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Pre-dawn Water Potential and Nutritional Status of Pedunculate Oak (*Quercus robur* L.) in the North-East of Slovenia

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Summary

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In the 1997 growth period monthly measurements of pre-dawn water potential, electrical resistance of the cambial zone, groundwater level and quality together with annual dynamics of macronutrive elements in leaves and heavy metals (Zn, Pb, Cd) were performed. Two plots having different groundwater tables and crown defoliation were studied in the pedunculate oak forest complex (Querco Roboris-Carpinetum M. Wraber) in the north-east of Slovenia.
Results showed lower (more negative) values of pre-dawn water potential and higher values of cambial electrical resistance on the plot with greater crown defoliation, which also had a lower groundwater table.

Groundwater seems to be the key factor in the process of oak decline.

Introduction

The process of massive oak decline, typical in the last century, periodically or occasionally reappears in most European countries, in the USA and in Central Asia.

Several theories are explaining the decline as the combined effect of several factors; primary factors are abiotic and antropogenic ones and secondary

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biotic factors. (FÜHRER 1992, RÖSEL & REUTHER 1995, SIWECKI & UFNALSKI 1995).

If the reason for the decline of forests in the 70's and 80's was air pollution (ŠOLAR 1991), the researchers are not of the same opinion about the primary causes of today's »new age« decline of forests, where the symptoms are very similar to those in air pollution, but their geographical range is much wider.

Most probably there is not a single factor causing the decline of oaks. The complex of interactions among factors is specific to the environment; from the pathogenic point of view it is difficult to isolate one specific cause when climatic stress, industrial pollution and management mistakes are all present. Therefore it is important to define the main factor in every case and to study the physiological weakening process.

Over the century there was evident weakening and mortality of oaks in Slovenia, especially pedunculate oak (*Quercus robur* L.), which is a key tree species in lowland forests (SMOLEJ & HAGER 1995). The decline is most evident in the north-east of Slovenia, most likely because of the dryer climate, unfavourable precipitation distribution and severe hydromelioration causing changes in groundwater table (LEVANIČ 1993, ČATER 1997). Especially older and mature trees are under attack.

Decline in health is confirmed by an annual crown defoliation inventory on permanent research plots all over Slovenia (ČATER 1997).

In this research study we wanted to evaluate the degree of water stress, assuming that it is the main factor in the process of oak decline in this region. The major aims of the experiment were as follows:

- to define the connection between groundwater table dynamics and pre-dawn water potential;
- to define the connection between pre-dawn water potential, electrical resistance of cambial zone and crown defoliation;
- to establish drought stress in a controlled environment and to define wilting and permanent wilting point according to measured stress indicators and
- to connect physiological weakening and decline with the results of groundwater and foliar chemical analysis.

Material and Methods

Two research plots were established at Murska šuma near the town of Lendava with different degrees of declining trees. At both plots the soil is a deep eutric fluvisol and a Q.Robori-Carpinetum M. Wraber association is present.

Within each plot ten trees with a breast height trunk diameter over 40 cm were randomly chosen.

From March to September 1997 measurements of pre-dawn water potential (PWP) and electrical resistance of the cambial zone (ERCZ) were performed monthly on every tree. Crown defoliation in the time of full crown development was also estimated by the expert visual estimate used by method ICP Forest (ANONYMUS 1994).

For weekly measurements of the groundwater table and quality piezometers were placed in each research plot.

Measurements of pre-dawn water potential were performed from 4 AM to 5.30 AM with a pressure chamber (Plant Moisture Vessel SKPM 1400, Skye, G. Britain). All oak twigs were sampled at 25 m above ground. Four twigs per tree were considered as one measurement.

The electrical resistance of the cambial zone at breast height of the trunk was measured four times and the average value used for every tree. Method proved to be successful in case of determining tree vitality (BLANCHARD & al. 1983, TORELLI & al. 1996, ČUFAR 1997), by determination of decaying oak trees and their mineral nutrition (KOMLENOVIĆ 1996) and as indicator of microsite differences in forest stands (FERLIN 1993). Measurements were performed in the morning with a conditiometer (Bolmann Systeme, Rielasingen, Germany). Electrode orientation was always parallel to the trunk axis.

The crown defoliation estimate was performed to an accuracy of 5% from June to September by an expert visual estimate (ANONYMUS 1994). For comparative purposes the data from August were used, since estimates at other research plots with oaks in Slovenia were made in that month.

Groundwater analysis: pH (potentiometry); NO_3^-N, by ion chromatography; NH_4^-N by spectrophotometry (Nessler reag.); Pb, Cd and Zn by AAS (Pb, Cd by graphite furnace-AAS). Foliar analysis: N by the micro Kjeldahl method, P spectrophotometrically, K, Ca, Mg by AAS (with a flame); samples were mineralised by wet digestion at room pressure and quiet boiling temperature with nitric and perchloric acid (ANONYMUS 1994).

Parallel to field measurements a pot experiment took place with five year old oak seedlings. They were exposed to drought stress in controlled conditions - to three different watering regimes: 2x, 1x weekly and without watering. Net photosynthesis was measured in optimal light conditions in a greenhouse (170-200 mmol/m^2s), air temperature 31.4°C, relative air humidity 22% and 380-450mmol/mol of CO_2 in the air. Light conditions were under the saturation point, but nevertheless uniform for all seedlings. Measurements of pre-dawn water potential, and soil humidity were repeated at 10 day intervals. One serie consisted of 15 oak seedlings.

Data were analysed by the Statistica 5 and Excel 7 programs. Significant differences were tested with variance analysis and simple regression for the relation between measured parameters.

Results and Discussion

Pre-dawn water potential, electrical resistance of the cambial zone and crown defoliation

Results were compared between the two research plots, between months within each plot and between trees. Average values for every plot are presented in the following diagrams (Fig 1, 2).

Among oaks is pedunculate oak very sensible to the water stress (DICKSON & TOMLINSON 1996, COCHARD & al. 1996, TIMBALL & AUSSENAC 1996) and drought (THOMAS & HARTMANN 1996) as a preconditioning factor of oak decline. Physiological changes appear if water potential drops below – 1.5 MPa and significant ones below – 2.0 MPa (TYREE & COCHARD 1996).

Our analysis confirmed significant differences between the two plots, except in June and July. The wider variability of data could be connected with the different physiological activation of each tree. Water potential always showed more negative values on plot P1 with the lower groundwater table. The reason for less negative water potential in June and July with respect to March and April was the precipitation arrangement in 1997 (Fig. 3).

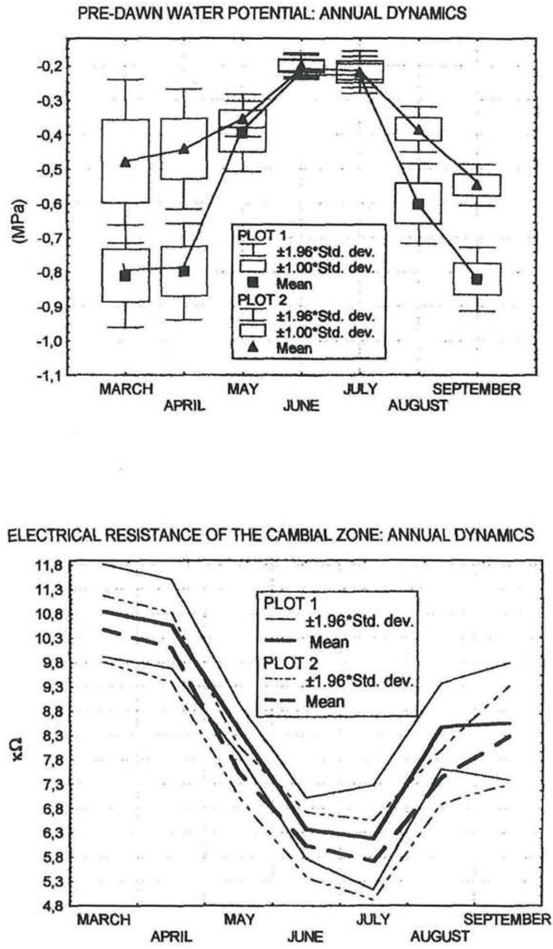

Fig. 1. Annual dynamics of water potential and electrical resistance of camb. zone on plots P1 and P2.

In the case of cambial electrical resistance, the differences between the plots were significant. Values were always higher on plot P1. Crown defoliation was also higher on plot P1; in August the difference between plot average values was 11%. (Fig. 2).

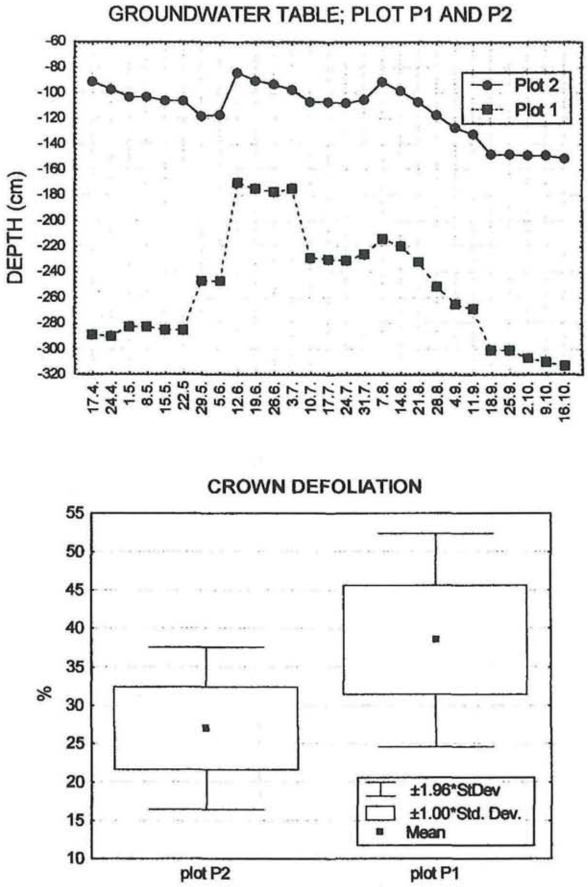

Fig. 2. Annual dynamics of groundwater table and crown defoliation on plots P1 and P2.

Comparison of field data confirmed the hypothesis about the connection between pre-dawn water potential and the groundwater table. The correlation was always higher on plot P1, with a lower groundwater table (rP1=0.76**, rP2=0.64*). The correlation between pre-dawn water potential and crown defoliation was also higher on plot P1.

Comparison of crown defoliation in August and the average pre-dawn water potential over the months March to September showed a stronger connection in periods of water stress conditions, especially at the beginning and at the end of the vegetation period.

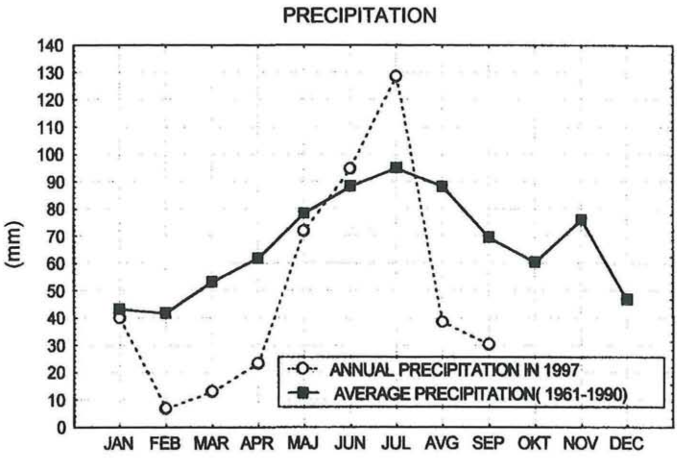

Fig. 3. Annual (1997) and average precipitation (1961-1990).

We can say that the water potential at the beginning of the vegetation period successfully indicates the degree of crown defoliation, if it is connected to water stress (Table 1).

Table 1. Correlation between PWP and crown defoliation.

MONTH	r_{P1}	r_{P2}
March	-0.69*	-0.63*
April	-0.43	-0.37
May	-0.07	-0.30
June	-0.67*	-0.21
July	-0.80**	-0.06
August	-0.89**	-0.53*
September	-0.92**	-0.74*

Significance:
5% ...*
1% ... **
0.1% ...***

The relation between the electrical resistance of the cambial zone and the groundwater table (rP1=0.85**, rP2=0.20), and between the average monthly predawn water potential for every plot (rP1=-0.93**, rP2=-0.81*) was always higher on plot P1. The experiment therefore confirmed significant differences between all of measured stress indicators when comparing plots P1 and P2.

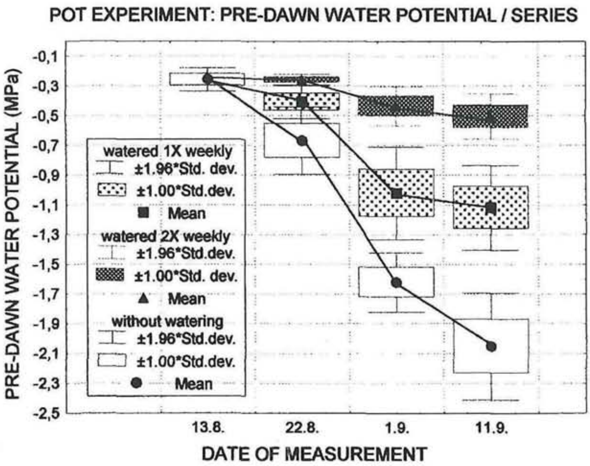

Fig. 4. Pot experiment: Pre-dawn water potential.

According to the experimental values of pre-dawn water potential, the wilting point was reached between 0.5 and 0.7 MPa and the permanent wilting point below 1.65 MPa. Similar results were obtained by DREYER & al. 1991, EPRON & DREYER 1993, VIVIN & al. 1996 and PICON & al. 1996. After the experiment 50 % of seedlings in the series without watering recovered, as well as all other seedlings. Comparison of field measurements and the pot experiment showed a slight indication of drought conditions in March, April and September.

Chemical groundwater and foliar analysis

Increased concentrations of nitrogen (NH_4^+ in NO_3^-) in groundwater and leaves at both plots can be connected with the vicinity of agricultural land and the process of eutrofication. The annual dynamics of potassium in leaves indicated the supply of water in trees very well, especially on plot P1. Other macronutrient (P, Ca, Mg) analysis showed optimal supply to the trees (SMOLEJ & HAGER 1995) on both research plots. In case of heavy metals the concentration of Pb and Zn were occasionally higher.

The experiment and analysis confirmed the hypothesis of the importance of the groundwater table and quality in the process of oak decline in the lowland forests of north-east Slovenia.

In spite of favourable water conditions in 1997, the differences between the two plots were statistically significant in regard to groundwater table. The change of groundwater table seems to be the most important stress factor at both plots, especially on plot P1. Therefore, groundwater table and quality may not be the only, but are certainly the most important site factors in the process of weakening and dying of the pedunculate oak.

Table 2. Groundwater and oak leaf analysis results for two research plots in Murska šuma (sampling period May-September 1997).

		Plot1					**Plot 2**				
Groundwater analysis		**Apr.- Sept.**					**Apr.- Sept.**				
pH		7.74-7.98					7.81-8.15				
NH_3	mg/l	1.60-2.63					0.5-2.27				
NO_3		4.10-18.2					4.1-11.95				
Pb	µg/l	0.63-32.04					0-6.29				
Cd		0-0.51					0-0.38				
Zn		91.1-758.3					110.1-577.1				
Foliar analysis											
N	(mg/kg)	23.0					24.8				
P		2.32					2.63				
Ca		9.91					9.90				
Mg		2.43					1.74				
	(Month)	5.	6.	7.	8.	9.	5.	6.	7.	8.	9.
K		1.74	0.96	0.99	0.99	1.26	2.47	1.28	1.42	1.20	1.22

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