Phyton (Austria) Special issue: "Plant Physiology"	**Vol. 39**	Fasc. 3	(25)-(28)	30. 11. 1999

Photoprotection in Forest Trees under Field Conditions

By

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Key words: Xanthophyll cycle, photoprotection, pigments.

Summary

TAUSZ M., MORALES D., JIMÉNEZ M. S. & GRILL D. 1999. Photoprotection in forest trees under field conditions. - Phyton (Horn, Austria) 39 (3): (25) - (28).

Light dependent xanthophyll conversions are dependent on the species, the health status of the photosynthetic apparatus, and on environmental conditions in general. The present work compiles data from different field studies on different tree species to reveal common physiological principles. Multivariate statistical methods allow an evaluation of response patterns underlying these pigment changes in different environmental conditions.

Introduction

The thylakoid membranes have to be protected against excess absorption of light energy, since an overreduction of photosystem II leads to the formation of aggressive oxygen species (ELSTNER & OSSWALD 1994). Oxidative destruction of proteins, membranes, and pigments is the consequence. The pigment composition in the thylakoids provide both optimal light harvesting potency as well as light protection. The xanthophyll cycle in its de-epoxidised state (high proportion of zeaxanthin) dissipates excess excitation energy under high light conditions, whereas in its epoxidised state (high proportion of violaxanthin) these xanthophylls contribute to light harvesting under low light conditions (DEMMIG-ADAMS & ADAMS 1994). Carotenoids and α-tocopherol provide further protection of thylakoids from singlet oxygen formed in spite of energy dissipation.

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In the present paper thylakoid pigment systems of ecologically different forest species are analysed to enlighten common physiological principles of photoprotective response patterns at natural sites.

Materials and Methods

Sampling and sites

Data in this study were compiled from different field studies in Austria and Tenerife. Detailed sampling and site descriptions are given in MORALES & al. 1997 for laurel forest trees in Tenerife (Fig. 1), TAUSZ & al. 1996 for *Picea abies* in Austria (Fig. 2), and TAUSZ & al. 1998 for *Pinus canariensis* in Tenerife (Fig. 3).

Pigment analysis

Pigments were determined on acetone extracts of the lyophilized leaf (needle) powder according to the HPLC gradient method of PFEIFHOFER 1989.

Results and Discussion

Conversions of xanthophyll cycle pigments are strongly dependent upon the species, even if they grow under the same environmental conditions (Fig. 1).

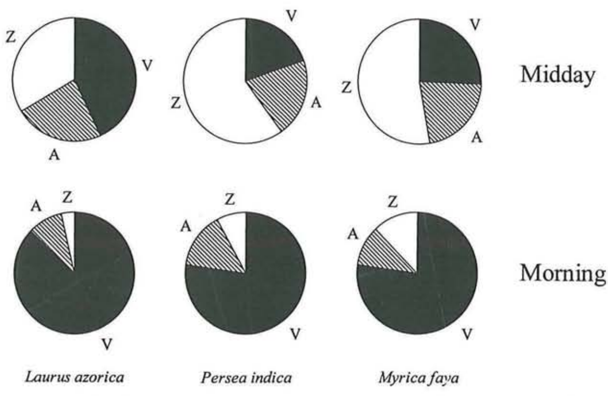

Fig. 1. The xanthophyll cycle conversions in leaves of three tree species growing together in the laurel forest in Tenerife. Morning = sampled at PAR < 20, midday at PAR = 1900 µmol m^{-2} s^{-1}. More details in MORALES & al. 1997. V=violaxanthin, A=antheraxanthin, Z=zeaxanthin.

The conversion state of the xanthophyll cycle of the same species under uniform environmental conditions depends upon the health of the leaves. Spruce needles with less chlorophyll – a widely used indication of biochemical damages - exhibit a higher de-epoxidation state of the xanthophyll cycle at the dark adapted stage (Fig. 2). This points to an increased need of photoprotection (provided by zeaxanthin) in biochemically slightly damaged thylakoid systems. Corresponding results were found upon stressful environmental conditions (low temperatures, ADAMS & DEMMING-ADAMS 1994 or mild drought stress, KRONFUSS & al. 1998).

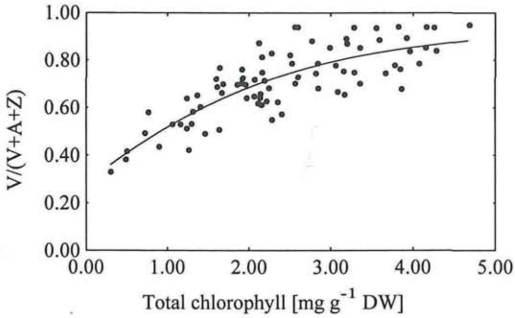

Fig. 2. Conversion state of the xanthophyll cycle in dark adapted previous year's needles of Norway spruce trees sampled at various locations in Austria in August. V, A, Z as in Fig. 1. DW = needle dry weight. Details in TAUSZ & al. 1996.

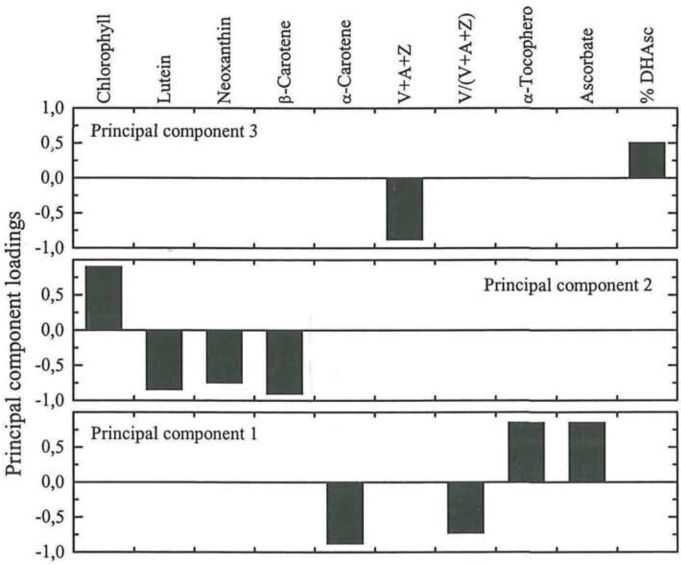

Fig. 3. Loadings of three resulting principal components by the originally measured variables. The dataset were 90 needle samples (previous year's and current, sampled in dark adapted stage) of field grown *Pinus canariensis* in Tenerife (Details in TAUSZ & al. 1998). Chlorophyll, tocopherol, and ascorbate (= total) are based on dry weight, carotenoids on chlorophyll contents. %DHAsc = percentage of oxidized ascorbate in total ascorbate. Only loadings with absolute values greater than 0.5 are drawn.

These responses of chloroplast pigments contain patterns underlying the originally measurable variables. A multivariate statistical approach (principal component analysis) reveals such accumulated variables (principal components). Fig. 3 shows the results of such an analysis on a collective of pine needles sampled in the field (TAUSZ & al. 1998).

Three of the four resulting components contained information on chloroplast pigments and are drawn in Fig. 3. The loadings indicate the contribution of the original items to the extracted component (0 = no contribution, ±1 = very strong). Component 2 reflects the light harvesting potency of the thylakoid system (total chlorophyll and light harvesting carotenoids). Component 1 refers to the redox state in the system (the antioxidants ascorbate and tocopherol, the xanthophyll conversions, and α-carotene, the most easily oxidized carotenoid). Component 3 contains the total pool size of the xanthophyll cycle and reflects its connection to the ascorbate system.

Such highly accumulated variables describe the concerted action of a biological system better than single variables. The present results indicate the three independent functions in which the different pigments participate to a different extent: Light harvesting, oxidative stress, and light protection potency.

Acknowledgements

Parts of this work were financially supported by the 'Forschungsinitiative gegen das Waldsterben, FIW II', WTZ Austria-Spain (Project number HU1997-0012), by the Heinrich-Jörg Foundation, Graz, and by the COST Action E6 (Eurosilva).

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