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No UV enhancement of litter decomposition observed on dry samples under controlled laboratory conditions

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ABSTRACT

In field studies, various workers have observed a stimulation of organic matter breakdown by visible light and UV radiation. We aimed to confirm the involvement of UV radiation under controlled laboratory conditions and quantify the magnitude of any stimulation. Grass and pine foliage samples were oven-dried and continuously exposed to UV radiation at room temperature for up to 60 days. A range of UV flux densities was established using shading to different levels. After UV exposure under air-dry conditions, samples were rewetted and incubated in the dark with microbial inoculums to investigate whether UV exposure had rendered samples more susceptible to subsequent microbial decomposition.

However, we found no weight loss associated with different UV flux densities. The same finding held true for grass and pine litter samples. Similarly, microbial decomposition of either grass or pine litter was not enhanced by prior UV exposure. These findings suggest that UV-induced photooxidation of dry materials cannot be responsible for the observed apparent enhancement of weight loss of litter samples under UV exposure in the field.

1. Introduction

It has long been known that microbial decomposition of organic matter responds strongly to temperature (e.g. Kirschbaum, 2000, 2010) and soil or litter moisture contents (Borken and Matzner, 2009). Global warming is likely to stimulate organic matter decomposition and lead to a loss of soil carbon (e.g. Sitch et al., 2008), and the extent of that stimulation will critically affect the future natural biogenic contribution to net CO_2 emissions to the atmosphere (Sitch et al., 2008; Kirschbaum, 2010).

Over recent years, a number of workers have shown, however, that organic matter decomposition can be affected not only by the known biological drivers but can also be enhanced through exposure to visible and UV (UV-A and UV-B) radiation (Moorhead and Reynolds, 1989; Anesio et al., 1999; Schade et al., 1999; Day et al., 2007; Austin and Vivanco, 2006; Rutledge et al., 2010; Brandt et al., 2010). To the extent that decomposition is controlled by abiotic processes such as photooxidation, it will reduce its dependence on biotic drivers. Systems would then be less responsive to changes in the key controllers of microbial decomposition, such as temperature.

Most notably, Austin and Vivanco (2006) found that the stimulation of decomposition by radiation occurred in the absence of microbial activity. Their observed increase of decomposition under radiation exposure must therefore have been due to direct photooxidation rather than through microbial facilitation, which is the breakdown of complex organic compounds into simpler ones that can be degraded more easily by microbial enzymes at some time after UV or light exposure. They observed the strongest decomposition rates when they allowed all wavelengths to reach their samples, including UV and photosynthetically active radiation.

UV-B is believed to be particularly effective at breaking down lignins (Gehrke et al., 1995; Lanzalunga and Bietti, 2000; Henry et al., 2008), which are resistant to breakdown by most microorganisms. Photochemical degradation of cellulose may also be possible through visible light although photooxidation appears to increase sharply with decreasing wavelength below about 500 nm (Schade et al., 1999; Brandt et al., 2009). We are not aware of any other attempt at generating an action spectrum of litter decomposition effects.

Further compelling evidence for direct photooxidation to play a role in litter weight loss has come from a recent study by Rutledge et al. (2010) who showed that CO_2 emissions from peat samples responded almost instantaneously to changes in radiation. Their exposed samples were air-dry during the experiment which effectively eliminated microbial CO_2, and there was no CO_2 release

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when samples were darkened. This work indicated not only that radiation played an important role for total CO_2 release, but also that the mechanism at least included direct photooxidation rather than relying solely on microbial facilitation.

There are fewer reports of the effect of radiation on decomposition under controlled laboratory conditions. Such studies under controlled conditions are important to not only confirm the apparent observations from the field, but to also better characterise the relevant action spectra, determine dose responses and identify to what extent an overall radiation effect is caused by direct photooxidation or microbial facilitation. Foereid et al. (2010) kept dried litter samples under broad-spectrum radiation sources including UV radiation for up to 289 days, and found no apparent weight loss with time. They did observe, however, that samples exposed to radiation for longer periods showed faster subsequent microbial degradation when samples had been rewetted. They concluded that microbial facilitation rather than direct photooxidative mass loss must have been responsible for any weight loss observed in the field.

Brandt et al. (2009) exposed different litter samples to UV radiation in the laboratory and found a clear enhancement of CO_2 efflux rates under UV exposure. However, their observed enhancement was very small, amounting to a weight loss of less than 0.5% over 70 days of continuous exposure, and there was no evidence for microbial facilitation by UV exposure. While Brandt et al. (2009) showed that litter degradation can be enhanced by UV exposure, their observed rates were too small to account for the large enhancement of decomposition observed in field experiments.

We conducted a laboratory experiment under controlled conditions to try and further quantify any effect of UV exposure on litter decomposition and separately assess any effects on direct photooxidation and microbial facilitation.

2. Materials and methods

In our experiment, we investigated the effect of UV radiation on *Pinus radiata* needles and perennial ryegrass (*Lolium perenne* cv Nui). First, we investigated the effect of intensity of UV exposure on grass and pine needle degradation by observing any direct weight loss. A range of UV intensities was generated either through a set of wire meshes or by using different amounts of grass litter through self-shading. After the end of UV exposure, samples were moistened and incubated in the dark to assess the extent of any microbial facilitation by prior UV exposure.

2.1. Litter UV exposure

A metal frame was erected over a metal bench top to house 6 fluorescent UV lamps (Phillips TL 40W/12RS). The bench top was covered with black cloth to stop back-reflection of the UV radiation and ensure that samples received radiation only from the UV radiation sources. Radiation received by our samples was measured with a UV-B Biometer Model 501 Radiometer (Solar Light Company, Pennsylvania, USA). The biometer was calibrated, and the spectral output of the UV lamps was measured with a Bentham spectroradiometer with DM150BC double monochromator, cosine diffuser and end window PMT detector (Bentham, Reading, UK).

Unshaded samples in our experiment received irradiance comparable to that received at noon in summer under typical New Zealand conditions, especially in the biologically more active lower wavelength range below about 310 nm (Fig. 1). The flux density of solar irradiance, on the other hand, was higher at wavelengths greater than 310 nm. Integrating over the whole UV-B range, solar noon irradiance in New Zealand is about 2.0 W m^{-2} for wavelengths from 290 to 315 nm and 3.7 W m^{-2} from 290 to 320 nm (McKenzie et al., 2009). This compares with irradiance received by our samples of 1.9 W m^{-2} up to 315 and 2.2 W m^{-2} up to 320 nm. The UV lamps also emitted about 0.27 W m^{-2} in the UV-C range below 290 nm (calculated from the data shown in Fig. 1).

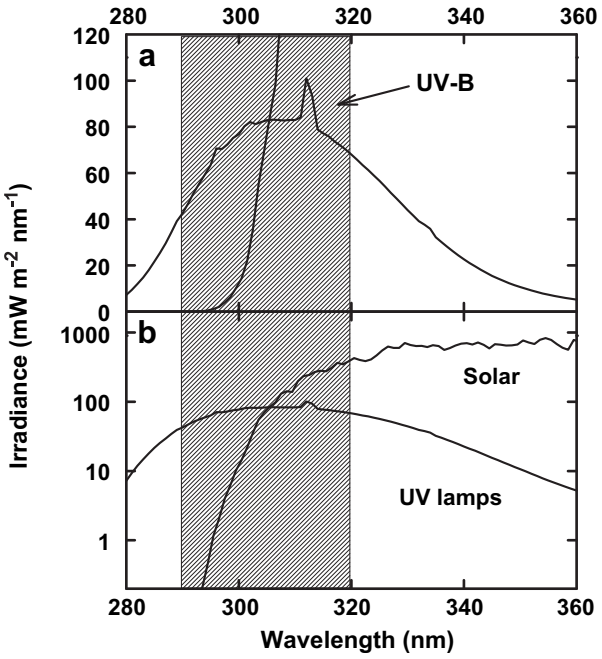

Fig. 1. Irradiance received by unshaded samples in the experiment compared to irradiance received at noon on a typical New Zealand summer day. Data are shown on either a linear (a) or logarithmic (b) scale. The shaded area shows the wavelength range usually designated as UV-B. Solar spectrum after McKenzie et al. (2009).

As samples were exposed to that radiation continuously for 60 days, the received UV radiation load was therefore comparable to that received by litter under field conditions over a whole summer. In addition, our experimental lamps produced a much greater proportion of shorter-wavelength radiation than solar radiation so that the radiation under our experimental conditions was likely to promote litter breakdown even more than natural sunlight.

The top of the lighting frame was covered with fine-meshed material to prevent dust collecting on top of the litter samples, which could have affected their weight during the experiment. The sides of the lighting frame were covered with reflective aluminium foil to backscatter radiation from the walls and create a more even radiation field for our samples. It also prevented UV light from escaping the UV exposure area as a safety precaution for staff working in the area.

Fresh pine needles were collected from 20-year-old *P. radiata* trees (Old West Road, Palmerston North, New Zealand; Roger Parfitt, pers. comm.) and oven-dried at 80 °C. Basal sheaths were removed from each fascicle and discarded, and needles were cut into approximately 2 cm lengths. Nui Ryegrass was grown under controlled conditions in a shade house, and irrigated daily. The grass was harvested periodically to maintain a short and vigorous sward. The harvested grass was dried at 80 °C and stored at room temperature until the start of the experiment. The grass was sorted to remove dead material and cut into approximately 2 cm lengths.

Both pine and ryegrass litter were exposed to six UV radiation levels of 1.4%, 18%, 41%, 60%, 73%, and 100% of incident UV radiation, with 5 replicates each. The level of UV exposure was controlled by a range of metal screens placed over individual litter samples. Frames were constructed of medium density fibre board with metal screens of the appropriate aperture size attached. Screens for the 100% treatment consisted of a frame with no mesh attached.