The Hot and the Classic

Effects of Ozone Depletion on Land Plants

The use of chlorofluorocarbons (CFCs) in the late 20th century, mainly as refrigerants and spray propellants, led to the destruction of stratospheric ozone (Molina and Rowland, 1974). The loss has been most dramatic in the lower stratosphere over the Antarctica continent, although mid-latitude and Arctic depletion has also been observed. Although the use of most CFCs has been phased out, ozone depletion is currently near or at its maximum (McKenzie et al., 2003). Recovery is expected to be slow and it may take 50 years for 1980s levels of ozone to be re-established. In the case of plants and other primary producers, ozone depletion has its greatest effects by increasing the atmospheric transmission of solar UV-B radiation (UV-B, 280–315 nm). January’s Hot and Classic examines some recent reports concerning the effects of this increased UV-B irradiation on terrestrial plants.

Effects of Altering UV-B Irradiation

Much of the early work concerning the effects UV-B illumination on terrestrial plants was conducted indoors using growth chambers or greenhouses. By the 1990s, a consensus was reached that many of these early reports of UV-B effects on terrestrial plants were exaggerated, and that extrapolating these results to field responses was a dubious endeavor (Caldwell and Flint, 1997). Since then, there has been more emphasis on field studies that take advantage of the UV irradiance provided by sunlight. The two most widely used approaches in these outdoor studies involve either supplementing natural UV-B irradiation by means of UV-B-emitting lamps or lowering ambient UV-B levels by means of UV-B-absorbing screens. Recent attenuation studies have revealed that solar UV-B exposure reduces the biomass production of some plant species by 10% to 35% (Krizek et al., 1998; Mazza et al., 1999; Xiong and Day, 2001). Although these recent studies are much improved, many technical problems still exist, both in modeling the effects of ozone depletion on UV-B irradiation and in mimicking these effects realistically in the field (reviewed by Day and Neale, 2002).

UV-B Screening Compounds

Concentrations of UV-B absorbing compounds commonly increase in the leaves of terrestrial plants that are exposed to enhanced levels of UV-B illumination (Searles et al., 2001). In higher plants these compounds include a wide variety of phenylpropanoids (Cockell and Knowland, 1999). High concentrations of these compounds are thought to reduce epidermal transmittance and provide greater protection to the leaf mesophyll. The relationship between the concentrations of these UV-B-screening compounds and epidermal transmittance is confounded by the fact that these compounds are not uniformly distributed across the epidermis, thereby leading to sieve effects (Day and Neale, 2002). Increases in UV-B absorbing compounds upon UV-B exposure of plants in growth chambers, however, have been correlated with reductions in transmittance (Cen and Bornman, 1993). For example, photosystem II inhibition in grape (Vitis vinifera) leaves decreased in parallel with increased epidermal screening (Kolb et al., 2001). However, soybean (Glycine max) leaves that had higher concentrations of screening compounds, and lower epidermal transmittance, experienced less DNA damage when challenged with a short exposure to solar UV-B (Mazza et al., 2000). In several cases, higher UV-B levels do not elicit increases in concentrations of these compounds, and plant performance is not impaired, suggesting that constitutive concentrations, together with internal repair and protection mechanisms, provide adequate protection (Day and Neale, 2002).

Effects on Photosynthesis

Excess UV-B exposure of non-acclimated plants impairs all of the main processes of leaf photosynthesis particularly Photosystem II (Allen et al., 1998; Teramura and Sullivan, 1994). The question of whether photosynthesis is inhibited in acclimated plants in the field has yielded mixed results. CO₂ assimilation rates are reduced in non-acclimated grape plants upon exposure to solar UV-B (Kolb et al., 2001), and UV-B enhancements over several years led to lower CO₂ assimilation rates in five tropical tree species (Keiller and Holmes, 2001). However, Xiong and Day (2001) found that gas-exchange rates per unit leaf area in Antarctic vascular plants were unaffected by solar UV-B exposure during periods of ozone depletion. Although photosynthetic function in the upper mesophyll was impaired in this later case, this impairment was compensated for by thicker leaves with higher pigment concentrations. Leaf thickening in response to UV-B (Ballaré et al., 1996; Xiong and Day, 2001; Phoenix et al., 2001) may provide protection by increasing the pathlength to UV-B sensitive mesophyll cells. In general, however, photosynthetic gas-exchange per unit leaf area is not reduced in acclimated plants in response to UV-B supplementation.

Biomass Production

Although photosynthesis is by and large unaffected by heightened UV-B illumination in the field, exposure to solar UV-B does reduce biomass production in many terrestrial plant species (Day and Neale, 2002). These reductions in total biomass are usually attributable to reduced aboveground biomass, which is often found in conjunction with slower leaf elongation rates, smaller leaves, and smaller whole-plant leaf area (Ballaré et al., 1996; Krizek et al., 1998; Mazza et al., 1999; Xiong and Day, 2001). The biomass production of some plant species is more affected by UV-B enhancement than others. For example, Robinson et al. (2003) found that the growth of the moss Sphagnum magellanicum in
Tierra del Fuego was relatively unaffected by UV-B irradiation. This enabled *Sphagnum* to outcompete several vascular plants, but the effect was subtle: No major changes in the plant community structure were noted.

**Ecological Effects**

Because of the subtle nature of UV-B effects on terrestrial plants, it is possible that effects of UV-B on other ecosystem components may actually have a greater impact on terrestrial plant performance than the direct effects of UV-B illumination on plants (Björn et al., 1998). Herbivores and pathogens can be negatively affected by UV-B illumination (Day and Neale, 2002). Mycorrhizal infections (Van de Staaij et al., 2001) and N₂ fixation by lichens may also be negatively impacted (Solheim et al., 2002). The direct exposure of leaf litter to enhanced UV-B can accelerate or slow litter decomposition and affect litter C:N ratios (Day and Neale, 2002). In addition to direct effects on other organisms in the ecosystem, the accumulation of leaf phenylpropanoids and related phenolics in response to UV-B irradiation may deter insects, fungal pathogens, and microbial decomposers. In short, the effects of enhanced UV-B irradiance on plant interactions with other organisms is complex and difficult to predict.

**LITERATURE CITED**


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