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Biomass production of *Viola reichenbachiana* L. in submountain beech forest of Kremnické vrchy Mts (Western Carpathians, Slovakia)

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Abstract

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Presented are our research results on biomass production of *Viola reichenbachiana* L. in a submountain beech stand with graded stocking density levels. The study ran at the Beech Ecological Experimental Site Kremnické vrchy Mts in years 1993–94 and 2005–06. The required density values were obtained by a controlled cutting intervention. Optimum, that means maximum production values of above ground as well as belowground biomass components were recorded on control plot without intervention. The maximum amount of above ground biomass representing 41.2 kg ha^{-1} was observed in summer aspect 1994, maximum of belowground biomass 67.2 kg ha^{-1} occurred in autumn of the same year. Most significant statistical differences were observed between clear-cut plot and plot treated by medium intensive regeneration cutting.

Key words

biomass production, submountain beech forest, *Viola reichenbachiana*, Western Carpathians

Introduction

Today, production potential of forest phytocoenoses is of increasing importance. This holds not only for production of wood mass – one of few permanent renewable natural resources. In this context emerges also the issue of production of herb layers in forest ecosystems. Herb component of a forest can be discussed in several different contexts. From the viewpoint of ecology, herb layers are inseparable constituent of forest ecosystems, and their role is crucial in almost all aspects (food webs, physiology, production, ecological indicators). For commercial purposes, herb layer is an important factor in assessment of effectiveness of regeneration cutting treatments in various geographic areas. Security of forest stands after a cutting cannot be separated from forest reproduction. Inappropriate cutting can disturb ecological equilibrium to serious extent. High production value of herb component, especially grass taxons (Fiala, 1996a, 1996b; Tůma, 1996) is frequently a dramatic problem in forest regeneration process.

Relevance of better understanding of the role of herb layer in forest ecosystems is also evident on the number of authors studying this problem: Mölder, A. et al. (2008), Kuklová and Kukla (2006, 2008), Schieber (2006, 2007), Kollár et al. (2008), Kontriš J. et al. (1988), Križová (1993), Križová and Mihálik (1985), Kubíček (1983), Kubíček et al. (2006, 2008), Łysik (2009), Chmura (2008), Havranová (2009) and many others.

Material and methods

Our research on primary production of herbs was pursued in years 1993–1994, 2005–2006, in a beech stand with graded stocking density (0.0; 0.3; 0.5; 0.7; 0.9) at the Ecological Experimental Site (EES) Kremnické vrchy Mts. The locality is situated in moderately warm climatic region, moderately warm and wet hilly climatic district with a mean annual temperature $t_{(1951–1980)}$ of 6.8 °C. The studied stand grows on a regular, WSW oriented slope with an inclination of 12.5–18 °C, at an altitude of 450–510 m (Kellerová, 2009). The dominant soil substrate consists of andesite tuffaceous agglomerates from which there has been developed a saturated variant of cambisol andosolic with high skeleton content, increasing with depth. The soil body is layered, built by the main and basal system of layers (Pichler, 1996). More details on the local soils can be found in Kukla (2002), Širáň (2003) and Dubová and Bublinec (2006). The plots belong to nutrient order B, group of forest types Fagetum pauper, lower degree and forest type Carex pilosa-nudum (Hančinský, 1972). The names of plant taxa have been given in the sense of Dostál (1989).

Above ground biomass component of herbs was determined by the method of indirect sampling designed by Kubíček (1977). As the study plot was chosen a plot serving for phytocoenological relevés (20 × 20 m). The main interest was put on the as objective as possible description of the studied phytocoenosis also with respect to non-uniform herb cover in the understorey, and so also with respect to more species showing irregular distribution across the plot. Within this plot, there have been established five representative mini-plots, each 1 m^2 in area for production-ecological research sensu Kubíček (1983). To avoid subjectivity, the plots were selected by using the table of random numbers (Šmelko, 1974). As individual plants were considered separate stalks without stolons. In some species, especially grasses, individuals were considered separate stems or leaves sprouting from a bunch (*Bromus ramosus* subsp. *benekenii, Brachypodium sylvaticum, Carex digitata.* Individuals of *Veronica officinalis* were defined as rooted stalks. In distinguishing between above ground and below-ground biomass, there were sampled entire herbs, and root systems were separated at the interface between soil surface and atmosphere. Measurements were taken across the entire growing period. The herbs were sampled in close proximity to the study plot, by one from each species (about 30 inds). In the laboratory, the material was dried and weighed, and the results were converted to unit mass and area (m^2, ha^{-1}). The frequency data were calculated according to the formula: F = M/n × 100, where F is the species's frequency on the representative plot in %, n is number of plots with occurrence of this species and N is the total number of squares on each study plot (in our case 5).

For quantification and evaluation of below-ground biomass we used the method described by Fiala (in Rychnovská et al., 1987). A special care was devoted to meticulous separation of the clear mass of "live" roots from undesired admixtures (soil fractions, dead roots, insects).

Results and discussion

Viola reichenbachiana, representing not even one per cent either in total above ground or below-ground biomass of all herbs, does not belong to dominant species as far as production capacity of forest ecosystems. The species is important due to its high frequency on individual partial plots at the study site. The frequency value obtained on the former clear cut was above 80%, on the control plot without intervention it did not sink below 40%.

Production on plot H with stocking 0.0

In the spring aspect 1993, the clear-cut plot produced 15.2 kg ha^{-1} of above ground biomass of this type. The root system weight did not exceed 4.0 kg ha^{-1}. The frequency values reached up to 40%. In the following summer and autumnal aspect, biomass of above ground organs was progressively reduced down to 8.4 kg ha^{-1} in autumn 1993. The trend in belowground biomass was opposite – an increase to 7.2 kg ha^{-1}; obviously thanks to nutrient reserves deposed in roots. The frequency values did not sink below 80%.

In 1994 was recorded a similar trend in biomass creation, with maximum values, however, in summer months. There were also differences in above ground and in belowground biomass amounts between the years. Good precipitation conditions in winter 1993–1994, with 289.1 mm fallen on the plot compared to 167.5 mm in winter 1992–1993 were followed by 259.9 mm in spring 1994 but only 55.0 mm in spring 1993. In total, much more favourable situation in throughfall was in 1994 (almost double amounts) than in year 1993. This fact was reflected in biomass production increase to 34.2 kg ha^{-1} in each component, and frequency values close to 100%.

In years 2005 and 2006, the production of the studied taxon was close to zero. Only in spring 2006 we recorded 0.3 kg ha^{-1} and 0.1 kg ha^{-1} of above ground and belowground biomass, respectively. This conspicuous reduction was caused by strongly reduced light supply inside the new-forming stand at stage of young growth exceeding 8–10m in height at the time. The frequency value was almost 30%.

The values of above ground and belowground biomass ranged between 51–76%, which indicates certain lack of homogeneity of the studied stands. The standard deviation values were relatively low: 9.6 and 12.4 in above ground and belowground biomass, respectively. Other characteristics of measure and position are in Table 2.

Pair testing revealed that the most significant differences were between plots H and S and between plots H and M in case of above ground biomass; and between plots H and M and between plots H and K in case of belowground biomass. The results of testing among the plots are summarised in Table 3.

Table 2. Descriptive statistic of biomass production of *Viola reichenbachiana* L. on the EES Kremnické vrchy Mts

Plots	H		I		S		M		K	
	Above ground	Below ground	Above ground	Below ground	Above ground	Below ground	Above ground	Below ground	Above ground	Below ground
Average	18.6	16.3	9.3	9.3	3.2	4.8	3.0	6.8	17.5	37.9
Median	17.0	15.2	7.1	9.2	3.4	4.8	2.6	4.7	15.9	39.4
Modus	15.2	7.2	5 .6	8.0	3.2	2.3	2.3	4.0	15.1	34.5
Geom. Mean	16.7	12.0	7.3	7.5	2.7	3.0	2.6	5.3	11.8	23.3
Variance	91.6	153.1	62.5	32.7	3.6	15.1	3.1	34.1	182.4	637.1
Std. Dev.	9.6	12.4	7.9	5.7	1.9	3.9	1.8	5.8	13.5	25.2
Std. error	3.9	5.1	3.2	2.3	0.8	1.6	0.7	2.4	5.5	10.3
Min.	8.4	3.8	2.9	2.8	0.8	0.5	1.1	2.6	1.3	1.3
Max.	34.2	34.2	24.7	16.3	6.4	9.6	6.0	18.0	41.2	67.2
Range	25.8	30.4	21.8	13.5	5.6	9.1	4.9	15.4	39.9	65.9
Vx [%]	51.6	76.0	84.9	61.9	55.9	69.2	69.2	85.3	77.1	63.9

H, clear cut (stocking 0.0); I, intensive cutting (stocking 0.3); S, medium (stocking 0.5); M, moderate (stocking 0.7); K, control (stocking 0.9); Vx [%], coefficient of variation; Std. Dev., standard deviation

Table 3. Comparison and testing of biomass production of *Viola reichenbachiana* L on the EES Kremnické vrchy Mts between partial plots

Plots	H		I		S		M		K	
	Above ground	Below ground	Above ground	Below ground	Above ground	Below ground	Above ground	Below ground	Above ground	Below ground
H Above ground	–	–	–1.7*	–	–2.8**	–	–2.8**	–	–0.2	–
H Below ground	–	–	–	–0.9	–	–0.2	–	–1.5*	–	1.3*
I Above ground	1.7*	–	–	–	–1.8*	–	–2.2**	–	1.2*	–
I Below ground	–	0.9	–	–	–	–1.7*	–	–0.7	–	1.8*
S Above ground	2.8**	–	1.8*	–	–	–	–0.2	–	2.0**	–
S Below ground	–	0.2	–	1.7*	–	–	–	0.7	–	2.2**
M Above ground	2.8**	–	2.2**	–	0.2	–	–	–	2.0**	–
M Below ground	–	1.5*	–	0.7	–	–0.2	–	–	–	1.8**
K Above ground	0.2	–	–1.2*	–	–2.0**	–	–2.0**	–	–	–
K Below ground	–	–1.3*	–	–1.8**	–	–2.2**	–	–1.8**	–	–

Above ground, aboveground biomass production; Below ground, below ground biomass production; H, clear cut (stocking 0.0); I, intensive cutting (stocking 0.3); S, medium (stocking 0.5); M, moderate (stocking 0.7); K, control (stocking 0.9); *statistically significant on the $p < 0.05$; **statistically very significant on the $p < 0.01$

Production on plot I with stocking 0.3

The production dynamics is illustrated in Table 1. In years 1993–94, we can see an evident decrease in above ground as well as underground biomass production compared to plot H. For the overall biomass it makes 58%. In this period, there were produced on average 5.2 kg ha^{-1} of above ground and 9.3 kg ha^{-1} of belowground biomass. Frequency values ranged from 40% (summer 1994) to 80% (spring 1993). Maximum production values of above ground and belowground biomass were recorded in spring 1994 (24.7 kg ha^{-1} and 16.3 kg ha^{-1}, respectively). In years 2005–2006, dry biomass production was observed strongly reduced both in above ground and in belowground biomass: on average 1.7 kg ha^{-1} and 2.1 kg ha^{-1}, respectively. Frequency values were between 60–70%.

Also on this plot, the values of variation coefficient were relatively high: almost 85% for above ground biomass and 62% for belowground biomass. On the other hand, the standard deviation in belowground biomass was small (1.9), and variation range relatively narrow (13.5).

The biggest differences were recorded between plots I and M for above ground biomass, and between plots I and K for belowground biomass.

Production on plot S with stocking 0.5, and on plot M with stocking 0.7

The course of production on plot S was very similar to plot M. In both cases, production gradually decreased over the whole period of study. The value of above ground biomass production on plot S (stocking density 0.5) was 2.2 kg ha^{-1}; in case of belowground biomass it was 3.4 kg ha^{-1}. The corresponding values on plot M (stocking 0.7) were 1.9 kg of above ground and 4.3 kg ha^{-1} of belowground biomass. The maximum amount of above ground biomass on plot S was recorded in spring 1994 – 6.4 kg ha^{-1}, maximum of belowground biomass in summer 1994 – 9.6 kg ha^{-1}. The maximum of above ground biomass on plot M was obtained in autumn 93 – 6.0 kg ha^{-1}, belowground biomass reached its maximum in autumn 1993 – 18.0 kg ha^{-1}. Frequency values were the lowest among the hitherto reported: 20–40%.

Variation coefficient maintained at high levels: 56% (S) and 81% (M). The biggest differences were found between plots S and H and between plots S and K.

Production on plot H with stocking 0.0

The control, untreated plot, displayed interesting facts. The share of above ground biomass produced by the species *Viola reichenbachiana* had increased almost up to 14% of the total biomass amount produced by all the herb taxons on the plot. In case of belowground biomass, it made even 24% of the total dry weight of belowground organs of all the herb species on the plot. Max. values of above ground biomass were obtained in summer 1994 (41.2 kg ha^{-1}). Belowground biomass reached its maximum in autumn 1994 with a value of almost 68.0 kg ha^{-1}. The max. values were higher than on the plot without parent stand: by 7.0 kg ha^{-1} in case of above ground and by more than 27.0 kg ha^{-1} in case of belowground biomass. This phenomenon was evidently caused by the light demands of the studied species. Mölder et al. (2008) studied correlation between production of herb species and tree canopy density, and they obtained the highest correlation coefficient (0.71) namely for *Viola reichenbachiana*. This means that this species is distinctly shadow-tolerating. This fact has also been confirmed by Kollár et al. (2008) who obtained in conditions of Carici fritschii-Quercetum xerophilous type in Moravia only 1.0 kg ha^{-1} of above ground biomass and 3.0 kg ha^{-1} belowground biomass of this species. Kubíček et al. (2006) report production values of this species in hard broadleaved forests near the Skalica town (Western Slovakia) being 13.0 kg ha^{-1} in case of aboveground biomass and 18.0 kg ha^{-1} in case of belowground biomass. In the same locality, but in forests of type ash-poplar floodplain, in which more light reached the forest ground, the production dropped to 1.0 kg ha^{-1} in case of above ground as well as in case of belowground biomass. Very similar production values report the authors also for the locality Kútsky les with dominant heliophytes *Urtica dioica* and *Alliaria petiolata*. Also on untreated plot, we obtained rather high variation coefficients: 77% in above ground and 66.5% in belowground biomass.

Statistically significant differences were obtained in almost all comparisons with the other plots (Table 3).

Conclusions

In years 1993–94, we evaluated production capacity of *Viola reichenbachiana* in varying conditions of submountain beech forests at the BEES Kremnické vrchy Mts. The experimental site consists of five partial plots differing in stocking density. We used the method of indirect sampling proposed by Kubíček (1983). The highest values of above ground biomass production were recorded in summer 1994 on the untreated, control plot: 41.2 kg ha^{-1}. The highest underground biomass values were obtained in the autumnal aspect 1994, on the control plot again: 67.2 kg ha^{-1}. In general, belowground biomass values culminate in autumn.

On the other hand, the highest frequency values were obtained on clear-cut plot H, about 80% on average.

The highest values of variation coefficient were observed on plot M: 69.2% for above ground and almost 86% for belowground biomass.

Pair tests revealed that the biggest differences in above ground biomass production were between plots

Table 1. Above and below ground biomass production of *Viola reichenbachiana* L.on the EES Kremnické vrchy Mts

Plots	H			I			S			M			K		
Biomass production	Above ground	Below ground	F	Above ground	Below ground	F	Above ground	Below ground	F	Above ground	Below ground	F	Above ground	Below ground	F
Period	kg	ha^{-1}	%	kg	ha^{-1}	%	kg	ha^{-1}	%	kg	ha^{-1}	%	kg	ha^{-1}	%
Spring 1993	15.2	3.8	60	4.8	3.2	80	3.6	7.2	20	2.8	2.8	40	9.4	18.8	40
Summer 1993	10.6	5.9	80	5.6	2.8	60	0.8	1.2	20	4.0	4.0	40	1.3	1.3	40
Autumn 1993	8.4	7..2	80	8.6	10.3	60	3.2	7.8	40	6.0	18.0	40	15.1	44.2	40
Total	**34.2**	**16.9**		**19.0**	**16.3**		**7.6**	**16.2**		**10.8**	**24.8**		**25.8**	**64.3**	
Spring 1994	24.5	23.1	100	24.7	16.3	60	1.8	2.3	20	1.1	2.6	40	16.7	34.5	40
Summer 1994	34.2	34.2	100	9.0	15.0	40	6.4	9.6	40	1.8	5.4	40	41.2	61.8	40
Autumn 1994	18.8	23.5	80	2.9	8.0	60	3.5	0.5	20	2.3	8.0	40	21.5	67.2	40
Total	**77.5**	**80.8**	–	**36.6**	**39.3**		**11.7**	**12.4**		**5.2**	**16.0**		**79.4**	**164.0**	–
Spring 2005	–	–	–	1.0	0.5	60		0.5	30	0.2	0.8	30	–	–	–
Summer 2005	–	–	–	–	–	–	–	–		–	–		–	–	–
Autumn 2005	–	–	–	2.0	1.0	60	1.0	1.0	40	0.5	1.0	30	–	–	–
Total	–	–	–	**3.0**	**1.5**		**1.5**	**1.5**		**0.7**	**1.8**	–	–	–	–
Spring 2006	0.3	0.1	30	0.8	4.0	60	0.3	0.3	40	–	–	–	–	–	–
Summer 2006	–	–	–	–	–	–	–	–		–	–	–	–	–	–
Autumn 2006	–	–	–	3.0	3.0	70	1.0	3.0	30	0.4	0.4	10	1.0	1.0	10
Total	**0.3**	**0.1**	–	**3.8**	**7.0**	–	**1.3**	**3.0**	–	**0.4**	**0.4**	–	**1.0**	**1.0**	–

H, clear cut (stocking 0.0); I, intensive cutting (stocking 0.3); S, medium (stocking 0.5); M, moderate (stocking 0.7); K, control (stocking 0.9); F, frequency

H and S, and between plots H and M. In belowground biomass was found the biggest difference between plots K and S. It follows that the intensity of management intervention has a very important influence on production capacity of individual herb taxons.

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Produkcia biomasy fialky lesnej v podhorských bučinách Kremnických vrchov (Západné Karpaty)

Súhrn

V rokoch 1993-94 a 2005-06 bol v podmienkach podhorských bukových porastov Ekologického experimentálneho stacionára Kremnické vrchy uskutočnený produkčný výskum *Viola reichenbachiana*. Ťažbovým zásahom boli upravené zakmenenia na požadované hodnoty. Optimálne a teda maximálne hodnoty produkcie tak nadzemnej ako aj podzemnej biomasy boli zaznamenané na kontrolnej ploche bez zásahu. Z časového hľadiska nadzemná biomasa dosiahla maximum v letnom aspekte roku 1994 s hodnotou 41,2 kg ha^{-1}, podzemná biomasa dosiahla maximum na jeseň toho istého roku so 67,2 kg ha^{-1}. Štatisticky najvýznamnejšie rozdiely boli medzi plochami, kde bol uskutočnený holorub a plochou s miernym resp. stredne silným ťažbovo-obnovným zásahom.

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