URC97145

W PHOTOPROTECTION IN TROPICAL MARINE ORGANISMS

Roy A. Armstrong
Tropical Center for Earth and Space Studies
University of Puerto Rico at Mayaguez

Introduction

Increasing levels of ultraviolet (UV) radiation reaching the earth's surface which results from stratospheric ozone depletions could have serious implications for terrestrial plants and for squat ic organisms within the euphotic zone. A documented 9% decline in ozone at mid-latitudes is considered to produce a 12% increase in harmful UV radiation (Kerr 1993). The biologically damaging effects of higher UV levels, particularly W-B (280-320 rim), could manifest earlier in the tropics because of the relative thinness of the earth's equatorial ozone layer. Tropical marine organisms are also living close to their upper tolerance levels of water temperature, However, despite the large potential effects on plants and animals, little is known about UV effects on tropical ecosystems. Long-term ecological studies are needed to quantify the effects of increased UV radiation on terrestrial and marine ecosystems and to produce reliable data for prediction.

Plants have developed several mechanisms to protect themselves from harmful UV radiation, one of which is the production of secondary leaf pigments that absorb W-B radiation (screening pigments). A higher concentration of screening pigments (e.g. flavonoids) in leaves may be interpreted as a natural response to increased *W* radiation. If higher concentrations of flavonoids filter out the excessive *W* radiation, no damage will occur, as suggested by Caldwell et al. (1989) and Tevini (1993). Failure to screen all W-B may result in deleterious effects on photosynthesis, plant genetic material, and plant and leaf morphology and growth. Eventually this will have an impact on ecosystem processes, structure, species composition, and productivity.

This paper describes an ongoing project that is assessing the responses of mangroves, seagrasses and corals to *W* radiation by studying pigment concentrations, biophysical parameters, and variations in spectral reflectance in the field and in W-reduction experiments. Preliminary results on the distribution of W-absorbing flavonoid compounds in red mangroves (*Rhizophora mangle*) and the seagrass *Thalassia testudinum, are* presented. This research also provides, for the first time, a permanent record of daily *W* irradiance measurements at a tropical location.

UV Effects on Plants

As suggested by Caldwell (198 1), Wellmann (1983), Beggs et al. (1986), and Braun (1991), anthocyanins and flavonoids have as one of their major functions the absorption of *W* radiation that might otherwise cause damage to the plant. Zeaxanthin, a widespread xanthophyll, is known to perform a protective role in plants by absorbing damaging *W* radiation (De Las Rivas et al. 1991). Increased *W* radiation affects photosynthesis rate and disrupts the chloroplast envelope (Barnes et al. 1987; Bornman et al. 1986; Sisson 1986; Campbell 1975; Caldwell et al. 1989; Tevini 1993). Damage seems to accumulate with duration of dose (Sisson 1986; Sullivan and Teramura 1992). Plant pathology is also augmented under increased UV-B radiation (Biggs and Webb 1986, Tevini 1993). Laboratory and field experiments in high latitudes have shown that increased W-B irradiance inhibits photosynthesis and increases accumulation of UV-absorbing pigments (Hardy et al. 1992). Pigment composition of red mangroves (Corredor, et al. 1995) closely follows the pattern found by De Las Rivas et al. (1989,1991) in several

species of deciduous trees from temperate environments further confirming the conservative nature of photosynthetic pigment suites in higher plants.

UV Effects on Marine Organisms

Both UV-A (320-400 nm) and UV-B (280-320 nm) are potentially important ecological factors in coral reefs (Jokiel and York 1982; Jokiel 1980). Reef building corals living near the equator tolerate higher UV levels than corals from high latitudes; shallow water corals also exhibit a higher UV tolerance than deeper corals (Maragos 1972). This adaptation results from variations in the concentration of a UV absorbing pigment, S-320, found in corals bearing endosymbiotic algae or zooxanthellae. Since the intensity of UV diminishes with increasing depth, less of this protective pigment is required at greater depths. The pigment S-320 is synthesized in response to UV light and not in response to other physical factors that also vary with depth (Jokiel and York 1982). Similar W-absorbing pigments have been extracted from marine algae (Sivalingham et al. 1974) and are probably common in other shallow water marine organisms.

Results

We have established a UV monitoring station in La Parguera, Puerto Rico using a Biospherical Instruments GUV-511 temperature-stabilized radiometer. This instrument has four bands centered at 308, 320, 340, and 380 nm in addition to PAR (400 -700 rim). Its purpose is to provide a high temporal resolution database of W irradiance. Data collection started in November 1996. Ozone data from the Total Ozone Mapping Spectrometer (TOMS) was acquired on-line from NASA's Climate Data System (NCDS) and from CD-ROM. Seasonal ozone variations in Puerto Rico show minimum values between November and the end of February (Figure 1). Maximum penetration of the shorter wavelengths of UV-B (<305 nm) is expected to occur at this time of the year. The highest surface irradiances of IN-A and the longer wavelengths of UV-B are expected to occur during the summer months, when lower solar zenith angles are present.
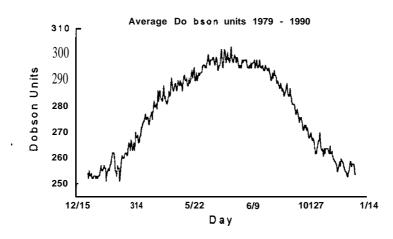

Figure 1: Seasonal ozone measurements using 12 year averaged data for Puerto Rico.

For this tropical location, the link between stratospheric ozone, solar zenith angle and surface UV spectral irradiance will be established after the first year of data collection by the UV monitoring station. For submerged plants and animals, such as seagrasses and corals, incident UV radiation also depends on water depth and the presence of dissolved and particulate organic matter in the water column. *In situ* UV measurements to a depth of 10 meters are being obtained with a Optronic Laboratories OL 754 spectroradiometer. This instrument offers an accuracy of ± 0.2 nm over the 200-800 nm spectral range (and ± 0.1 nm for the 280-320 nm range), is highly sensitive and has a large dynamic range, with user-selectable bandwidths of 1 to 10 nm.

Preliminary measurements of screening pigments in mangrove and seagrass leaves have been obtained by solvent extractions and spectrophotometric analysis. Figure 2 shows the absorption spectrum of W-absorbing pigments for upper-canopy (top) and shaded (bottom) red mangrove leaves. The sun-exposed upper-canopy leaves have higher amounts of photo protect ive pigments. Distinct peaks are present at about 280 and 330 nm.

UV absorption of *Rhizophora mangle*
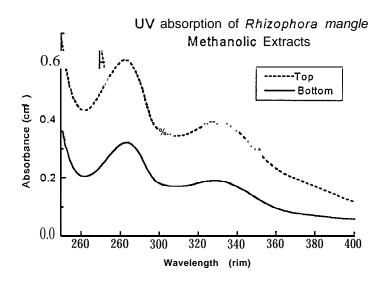Methanolic Extracts

------- Top
———— Bottom

Figure 2: Absorption spectrum of photoprotective pigments in *R. mangle* leaves.

Pigment separation and identification in mangroves as well as seagrasses and corals is in process. This is being performed by a two-step isocratic HPLC/DAS following a modification of the procedure detailed by De Las Rivas et al. (1989, 1991). A C-18 reverse phase column is being used for pigment separation. For seagrasses and corals, the amount of photoprotective pigments is inversely proportional to water depth, due to the filtering effects of the water column. Figure 3 shows the absorption spectra of photoprotective pigments in the seagrass *T. testudinum* present at various depths and under full sun and shaded conditions. Shallower seagrasses have lesser amounts of UV-absorbing pigments. At the same depth, shaded seagrasses also have lesser amounts of protective pigments. A distinct absorption peak, most likely due to flavonoids, is present at about 330 nm.
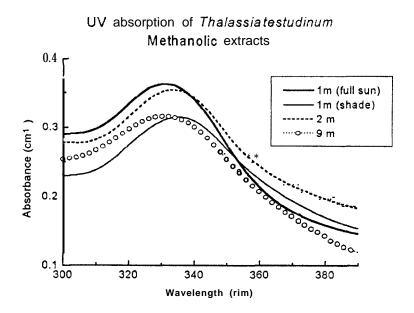
UV absorption of *Thalassia testudinum*
Methanolic extracts

Figure 3: Absorption spectra of photoprotective pigments in *T.Testudinum.*

Conclusions

Preliminary results indicate that the total content of leaf photoprotective pigments, such as flavonoids in seagrasses and mangroves is irradiance dependent. Thus, for mangroves, lower canopy leaves exhibit lower flavonoid contents while upper canopy leaves exhibit higher contents. Similarly, seagrass flavonoid content is inversely correlated to depth with greater contents at shallow depths and vice-versa. Corals (or their symbiotic zooxanthellae) do not produce flavonoids but are known to produce a separate type of W-absorbing compound known as mycosporine-like amino acids or S-320's. S-320 content of corals is also irradiance dependent and increases dramatically upon bleaching; the stress-induced expulsion of zooxanthellae.

In the course of this study, we intend to document present levels of UV-photoprotective compounds in the major classes of sessile tropical marine organisms and to document variations in the levels of these pigments in response to natural and experimentally induced UV flux rates. This information will serve to assess the capacity of these organisms to modulate their response to variations in UV flux as well as to provide a baseline for assessment of the organismic response to expected increases in UV flux due to stratospheric ozone depletions.

Acknowledgments

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