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Epidermal transmittance for UV-B radiation in arctic-alpine vascular plant species

Plants protect themselves against damaging UV-B radiation by two different strategies. They efficiently repair damage, e.g., by DNA photolyases, and they screen radiation by UV absorbing compounds such as flavonoids accumulating in their epidermis. The accumulation of screening compounds is inducible by UV-B radiation. Hence, one would expect low screening efficiency at high latitudes where UV-B irradiance is low due to a steep solar angle and a comparatively thick stratospheric ozone layer. On the other hand, not only the antarctic but also the arctic ozone layer are being depleted. Therefore, it is important to evaluate the existing protection of arctic plants.

We studied the epidermal transmittance for UV-A (λ_{max}=366 nm) and UV-B (λ_{max}=314 nm) radiation using a newly developed method based on chlorophy fluorescence. Since this method is rapid and non-intrusive and the apparatus i portable, it was possible to investigate 12 different vascular species from Svalbard (Longyearbyen, 78° N, 10 m above sea lebel (a.s.l.)) in three consecutive years (1999 – 2001) growing in their natural environment and compare the results with measurements on 6 identical species at two other locations, Finse, Hardangervidda, S. Norway (60° N, 1200-1600 m a.s.l.), and Col du Lautaret, Alps, France (45° N, 2000-2700 m a.s.l.) (Nybakken et al. 2004a, b).

Table 1 *Epidermal UV-A and UV-B transmittances (%) for the investigated species, sorted according to UV-B transmittance. "Ambient" refers to natural conditions, whereas "+ UV-B" refers to an experiment with artificially enhanced UV-B irradiation simulating 11% ozone depletion. Data are means over the years 1999–2001.*

Species	UV-A Ambient	+ UV-B	UV-B Ambient	+ UV-B
Saxifraga cespitosa L.	5.8	–	2.8	–
Saxifraga nivalis L.	5.1	–	3.2	–
Salix reticulata L.	3.8	–	4.0	–
Cassiope tetragona (L.) D. Don	5.2	5.4	4.0	4.5
Saxifraga cernua L.	7.2	–	4.9	–
Salix polaris Wahlenb.	5.1	4.6	5.1	4.8
Papaver dahlianum Nordh.	7.4	–	5.5	–
Oxyria digyna (L.) Hill	8.3	6.7	6.2	5.7
Dryas octopetala L.	7.2	6.4	7.1	6.6
Silene acaulis (L.) Jacq.	7.0	–	7.2	–
Bistorta vivipara L.	7.5	8.4	8.2	9.7
Saxifraga oppositifolia L.	10.4	–	9.6	–

Epidermal transmittances for the investigated species from Svalbard are shown in Tab. 1 as means for the three studied years. UV-B transmittance varied between species, but maximal transmittance was about 10%. UV-A transmittance was in the same order of magnitude, indicating a strong contribution of flavonoids to the screening. The potential for acclimation to increased radiation was explored with artificially increased UV-B, simulating 11% ozone depletion (+UV-B in Tab. 1). Open top chambers simulated an increase in temperature of 2-3 °C in addition to the UV-B manipulation (data not shown). Artificially increased UV-B radiation and temperature did not significantly influence the epidermal UV-B transmittance in any of the five measured species (see Tab. 1), suggesting that they may not have the potential to increase their epidermal screening, or that control of screening development is dominated by other factors besides the applied UV-B level.

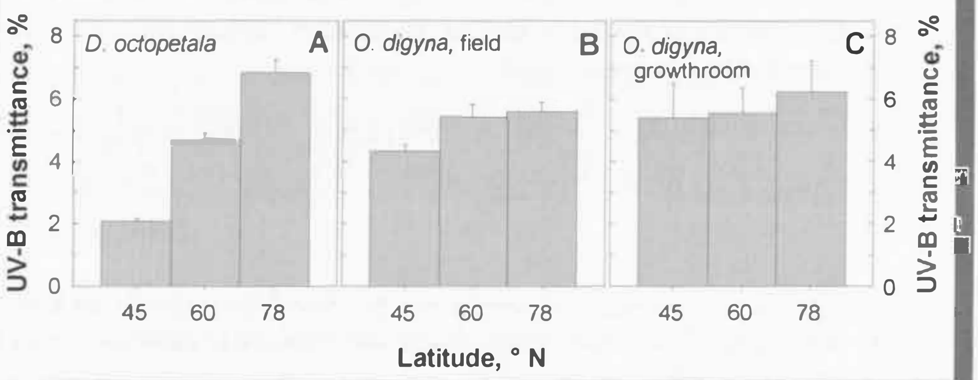

Figure 1 *Epidermal UV-B transmittance of Dryas octopetala (A) and Oxyria digyna (B) leaves at the different locations and of O. digyna leaves of ecotypes from the three locations grown in a growthroom in the absence of UV-B (C). Data are means of 3 years (A, B, n>29), or from one experiment (C, n = 10), ± S.E.*

Along the investigated latitudinal gradient daily biologically effective UV-B doses during the growing season (mid June to mid August) 2002 were for the French Alps site on average 2.7 times higher than at Svalbard. Epidermal transmittance of leaves of *Dryas octopetala* reflected this ratio proportionally (Fig. 1A) whereas five other investigated species showed a similar gradient only in some years, or, in the case of *O. digyna*, not at all (Fig. 1B). Cultivation of *Oxyria digyna* from seeds collected at the three sites under controlled conditions in the absence (Fig. 1C) or presence of UV-B (2.6 kJ d^{-1}, data not shown) showed that this plant had a constitutively high epidermal screening, which was not further enhanced by UV-B treatment.

UV absorbing compounds were analysed by HPLC in methanolic extracts from *O. digyna* leaf samples collected in the field at the three locations and in the greenhouse. The concentrations of flavonoids and hydroxycinnamic acid derivatives were not quantitatively correlated to epidermal transmittance, pointing to the existence of compounds which were either not extractable or located in the mesophyll of the leaves, where they do not function in screening. The qualitative analysis showed that the French Alps ecotype had a different composition of flavonoids compared with the two others, and that the ratio between di- and monohydroxylated flavonoids increased from south to north.

Comparing epidermal transmittance of the arctic plants with those from the other two alpine sites suggests that the studied arctic species have a comparatively high epidermal screening. Although we cannot estimate repair capacity or the sensitivity of other functions in arctic plants, from the viewpoint of epidermal transmittance they may be able to tolerate increased UV-B radiation in spite of their restricted ability to acclimate. A reason for this may be induction of UV screening by other environmental factors besides UV-B radiation.

References

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