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Health condition of young spruce stands growing in Poľana in different altitudes

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ABSTRACT: This paper presents the first results of chlorophyll fluorescence measurements on assimilatory apparatus of Norway spruce. Three young spruce stands located in various altitudes (600, 1,050 and 1,250 m above sea level) were selected for the measurements. Chlorophyll fluorescence *a* was measured by a portable fluorimeter PEA. These measurements were performed on three needle year-classes. We found greater stand damage on the areas which are located in higher altitudes, but only at the end of growing season.

Keywords: chlorophyll fluorescence; assimilatory apparatus; Norway spruce

In our country forests form 41% of the whole area of the territory. They are important components of the environment and they essentially influence of the ecological stability in Central European region. Negative changes of ecological conditions are not caused by a single stress factor alone, but by several stress factors which come and act together. Forest decline as a whole (dying of broadleaf and conifer trees) which has arisen in the last 20 years is also a combined effect of many natural and anthropogenic stress factors, which set limitations for photosynthesis, plant growth and plant vitality (LICHTENTHALER, BUSCHMANN 1984; STRASSER et al. 1987; LICHTENTHALER, RINDERLE 1988). When the natural climatic stress is more favourable for plant growth, the plants can withstand a higher amount of anthropogenic stress conditions.

It is assumed that advance of altitudinal vegetation zones will be caused by a warming and thus the total change of the forest character will come. The forest decline will begin at wood species growing on the limit of ecological amplitude. Owing to expressive climate change, the forest trees growing in the temperate zone of the north hemisphere will lose the conditions for their existence.

MATERIAL AND METHODS

Three young stands of *Picea abies* (L.) Karst. were selected in reserve of Poľana. They grow in three different altitudes. The first experimental area is located in the stand No. 336 in altitude 1,250 m. Here the unutilized pastureland is gradually forested by a succession of *Picea abies* (L.) Karst. The crop density is 0.8, exposure SE and slope is 20%. In this stand the species composition is as follows: beech 70% and spruce 30%. Spruce are 17 years old and mixed irregularly.

The second experimental area is located in the stand No. 320 where the borrow pit is also situated. It is again gradually forested by 100% natural seeding of *Picea abies*. The average age of selected trees was 16 years. The crop density is 0.5, irregular, SE exposure, 15% slope. This stand is situated in the altitude of 1,050 m.

The third experimental area is the part of the stand No. 276a. Young spruce (15 years old) create the majority of stand. Older spruce and beech are situated only in the south. The crop density is 0.6, irregular, SE exposure, 30–40% slope. This stand is situated in the altitude of 600 m.

On all three plots 10 spruce individuals were selected and fixed. Mensurational characteristics of selected trees are given in Table 1. Two branches (from south and north) were indicated on each selected tree. In 1997 the fast kinetics of chlorophyll fluorescence *a* was measured on these indicated branches. We measured always three needle year-classes (1997, 1996 and 1995). Chlorophyll fluorescence *a* was measured by a portable PEA fluorimeter. The advance of measurement has already been published in detail in a paper (ČAŇOVÁ 1999). From the individual parameters *Fv/Fm* is the most important parameter for us. *Fv/Fm* ratio (*Fv/Fm = Fm – Fo/Fm, Fv* – variable fluorescence, *Fm* – maximum fluorescence, *Fo* – initial fluorescence) is proportional to the quantum

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Table 1. Mensurational characteristics of selected trees

Tree No.	Poľana 1,250 m a.s.l.			Poľana 1,050 m a.s.l.			Poľana 600 m a.s.l.		
	Height (m)	Thickness $d_{1.3}$ (cm)	Age	Height (m)	Thickness $d_{1.3}$ (cm)	Age	Height (m)	Thickness $d_{1.3}$ (cm)	Age
1	4.5	9.2	18	5.5	8.4	15	4.5	6.2	15
2	4.0	8.0	18	4.0	4.9	12	4.0	7.2	14
3	3.5	5.6	16	4.5	8.1	15	4.0	5.9	12
4	4.5	4.1	20	4.5	6.4	16	4.0	5.4	13
5	4.0	5.9	20	2.5	3.8	12	4.5	6.7	13
6	3.5	4.5	16	5.5	7.5	21	4.0	5.6	13
7	5.0	7.6	21	3.5	5.4	15	4.0	5.7	13
8	2.5	2.9	15	4.0	5.1	18	4.0	5.7	13
9	3.5	4.1	15	5.0	7.0	20	4.0	6.0	13
10	2.5	3.2	13	3.5	3.8	15	4.0	5.9	12

yield of photochemistry and highly correlated with the quantum yield of nett photosynthesis, which is a measure of the effeciency of light utilizing.

A decrease of *Fv/Fm* in dark adapted plants is a good indicator of photoinhibitory damage in plants subjected to stress. The *Fv/Fm* values are in undamaged plants in the range of 0.75–0.85. The values below 0.725 refer to distinct decrease of photochemical capacity of PS II and they are under the threshold value of failures (BOLHÁR-NORDENKAMPF et al. 1989).

RESULTS

Figs. 1–3 present *Fv/Fm* parameter which was measured during the year 1997 on the youngest needle year-class (1997) in the altitudes of 600, 1,050 and 1,250 m above

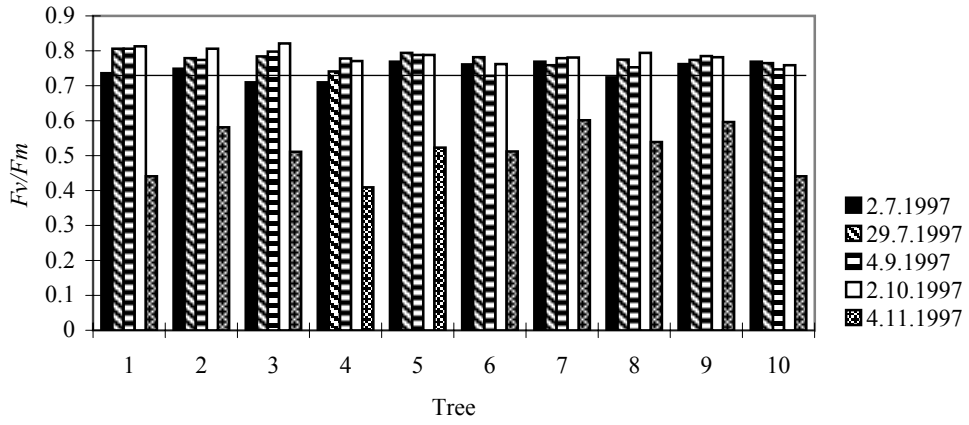

Fig. 1. Parameter *Fv/Fm* measured at altitude 600 m in needle year-class 1997

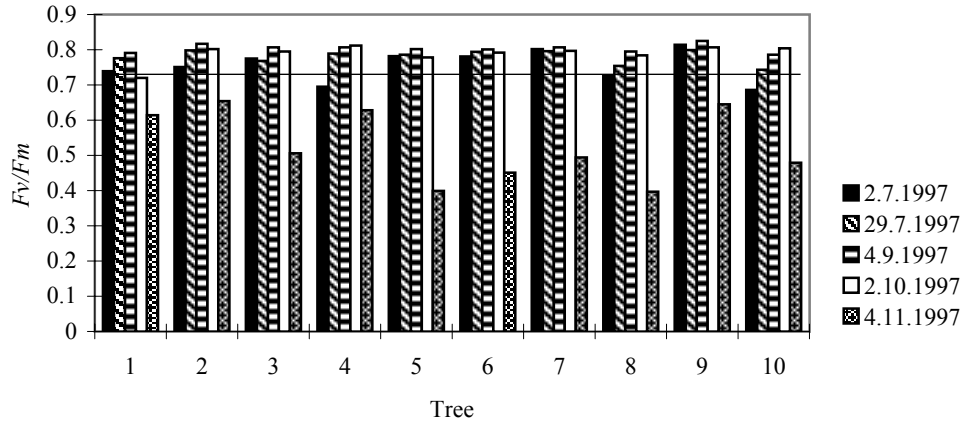

Fig. 2. Parameter *Fv/Fm* measured at altitude 1,050 m in needle year-class 1997

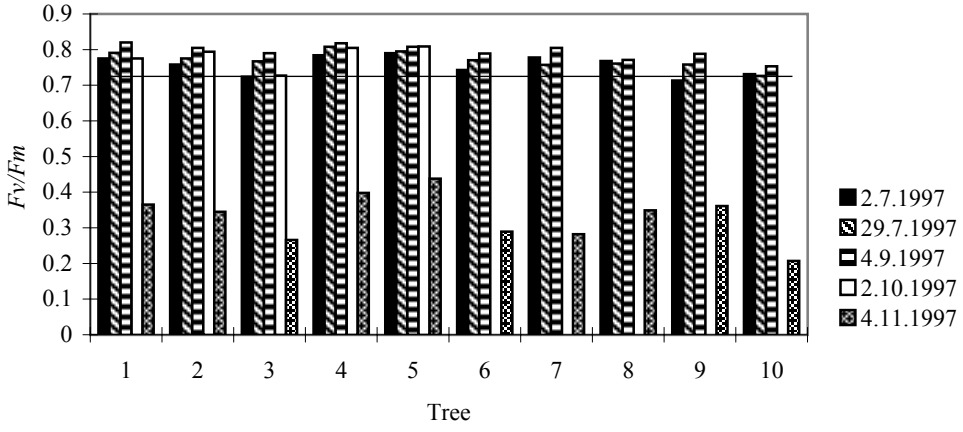

Fig. 3. Parameter *Fv/Fm* measured at altitude 1,250 m in needle year-class 1997

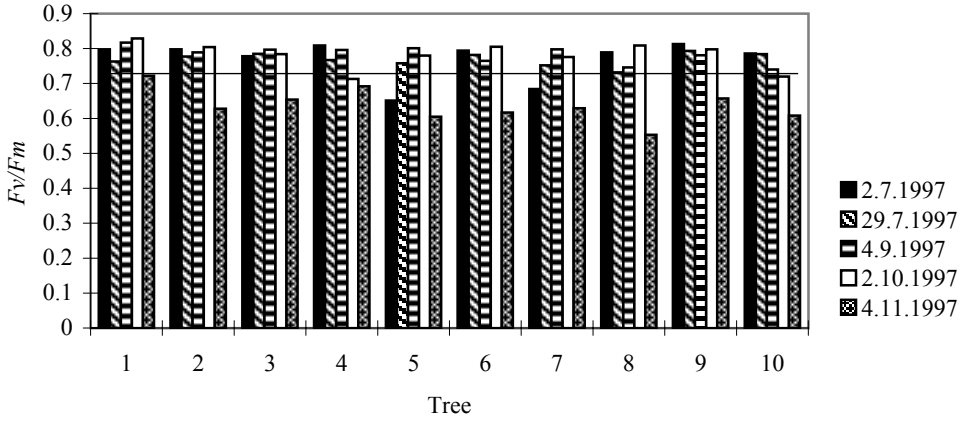

Fig. 4. Parameter *Fv/Fm* measured at altitude 600 m in needle year-class 1996

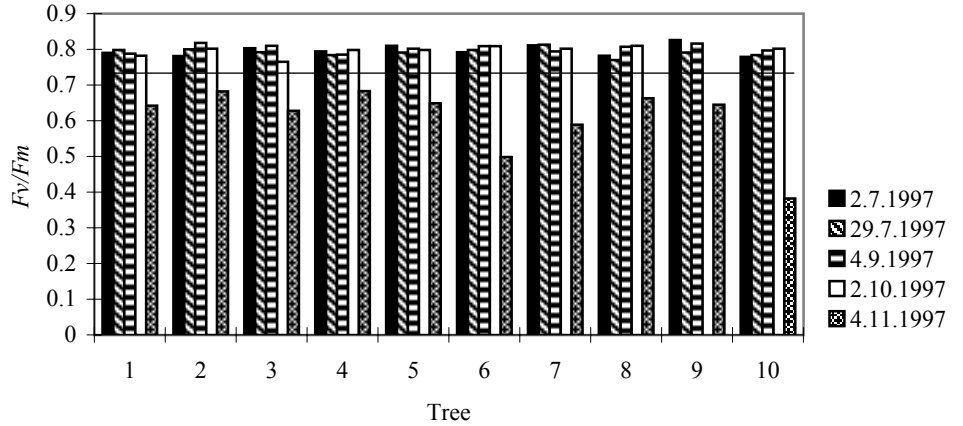

Fig. 5. Parameter *Fv/Fm* measured at altitude 1,050 m in needle year-class 1996

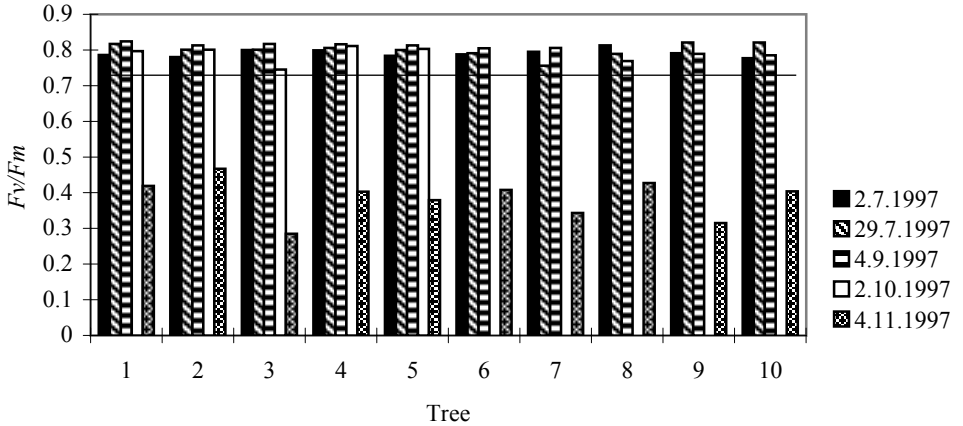

Fig. 6. Parameter *Fv/Fm* measured at altitude 1,250 m in needle year-class 1996

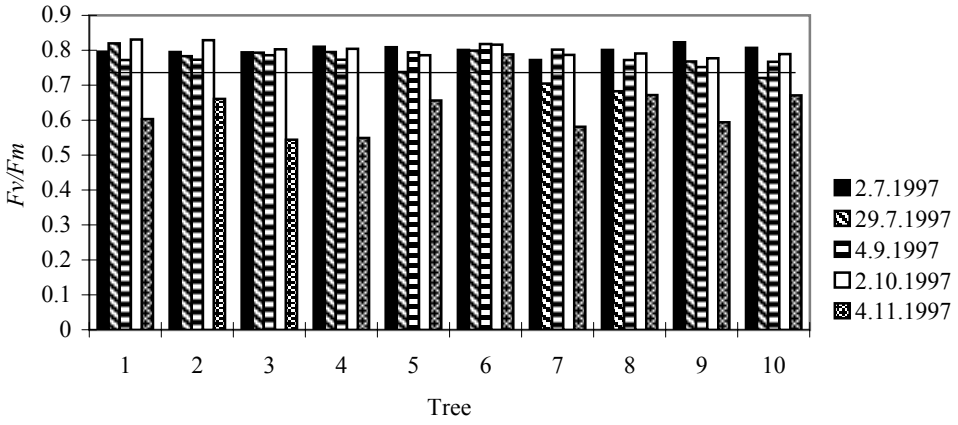

Fig. 7. Parameter *Fv/Fm* measured at altitude 600 m in needle year-class 1995

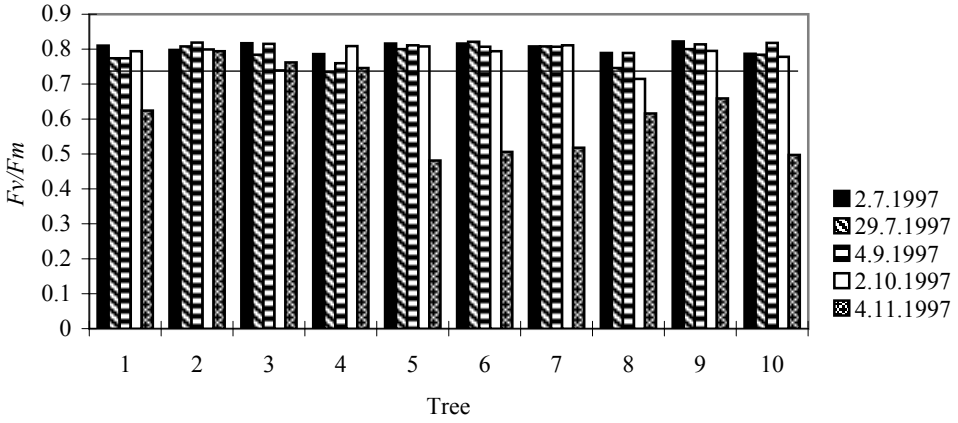

Fig. 8. Parameter *Fv/Fm* measured at altitude 1,050 m in needle year-class 1995

sea level. On their basis we can state the relatively balanced course of the values during the first three measurements (2. 7., 29. 7. and 4. 9.) on all three localities. However, we determined the temperate decrease of *Fv/Fm* already at the next measurement (2. 10.). This decrease was the most expressive on the locality with the altitude of 1,250 m, where the average value of *Fv/Fm* was 0.764.

In the altitude of 1,050 m this average was 0.784 and in the altitude of 600 m it was 0.789. At the last measurement (4. 11.) we determined a very intense decrease of *Fv/Fm* and this decrease was the supreme on the locality with the altitude of 1,250 m. In the altitude of 600 m the average value was 0.515, in the altitude of 1,050 m it was 0.526 and in 1,250 m it was only 0.364. It means that the investigated trees were deeply under the threshold value of physiological failures on all three localities. At this last November measurement (4. 11.) the values were probably considerably influenced by unfavourable climatic conditions, first of all by the intense temperature decrease at night, by deficit of the physiological accessible water and by the increased influence of ozone.

Parameter *Fv/Fm* which was measured on the other needle year-classes (1996, 1995) had the similar course, which is demonstrated in Figs. 4–9. At the last measurement (4. 11.) we determined with 99% reliability a statistically significant difference between individual localities. The most expressive decrease of *Fv/Fm* and the worst health condition was at the spruces situated in the highest altitude and better condition was at spruces situ-

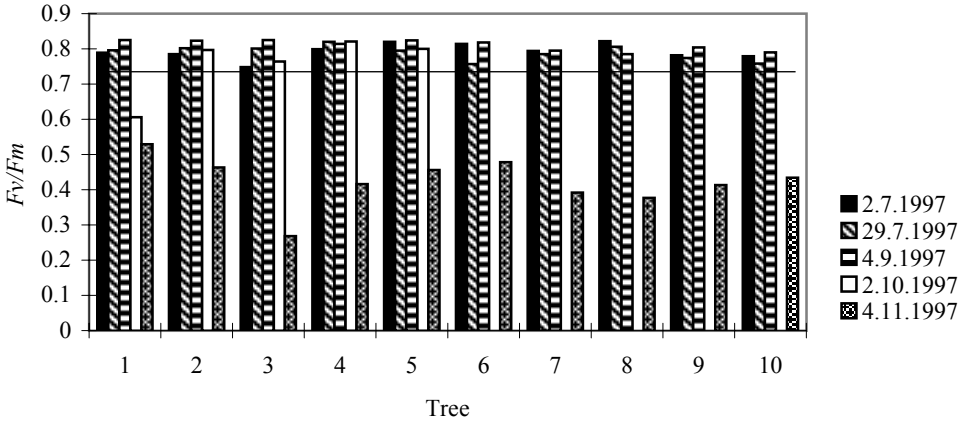

Fig. 9. Parameter *Fv/Fm* measured at altitude 1,250 m in needle year-class 1995

Table 2. ANOVA from the values of *Fv/Fm* parameter ($P < 0.05^{*}$, $P < 0.01^{**}$, $P < 0.001^{***}$)

Source of variability	Degrees of freedom	Parameter *Fv/Fm* *F*-test	Variation components (%)
Area	2	42.49^{***}	1.87
Tree	9	4.03^{*}	0.60
Needle year-class	2	19.93^{***}	0.93
Exposure	1	1.70	0.02
Date of measurement	8	366.59^{***}	61.30
Residual	1,925		28.05

ated in the lowest altitude. If we compared the individual needle year-classes, we found the least values of *Fv/Fm* parameter at the youngest needle year-class (1997). These youngest needles probably the most intense responded to the deterioration of the environmental conditions, which was confirmed with 99% reliability.

From *F*-test analysis variance (Table 2) we determined a statistically significant difference between localities which were situated in the various altitudes and this difference was determined on the significance level $\alpha = 0.001$. The locality participates 1.87% on the total values of *Fv/Fm* parameter. From *F*-test we determined a statistically high significant difference between needle year-classes and they participate 0.93% on *Fv/Fm* values.

As to exposition, the significance of differences between north and south expositions was not confirmed and the exposition participates by the least percentage (0.02%) on the measured *Fv/Fm* values. Difference between the individual dates of measurements was statistically highly significant (on the significance level $\alpha = 0.001$). From the calculated components of variance it was found that the date of measurement most participates on the determined *Fv/Fm* values.

On the basis of these results we can state that the spruce stands respond to influence of unfavourable environment factors already in the young age similarly as at older stands. The deteriorated health condition showed first of all the trees growing in the higher altitudes although visually we did not determine any symptoms of their damage.

DISCUSSION

The most endangered wood species is *Picea abies* (L.) Karst. because, owing to increase of the temperature quotient of the environment due to climate changes, the deficit of the physiological permissible water at spruce is increased. Spruce is the most damaged by the physiological drought in comparison with the other boreal conifers such as *Pinus sylvestris* or *Larix decidua* (CHRISTENSON et al. 1990). The winter desiccation which damages conifers is often caused by desiccation of assimilatory organs rather than by direct thermal effect (KOZLOWSKI et al. 1991).

The light absorbed by the photosynthetic pigments (chlorophylls or carotenoids) will be used for photosynthesis (photosynthetic quantum conversion) or dissipated as heat or as red chlorophyll fluorescence. Chlorophyll fluorescence is inversely related to the rate of photosynthesis (LICHTENTHALER 1986) and therefore in the last period some authors investigated the fast kinetics of chlorophyll *a* fluorescence.

BOLHÁR-NORDENKAMPF together with his co-workers researched (1989) the influence of various stress in different altitudes at older spruce stands. They determined similarly as we lower values of *Fv/Fm* ratio and worse health condition of spruce stands which grew in higher altitude. They explain lower values of *Fv/Fm* which were measured on younger needle year-classes by speciality of fluorescence induction in the flushing time of new spruce shoots. It was found that during the flushing, the youngest needle year-class has increased initial fluorescence (*Fo*) in comparison to older needle year-classes.

The increase of initial fluorescence shows in principle to inactivation of PS II reaction centers which was determined at photoinhibition conditions. However, it was ascertained that at photoinhibition the maximum fluorescence *Fm* simultaneously decreased. On the other hand, during the flushing of needles maximum fluorescence increased together with *Fo*. BOLHÁR-NORDENKAMPF (1989) ascertained the intense *Fv/Fm* decrease at older spruce stand growing in higher altitude. It is probably conjoined with course of night temperature (the low night temperature causes the direct decrease of photosynthetic capacity owing to temperature stress). In damaged forest trees and stressed plants, the photosynthetic activity declines (LICHTENTHALER, RINDERLE 1988) and the chlorophyll fluorescence emission increases.

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Zdravotný stav mladých smrekových porastov rastúcich na Poľane v rôznej nadmorskej výške

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ABSTRAKT: Práca obsahuje prvé výsledky meraní fluorescencie chlorofylu, ktoré sa uskutočnili na asimilačných orgánoch smreka obyčajného. Pre tento účel sme si vybrali tri mladé smrekové porasty, ktoré rastú v rôznych nadmorských výškach (600, 1 050 a 1 250 m n. m.). Fluorescenciu chlorofylu sme merali prenosným fluorimetrom PEA. Samotné merania sme uskutočnili na troch ročníkoch ihlíc. Na základe našich výsledkov sme zistili väčšie poškodenie porastov, ktoré sa nachádzajú vo vyšších nadmorských výškach, ale len ku koncu vegetačného obdobia.

Kľúčové slová: fluorescencia chlorofylu; asimilačný aparát; smrek obyčajný

Pri hodnotení výsledkov musíme mať vždy na zreteli skutočnosť, že stresové stavy sú prevažne spôsobené nie jedným jednoduchým stresovým činiteľom, ale niekoľkými, ktoré prichádzajú a pôsobia spoločne. Obzvlášť vysoká intenzita slnečného žiarenia pri nízkych teplotách môže fotooxidáciou listových pigmentov vyvolať priame škody fotosyntetického aparátu. Sucho vyvolané mrazom a tiež prirodzene sa vyskytujúci vyšší obsah ozónu vo vyšších nadmorských výškach toto poškodenie ešte zosilňuje. Takéto poruchy sa potom prejavujú bezprostredne v poklese kapacity fotosyntézy, stanoviteľnej tiež pomocou fluorescencie chlorofylu.

Práca prináša prvé experimentálne výsledky merania fluorescencie chlorofylu *a* u mladých smrekových porastov. Smrek má totiž v porovnaní s inými ihličnanmi najväčšiu dispozíciu voči zimnému vysychaniu a je tiež najmenej odolný voči imisiám. V práci sme sa zamerali na meranie rýchlej kinetiky fluorescencie chlorofylu *a*. Na ploche biosférickej rezervácie Poľana boli vybrané mladé porasty smreka obyčajného rastúce v troch rôznych nadmorských výškach. Prvá pokusná plocha patrí do porastu č. 336 a nachádza sa v nadmorskej výške 1 250 m, druhá plocha je umiestnená v poraste č. 320 v nadmorskej výške 1 050 m a tretia je súčasťou porastu č. 276a a jej nadmorská výška je 600 m. V rámci všetkých troch lokalít sme v júni 1997 vybrali a následne označili desať pokusných stromov. Na každom z nich sme následne označili dva konáre, na ktorých sa potom opakovane v priebehu vegetačného obdobia merala rýchla kinetika fluorescencie chlorofylu *a*. Merania sme robili vždy na posledných troch ročníkoch ihlíc. Na praktické meranie sa použil fluorimeter PEA od firmy Hansatech. Samotný postup merania je podrobne opísaný už v práci ČAŇOVEJ (1999).

Obr. 1–9 znázorňujú priebeh parametra *Fv/Fm*, ktorý sme zistili v nadmorskej výške 600, 1 050 a 1 250 m n. m. Z výsledkov môžeme konštatovať prudký pokles hodnôt *Fv/Fm,* ku ktorému došlo hlavne na konci vegetačného obdobia, pričom tento pokles bol najvýraznejší v lokalite s nadmorskou výškou 1 250 m n. m. Zhoršené fungovanie asimilačného aparátu u smrekov rastúcich vo vyšších nadmorských výškach v porovnaní s nižšie položenými pravdepodobne zapríčinili nepriaznivejšie klimatické podmienky, ktoré boli v tých polohách, a to predovšetkým prudký pokles teplôt v nočných hodinách, nedostatok fyziologicky prístupnej vody, ale aj zvýšený vplyv ozónu. Pri porovnaní jednotlivých ročníkov ihlíc sme zistili, že najmladšie ihlice najintenzívnejšie reagujú na zhoršujúce sa podmienky prostredia, čo sa potvrdilo s 99% mierou spoľahlivosti.

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