and establish new collaborations. The meetings are organized every two years, the latest 17th congress being held in Pisa in early autumn (4th–8th September) of 2017. It was still warm then in this part of Italy, which gave us an opportunity to enjoy the beautiful Tuscany city, in addition to participating in the congress (Figure 7.1).

The conference was huge, in total 30 symposia and 8 keynote lectures, with several parallel sessions. These included a symposium focusing on the recent advances of UV research in plants and organised jointly by ESP and UV4Plants and a Satellite meeting on 'Turning photobiology into commercial reality: exploiting UV radiation for sustainable and innovative food', both jointly organised by UV4Plants and ESP.

Among the presentations in the symposium we found the presentation: "UV-B radiation as a regulator of photosynthesis in *Arabidopsis thaliana*" especially interesting. This research was presented by Rixta Siev-

Figure 7.1: The authors on the *Ponte di Mezzo* over the River Arno in Pisa. From left to right, Neha, Yan and Sari. Photo: Martina Barilari.

ers who is studying for her PhD with Jason Wargent at Massey University in New Zealand. Many studies using unrealistic high UV-B radiation in controlled environment have suggested that high levels of UV-B radiation can lead to deleterious effects on plants: e.g. a reduction in photosynthetic capacity. However, the presenter had found that at realistically moderate levels, UV-B exposure can stimulate an increase in net photosynthesis by regulating a number of genes involved in chloroplast import. This suggests that UV-B might serve as a positive environmental regulator in sunlight that and artificial supplementation when it is absent could enhance food production.

Three PhD students from our research group were able to participate this congress with funding from the fellowship of European Society for Photobiology (Yan Yan) and travel grant from Doctoral Program in Plant Science in University of Helsinki (Neha Rai and Sari Siipola). Each of us had a poster presentation in interactive poster sessions during the congress. Yan presented her result from an outdoor experiment with two accessions of *Vicia faba* under four different optical filter treatments. Data from morphological measurements and analyses of secondary metabolites indicate that the two accessions used in the experiment, from Sweden and Ecuador, responded differently to solar UV and blue radiation. Neha presented her work from an outdoor experiment assessing leaf metabolic profile of two *Medicago truncatula* cultivars exposed to solar UV radiation and drought stress. Results showed that different groups of flavonoid compounds and their derivatives identified in the leaves of *Medicago truncatula* depend on the cultivar and that there was an interaction between solar UV and drought

Figure 7.2: The conference dinner provided to ESRs opportunites for informal discussions among them and with experienced researchers. Chats on subjects related to their thesis work and future career development can lead to opportunities for collaboration and/or future employment.

stress. Sari presented her results from an outdoor experiment with *Arabidopsis thaliana*. The data from the experiment showed that accumulation of flavonoids, both in the wild type and several photoreceptor mutants, can be detected already after 6 hours of exposure to natural sunlight and that both cryptochromes and UVR8 are involved in this accumulation. Also, concentrations of aglycones and sugars vary at different time points.

We had lively discussions in the poster sessions and dinner (Figure 7.2). Some of the conversations provided us new perspectives to interpret our results. The congress also offered a chance to meet our collaborators: Dr. Andreas Albert and Dr. Barbro J. Winkler from Helmholtz Zentrum in Munich, Melanie Wiesner and Susanne Baldermann from Leibniz-Institute of Vegetable and Ornamental Crops in Berlin. We utilized this opportunity to discuss experiments done in collaboration with the two German institutes and possible future collaborations.

We also attended a few sessions which were not specific to plant photobiology, but were however interesting to us. One such session was about benefit and hazard of sunlight exposure to human skin. The different fields of research presented in the congress widened our knowledge and educated us about recent scientific developments in photobiology as a whole, which will benefit our scientific career in the long run.

We enjoyed the participation in this four-day congress: the joy of sharing scientific knowledge, making new connections and last but not least the beautiful late-summer weather in Pisa.

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Doctoral thesis abstract

Climate change and Mediterranean ecosystems: plant and soil responses to UV radiation and water availability before and after a perturbation

Doctoral candidate: Laura Díaz Guerra, ORCID: 0000-0002-0984-9751
Supervisors: Dolors Verdaguer and Laura Llorens

Date of defence: 2017-07-21

Area of Plant Physiology, Department of Environmental Sciences, Faculty of Sciences, Spain
University of Girona

Unpublished monograph, no ISBN available.

External link to thesis: http://hdl.handle.net/10803/457150 (© 2017 The Authors.)

Abstract

In the Mediterranean basin, reductions in cloud cover as a consequence of climate change is expected to enhance solar UV levels (UV-A and UV-B) and to decrease precipitation amount over the coming years, especially during summer months. In addition, more frequent and intense wildfires are also expected due to drier and warmer conditions. At plant level, the potential effects of higher UV doses and diminished water availability on the biochemical, morphological, physiological and growth traits could alter the regeneration ability of Mediterranean resprouter species after a disturbance. In this sense, variations in the resprouting success of plant species in response to UV and water levels could have implications on the resilience of shrubland ecosystems, a common Mediterranean-type terrestrial community. The role of UV radiation in the functioning of Mediterranean shrublands, particularly in C and N pools of plants and soils, remains still unclear, with null information about the possible interactive effects between UV radiation and precipitation and/or fire. Because of that, the present study aimed to contribute to the elucidation of the effects that projected changes in UV radiation and precipitation could have on Mediterranean resprouter species and shrubland ecosystems in the near future, taking also into account how aerial plant biomass removal due to a disturbance (such as a fire) could modulate these effects.

In this context, the specific objectives pursued in this thesis were: 1) to examine the effects of enhanced UV radiation (UV-A and UV-B) and diminished water supply, before and after a disturbance implying aerial plant biomass removal, on the leaf content of phenols and antioxidants, leaf morphology and physiology, plant growth, root reserves and resprouting capacity of two common Mediter-

Figure 8.1: Pictures of the two experiments performed during this thesis: an outdoor experiment involving UV supplementation combined with two levels of irrigation conducted using seedlings of two resprouter species (photo abova); and a field experiment in a natural shrub community where the levels of UV and water availability reaching the ecosystem were modified (photo below).

ranean resprouter species; and 2) to investigate the role of UV radiation (UV-A and UV-B) in C and N pools of the soil and dominant plant species of a Mediterranean shrubland before and after a fire, and whether this role can be altered by the expected reduction in precipitation. To achieve objective 1, an outdoor experiment involving UV supplementation combined with two levels of irrigation was conducted (Fig. 1) using seedlings of *Arbutus unedo* and *Quercus suber*, two sclerophyllous resprouter species, whose aerial biomass was removed during the study period. Several parameters associated to leaf biochemistry, morphology and physiology, plant biomass, root biochemistry and resprouting success were measured in seedlings and resprouts. To accomplish objective 2, a field experiment was conducted in a natural Mediterranean shrub community, where the levels of UV and water availability reaching the ecosystem were modified (Figure 8.1). At the middle of the study period, all the vegetation was burned simulating a natural fire. In addition to plant and litter cover, different parameters related to C and N pools were measured in the soil, and in the litter and leaves of *A. unedo* and *Phillyrea angustifolia*, two of the resprouter species dominant in this shrubland community.

As main results, responses of *A. unedo* seedlings to enhanced UV, especially UV-B, were mainly addressed to the reinforcement of the antioxidant machinery through increases in the levels of quercetins, ascorbate and glutathione coupled with an upregulation of catalase activities. In contrast, *Q. suber* seedlings augmented UV-screening to face UV-B enhancement via accumulation of kaempferols. This species was also sensitive to enhanced UV-A, but, in this case, the response implied morphological adjustments to harden the leaves (smaller leaves with greater leaf mass per area (LMA)) coupled with a proportionally greater carbon allocation to roots (lower leaf to root biomass ratio). Concerning water supply, *A. unedo* appears to counteract water constraints by a stimulated antioxidant activity, as in response to enhanced UV-B, while the main response in *Q. suber* was a reduction in biomass allocation to leaves in relation to roots and to total biomass, likely as a strategy to minimize water loss by transpiration and increase water absorption by roots. The protective strategies displayed by both species were apparently efficient, since no reductions in root reserves or in resprouting success were found. However, after the loss of the aerial biomass, the sensitivity of resprouts to UV or water levels was notably different in relation to that of seedlings, being higher in *A. unedo* but lower in *Q. suber* resprouts. At ecosystem level, UV-A and UV-B exposure had opposite effects on C and N pools, being these effects often exacerbated by reduced levels of precipitation. During the pre-fire period, UV-A exposure increased soil moisture, respiration and □-glucosidase activity, suggesting increased soil biological activity and C turn-over. The additional presence of UV-B increased C concentration in *P. angustifolia* leaves and decreased soil respiration, pH and □-glucosidase activity, pointing to a lower soil microorganism activity probably slowing down C and N cycling. Under reduced rainfall, UV-B exposure also enhanced δ^{15}N values in leaves and litter of *A. unedo*, suggesting higher nitrification and N losses by leaching in the soil. Most of the effects were only found before the fire, indicating a homogenizing influence of this perturbation.

To sum up, over the coming decades, changes induced by enhanced UV doses and diminished precipitation levels on C and N dynamics in Mediterranean shrublands would be in part driven by opposite effects of UV-A and UV-B on soil processes, being modulated by water availability and plant species-specific responses to these factors, which would differ before and after a disturbance (fire, clear-cut, grazing).

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■ Doctoral thesis abstract

Computational Studies of UV-B Induced Signalling Pathways in Plants

Doctoral candidate: Min WU
Supervisors: Leif A. Eriksson and Åke Strid

Date of defence: 2017-06-09

Department of Chemistry and Molecular Biology, Faculty of Science, University of Gothenburg, Sweden

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Abstract

This thesis presents theoretical studies of UV-B induced signaling pathways in plants using molecular dynamic methods combined with (TD)-DFT calculations.

Ultraviolet B (UV-B) radiation is a component of sunlight covering wavelengths 280–300 nm. Despite it being a minor component of sunlight, it has a major influence not only on formation of reactive oxygen species (ROS) leading to oxidative stress, but also on regulation of plant growth and development. Albeit low levels of ROS production are required to maintain physiological functions, high levels of ROS cause harmful oxidative damage to DNA, protein and lipids. In plants, UV-B radiation has been identified to induce specific changes in gene expression resulting in a UV-B induced self-protection in plants, such as flavonoid biosynthesis, DNA repair upregulation and antioxidant activity. Expression of more than 100 genes have been identified to be regulated by the UV resistance Locus 8 (UVR8) photoreceptor which provides the initial response to UV-B stress and initialize the UV-B induced signalling pathways which also include downstream regulatory proteins such as Constitutively photomorphogenic 1 (COP1), Elongated hypocotyl5 (HY5) and Repressor of UV-B photomorphogenesis (RUP) proteins.

The UVR8 protein is a homodimer using tryptophan amino acids W285 and W233 as intrinsic chromophores to absorb UV-B radiation, followed by monomerization by the dimer. The tryptophan amino acids are located at the dimer interface and are essential for the photoreception. Residues R286 and R338 are identified to be involved in salt bridge interactions at the interface, stabilizing the dimer structure. The UVR8 monomers are able to interact with the WD40 repeat domain of the downstream protein COP1, through the UVR8 C-terminus including 27 amino acids (sequence 397–423). This interaction is necessary and essential for regulation of the signalling pathways. The UVR8 dimer is localized in the cytoplasm in plants but rapidly accumulates in the nucleus in the presence of UV-B. It is found that the nuclear localization signal (NLS) domain of COP1 is required for the nuclear addressing of UVR8. The negative regulator RUP proteins stimulated by UV-B exposure via UVR8 signalling prevent hyper-activation of the responses by

constraining UVR8 action through a combination of COP1 displacement and reversion of the signalling active monomers to the dimeric form.

In order to study the mechanisms of UV-B induced signalling pathways in plants, several computational methods were used. TD-DFT calculations were performed to identify the key tryptophan residues in the response to UV-B radiation at the wavelength 300 nm (Paper IV). The steered molecular dynamics (SMD) and umbrella sampling simulations of wild type and mutant systems were performed to explore the stability of the dimer and to identify the key salt bridges at the dimer interface that stabilize the dimer structure (Paper V). A new generalized AMBER force field for neutral arginine radicals was obtained using the ab initio HF/6-31G* method in Paper III. The mechanisms of UVR8 monomerization induced by UV-B radiation was studied in Paper VI using (S)MD with the new generalized AMBER force field for neutral arginine radicals, and (TD)-DFT calculations. The inverted free energy landscape of the intrinsically disordered C-terminus was obtained in Paper VII. In Paper VIII, the interaction between the UVR8 C-terminus and the COP1 protein was studied.

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.

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