EFFECTS OF TEMPERATURE ON SELECTED PHYSIOLOGICAL PARAMETERS OF YOUNG BEECH TREES UNDER STRESS CONDITIONS

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Abstract

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We assessed physiological characteristics (chlorophyll *a* fluorescence, photosynthetic pigments) of shade leaves of the beech (*Fagus sylvatica* L.) in (measured 1, 2, 3, 7 and 14 days before the leaf sampling). The study was performed in two locations under different pollution load. The leaf characteristics were observed on 15 year old trees from the understorey. We identified a significant negative influence of the temperature difference related to the long term average (25 years) on the basic fluorescence (F_0) and a positive influence of deviation of maximum temperatures from the long term average on the ratio of the variable to maximum fluorescence (F_v/F_m). These trends were observed for short time periods (1–3 days) and they were mainly true for parameters measured on upper (adaxial) side of assimilatory organs of trees at both localities. In the photosynthetic pigments it is significant influence of the deviation of maximum temperatures measured one day before the leaf sampling on the pigment content values (mg.dm^{-2}) at both localities.

Key words: stress physiology, chlorophyll fluorescence, chlorophylls, temperature stress, *Fagus sylvatica* L.

Introduction

Within the influence of stress load on forest woody plants climate factors play a significant role. The resistance of woody plants against stress load can decrease owing to frequent air temperature extremes, overall increase of temperature, decrease of precipitation totals and their non-uniform distribution. All these factors result in an increasing frequency and intensity of dry periods in Slovakia.

Climate is an important factor influencing physiological and production processes in forest ecosystems. The expected global climate change will probably trigger a sequence of changes – not only in these processes themselves. They also will be reflected on the health state and the development processes in forest communities. The most frequently mentioned stress factors influencing the forest ecosystems in association with the global climate change are the following ones: increasing CO_2 concentration, increasing mean temperature, changes in precipitation amount and distribution followed by changes in water balance, increasing intensity of UV-B radiation, changes in frequency and intensity of extreme phenomena (extremely dry or cold periods, drought, etc.) (Landsberg et al., 1993). The analysis of the basic climate characteristics of the main vegetation altitudinal zones in the Western Carpathians (Škvarenina, Tomlain, 2000) in terms of their water balance and their changes under the changing climate extrapolated up to 2075 showed that in the future, the main limiting factors in lower vegetation altitudinal zones (1st to 3rd, and partially also the 4th) will be the precipitation and a high evapo-transpiration in the summer. These changed bioclimatic conditions will endanger the present forest communities, stand composition, primarily the presence of beech.

The aim of this contribution was to evaluate the influence of temperature stress (maximum and minimum values in comparison to a value of the long-term mean) on selected physiological characteristic's in beech assimilatory organs. We compared the trees growing at two localities with different pollution-ecological loads and tried to identify the effect of temperature as a stress factor deteriorating the physiological state of a given tree (of impact short-term and medium-term stress).

Materials and methods

The first experimental plot is in forest stand No. 289 situated in the Žiarska kotlina (north of the Štiavnické vrchy Mts) near an Aluminium plant, Žiar nad Hronom (Central Slovakia). The second plot belongs to the Ecological Experimental Station (EES) of the Institute of Forest Ecology situated in the Kremnické vrchy Mts. A detailed description of the plots can be found in our previous paper (Ditmarová, Kmeť, 2002).

At both localities there were selected five individuals of beech (*Fagus sylvatica* L.) aged approximately 15 years (in 1996). The sample of the trees were situated under the crown cover. The sampling has not included the trees growing on the research plot boundary and near the footpaths. During the growing seasons 1996-2000, assimilatory organs from beech samples were collected at both localities always on the same day of the corresponding year. For each year the plant material was sampled 8-10 times (from May to October). In total, 33 measurements were accomplished.

Chlorophyll *a* fluorescence measurement: We measured the chlorophyll fluorescence on two branches from each individual sample of the tree. Measurements were carried out both on the adaxial and abaxial leaf sides. To determine the parameters of rapid kinetics of chlorophyll *a* fluorescence (F_0, F_m, F_v, F_v/F_m, T_m, Area - nomenclature by Kooten, Snel, 1990), we used a portable fluorometer (Plant Efficiency Analyser - PEA, Hansatech Ltd., Kings Lynn, UK). A recording interval of 1 second was chosen. Before the measurement, leaves were kept for 30 minutes for dark adaptation under leaf clamp cuvettes. Measurements were performed at a 50 % level of light energy saturating intensity (2100 mmol m^{-2} s^{-1}). A detailed description of the measuring equipment is given in Kmeť (1999).

Quantitative analysis of pigments: Chlorophyll analyses were carried out in 80 % acetone-water extracts. The chlorophyll *a*, *b*, and *a+b* contents of the extracts were determined spectrophotometrically. The concentrations of the chlorophyll *a*, chlorophyll *b*, and chlorophyll *a+b* (caltulated according to Lichtenthaler, 1987) were related to the both dry-mass ($mg.g^{-1}$) and leaf area unit's ($mg.dm^{-2}$).

Statistical evaluation of the results

The temperature stress was assessed as the deviation (positive or negative) of the actual maximum, minimum or mean daily temperatures at the day of measurement of physiological traits or at days before this measurement from the long-term daily average temperature. Long-term daily mean temperatures were calculated as an mean over the period of 25 years (measurements at the standard meteorological stations Sliač (Kremnické vrchy Mts) and Žiar nad Hronom (Žiarska kotlina basin), which are the most closely located to sample plots, were available for the period 1964–1988). Since these 25-year averages exhibited still random oscillations among days, the course of normal temperatures was smoothed by 5-day sliding averages. For each particular day within the observation periods, the following parameters were calculated:

$$D_1(i) = T_{max}(i) - T_{norm}(i),$$

$$D_2(i) = T_{min}(i) - T_{norm}(i),$$

where $T_{max}(i)$ is the maximum daily temperature of the *i*th day, T_{min} is the minimum daily temperature of the *i*th day, and $T_{norm}(i)$ is the 5-day sliding average of the 25-year long-term daily temperature of the *i*th day. The 25-year averages of daily maximum and minimum temperatures showed considerable oscillations, which could not satisfactorily be smoothed by sliding averages, but their course during the observation periods was essentially the same as that of mean daily temperatures. Nevertheless, we wanted to account for the effects of temperature extremes which may have occurred within the daily course of temperature. Since the long-term averages of the daily temperature minima and maxima (which would be the most logical comparison level) were unavailable, we calculated the parameters $D_1(i)$ and $D_2(i)$ related to the mean daily temperatures of particular days. The higher is the absolute value of D, the stronger is the stress affecting the sampled trees, whereby high positive values of D indicate that the plant was stressed by a temperature higher than expected at the day *i* (the expectation is defined by the long-term average), whereas high negative values mean that the *i*th day was colder than expected.

The correlations of the assessed physiological traits (chlorophyl fluorescence kinetics and chlorophyll content) with the parameters D of the measurement day *i* were not estimated, because of the temperature differences are (in case of the mean daily temperature) or may be (in case of extreme temperatures) affected by the course of temperatures after the measurement of physiological traits was performed. We defined two sets of stress parameters (Table 1, Fig. 1). The parameters $D_j(1)$, $D_j(2)$, and $D_j(3)$ reflected the effect of immediate or short-term stress which the trees were exposed to shortly before the physiological measurements (mean temperature differences D over 1, 2 or 3 days before the day of measurement), whereas the parameters $D_j(7)$ and $D_j(14)$ characterized the medium-term

Table 1. The assessed parameters of the temperature stress

Maximum temperature	Minimum temperature
Parameters of the short-term stress	
$D_1(1) = \Delta_1(i\text{-}1)$	$D_2(1) = \Delta_2(i\text{-}1)$
$D_1(2) = (\Delta_1(i\text{-}1) + \Delta_1(i\text{-}2))/2$	$D_2(2) = (\Delta_2(i\text{-}1) + \Delta_2(i\text{-}2))/2$
$D_1(3) = (\Delta_1(i\text{-}1) + ... + \Delta_1(i\text{-}3))/3$	$D_2(3) = (\Delta_2(i\text{-}1) + ... + \Delta_2(i\text{-}3))/3$
Parameters of the medium-term stress	
$D_1(7) = (\Delta_1(i\text{-}1) + ... + \Delta_1(i\text{-}7))/7$	$D_2(7) = (\Delta_2(i\text{-}1) + ... + \Delta_2(i\text{-}7))/7$
$D_1(14) = (\Delta_1(i\text{-}1) + ... + \Delta_1(i\text{-}14))/14$	$D_2(14) = (\Delta_2(i\text{-}1) + ... + \Delta_2(i\text{-}14))/14$

i – the day of the measurement of physiological parameters

stress, which affected the sampled trees during a longer period (average temperature differences D over 1 or 2 weeks before the day of measurement).

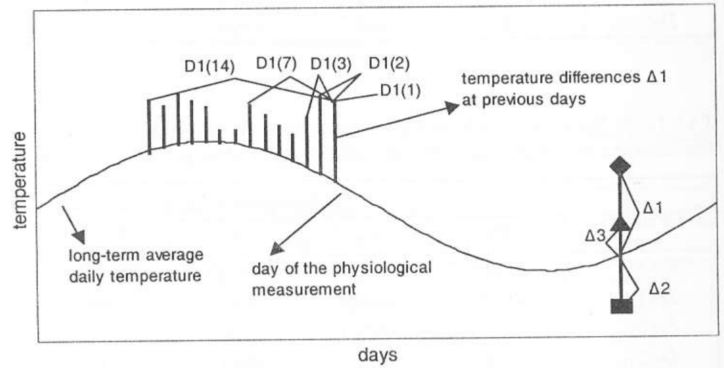

Fig 1. Illustration of the measured tempretature differences Δ and stress parameters D.

Since we supposed the relationships between the measured physiological traits and the calculated temperature stress parameters to be monotonous (the stronger is the stress, the stronger is the physiological response), but not necessarily linear, the existence and the strength of these relationships was assessed using Spearman's rank correlation coefficients.

Results and discussion

Table 2 illustrates an evident, highly significant ($\alpha = 0.001$) positive effect of short-term temperature stress – $D_1(1)$, $D_I(2)$ and $D_I(3)$ on the ratio of the variable to the maximum fluorescence values F_v/F_m from the abaxial side of the assimilatory organs at the EES in the Kremnické vrchy Mts. These temperatures have a similar role in the given trait also from the adaxial side of the assimilatory organs (Table 3).

In the studied period (1996–2000) there were no long lasting high temperature extremes. On the other hand, the high temperatures measured at the beginnings of growing seasons

T a b l e 2. Spearman´s rank correlation coefficients for the chlorophyll fluorescence in beech leaves (adaxial leaf side) and air temperature – EES Kremnické vrchy Mts ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$)

Temperature	Chlorophyll *a* fluorescence parameters					
	F_0	F_m	F_v	F_v/F_m	T_m	Area
$D_1(1)$	–0.394***	–0.100	–0.059	0.351***	–0.052	–0.056
$D_2(1)$	–0.296***	–0.049	–0.022	0.186*	–0.044	–0.064
$D_1(2)$	–0.251***	0.058	0.092	0.366***	–0.117	0.104
$D_2(2)$	–0.263***	–0.032	–0.008	0.195*	0.008	–0.066
$D_1(3)$	0.186*	0.104	0.136	0.364***	–0.056	0.150
$D_2(3)$	–0.209**	–0.001	0.015	0.186*	0.022	0.004
$D_1(7)$	–0.227**	–0.033	0.006	0.290***	–0.024	0.042
$D_2(7)$	–0.260**	–0.227**	–0.225**	–0.086	0.179*	–0.203**
$D_1(14)$	–0.371***	–0.265***	–0.229**	0.120	0.100	–0.202**
$D_2(14)$	–0.197*	–0.200**	–0.196*	–0.111	0.296***	–0.125

T a b l e 3. Spearman´s rank correlation coefficients for the chlorophyll fluorescence in beech leaves (abaxial leaf side) and air temperature – EES Kremnické vrchy Mts ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$)

Temperature	Chlorophyll *a* fluorescence parameters					
	F_0	F_m	F_v	F_v/F_m	T_m	Area
$D_1(1)$	–0.259***	–0.142	–0.119	0.239**	–0.007	–0.164*
$D_2(1)$	–0.199**	–0.120	–0.102	0.089	–0.082	–0.093
$D_1(2)$	–0.144	–0.021	0.000	0.258***	–0.015	0.006
$D_2(2)$	–0.202**	–0.134	–0.115	0.115	–0.010	–0.103
$D_1(3)$	–0.125	–0.007	0.015	0.258***	0.024	0.032
$D_2(3)$	–0.161*	–0.101	–0.085	0.125	0.018	–0.055
$D_1(7)$	–0.159*	–0.048	–0.028	0.237**	0.004	0.025
$D_2(7)$	–0.281***	–0.285***	–0.279***	–0.093	0.154*	–0.201**
$D_1(14)$	–0.247**	–0.206**	–0.198**	0.076	0.086	–0.137
$D_2(14)$	–0.205**	–0.258***	–0.258***	–0.149	0.312***	–0.154*

1996 (5 June: 29.4°C), 1997 (21 May: 27.5°C) and 1998 (7 June: 32.6°C) could have an important role. Nevertheless, from the general viewpoint, the short-term as well as medium-term deviations of the maximum temperature values from the long-term average [$D_1(i)$] showed a positive correlation with the corresponding values of the parameter F_v/F_m.

It is should be stressed the significant negative correlation of the short term temperature stress - $D_1(1)$, $D_2(1)$, $D_1(2)$ and $D_2(2)$ with the basic fluorescence (F_0) from both adaxial and abaxial leaf sides. The correlation coefficients imply that the larger was the positive or negative deviation of the current temperature from the optimum, the lower was the corresponding value of F_0. It means that the effect of temperature stress was not such strong as to cause physiological damage (reversible or irreversible). It should be also stressed

T a b l e 4. Spearman´s rank correlation coefficients for the chlorophyll fluorescence in beech leaves (adaxial leaf side) and air temperature – Žiarska kotlina basin ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$)

Temperature	Chlorophyll *a* fluorescence parameters					
	F_0	F_m	F_v	F_v/F_m	T_m	Area
$D_1(1)$	–0.413***	–0.033	0.042	0.337***	–0.224**	–0.142
$D_2(1)$	–0.334***	–0.046	–0.014	0.207**	–0.122	–0.094
$D_1(2)$	–0.319***	0.019	0.075	0.300***	–0.223**	–0.050
$D_2(2)$	–0.345***	–0.099	–0.065	0.171*	–0.053	–0.111
$D_1(3)$	–0.270***	0.062	0.108	0.254***	–0.171*	0.012
$D_2(3)$	–0.292***	–0.062	–0.032	0.170*	0.028	–0.060
$D_1(7)$	–0.260***	–0.007	0.022	0.194*	–0.027	–0.078
$D_2(7)$	–0.272***	–0.242**	–0.220**	0.008	0.220**	–0.203**
$D_1(14)$	–0.313***	–0.173*	–0.155*	0.100	0.059	–0.265***
$D_2(14)$	–0.328*	–0.296***	–0.293***	–0.085	0.371***	–0.127

T a b l e 5. Spearman´s rank correlation coefficients for the chlorophyll fluorescence in beech leaves (abaxial leaf side) and air temperature – Žiarska kotlina basin ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$)

Temperature	Chlorophyll *a* fluorescence parameters					
	F_0	F_m	F_v	F_v/F_m	T_m	Area
$D_1(1)$	–0.194*	0.055	0.089	0.235**	–0.055	–0.160*
$D_2(1)$	–0.170*	–0.066	–0.056	0.088	–0.020	–0.076
$D_1(2)$	–0.067	0.118	0.130	0.191	–0.080	–0.067
$D_2(2)$	–0.169*	–0.115	–0.109	0.048	0.076	–0.103
$D_1(3)$	–0.002	0.182*	0.190*	0.184*	–0.017	0.014
$D_2(3)$	–0.150	–0.082	–0.076	0.067	0.157*	–0.054
$D_1(7)$	–0.107	0.137	0.157*	0.216**	0.064	–0.011
$D_2(7)$	–0.210**	–0.198**	–0.194*	–0.069	0.287***	–0.148
$D_1(14)$	–0.198**	–0.068	–0.052	0.102	0.104	–0.171*
$D_2(14)$	–0.198**	–0.254***	–0.265***	–0.108	0.375***	–0.140

that at the EES Kremnické vrchy Mts were the frost events in the study period detected twice (14.10. 1997: – 1.5°C; 24.5. 1998: –1.6°C). Especially, the frost in the end of May can be taken as an important stress co-factor. However, in this case we only dealt with an unique episode. In the parameter F_0 measured on the adaxial side of the assimilatory organs a significant negative effect of an average term temperature stress: $D_1(7)$–$D_2(14)$ was observed.

Similar trend was also evident in the influence of short-term temperature stress on the parameter F_v/F_m from adaxial side of assimilatory organs at the locality in Žiarska kotlina basin (Table 4). In the parameters from the abaxial leaf side, this effect was not such significant (Table 5). The occurrence of maximum temperatures was similar than at the EES Kremnické vrchy Mts. Un the five year period of measurement and sampling in the Žiarska

T a b l e 6. Spearman´s rank correlation coefficients for the photosynthetic pigments in beech leaves and air temperature – EES Kremnické vrchy Mts (*p < 0.05, **p < 0.01, ***p < 0.001)

Temperature	Chlorophylls						
	Chl *a*	Chl *b*	Chl *a+b*	Chl *a/b*	Chl *a*	Chl *b*	Chl *a+b*
	[mg.g^{-1} d.m.]	[mg.g^{-1} d.m.]	[mg.g^{-1} d.m.]		[mg.dm^{-2}]	[mg.dm^{-2}]	[mg.dm^{-2}]
$D_1(1)$	0.191*	0.155*	0.191*	–0.012	0.238**	0.216**	0.228**
$D_2(1)$	–0.013	0.054	0.009	–0.164*	0.077	0.121	0.087
$D_1(2)$	0.035	0.064	0.047	–0.104	0.085	0.098	0.082
$D_2(2)$	–0.098	0.001	–0.069	–0.194*	0.024	0.095	0.038
$D_1(3)$	–0.007	0.089	0.020	–0.193*	0.037	0.084	0.040
$D_2(3)$	–0.137	–0.035	–0.107	–0.191*	–0.004	0.072	0.010
$D_1(7)$	0.008	0.124	0.042	–0.228**	0.095	0.162*	0.111
$D_2(7)$	–0.175*	–0.055	–0.141	–0.199**	–0.076	0.005	–0.056
$D_1(14)$	0.039	0.038	0.045	–0.035	0.151*	0.156*	0.157*
$D_2(14)$	–0.254***	–0.159*	–0.224**	–0.131	–0.177*	–0.083	–0.152*

T a b l e 7. Spearman´s rank correlation coefficients for the photosynthetic pigments in beech leaves and air temperature – EES Kremnické vrchy Mts (*p < 0.05, **p < 0.01, ***p < 0.001)

Temperature	Chlorophylls						
	Chl *a*	Chl *b*	Chl *a+b*	Chl *a/b*	Chl *a*	Chl *b*	Chl *a+b*
	[mg.g^{-1} d.m.]	[mg.g^{-1} d.m.]	[mg.g^{-1} d.m.]		[mg.dm^{-2}]	[mg.dm^{-2}]	[mg.dm^{-2}]
$D_1(1)$	0.182*	0.071	0.163*	0.124	0.269***	0.205**	0.266***
$D_2(1)$	0.042	–0.073	0.026	0.056	0.148	0.127	0.151
$D_1(2)$	0.112	0.049	0.107	0.025	0.155*	0.142	0.162*
$D_2(2)$	–0.015	–0.125	–0.031	0.068	0.058	0.029	0.057
$D_1(3)$	0.081	0.060	0.084	–0.014	0.124	0.156*	0.140
$D_2(3)$	–0.061	–0.134	–0.068	0.020	0.011	0.011	0.014
$D_1(7)$	0.098	0.069	0.100	0.011	0.145	0.198*	0.166*
$D_2(7)$	–0.057	–0.192*	–0.082	0.144	0.007	–0.030	0.004
$D_1(14)$	0.065	–0.038	0.044	0.084	0.095	0.068	0.093
$D_2(14)$	–0.145	–0.241**	–0.165*	0.131	–0.059	–0.109	–0.074

kotlina basin we detected negative temperature values at two dates (29. 9. 1997: – 0.2°C; 24 .5. 1998: – 0.8°C). The responses of the fluorescence (F_0) to the medium-term temperature stress at this site were significantly negative both at adaxial and abaxial leaf sides [D_1 (7)–D_2 (1)].

Noticeable is also a significant influence of the short-term temperature stress - D_1(1) on the content of photosynthetic pigments expressed per leaf area unit (chlorophylls *a*, *b*, *a+b* in mg.dm^{-2}). This correlation being positive reflects the fact that the short-term response of beech trees to the temperature stress was in increasing pigment contents per leaf unit area. This fact points out that the effect of temperature ranged already within stress

limits, nevertheless, still without evident physiological damage on the photosynthetic organs. This is true for both studied localities – EES Kremnické vrchy Mts and Žiarska kotlina basin (Tables 6 and 7).

Our result showed that short and medium term temperature stress correlated with selected physiological stress biomarkers is not the determining negative site factor that was expected to worsen the physiological state of beech trees growing on the more loaded plot (Žiarska kotlina basin). During our five year (1996-2000) monitoring of the physiological state of beech trees at the EES Kremnické vrchy Mts and in the Žiarska kotlina basin we did non record either short-term or long-term extreme temperatures that could potentially caused irreversible physiological damage. The significant correlations between the stress characteristics (temperature deviations from the normal) and the fluorescence of chlorophyll *a* or the chlorophyll content expressed per mg.dm^{-2} reveal the dependence of these physiological characteristics on the observed temperature extremes. The results point out the stress response of the photosynthetic organs of beech trees growing at both localities. However, it is also necessary to consider the co-influence of the further negative factors (e.g. shortage in precipitation, disturbed mineral nutrition, pollution load, etc).

During the recent years, the tolerance and damage symptoms on beech trees in different pollution-ecological conditions was given a special attention. A more complex research on dynamics of damage on beech ecosystems in Slovakia as well as abroad is rather an exception than a rule. In addition, there are numerous unanswered theoretical and practical questions linked with the methods as well as with very various pollution-ecological conditions (Vacek, 1993).

Within the air-pollution effect on forest woody species in terms of the pollution load, the interaction between extreme values of the climate factors, primarily high and low temperatures, over-abundant PhAR and drought, plays a very important role, what results in the lowering of the stress resistance capacity of forest woody plants. Only a little attention is devoted to the temperature on leaf surface, which is a very flexible variable parameter. A considerable difference between the surface temperature of photosynthetic organs and air temperature is well known. Priwitzer (1999) reported that the leaf temperature in the lower part of beech trees ranged from 1.5 to 6.5°C lower than the leaf temperature in the upper part of beech – as a consequence of the lower sun irradiance uptake.

If the temperature evidently decreased below 0°C, the frost can induce changes in the membrane system of thylacoids. Regardless the light intensity, the damage on the whole chain of the electron transport can cause a decrease in the ratio of the variable and the maximum fluorescence amounts (F_v/F_m). According to Bolhar-Nordenkampf, Lechner (1988), at temperature below – 4°C are the photosynthetic membranes disintegrated. It follows that the highest sensitivity to fluctuations in temperature exhibit the thylacoid membranes of chloroplasts. The fluorescence characteristics (intensity, spectral competition, time dependence) provide a complex response to changes in the primary photosynthetic reactions; that means, also in the fluorescence induction curve, in association with the influence of extreme temperature values. Under laboratory condition, an air temperature 35-45°C resulted in a decrease in the PSII activity, in the denaturation of the pigment-protein complex connected with photolysis of water and with a stimulation of the cyclic transport of electrons about PSI. However, changes still remain reversible. Under conditions *in situ*, the reversibility is kept up to the air temperature of 40°C (Kmeť, 1999). At temperatures 50-60°C there is as important increase in permeability of chloroplast membranes and plasmalema, and the vesiculation of thylacoids occurred. At temperature values over 60°C, unambiguous cracking of thylacoids begins (Ilík, personal communication). According to several authors, the site between plastochinone and cytochrome b6 is considered to be the most sensitive for the electron transport in the primary photosynthetic processes (Špunda, personal information).

Šrámek (2000) analysed influence of climatic and meteorological factors on vitality of forest woody plants and on the ecological stability of the forest stands (primarily spruce and birch) and he found significant interactions between meteorological stress factors and immisions in strong loaded locations in the Krušné hory Mts. According to Masarovičová et al. (1996), the water retention capacity of the beech leaves at the EES Kremnické vrchy Mts (locality without any direct immision influence) was higher, that means the resistance of leaves against drought was higher than of the leaves in the Žiarska kotlina basin (pollution load) where the water mechanism seems to be disturbed by the air pollutant influence. The water retention capacity was at both the localities the highest in the sun leaves and the lowest in the leaves on understorey trees. This difference was very remarkable mainly in long lasting dry periods. According to Brestič, Olšovská (2001), the radiation excess, often linked with a high temperature and drought, are the most important environmental stress factor causing the mid-day depression in photosynthetic rate.

Unfavourable environmental conditions such as low temperatures, high light intensities, drought stress, air pollution, etc. can cause an increased production of reactive oxygen species in plant tissues (Polle, Rennenberg, 1993). Polle, Morawe (1995) studied seasonal changes of the antioxidative systems in foliar buds and leaves of field-grown beech trees in a stressful climate. They established that foliar buds in spring, prior to the emergence of new leaves, exhibited a lower chlorophyll content but a higher protein content and higher activities of ascorbate peroxidase and monodehydroascorbate radical reductase than mature leaves in summer. High antioxidative capacity was conferred by mature beech leaves and may be an important protection measure for coping with the large fluctuations in temperature and exposure to elevated ozone concentrations in summer.

In the near future, attention is to be devoted to the occurrence of extreme values of climate factors in connection to air-pollution stress within a wider time range. It will be necessary to examine the influence of shortage in precipitation on the monitored physiological traits of beech leaves. These problems will be dealt with in the second part of our paper.

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Ditmarová Ľ., Kmeť J., Střelcová K., Gömöry D.: **Analýza vplyvu teploty na vybraté fyziologické parametre mladých jedincov buka v stresových podmienkach.**

Fyziologické charakteristiky (fluorescencia chlorofylu *a*, fotosyntetické pigmenty) tienných listov buka (*Fagus sylvatica* L.) sme sledovali vo vzťahu k maximálnym a minimálnym teplotám (merané 1, 2, 3, 7 a 14 dní pred odberom vzoriek) z oblastí s rozdielnou imisnou záťažou. Charakteristiky listov sme sledovali pri podrastových jedincoch vo veku 15 rokov.

Z parametrov fluorescencie chlorofylu sme zistili signifikantný záporný vplyv rozdielu teplôt voči dlhodobému priemeru (25 rokov) na základnú fluorescenciu (F_0) a kladný vplyv hlavne rozdielu maximálnych teplôt voči dlhodobému priemeru na pomer variabilnej a maximálnej fluorescencie (F_v/F_m) z kratšieho časového hľadiska (1 až 3 dni pred odberom vzoriek). Týka sa to parametrov nameraných hlavne na vrchnej strane asimilačných orgánov na obidvoch lokalitách. Pri fotosyntetických pigmentoch je zrejmý kladný signifikantný vplyv rozdielu maximálnych teplôt jeden deň pred odberom vzoriek na obsahy pigmentov (mg.dm^{-2}) na obidvoch lokalitách.