Seasonal changes of UV-absorbing compounds in the leaves of two native trees

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Abstract. The influence of present-day levels of ultraviolet (UV) radiation on growth and the production of UV-absorbing compounds was examined in a field study of two evergreen trees, mountain beech (*Nothofagus solandri* var *cliffortioides*) and manuka (*Leptospermum scoparium*). Intact branches of naturally occurring trees were suspended below UV-B (280-320 nm) transmitting and absorbing plastics. Measurements of UV dose were made continuously and UV-absorbing compounds were measured at approximately monthly intervals from bud-burst until leaf senescence (14 months later).

The daily erythemally effective UV dose ranged from 6.5 in summer to 0.5 kJ m^{-2} d^{-1} in winter, with a total leaf life-time dose of approximately 1000 kJ m^{-2}. Bud-burst in both species occurred near the time of maximum daily UV dose. A cabinet experiment suggested that the production/reduction of UV-absorbing compounds in mountain beech is more responsive to fluctuations in UV than manuka.

In the presence of UV-B radiation, the concentration of UV-absorbing compounds (A_{300} cm^{-2}) were greatest in leaves exposed to the ambient UV dose. Seasonal changes in UV-absorbing compounds of beech leaves were more dynamic than in manuka. The young leaves of both species started with high levels of UV-absorbing compounds (beech = 3.9 cm^{-2}, manuka = 2.6 cm^{-2}). In both species, UV-absorbing compounds fell to a low in late winter and then rose again in response to the increasing UV dose. For the same dose of UV, young leaves produce more UV-absorbing compounds than older leaves, suggesting a decline in investment as leaves age.

Introduction

Terrestrial plants are sessile and have to adapt and cope with the UV-radiation environment that is imposed upon them. Since the evolutionary process is not perfect and plants are not necessarily best adapted for the current conditions they grow in, some plant species are less resistant to UV-radiation then other species. UV-radiation sensitivity can result in a decrease in leaf area and biomass, and changes to flowering, reproduction and competition (e.g. Caldwell *et al.* 1995).

There are many protective mechanisms that plants use to both tolerate and avoid UV-damage. UV-B can stimulate an increase in the antioxidant systems and the repair of UV-induced DNA damage (A.-H.-Mackerness *et al.* 1998). The accumulation of UV-absorbing compounds can aid in avoidance of UV penetration to sensitive layers within the leaf. These compounds accumulate in the upper epidermal layers of the leaves of many higher plants, including trees, following irradiance with UV-B (Schnitzler *et al.* 1997).

This study looks at the time constant for the production and decay of UV-absorbing compounds of two native tree species, mountain beech and manuka in a laboratory experiment. In the field we followed the response of UV-absorbing compounds, in the same species, to natural changes in UV-B radiation.

Methods

A broad-band UV measuring instrument (Biometer, model 501, Solar Light Co. Inc, Philadelphia) was installed at Craigieburn Forest (Lat 43.15° S, Long 171.72°E, alt 914 m) in December 1996. The daily clear-sky UV dose ranged from 6.5 in summer to 0.5 kJ m^{-2} d^{-1} in winter, with a total leaf life-time dose of approximately 1000 kJ m^{-2} d^{-1}. Bud-burst in both species studied occurred in January, near the time of maximum daily UV dose, and leaves lived for about 14 months.

Twenty young plants were collected from the field and each plant was covered with either UV-B absorbing or UV-B transmitting plastics, as used by Hunt and McNeil (1999), and placed in a growth cabinet. The plants were exposed to saturating levels of light (1200 :mol m^{-2} s^{-1}) for 16 hours each day. Plants were irradiated with UV for 16 days with 5 kJ m^{-2} d^{-1} of plant-weighted UV-B radiation emitted from fluorescence tubes (Philips TL 40/12 RS) and then the UV lamps were turned off. All plants were sampled 10 times through the experiment and UV-absorbing compounds were measured following Hunt and McNeil (1999).

In the field, three replicates of branches were covered with either UV-absorbing or UV-transmitting plastics. Ten leaves of both species were sampled at approximately monthly intervals and analysed for UV-absorbing compounds.

Results and Discussion

In both species, UV radiation caused a rapid increase in UV-absorbing compounds reaching a plateau after 16 days. The rate of increase of UV absorbing compounds was faster in mountain beech than manuka. The maximum absorbance at 300 nm for mountain beech was 2.87 compared to 2.67 for manuka. The time constant for both species was about 7 days. On removal of UV mountain beech also had a faster decline in UV-absorbing compounds. This suggests that mountain beech is more responsive to fluctuations in UV and can rapidly track a changing UV environment.

In the field, the young leaves of both species were already high at budbreak, suggesting that UV-absorbing compounds were synthesised before the leaf was exposed to ambient UV conditions. In both species the maximum UV absorbance occurred in January , decreased through winter and slowly rose again during the next summer. If the absorbance measurements are converted to transmission of UV through the samples, then there is a 60-fold decrease in transmission of compounds in mountain beech compared with a 5-fold change in manuka. Therefore, although there are differences in the absorbance measured in the laboratory compared with the field, there was a similar pattern in that mountain beech was more responsive than manuka to changes in UV dose.

Even though the UV dose during the second summer (1998) was as high as the first summer (1997), in both species the absorbance never reached the initial maximum. In some other plants, older leaves are more susceptible to damage than young leaves (A.-H.-Mackerness and Thomas 1999). The decline in synthesis of UV-absorbing compounds in both of these species may be due to an optimal investment strategy - where leaves that are about to be discarded have reduced allocation to stress avoidance.

Conclusions

Species differ in both the amount of UV-absorbing compounds contained in their leaves and also their responsiveness to a step change in the UV dose. Under natural conditions, the initial levels of UV-absorbing compounds were high at budbreak – protecting the young leaves from UV damage. However, the responsiveness to UV dose decreased with age, so that under similar conditions, one-year old leaves did not produce the same amount of UV-absorbing compounds as young leaves.

References

A. -H. -Mackerness, S., S. L. Surplus, B. R. Jordan, and B. Thomas, Effects of supplementary ultraviolet-B radiation on photosynthetic transcripts at different stages of leaf development and light levels in pea (*Pisum sativum* L.): Role of active oxygen species and antioxidant enzymes, *Photochem. Photobiol.,* 68, 88-96, 1998.

A. -H. -Mackerness, S., and B. Thomas, Effects of UV-B radiation on plants: gene expression and signal transduction pathways, in *Plant Responses to Environmental Stress*, edited by M. F. Smallwood, C. M. Calvert and D. J. Bowles, pp. 17-24, Bios Scientific Publishers, Oxford, 1999.

Caldwell, M. M., A. H. Teramura, M. Tevini, J. F. Bornman, L. Björn, L., and G. Kulandaivelu, Effects of increased solar ultraviolet radiation on terrestrial plants, *Ambio*, 24, 166-173, 1995.

Hunt, J. E., and D. L. McNeil, The influence of present-day levels of ultraviolet-B radiation on seedlings of two Southern Hemisphere temperate tree species, *Plant Ecol*., 143, 39-50, 1999.

Schnitzler, J. -P., T. P. Jungblut, C. Feicht, M. Köfferlein, C. Langbartels, W. Heller, and H. Sandermann Jr., UV-B induction of flavonoid biosynthesis in Scots pine (*Pinus sylvestris* L.) seedlings, *Trees*, 11, 162-168, 1997.

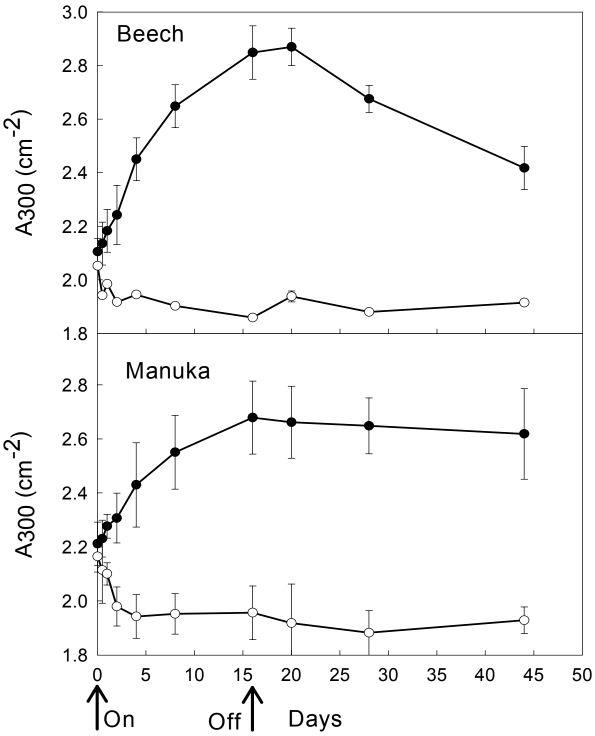

Figure 1. Changes in UV-B absorbing compounds from two tree species exposed to UV (●) and screened from UV (○). UV lamps in the growth cabinet were turned on at the beginning of the experiment and turned off after 16 days.

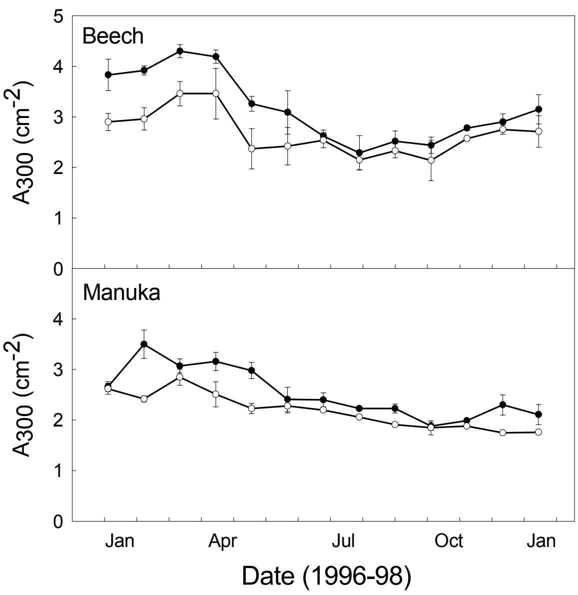

Figure 2. Monthly changes in UV-B absorbing compounds of two tree species under natural UV conditions. Control leaves were screened from UV (○) and treatment leaves (●) received near ambient levels of UV.