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DYNAMICS OF ILLUMINATION UNDER VARYING CONDITIONS IN BEECH FOREST STANDS

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Abstract

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We studied intensity of illumination in several submountain beech stands differing in stocking density. The measurements were repeated two times: in period without leaves (March 12, 2002) and in period of full foliage (August 27, 2001). Maximum values of light intensity, in period without leaves equally as in period of full foliage were recorded from 12:00–14:00 h, practically on all the plots. The absolute highest values were measured on open plot in August, and they represented 56.0 klx. In the spring measurement, we detected somewhat lower maximum values 52.0 klx. Optimum conditions in context of light amount were obtained on plot treated with medium strong cutting several years ago. The mean values on this plot were found to be 0.9 klx and 7.9 klx in summer and in spring, respectively. The least favourable light conditions were on the former clear cut where we recorded only 0.5 klx and 6.7 klx in summer and in leafless period, respectively. We found out that the influence of cutting intervention grade on illumination intensity on the individual plots was high significant. Comparison between the individual measurements resulted in finding that significant differences were only obtained in case of open plot compared with each of the other plots.

Key words: dynamics of illumination, submountain beech stands, testing of influence

Introduction

The crucial importance of sunlight was already recognised at the very down of human history (proved e.g. by discovered ancient rituals). In the modern times, a number of authors, representing various professions and countries, were and are taking efforts to understand thoroughly the performance and influence of this, for our existence necessary. Apart from others, the sunlight is a driving factor for important vital processes taking place in all plant and animal communities – acting both in direct and indirect way. Based on the hitherto obtained knowledge, we can assess the impact of solar radiation in the following context. Matějka and Huzulák (1987) report that the thermal effect of solar radiation controls transpiration and temperature in plant tissues, and, consequently, determines the rate of metabolic processes. Certain parts of absorbed solar radiation are used for synthesising energy-rich

bonds during photosynthesis. Amount and spectral composition of short-wave radiation has an important role in controlling plant growth and development (photo-morphogenetic effects). Sláviková (1986) suggests that any either purpose-oriented or accidental intervention of man in a plant community is connected with immediate, more or less abrupt changes in certain external site conditions. Cicák and Štefančík (1994) state that namely forestry practice is a typical example of intended intervention of the man in plant communities. Recognising the delicate relationships between individual components of forest ecosystems, it is vitally important to consider not only "sustainable development" of our management but also preserving the life itself.

The aim of this work was quantification of at least one component of solar radiation – intensity of illumination in conditions of sub-mountain beech stands influenced by regeneration cutting with different intensity levels.

Material and methods

We carried out our study on research plots situated at the Beech Ecological Experimental Site (BEES), 450–520m a.s.l, in the Kremnické vrchy Mts (48°38´ N and 19°04´ E), the Western Carpathians Mts. The dominant woody plant on the plots is beech; the trees are 80–100 years old. The local climate belongs to moderately warm, moderate highland district B5 with an average annual temperature $t_{1951\text{-}1980}$ 6.8 °C and annual precipitation total of 778 mm (Střelec, 1993). The vegetation cover mostly consists of patches of *Carici pilosae-Fagetum* O b e r d . and *Dentario bulbiferae-Fagetum* with permanent elements such as *Carex pilosa* S c o p ., *Carex digitata* L., *Dentaria bulbifera* L., *Galium odoratum* S c o p ., *Athyrium filix femina* L. (R o t h) and *Dryopteris filix mas* L. (Schieber, 2006, 2007). The soils are described in Bublinec (1990), Kukla (2002) and Širáň (2003) who declare that the substrate, the basic soil forming material at the site, consists of andesite-tuffaceous agglomerates. On this substrate has been formed a saturated variant of cambisol andosolic with a high skeleton content that increases with the increasing depth. The soil body has a stratified structure and consists of the main and basal complex of strata (Pichler 1996). The more detailed data about the plots can be found in Schieber et al. (2008), Kellerová (2006) and Barna (2004, 2008). The studied series of five partial plots is a result of applying shelterwood cutting with different intensity grades, necessary for obtaining the required stocking density. The plot H-clear cut, stocking 0.00, plot I-high intensity cutting, stocking 0.30 in the year 1989 and stocking 0.40 in the year 1996, plot S-medium intensity cutting, stocking 0.50/0.62, plot M-low intensity cutting with stocking 0.70/0.78 and one of the plots was left without intervention – as a control, stocking 0.90/0.87. The cutting was done in year 1989. Twelve years later, in 2001–2002, we measured intensity of illumination. Our research followed with the measurements carried out by Střelec in year 1990 (Střelec, 1992). We used the method designed by Petrík (1968). We used the measuring points established in the first phase. Illumination was measured in so-called segments for microclimate measurements – one on each plot. Each segment (5) was established close to the plot's centre, in such a way as to represent the required value of differentiated stocking density The research, in both phases, ran on measuring points established in a sufficient number (10) on each partial plot. The points were fixed with sticks, each provided with a fixed horizontal plate on the top – for placing photocells of the equipment. The plates were situated at 50 cm above the ground. In year 1991, the surroundings of measuring points were practically without cover by either forest stand or natural regeneration. In 2001–2002, the natural regeneration had reached a considerable height, especially on partial plots with higher degree of reduction in the parent stand – the height of succession stand on the former clear-cut was about 6 m.

All measurements were carried out with equal Luxmeters PU 150 (METRA Blansko) performing with an accuracy of +/–10%. The measurements on all the plots were synchronised, and there were recorded each hour. Both phases took place under anticyclone conditions: August 27, 2001 under full foliage and March 12, 2002 in the period without leaves.

T a b l e 1. Illumination in a beech stand before (March 11,2002) and of full foliation (August 27, 2001) on areas with different cutting.

Plots	OP	OP	H	H	I	I	S	S	M	M	K	K
	spring	sum-mer	spring	sum-mer	spring	sum-mer	spring	sum-mer	spring	sum-mer	spring	sum-mer
Time	klx											
6:00	0.6	0.5	0.3	0.02	0.3	0.08	0.5	0.07	0.5	0.04	0.3	0.05
7:00	1.8	0.7	0.9	0.07	0.9	0.3	0.9	0.3	1.1	0.2	0.9	0.2
8:00	16.0	0.8	1.2	0.1	2.1	0.5	2.1	0.5	1.8	0.4	1.6	0.3
9:00	20.0	4.4	2.1	0.1	4.1	0.7	3.4	1.2	5.9	0.8	2.5	0.6
10:00	28.0	28.8	3.9	0.3	5.5	1.2	8.9	1.5	7.8	1.6	6.9	0.8
11:00	48.0	42.0	8.8	0.5	8.1	2.4	16.2	2.2	14.3	1.8	10.4	5.2
12:00	52.0	56.0	13.8	1.1	17.0	2.7	19.2	6.6	20.8	3.3	16.9	4.8
13:00	48.0	56.0	20.7	1.4	21.1	3.2	21.4	4.5	21.0	3.4	19.7	2.6
14:00	40.0	56.0	17.9	1.1	16.2	2.6	16.5	3.0	16.1	2.7	15.6	5.9
15:00	26.0	32.0	10.4	1.1	10.0	4.3	10.2	2.8	8.3	4.9	9.0	5.3
16:00	17.0	32.0	5.7	0.9	4.4	2.9	3.2	1.7	3.2	3.6	2.8	2.0
17:00	13.0	20.0	0.9	0.6	1.1	2.6	0.9	0.9	1.3	1.4	0.8	1.1
18:00	0.7	6.0	0.2	0.3	0.2	1.4	0.3	0.3	0.3	0.9	0.2	0.8
19:00	-	1.3	-	0.1	-	0.4	-	0.2	-	0.2	-	0.2
Aver-age	**20.3**	**24.2**	**6.7**	**0.6**	**6.9**	**1.8**	**7.7**	**1.9**	**7.9**	**1.6**	**6.7**	**1.2**

Notes: OP – open plot, S – stocking 0.50/0.62, H – stocking 0.00, M – stocking 0.70/0.78, I – stocking 0.30 in year 1989, 0.40 in year 1996, K – control plot, stocking 0.90/0.87.

Results and discussion

In the period without leaves (March 12, 2002), maximum amount of light was transmitted through beech crowns on partial plot S (stocking 0.5) that was subjected to medium intensive shelterwood cutting in 1989–1990. The average value was 7.9 klx, and the maximum value, representing 21.4 klx was measured at 13:00 h – equally as on the other partial plots. The absolute highest values were recorded on the open plot at 12:00 h – 52.0 klx, 20.3 klx on average (Table 1). For comparison, Johnson (1954) reports a value of approx.137.0 klx for the upper boundary layer of the atmosphere. Střelec (1992) measuring the light intensity on the same plots in April 1991, found maximum values – making 68.5 klx on plot H at 12:00 h. The plot was clear-cut by the time. The lowest values, by 50% lower, on average, compared to plot H, this author found on control plot – without cutting intervention. We measured the lowest values, making on average 6.7 klx only, exactly on the former clear cut – due to presence of an 11-year-old, 4–6 m high young growth –reducing the illumination intensity by more than 70 %.

T a b l e 2. Results of testing between partial plots and between measurements before and full foliage.

PP	OP1	OP2	H1	H2	I1	I2	S1	S2	M1	M2	K1	K2
OP1	-	0.01	3.9**	-	3.8**	-	3.7**	-	3.8**	-	3.8**	-
OP2	-0.01	-	-	3.2**	-	3.1**	-	2.7**	-	2.9**	-	2.9**
H1	-3.9**	-	-	3.2**	-3.4**	-	-3.0**	-	2.9**	-	2.4**	-
H2	-	-3.2**	3.2**	-	-	-0.1	-	-0.7	-	-0.4	-	-0.2
I1	-3.8**	-	-3.4**	-	-	2.8**	-0.6	-	-0.2	-	1.0	-
I2	-	-3.1**	-	0.1	2.8**	-	-	-0.5	-	-0.3	-	-0.1
S1	-3.7**	-	3.0**	-	-0.6	-	-	3.1**	0.7	-	1.4	-
S2	-	-2.7**	-	0.7	-	0.5	3.1**	-	-	0.3	-	0.4
M1	-3.8**	-	-2.9**	-	0.2	-	0.7	-	-	3.0**	0.8**	-
M2	-	-2.9**	-	0.4	-	0.3	-	-0.3	3.0**	-	-	0.2
K1	-3.8**	-	-2.4**	-	1.0	-	-1.4**	-	-0.8	-	-	3.2**
K2	-	-2.9**	-	0.2	-	0.1	-	-0.4	-	-0.2	3.2**	-

Notes: PP – partial plots, t – t characteristics of T test, 1 – before foliation, 2 – full foliation ** – statistically high significant.

In summary, the tree crowns on all the plots transmit 32–40% of light reaching the open plot. Střelec (1992, 1993) reports for the control plot a value representing 52% of the open plot illumination. It is evident that the light amount increases with decreasing stocking density. Petrík (1971) informs about a value making 23–45% of the external light for beech stands without leaves. Tranquilini (in Mitscherlich, 1971) found a relative value of 51% in February–April and in November and December for a beech stand aged 70 years. The same author reports for the same stand only 5% in July, September and October. The results of testing the differences among the measured values (Table 2) show that conspicuous differences were only found when we compared between the open plot and one of the others. The differences within the other plots (except of open), were not found such significant in period without leaves.

In period of full foliage (August 27, 2001), the course of illumination dynamics was similar, with different absolute values, of course. Maximum values were again found on open plot, and they represented 56 klx in time interval 12:00–14:00 h. This, almost 10% increase was caused by changed declination of the Earth with respect to the Sun. Klabzuba and Kožnarová (1991) report that the over-day solar radiation intensity fluctuates considerably, depending on the sun height and cloudiness. Also this measurement resulted in founding that the lowest light amount was transmitted through the young growth on the former clear cut. The full foliage contributed to further reduction in the penetrating light – to 0.6 klx on average, representing only 2.3% of the light reaching the open plot. The maximum on this plot was measured at 13:00 h, and had a value of 1.4 klx. The tree crowns on control plot transmitted 5.1% of light reaching the open plot; the average value was 1.2 klx. The maximum of 5.9 klx was measured at 14:00 h. Also this measurement confirmed the highest light amount, almost 2.0 klx on average, on plot S. Comparing these data with the results obtained in year 1990 we can see that proceeding growth of forest understorey

T a b l e 3. Descriptive statistics of measurements of illumination in the BEES.

	Valid	Vx%	Range	Median	Summ	Std.dev.	Min	Max
	spring 2002							
OP	13	92.6	55.5	24.0	335.7	22.2	0.5	56.0
H	13	87.0	1.3	0.4	7.7	0.4	0.1	1.4
I	13	68.9	3.1	1.8	23.1	1.1	0.1	3.2
S	13	85.0	5.0	1.6	27.2	1.6	0.1	5.1
M	13	76.4	3.2	1.5	21.9	1.2	0.1	3.3
K	13	78.1	3.0	1.0	17.3	0.9	0.1	3.1
	summer 2001							
OP	14	76.9	51.4	20.0	311.1	18.4	0.6	52.0
H	14	106.0	20.5	3.6	86.6	7.1	0.2	20.7
I	14	101.0	20.9	4.4	91.0	7.1	0.2	21.1
S	14	91.7	20.9	6.1	103.4	7.9	0.5	21.4
M	14	97.2	20.7	5.9	101.7	7.6	0.3	21.0
K	14	95.6	19.5	4.9	87.2	6.9	0.2	19.7

Notes: Vx% – coefficienf of variation, Std.dev. – standart deviation.

and young growth can reduce the intensity of light penetrating tree crowns by 30% at the moment of light intensity culmination. Smolen (1976) informs about an average value of 73.8 klx over time interval 11:00–13:00 h at 16m above the ground, that means above the tree crowns, measured in July. Petrík (1986) reports about 5% of solar radiation reaching the soil surface in a 150-year old, full foliated beech stand. Saniga (1990) declares that the relative illumination in spruce-beech stands is only 1.7–3% at shading grade 100–77.5%, which in our case corresponds to situation on the control plot without intervention. In mature stands with shading of 62–40.5%, the author reports considerably higher illumination values: 15–23.3%. Tužinský et al. (2003) suggest that the light intensity in years 1982–1993 (in beech forests) was reduced to 9% on plot subjected to intensive cutting in the past, and to 2–1.5% on the control plot, compared to the clear cut.

The variation coefficient obtained for the results of the summer measurement reached the lowest values on the open plot (Table 3). Also in this case, considerable variability in this factor was evident. Střelcová, Jankovič (2009) suggest that the solar radiation in forest stands represents the horizontally most variable factor of their microclimate.

T-test confirmed more significant differences in illumination values for the period of full foliage compared to the stands without leaves. These differences were primarily confirmed between the plots previously subjected to more intensive cutting. High significant were also found the differences between the values obtained in the individual measurements on the same plot. That means there exist high significant differences in light amounts on the former clear cut as well as the other plots between the period without leaves and the period of full leafing. No significant difference between the two periods was identified. The summary of the tested characteristics is given in Table 2.

On the other hand, it is necessary to keep in mind that the amount of light reaching the soil in forest stands is very important for forest management because it primarily controls the existence and unperturbed performance of these ecosystems as well as of their components. For this reason, it is also necessary to assess the measure of influence of this factor on production abilities of the above-mentioned components. Cicák, Štefančík (1994) report that the shading degree is the most important factor controlling biomass production in 1–3-year old beech seedlings in natural regeneration. The production decrease dependent on increasing degree of shading has been confirmed, regardless of age. The results of regression analysis as well as the values of correlation coefficient (0.9 on average) manifested unequivocal significance of this factor (Janík, 1995).

Conclusion

In general it holds that the intensity of natural illumination is directly dependent on the overall intensity of the global radiation inciding horizontal surface.

The highest mean daily values of illumination in the studied beech stands both in period without leaves and in period of full foliage, representing 20.3 and. 24.1 klx, respectively, were recorded on the open plot without forest stand cover. The absolute daily maximum did not exceed 56.0 klx. In case of period without leaves, we can see a one-hour time delay in occurrence of light maximum in the beech stands – compared to the open plot, regardless of the cutting intensity. The summer measurements indicated the highest illumination values in afternoon, from 12:0–14:00h on all partial plots. Eleven years after the treatment, most light reached the ground on plot S, subjected to medium strong cutting resulting at a stocking density of 0.5. On average, there were reached values of 7.9 klx and 1.9 klx in leafless spring and under full foliage, respectively. On the other hand, the lowest values were recorded on the former clear cut when the spring values did not exceed 6.7 klx, and the average summer value was found to be 0.5 klx. These facts were controlled by the height and canopy density of the succession forest stand (11-year-old young growth). Saniga (1990) evaluating the height increments in beech young growth obtained results similar to Huss and Stephani (1978). In case of shading lower than 90% up to the value of 40%, beech manifests a considerable plasticity in its adaptive abilities in heading variable light conditions. The amount of light reaching the tree crowns in summer is higher by almost 18% compared to spring values. In contrary, the amount of light reaching the forest is higher (10–90%) in spring. The tests results confirmed significant differences in the measured illumination values mainly in case of comparing the open plot without forest cover and any other partial plot. The same holds for the differences in summer values between the plots. Significant were also found the differences between the spring and the summer values measured on individual plots.

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