FOLIA OECOLOGICA – vol. 40, no. 2 (2013). ISSN 1336-5266

Ecophysiological research of European beech (*Fagus sylvatica* L.) in high-productive mixed forests of the Poľana Mts in Central Slovakia

Tibor Priwitzer, Vladimír Čaboun

National Forest Centre, T. G. Masaryka 22, 960 92 Zvolen, Slovak Republic,
e-mail: priwitzer@nlcsk.org, caboun@nlcsk.org

Abstract

Priwitzer, T., Čaboun, V. 2013. Ecophysiological research of European beech (*Fagus sylvatica* L.) in high-productive mixed forests of the Poľana Mts in Central Slovakia. *Folia oecol*., 40: 243–250.

This paper presents the results of ecophysiological research of European beech (*Fagus sylvatica* L.) in high-productive mixed forests of the Slovak Poľana Mountain. This research was performed in the research and demonstration object Poľana - Hukavský grúň. The radiation, temperature and humidity regimes, as well as daily dynamic of photosynthetic activity and electric resistance of cambial tissue are presented within the whole beech crown profile. The impact of meteorological conditions on selected physiological processes was studied. The results confirmed close correlation between a diameter of trees $d_{1,3}$ and biofield, as well as between a biofield and cambial tissue's electric resistance. The considerable differences in CO_2 uptake within individual beech crown layers were determined.

Keywords

beech, cambial tissue, electric resistance, gas exchange

Introduction

The site conditions can be considered to be the determining complex of indices and factors from the point of view of quantity and quality of physiological processes in forest trees. Knowledge on time and spatial dynamic of individual characteristics within the whole forest ecosystem is necessary for quantification of impact of meteorological characteristics on photosynthesis and production processes, damage of foliage (frost, radiation, immissions), water and energy regime of tree species, etc.

This paper presents the results of ecophysiological research of European beech (*Fagus sylvatica* L.) – the tree species with the largest distribution in the Slovak forests. The main attention is paid to the impact study of site conditions on selected physiological processes (mainly photosynthetic activity and electric resistance of cambial tissue). This contribution is based on the results gained within the framework of ecological and ecophysiological research being realized in the research and demonstration object Poľana – Hukavský grúň.

Material and methods

Description of research plot

All measurements were done in the research and demonstration object (RDO) Poľana - Hukavský grúň which is a part of the Biosphere Reserve – Protected Landscape Area Poľana. The highest attention of research activity has been paid to the Permanent Research Plot – 0 (PRP 0) of which more detailed description, as well as the whole spectrum of problems being solved were published by Čaboun et al. (1996). Basic geographic, pedological, meteorological and typological characteristics of the RDO and PRP 0 are presented in (Table 1).

Measurement of meteorological characteristics and ozone concentration

All meteorological characteristics within the PRP 0 were continuously measured and recorded to the data logger (DELTA T). The following meteorological characteristics were measured: air temperature (Ta) and rel-

Table 1. Selected characteristics of the RDO Poľana – Hukavský grúň and the PRP 0

Characteristics of RDO		Characteristics of PRP – 0 (area 0.55 ha)		
Orographic unit	Poľana	Elevation	850–860 m	
District	Detva	Slope	5–15 %	
Forest Enterprise	Kriváň	Stand age	90–120	
Forest Administration	Poľana	Number of trees	342	
Elevation	820–915 m	Tree species	Beech	70.0 %
Exposure	North-east		Spruce	19.6 %
Slope	5–35 %		Sycamore maple	4.6 %
Geological substrate	Volcanic		Fir	3.5 %
Forest Management	Beech forests (411)		Ash	2.0 %
Type Group fertile	Fertile fir beech		Aspen	0.3 %
	Forests (511)	Canopy	90	
Number of PRP	8	Forest type	nitrophilous fir beech forest (5302)	
		Soil type	Ando-eutric Cambisol	

ative air humidity (RH) (0.3 m, 6 m, 29, 34, 46 m above the soil surface), soil temperature (Ts) (depth 0, 5 and 10 cm), global radiation (Q) (34 m), photosynthetically active radiation (PhAR) (37 m, 32 m, 29 m, 19 m above soil surface), precipitation (34 m), wind direction (46.5 m), wind speed (46.5 m, 38.8 m, 37m). More detailed technical parameters of meteorological measurements were published by Čaboun et al. (1996).

A daily dynamics of Ta, RH was determined for three height levels (34, 29, 6 m). The amount of incident PhAR upon the forest stands was calculated from the values of Q according to the relations presented by Rovňáková (1986). The values obtained by this method were consequently quantified for individual height levels on the basis of direct measurements (cloudless days with typical daily course of PhAR).

In addition to meteorological characteristics, the concentrations of atmospheric ozone (O_3) were continuously measured above the stand. The analyzer ML 8810 (based on UV photometry) was used. The ozone concentrations were calculated according to Lambert–Bersch rule. More detailed methodology of atmospheric quality measurement in PRP 0 is presented by Čaboun et al. (1996).

Determination of photosynthetic activity of beech foliage – ecophysiological measurements were realized on representative co-dominant beech (diameter $d_{1,3} = 49$ cm and height 35 m.). Its crown was divided into three separate crown layers (upper 32 m, central 29 m, lower 19 m from soil surface) on the basis of the previous measurements of leaf area, anatomical leaf structure, density of stomata, chlorophyll content (Priwitzer et al., 1996), as well as the incident PhAR.

For determination of photosynthetic activity was used the portable photosynthetic system Li-6200 (Licor, Nebraska, USA). The detailed description of instrument and method of work with it was published by Priwitzer (1993, 1998). All measurements were performed directly in the crown space using the tower. The measurements were usually performed from June to September during favourable weather (days without precipitation) on physiologically mature leaves (leaves in phenophase of adult leaf) and ambient CO_2 concentration (330–350 ppm). Daily dynamic of photosynthetic activity was determined by two methods as follows:

- Measurement of CO_2 exchange in hourly intervals for upper part of crown (sun type of leaves). More detailed methodology was published by Priwitzer et al. (1996).
- Calculation using light response curves (relation of photosynthesis and PhAR intensity) determined on the basis of direct measurement, as well as conversed for individual crown layers according to the methodology presented by Marek et al. (1989), Marek et al. (1992) and Pirochtová and Marek (1991).

Measurement of electric resistance of cambial tissue – within the framework of observing the relative tree vitality was used the TREE VITALITY METER – TVM 01. It is a portable electronic instrument for determination of health condition of standing trees, and occasionally damage of wood mass, operating on principle of electronic measurement of cambial layer resistance and wood tissue respectively. Air temperature is being scanned by thermal sound. The 24-hour dynamic, as well as seasonal resistance dynamic were finding out. More detailed methodology of measurement of forest trees' cambial resistance was published by Čaboun (1994, 1997). Measurement of tree species biofield – a magnitude of tree species biofield was measured in sense of the methodology published by Čaboun (1993).

Results

As an example of beech ecophysiology we present the measurement performed on warm summer day with all-day occurrence of cumuliform cloudiness.

Radiation regime – the curve of global radiation showed typical daily course with the values around 900 Wm^{-2} between 10 a.m. and 2 p.m. (daily max. 950 Wm^{-2} around the midday). Daily course of ozone concentration has slightly upward character with maximal values (58–63 ppb) between 2 p.m. and 4 p.m. At that time, the maximal values of air temperature were measured (Fig.1).

The daily dynamic of PhAR above the stand has a similar character as for global radiation. Changes in intensity and amount of PhAR in crown space are showed in the Fig 1. The individual daily course differs significantly in certain parts of crown and during the day. While PhAR in the upper part of crown showed very similar daily dynamic like above the crowns (max. – 1,397 µE m^{-2} s^{-1} around the midday), in central part of crown (29 m) the max. daily value of PhAR (1,085 µE m^{-2} s^{-1}) was recorded between 7 a.m. and 8 a.m. Fairly balanced intensity of PhAR characterized the lower part of the crown during the whole day. An increase of PhAR was recorded only in very short periods of time, while maximal daily values (520 µE m^{-2} s^{-1}) were found out between 8 a.m. and 9 a.m. As regards a decrease of PhAR amount, due to its penetration through the crown (Fig. 1), it can be observed for selected part of the day, that 95% of PhAR from the amount measured above the crown was found out in the upper part of crown at 8 a.m., 61% at midday, and 39% at 6 p.m. Within the central crown layer the values of PhAR reached 50, 42 and 8% of values measured above the crown resp. 11%, 5% and 2% in the lowest part of crown. Similarly there was found out that in the upper part of crown 70% of PhAR values were in the interval of 500–200 µE m^{-2} s^{-1}, while in the lower layer 70% of values in the interval of 0–50 µE m^{-2} s^{-1} during the day.

Temperature and humidity regime – daily course of air temperature and air humidity above the stand, as well as in the individual layers of the stand is shown in the Figure 2. Air temperature (Ta) in all height layers has gradually increased since early morning and it reached maximal daily values (from 18.7 to 20.4 °C)

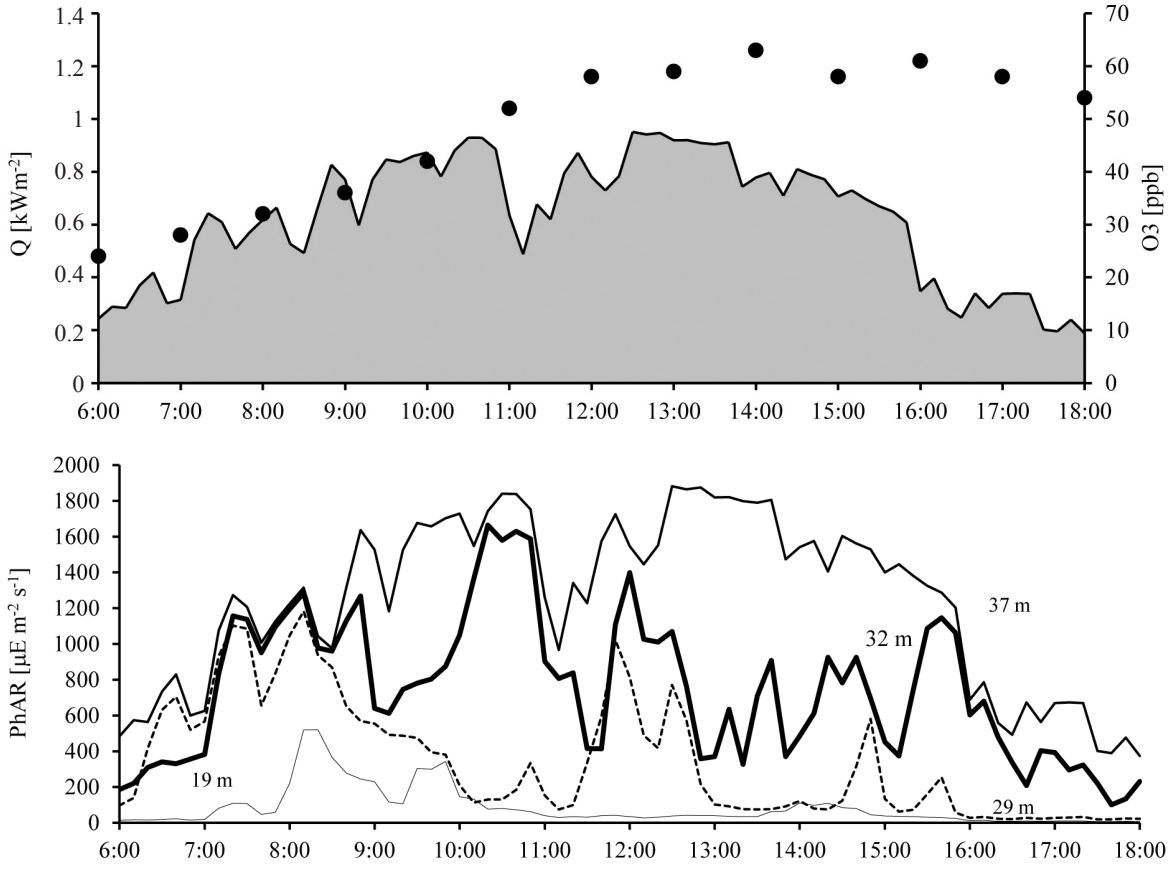

Fig. 1. Daily course of global radiation (Q) and ozone (O_3) concentration above the forest stand (34 m) and PhAR measured in 37, 32, 29, 19 m above the forest floor.

at around 3 p.m. The highest values of Ta during the day were measured in the height of 34 m above the surface of soil. It is a consequence of quicker warming of air layer in the area immediately above the crowns and followed radiation of crowns' active surface within the infrared range of spectrum.

Air humidity (RH) was fairly constant (80%) during the period between 6 a.m. and 10 a.m. in the whole vertical profile of the stand. After that time we recorded its decrease while minimal daily values (48–57%) it reached in all height layers at around 3 p.m. The lowest RH values were measured in 37 m, between 10 a.m. and 6 p.m.

Photosynthetic activity of individual parts of the crown – daily dynamic of CO_2 (A_N) uptake determined for individual parts of the crown is shown in the Figure 3. When we look at the course of measured values (Fig. 3 – right), we find out the considerable differences in CO_2 uptake in individual crown layers.

While assimilation apparatus reached maximal daily values A_N (8.09 µmol CO_2 m^{-2} s^{-1}) at around 11 a.m. in the upper part of the crown (sun type of leaves), in lower part of crowns (shade type of leaves) it was between 8 a.m. and 9 a.m. In the central crown layer (occurrence of both types of leaves), the maximal daily values A_N (4.37 µmol CO_2 m^{-2} s^{-1}) were found out at around the midday. A considerable depression of CO_2 uptake was recorded mainly in the central (at around 2 p.m.) and lower (between 11 a.m. and 1 p.m.) part of the crown. After a decrease of CO_2 uptake we recorded more considerable increase of A_N value (crown centre at around 3 p.m., lower part at around 2 p.m.) in the both crown layers. Significant decrease of CO_2 uptake in all layers of the crown occurred after 4 p.m. When comparing the maximal values A_N we can find out that central part of the crown reaches 49% and in lower crown part only 28% of A_N of the upper crown part.

When assessing the daily dynamic of CO_2 uptake (sun leaves) obtained on the basis of direct measurement we recorded certain differences in comparison with simulated daily dynamic. While in direct measurement the daily maximum was between 6 a.m. and 8 a.m., and after that there occurred the consequent whole day decrease of values A_N, in case of simulated determination of A_N the daily maximum was between 10 a.m. and 11 a.m., and values of CO_2 uptake were fairly constant during the bigger part of the day (7 a.m.–3 p.m.).

Electric resistance of cambial tissue – daily course of electric resistance of cambial tissue in the investigated beech is given in the Figure 4. From the values measured in various cardinal points we can see that values of electric resistance of cambial tissue have similar daily dynamic, however, the values of resistance measured in northern direction are higher than in three other direc-

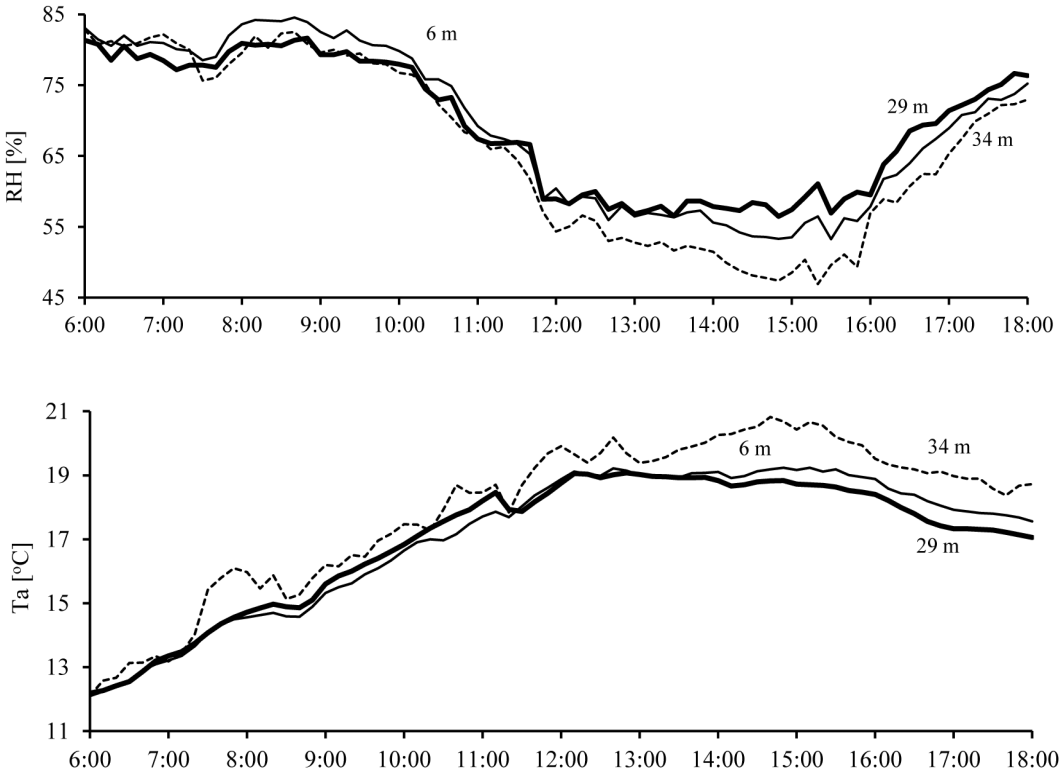

Fig. 2 Daily course of air humidity and air temperature, measured in height of 34, 29, 6 m a bove the forest floor.

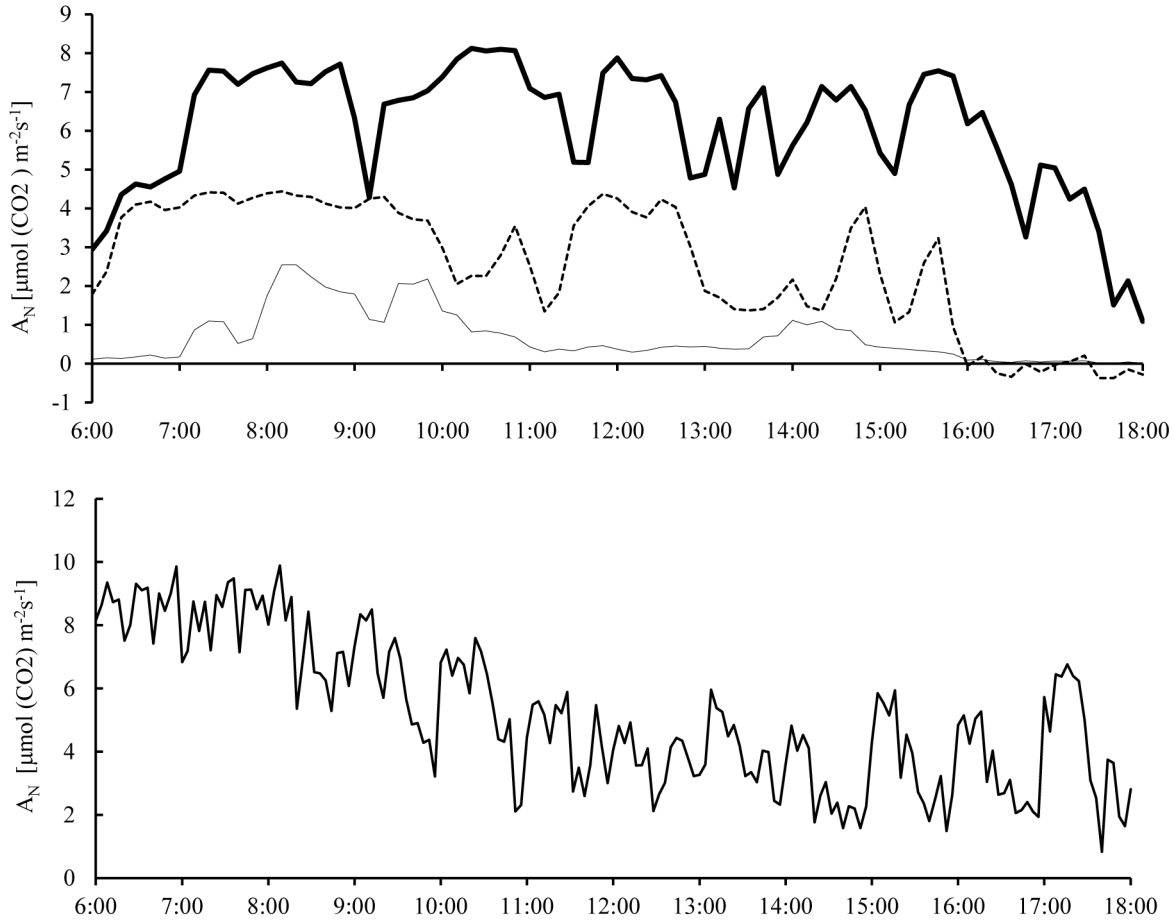

Fig. 3. Daily dynamic of CO_2 uptake (A_N) simulated for upper (32 m), middle (29 m) and lower (19 m) part and measured in upper (32 m) part of beech crown.

tions. The increased resistance of tissues in the north side has been significantly expressed also in average values. The difference between average values of electric resistance of cambial tissue calculated from three and four measured values can be seen in the Figure 4. The highest dependence between electric resistance of cambial tissue and air temperature was discovered.

Biofield of beech – the daily dynamic of biofield's value has not been expressed. The following values of biofield: 56 cm, 47 cm, 38 cm, 29 cm, 20 cm and 11 cm from the stem of the tree were recorded. On the basis of measured values we can determine a regular 9-centimetre interval, it means a wave course of biophysical component of observed beech's biofield.

Discussion

The daily dynamic of physiological processes can, according to Schulze and Hall (1982), provide the basic information on responses and adaptation of plants to the nature conditions of the environment. At the same time it is a reflection of effect of outside factors on individual physiological processes, as well as it can provide a great number of information about behaviour of tree species in their natural environment. Kozlowski et al. (1991) present that photosynthetic rate frequently varies between the tree species and their provenances, between the sun and shade type of leaves, during the day, as well as during the growing season. These variations are the result of interactions between the characteristics of plants such as leaf age, its structure and position, development of canopy, behaviour of stomata, amount and activity of Rubisco, as well as the factors of the environment such as light intensity, temperature, water supply, atmospheric CO_2 concentration, air pollutants and soil conditions. Larcher (2003) presents that the gas exchange rate, investigated directly under the conditions of the forest stand, is a result of mutual effect of number of internal factors and factors of the environment of which the specific effect can be recognized in a very difficult way. From the whole group of factors, one of them usually limits photosynthetic rate, while others support it further. We can see from the daily dy-

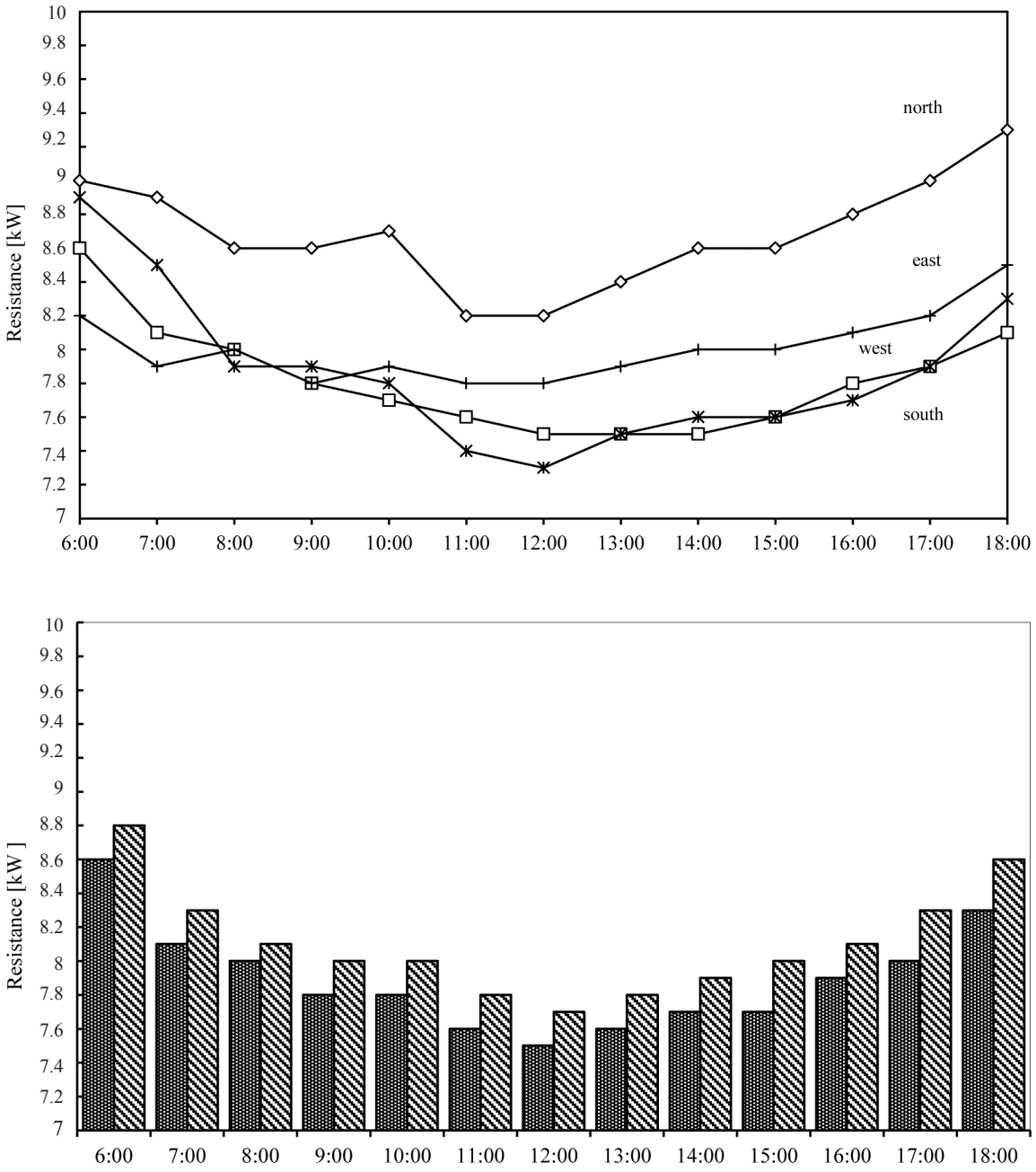

Fig. 4. Daily course of electric resistance of cambial tissue measured from north, east west and south direction and average values from 3 direction (dotted) and 4 direction (hatched) (E,W,S, N).

namic of selected physiological processes a close connection between individual processes and meteorological characteristics.

The daily dynamic of photosynthetic activity of beech leaves stated by simulation is decisively being determined by light conditions in the individual parts of tree crown. The reason is the fact that intensity of PhAR was considered in advance to be the main factor influencing the CO_2 uptake. The influence of other factors has not been considered since the measurements of dependence of PhAR – A_N were done at leaf temperature 20 °C and relative atmospheric humidity 60%. In addition, we can see from the daily dynamic of meteorological characteristics that Ta and RH have not reached the values which influence more considerably the CO_2 uptake in beech leaves (Schulze, 1970). As for the Ta, Schulze (1970) presented that max. values of A_N in mature beech leaves were measured at air temperature between 18–20 °C.

A favourable RH (80%), sufficient intensity of PhAR, as well as low ozone concentration can be considered a reason for the maximal daily values of A_N in

upper part of crown in the morning. The consequent whole-day decrease of CO_2 uptake, as well as the occurrence of considerable depression of photosynthesis between 11 a.m. and 3 p.m. could be caused by a high intensity of PhAR, reduction of RH, increase of leaf temperature (Čaboun et al., 1996), and by an increase of ozone concentration during this part of the day. For instance Masarovičová and Štefančík (1990), Xu and Shen (1996) present the high intensity of PhAR, low RH and high Ta as causes of midday depression of photosynthesis.

The most well–known dependence of values of cambial tree tissue's electric resistance, frequently denoted as relative vitality, is a dependence on diameter of measured tree. The dependence of values of cambial tissue's electric resistance on their diameter, was found out in observing the daily or seasonal dynamic of electric resistance within all cases. On the basis of our current and previous research results (Čaboun et al., 1993; Čaboun, 1994, 1997) we can state that the less diameter tree species has, the higher annual variability of values of cambial tissue' electric resistance is. Thus, tree species with lower diameter react more sensitively on the environment's influences. Similarly, daily dynamic in trees with bigger diameter is not so marked than in trees with low diameter. Considerably it has been expressed in all cases and had an opposite course than atmospheric temperature. We have found out a considerable correlation in all our measurements between temperature and electric resistance of cambial tissue. The closest correlation has been found out between electric resistance of cambial tree tissue and average maximal temperature calculated from maximal temperatures of three days before measuring the resistance. From the above mentioned follows that the resistance of cambial tissue is influenced more by three-day, mainly maximal temperature, resp. by the weather (where temperature plays a dominant role especially in beech) than moment temperature during measurement. On the basis of previous results we can state that since the yearly or seasonal dynamic of electric resistance is considerably higher than daily dynamic, the date of measurement is essentially more important than day's time.

We have found out, within our long-term measurements in a great sample of tree species, very close correlation between a diameter of trees $d_{1,3}$ and biofield (Čaboun, 1993; Čaboun et al., 1996). We have also found out a close correlation between biofield and electric resistance since it correlates very closely with diameter of measured tree species as well. In spite of certain variability of a magnitude of tree species biofield, considerable trend of biofield change during the year has not been expressed. From the measurements we can see that correlation between the magnitude of biofield and temperature of atmosphere does not exist as well. The differences in magnitude of biofield during the year and also during the day, however, are not so high that we could speak about the seasonal or daily biofield dynamic but only about average values of biofield individual levels. However, besides diameter and kind of tree species also site conditions and intraecosystem relations have an influence on a magnitude of tree species biofield. On the basis of our previous observations we can state that biofield of trees is not the same for each measuring man. When we proceed with the definition of allelopathy (Čaboun, 1990); each organism can react differently on biochemical and biophysical effect of other organism.

Acknowledgements

This work was supported by the Slovak Research and Development Agency under the contracts No. APVV-0608-10 and No. APVV-0111-10.

References

Čaboun, V. 1990. *Alelopatia v lesných ekosystémoch* [Alelopathy in forest ecosystems]. Bratislava: Veda, SAV. 120 s.

Čaboun, V. 1993. *Biopole lesných drevín* [Biofield of forest tree species]. Lesn. Čas. – For. J., 39: 415–425.

Čaboun, V. 1994. Sledovanie relatívnej vitality drevín elektrickou odporovou metódou [Research of tree species relative vitality by electric resistence method]. *Acta Fac. Ecol. Zvolen*, 1: 53–75.

Čaboun, V. 1997. Relative vitality of forest trees on research area Hukavský grúň in Biosphere reserve Poľana. *Ekológia (Bratislava)*, 6: 33–47.

Čaboun, V., Minďáš, J., Priwitzer, T., Štrba, S., Hladká, D., Šablatúrová, E., Tužinský, L, Škvarenina, J., Kukla, J., Meszároš, I., Molnár, Ľ., Zaušková, J., Konôpka, M., Ferjenčík, L., Slivková, E. 1996. *Výsledky ekologického a ekofyziologického výskumu lesných ekosystémov na Výskumno – demonštračnom objekte Poľana Hukavský grúň* [Results of ecological and ecophysiological research of forest ecosystems in the research and demonstration object Poľana – Hukavský grúň]. Lesnícke informácie, č. 1. Zvolen: Lesnícky výskumný ústav. 82 p.

Kozlowski, T.T., Kramer, P.J., Pallardy, S.G. 1991. *The physiological ecology of woody plants*. New York: Academic Press. 657 p.

Larcher, W. 2003. *Physiological plant ecology*. Berlin, Heidelberg: Springer-Verlag. 513 p.

Marek, M., Masarovičová, E., Kratochvílová, I., Eliáš, P., Janouš, D. 1989. Stand microclimate and physiological activity of tree leaves in oak-hornbeamforest. II. Leaf photosyntetic activity. *Trees*, 4: 243–240.

Marek, M., Pirochtová, M., Marková, I. 1992. Production activity of mountain cultivated Norway spruce stands under the impact of air pollution. II. Vertical distribution of photosynthetic activity in the stand canopy. *Ekológia (Bratislava)*, 11: 121–132.

Masarovičová, E., Štefančík, L. 1990. Some ecophysiological features in sun and shade leaves of tall beech trees. *Biol. Plant*., 32: 374–387.

Pirochtová, M., Marek, M. 1991. Metoda matematického vyhodnocování fotosyntetické aktivity lesních dřevin [Evaluation of photosynthetic activity of forest trees by mathematical method]. *Lesnictví*, 37: 399–408.

Priwitzer, T. 1993. Prenosný fotosyntetický systém Li 6200 a jeho využitie v lesníckom ekologickom výskume [Portable photosynthetic system Li 6200 – using for forest ecological research]. In Kamenský, M. (ed.). *Lesníctvo a výskum v meniacich sa ekologických a ekonomických podmienkach v Slovenskej republike. Zborník z jubilejnej konferencie LVÚ. 2. sekcia*. Zvolen: Lesnícky výskumný ústav, p. 216–221.

Priwitzer, T. 1998. Denná dynamika výmeny CO_2 a H_2O slnných listov buka lesného (Fagus sylvatica L.) pri rôznych meteorologických situáciách [Daily dynamics of CO_2 and H_2O exchange in sun beech leaves during different meteorological conditions]. In Škvarenina, J., Minďáš, J., Střelcová, K. *Atmosférická depozícia a ekofyziologické procesy v ekosystémoch. Zborník referátov z medzinárodného pracovného seminára, Poľana 12.–13. jún 1996.* Zvolen: Technická univerzita, p. 201–208.

Priwitzer, T., Šablatúrová, E., Hladká, D. 1996. Vybrané fyziologické a biochemické charakteristiky asimilačného aparátu buka [Selected physiological and biochemical characteristics of beech foliage]. *Lesn. Čas. – For. J*., 42: 371–380.

Rovňáková, A. 1986. *Fotosynteticky aktívne žiarenie* [Photosyntetically active radiation]. Diploma work. Bratislava: Comenius University in Bratislava, Faculty of Mathematics and Physics. 57 s.

Schulze, E.D. 1970. Der CO_2-Gaswechsel der Buche (Fagus sylvatica L.) in Abhängigkeit von den Klimafaktoren im Freiland. *Flora*, 159: 177–232.

Schulze, E.D., Hall, A.E. 1982. Stomatal responses water loss and CO_2-asimilation rate of plants in contrasting environments. In Lange, O.L., Nobel, P.S., Osmond, C.B., Ziegler, H. (eds). *Physiological plant ecology II.* Encyclopedia of plant physiology, new series, vol. 12B. Berlin, Heidelberg, New York: Springer-Verlag, p. 181–230.

Xu, D.Q., Shen, Y.K. 1996. Midday depression of photosynthesis. In Pessarakli, M., (ed.). *Handbook of photosynthesis*. New York: Marcel Dekker, p. 451–459.

Received December 6, 2012
Accepted April 8, 2013