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Symposium-in-Print Introduction

Ultraviolet Radiation and Terrestrial Ecosystems†

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The five articles contained in this Symposium-in-Print represent a cross section of invited papers that were presented at the Symposium on UV Effects on Terrestrial Ecosystems, which was held at the American Society for Photobiology Meeting in Baltimore, MD, on 5–9 July 2003. One of the invited papers, by Parisi and Kimlin, was presented in part at the International Symposium on Optical Science and Technology in San Diego, CA, on 4–8 August 2003. The papers presented in this Symposium-in-Print address both basic and applied aspects of UV research on terrestrial organisms and cover a wide range of topics.

Three additional papers were submitted too late to be included in this Symposium-in-Print and will be published in subsequent issues of *Photochemistry and Photobiology*.

Heisler *et al.* will describe their measurements of solar UV-B radiation in an urban environment using Baltimore as a case study; Gao *et al.* will describe their results on a field environment on the effects of supplementary UV-B irradiance on maize; and Qi *et al.* will describe the dynamics and temporal changes of leaf UV-B absorbing capacity in 35 broadleaf tree species.

The possible impact of stratospheric ozone reduction, brought about by inadvertent release of chlorofluorocarbons (CFC) and other trace gases, and the attendant increase in biologically effective ultraviolet radiation on terrestrial and aquatic ecosystems has been a major concern to researchers and policy makers since the early 1970s (1,2). Since about 1980, marked declines in total ozone concentrations have been observed over many regions, and global stratospheric ozone concentration has declined nearly 10% (1,2). Polar regions have experienced the most striking decreases in the ozone column; during each austral spring the ozone column over Antarctica is depleted by nearly 50% (1,2). These ozone-depleted air masses disperse during spring and can ultimately dilute ozone concentrations over more temperate latitudes, thereby exacerbating the problem.

The literature on UV-B radiation effects on terrestrial ecosystems is extensive (2–18). The need for conducting mechanistic field studies to establish plant responses to enhanced UV-B radiation at the ecosystem level to include interactions over multiple trophic levels has been recognized by an increasing number of researchers (19–27). However, in his review article on ecosystem consequences of enhanced solar ultraviolet radiation, Bassman points out that, unfortunately, many ecosystem studies have been correlative rather than mechanistic.

In his invited review, Bassman provides the reader with a synopsis of the biosynthesis and chemical ecology of three major classes of secondary metabolites—terpenoids, alkaloids and phenylpropanoids—and describes the important role that secondary plant metabolites have as mediators of multiple trophic interactions in terrestrial plant communities. He points out that changes in the concentration and composition of secondary metabolites may affect herbivores, other primary consumers and secondary consumers, which in turn can affect plant size, abundance, competitive interactions and community structure.

Increasing numbers of workers have recognized the importance of examining trophic level responses to UV radiation: see recent reviews by Day and Neale (13), Paul *et al.* (28), Paul and Gwynn-Jones (29) and Day (30). Bassman cautions that it is difficult to draw generalizations as to the interaction of UV radiation, secondary metabolites and higher trophic levels because of the complexity of these interactions.

Despite the large number of studies that have been published on the effects of ambient and elevated UV-B radiation on terrestrial plants, it is often difficult to compare results because of technical difficulties in predicting, measuring and applying realistic UV-B levels; differences in irradiation protocols in field, greenhouse and growth chamber experiments; and failure to provide adequate levels of photosynthetically active radiation and UV-A radiation (2,31).

Flint and his coworkers at Utah State University described experiments conducted near Logan, UT, to test different biological spectral weighting functions (BSWF) under realistic field conditions. They compared five different published BSWF as an array of different spectral responses that might be suitable for representing the induction of UV-absorbing compounds. For each of the four species examined [cultivated oat, *Avena sativa* L. cv. Otana; the weed kochia, also known as summer cypress, *Kochia scoparia* (L.) Schrad.; cultivated green bell pepper, *Capsicum annuum* L. var. California Wonder; and sorghum, *Sorghum bicolor* (L.) Moench var. DK 18], they indicated the predicted response from the BSWF that most closely fit the measured response. They conducted both UV enhancement and UV exclusion studies and observed that for the four

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species tested, BSWF that extend into the UV-A region best represented the observed results. When compared with the generalized plant response (32), which is commonly used, these BSWF suggest that greater UV doses will be required to simulate stratospheric ozone depletion than in past experiments. They also suggest lower radiation supplements than a new plant growth BSWF that has a greater emphasis on UV-A wavelengths.

On the basis of the results of UV exclusion studies on cucumber (33), lettuce (34), *Arabidopsis* (35) and other species (36), there is growing evidence that the biological effects of ambient UV-A radiation have been overlooked and that improved BSWF are needed that give greater weight to wavelengths in the UV-A region (31,37,38).

Polysulphone has been widely used in the construction of personal dosimeters to monitor exposure of humans to solar UV radiation (39–43). This film absorbs strongly in the UV-B region. Under high–solar UV conditions, standard polysulphone dosimeters typically can only be used to measure solar UV over periods of 3–6 hours. In their paper, Parisi and Kimlin described modifications made to a standard polysulphone dosimeter by adding an easy-to-use filter made out of black-and-white photographic film that had been developed with a standard processing technique. By using this filtered polysulphone dosimeter, they were able to extend the dynamic measurement range of personal solar UV exposures from a matter of hours to an extended period of 3–6 days without the need to replace the dosimeters owing to saturation. These results indicate the efficacy of filtered dosimeters over unfiltered ones.

How plants cope with changes in temperature and other climatic changes that might be brought about by increases in the concentration of carbon dioxide and other greenhouse gases (*e.g.* methane, tropospheric ozone, nitrous oxide and halogenated compounds such as CFC) has been the subject of intense study during the past three decades. The paper by Reddy and colleagues describes experiments that were conducted in sunlit growth chambers to determine the interactive effects of UV-B radiation and temperature on the growth and development of cotton plants. They found that square and boll retention were among the processes most sensitive to elevated temperature and UV-B radiation. The authors also obtained leaf hyperspectral reflectance curves from 400 to 2500 nm as influenced by UV-B radiation, temperature and leaf age. Their studies showed that UV-B radiation reduced reflectance in the blue region of the spectrum because of the presence of UV-B–absorbing compounds. They found that the adverse effects of elevated temperature and UV-B on boll retention in cotton were additive, resulting in severe loss of bolls. They recommended that efforts be made to develop cultivars that are adapted to both high temperatures and elevated UV-B radiation.

In their paper Milchunas and coworkers described UV exclusion experiments on plant growth and forage quality conducted in a semiarid shortgrass steppe ecosystem in north-central Colorado. They used open-sided structures covered with filters that either passed or blocked wavelengths shorter than *ca* 370 nm. They used Lexan (polycarbonate) to block UV (from 290 to 368 nm) and Solacryl to transmit UV (from 300 to 940 nm). Precipitation was controlled to create a drought or a very wet year. Subplots were either nondefoliated or defoliated to simulate grazing by livestock. They assessed the effects of UV, precipitation and grazing stress on plant community productivity and forage quality.

Significant UV effects were observed in three of the four species studied. Results from this semiarid ecosystem indicate that productivity and seasonal standing biomass of the dominant grass species were reduced under different levels of precipitation even for near-ambient compared with reduced levels of UV radiation. Although grass species (monocots) are typically less sensitive to UV damage than dicots, the authors observed reductions in seasonal standing biomass for both grasses and forbs (dicots) and for both C_3 and C_4 grass species. They also obtained an increase in forage quality for ruminants under a UV-transmitting filter *versus* a UV-blocking filter, as determined by *in vitro* digestible dry matter, depending on species and precipitation.

We hope that this symposium-in-print will provide readers with some of the key issues involved in conducting meaningful assessments of UV effects on terrestrial ecosystems and will stimulate further work in this important area of photobiology.

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