Phyton (Horn, Austria) Special issue: "Bioindication ..."	Vol. 36	Fasc. 3	(31)-(34)	15.09.96

The Use of Physiological Parameters of Spruce Needles as a Bioindication Tool

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Key words: *Picea abies*, stress responses, antioxidants, pigments, bioindication.

Summary

TAUSZ M., GRILL D. & GUTTENBERGER H. 1996. The use of physiological parameters of spruce needles as a bioindication tool. — Phyton (Horn, Austria) 36(3): (31) - (34).

This paper shows the results of the application of explorative statistical techniques to physiological data of spruce needles obtained in field studies. The data set was comprimed to six variables by principal-component analysis. Based on this new data set the trees were classified by cluster analysis. The results were in good accordance with original interpretations of the data of single case studies based on comparisons of physiological, aerochemical, and biochemical parameters. Classification of the trees according to these reproducible and objective algorithms allowed comparisons between different study areas. We found that response patterns were similar in high altitudes, but more different at valley sites of different locations.

Introduction

Various components of the antioxidative defence system (enzymes, low molecular weight antioxidants, carotenoids) were tested as bioindicators after their responses to various air pollutants were proved in fumigation experiments (MEHLHORN & al. 1986, BERMADINGER & al. 1990). However, the experimental results were not easily transferable to field conditions and the establishment of a reliable bioindication system based on physiological responses has not yet been successfully accomplished. Field studies were restricted to comparative evaluations of the results within a single study area (POLLE & RENNENBERG 1992, TAUSZ & al. 1994a). For the comparison of the physiological status of spruce trees from different evaluation of patterns of physiological parameters, instead of single variables, proved to be necessary.

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In this work we present a first example of the results of the application of explorative multivariate statistics on data obtained from various research projects in Austria in the last decade.

Material and Methods

Biochemical Analyses: Sample collection and biochemical analyses were carried out according to the methods described and cited in TAUSZ & al. 1994a and b. It was made sure that data were obtained under comparable conditions.

Data Set: The data set consisted of concentrations of ascorbic acid and water extractable thiols (major antioxidants), peroxidase activity, and total sulfur concentrations for the first two needle age classes, and pigment concentrations for four needle age classes. Pigment data comprise concentrations of neoxanthin, violaxanthin, antheraxanthin, lutein, zeaxanthin, chlorophyll a, chlorophyll b, α-carotene, and β-carotene as well as ratios of pigment groups (green to yellow pigments, xanthophylls/carotenes, α-carotene/β-carotene, xanthophyll-cycle). Samples were collected from 107 spruce trees (*Picea abies* (L.) KARST.) of six different locations in Austria (BERMADINGER-STABENTHEINER & GRILL 1992, TAUSZ & al. 1994a, 1994b).

Statistics: Principal component analysis (Variance maximizing normalized rotation of axes, KAISER criterion) was used to reduce the number of variables (LAWLEY & MAXWELL 1971). Among equally correct solutions we chose the one that could be interpreted best from a physiological point of view.

Cluster analysis (WARD's method, Euclidian distances) on this reduced, standardized data set completed the classifation of the trees (HARTIGAN 1975).

STATISTICA© (Copyright STATSOFT, USA 1994) software package was used for statistical calculations.

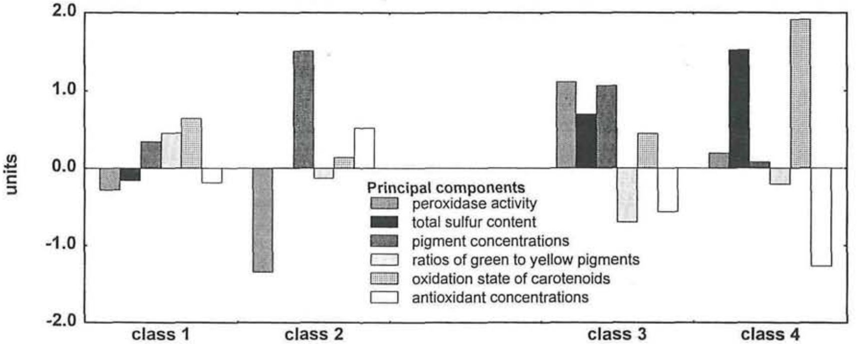

Fig. 1. Biochemical characteristics of four physiological classes of spruce trees described in two field studies. The ordinate is scaled in relative units with 0 representing the average of all trees in the analysis.

Results and Discussion

Principal component analysis allowed to reduce the number of variables to six components explaining more than 90% of the variance of the original data set. These physiologically meaningful components contained information about pigment concentrations, pigment composition, oxidation state of carotenoids, antioxidative capacity, sulfur content, and peroxidase activity (Fig. 1): Low pigment concentrations may be seen as an indicator for declining vitality (compare OREN & al. 1993) whilst depressed ratios of green to yellow pigments are interpretable as a sign for stress impact and a beginning of chlorosis (LICHTENTHALER 1993). High levels of antioxidants and peroxidase activity indicate a high antioxidative defence capacity and may occur as a response of vital trees to oxidative stress influences (POLLE & RENNENBERG 1992, TAUSZ & al. 1994a). Total sulfur content of the needles is a widely accepted indicator for sulfur dioxide burden on forests (compare TAUSZ & al. 1994b).

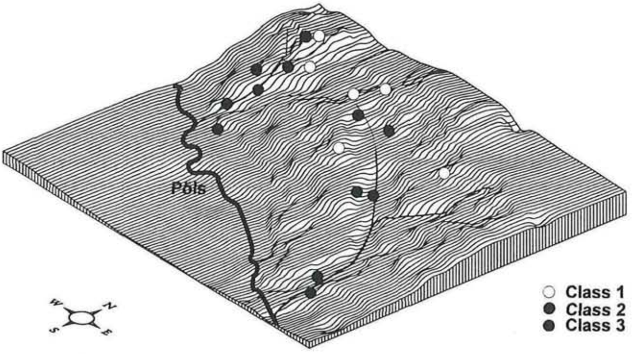

Fig. 2. Distribution of physiological classes of spruce trees (characterized according to Fig. 1) in the Pöls area (Styria, Austria, 47° 14' N, 14° 35' E).

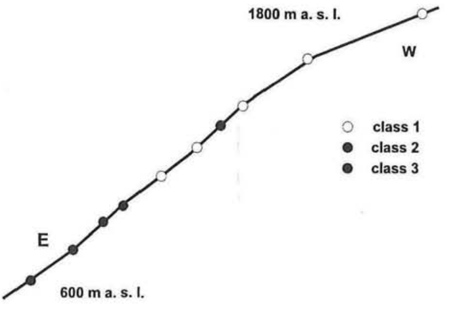

Fig. 3. Distribution of physiological classes of spruce trees (characterized according to Fig. 1) in the Zillertal area (Tyrol, 11° 51' E, 47° 12' N).

Four classes characterized by different patterns of parameters (Fig. 1) were established. Figures 2 and 3 show the spatial distribution of these classes in two investigated areas. Members of class 4 were observed only at low elevated sites of the Pöls area (Fig. 2). Biochemical characteristics of this class were in full accordance with previous interpretations of biochemical data of sulfur dioxide damaged trees (TAUSZ & al. 1994b): high sulfur contents together with low antioxidant concentrations, a high oxidation state of carotenoids, and low pigment concentrations (Fig. 1). At the Zillertal area (Fig. 3) the low elevated plots were occupied by spruce trees belonging to class 3. Compared to class 4, these trees exhibited comparably high sulfur content together with higher pigment contents and a lower oxidation state of carotenoids. In accordance with BERMADINGER-

STABENTHEINER & GRILL 1992 this pattern could be interpreted as a sign of a certain sulfur influence, but the trees were able to prevent damages. Spruce trees of class 1 were found on high elevation sites and showed the same characteristics at both areas (Fig. 2 and 3). They were characterized by relatively low pigment concentrations, low sulfur contents, and a slightly decreased antioxidative capacity together with a higher oxidation state of carotenoids were repeatedly ascribed to oxidative influences (BERMADINGER-STABENTHEINER 1994, TAUSZ & al. 1994a, b). Class 2 was represented by comparably 'un-stressed' trees according to the criteria discussed above.

The explorative data treatment provides supplementary information to the previous conclusions drawn from these case studies: spruce trees at high (and medium) elevation sites in different regions of Austria show the same physiological characteristics (classes 1 and 2 were observed in both areas). Reproducability and objectivity are essential for a classification of the described physiological patterns. Thus, it can be adapted for a computer-based expert system for the classification of physiological data.

Acknowledgements

Financial support by the Austrian 'Forschungsinitiative gegen das Waldsterben' (FIW II) and the Styrian Local Government and the help of J. GSPURNING (Institute of Geography, University of Graz) with the 3D-model of the Pöls area is gratefully acknowledged.

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