Ultraviolet radiation research: from the field to the laboratory and back


The interest in the effects of increased ultraviolet-B (UV-B) radiation at ground level that was stimulated by stratospheric ozone depletion has waned partly thanks to the success of the Montreal protocol in reducing the production and release of ozone depleting substances, particularly chlorofluorocarbons (CFCs). Nevertheless, the future evolution of UV-B climatology still presents uncertainties, at the global, regional and local scales (UNEP 2015). CFCs are not the only cause of stratospheric ozone depletion, and stratospheric ozone is not the only determinant of UV-B irradiance, so it remains difficult to predict future UV climatology. At the regional scale, changes in cloudiness and/or aerosols, and the redistribution of ozone due to changes in atmospheric circulation patterns, are expected to affect UV irradiance in a, thus far, unknown way.

After decades of research into the effects of UV radiation on plants, disparate opinions persist on the role of UV radiation in modifying plant behaviour and growth and its relevance to future food supply. Three recent examples are the reviews of Singh et al. (2014) and Kataria et al. (2014) on photosynthesis, and the review by Williamson et al. (2014) written from a much wider perspective. Much of the controversy results from the interpretation of experimental results and their extrapolation from the inevitably artificial conditions used in experiments to the much more complex conditions prevalent in natural and human-managed plant production systems.

The importance of context explains why contradictory assessments about the importance of UV radiation for plant production still persist in the recent literature: extrapolation is difficult and subject to bias when based on data that are not sufficiently comprehensive.

Another problem is that it is difficult to realistically simulate changes in the solar spectrum, and especially these that could be expected to occur as a result of ozone depletion or climate change. This is basically a technological issue, but contributes to the difficulties encountered when we attempt to link the effects of experimental manipulations of the UV environment to those changes that can be effected by alteration of the solar spectrum. Since UV radiation is technically difficult both to manipulate and to quantify, it is not unusual for experimental treatments used to be of little ecological relevance. These problems can be compounded by low awareness of these difficulties.

Attempts to classify modifications in behaviour or responses to UV exposure as resulting from either damage or acclimation are in many cases fraught with difficulties (Kalbin et al. 2001). For example, is a reduction in growth the result of damage, or does it result from the cost of acclimation mechanisms which have evolved to avoid damage? An emerging perspective is that of UV-B as a source of information, implying that any reduction in growth may be a trade-off for plants pre-emptively acclimating to future events such as herbivory or drought. Thus, what may be interpreted as a negative effect of UV radiation in the absence of herbivores or drought, may be in fact be a positive effect through an interaction. From the point of view of agricultural production, the maximum yield under the most favourable growing conditions is not always the only target for breeding (Sadras & Richards 2014). Depending on species or target region, quality of produce or stability of yield can be very important additional criteria for which plant responses to UV radiation can play a significant positive role.
This idea that UVB radiation can be a regulator of plant growth, morphology and development, has led to renewed interest in UV research, in the context of its possible use as a management tool in agriculture, and into the ecological role of UV perception by plants (Schreiner et al. 2012).

The COST Action FA0906 “UV4Growth” that organized the conference that gave birth to this Special Issue was remarkable in gathering together researchers working at different levels from molecular to ecological and using different research approaches. This led to a broadening of viewpoints, and new projects bridging boundaries, as reflected in this Special Issue.

Papers in this Special Issue highlight, amongst others, the recently recognized regulatory role of UV-B radiation, and how it may be affected by interactions with UV-A and VIS radiation, and other environmental parameters. Responses to UV radiation involve the regulation of a wide array of metabolic, morphological and phenological responses, and we can interpret responses to UV-B radiation as a syndrome having a role in acclimation and adaptation (Kalling; Robson, Klem, et al.; Stromme; Zavala, in this issue). As a consequence it is almost impossible to assign an ecological role to isolated physiological or molecular plant responses to UV radiation. Similarly, UV radiation should not be viewed in isolation, and visible light also needs to be taken into account. We need to study the cues that are sensed by plants in the context of the full solar spectrum as the composition of visible and UV radiation can determine the signals perceived by plants and their responses (Siipola in this issue). This argument can be extrapolated even further when we consider UV radiation as a source of information for plants. Did UV induced responses evolve in response to UV radiation itself, or are they driven by environmental correlations between high UV exposure and other stresses? (Robson, Hartikainen & Aphalo; Zavala, in this issue). Thus, an important question for future research is whether environmental correlations can make UV irradiance a source of information about other events useful for plant acclimation. Despite the rapid increase of our understanding of UV-B induced regulatory processes, it is important to be aware that not all UV-induced processes are regulatory. Photochemistry driven directly by UV radiation also plays a role in the responses of plants to UV radiation, and some reported responses to UV of plants do not depend on regulation of plant metabolism or altered gene-expression or damage to the “biological machinery” (Fraser, in this issue). Studying both direct and regulatory UV-induced processes requires further development of UV-B exposure protocols. Whole growth cycle exposure, compared to step changes in UV as treatment protocols, have been found to trigger distinct plant responses, raising the question about which approach is most relevant to address physiological, ecological or agronomic questions (Siipola; Morales; Liu; in this issue). Sun simulators are a very useful tool for bridging the gap between controlled environment and field studies (Vidovic, in this issue). In contrast to normal controlled environment facilities, solar simulators can mimic both the spectral properties and irradiance of sunlight in addition to controlled air temperature, humidity and composition. Simulating and experimentally manipulating solar exposure can highlight the role that UV-B plays in determining crop yield and quality. UV responses can have either positive or negative effects on agricultural yield and produce quality, and this is supporting the interesting perspective that UV radiation manipulations can be used as a crop management tool (Wargent; Zavala; Liu; in this issue).

We can conclude that given the span of positive and negative effects of UV radiation on vegetation and crops, and other organisms they interact with, the impact of UV will be strongly context dependent, involving a balance of winners and losers among individual species. The range of possible interactions is vast, but an understanding of these interactions is needed for successful prediction of the consequences of UV radiation from ecological or plant production perspectives. A metabolic and molecular understanding of UV responses under controlled environmental conditions
is necessary, but not sufficient, for understanding their relevance to the fitness of plants growing in natural or agricultural environments or for predicting crop productivity.

For crops, responses to UV radiation cannot be assessed without taking into account the ecology of the crop species and management practices used. Some examples are: a) The natural environmental correlation between sunny weather, and corresponding high UV-B exposure, with restricted water supply will break under irrigation. b) Effects of UV radiation on crops exposed to insect pests and fungal diseases will depend on the parallel responses of all the interacting organisms to UV radiation, rather than only the response of the cultivated species. c) Crops grown under cover or in the open are usually qualitatively different, as most “normal” cladding materials used absorb UV radiation. Special UV-transparent cladding can improve produce qualities such as colour, taste or nutritional value.

The evaluation of effects of UV radiation has to be based on quality and quantity of produce, and the environmental load resulting from production. From the point of view of crop breeding, the interaction of UV responses with acclimation and tolerance to other stresses suggests that phenotyping-data obtained under controlled environments in the absence of UV radiation can only be expected to correlate weakly with field performance of the selected genotypes.

Initially, UV-B research had its focus on ozone depletion and predicting plant responses to increased UV-B exposure. In recent years the application of molecular methods to *Arabidopsis* grown in controlled environments was a main avenue of progress, while currently the role of UV radiation in ecological interactions is becoming increasingly topical, including the use of molecular methods in the field and in species other than *Arabidopsis* (Blum et al. 2004, Dinh et al. 2012).

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References


