Quantity and distribution of fine root biomass in the intermediate stage of beech virgin forest Badínsky prales

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ABSTRACT: The fine root biomass represents 3,372 kg/ha in the intermediate stage of the beech virgin forest with different admixture of goat willow, where the vast majority of this biomass is located in the uppermost mineral soil layer 0–10 cm. The variability of the fine root biomass calculated from 35 sample points represents approximately 90% of the mean value and reaches the highest value within the humus layer. The total fine root length investigated in 10 cm thick soil layers decreases with increasing soil depth. A significant linear relationship between the fine root length (calculated per 1 cm thick soil layer and 1 m^2 of stand area) and the soil depth was confirmed, although the correlation is rather weak. The number of root tips decreases with increasing soil depth faster than the root length. As the number of tips per 1 cm of root length remains in the finest diameter class without significant changes, the reason is above all a decreased proportion of the finest root class (diameter up to 0.5 mm) from the total fine root length within the particular soil layer.

Keywords: fine roots; European beech; goat willow; Badín virgin forest; root tips

Rapid changes in the stand structures caused by abiotic factors belong to the natural components of the ecosystem development in a virgin forest. The comeback of the climax community to the given site follows the stage of pioneer and intermediate forest within the secondary succession. The stand structure of the intermediate forest is characterized particularly by the common occurrence of pioneer and climax tree species during this stage. Together with changes in the tree species composition in the stand, successive accumulation of aboveground and underground biomass takes place as well.

Production and relationships within the aboveground part of the intermediate forest ecosystem in the National Nature Reserve (NNR) Badínsky prales (Badín virgin forest) were analyzed in detail thanks to the long-term research of Korpeľ (1958, 1989), Saniga (1998) and Richter and Saniga (2006). Root biomass production, its changes and competition between the tree species within the root space of the intermediate forest have not been analyzed yet. Due to the extensity and destructive character of reliable rhizological methods, we cannot consider the investigation of whole root systems in a virgin forest as it represents an area with the highest level of nature protection. Therefore rhizological research has to concentrate only on the analysis of the fine root fraction that does not represent any serious ecosystem disturbance.

The fine roots (roots up to 2 mm in diameter) fulfil mainly nutritional, metabolic and symbiotic functions. Considering that it is understandable that the vast majority of fine root biomass is allocated in the upper soil layers and horizons (Hendrick, Pretziger 1996). According to Šály (1988) the depth of the main rhizosphere in forest stands of the temperate zone reaches approximately 40 cm. Burke and Raynal (1994) confirm that more than

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50% of total root biomass is located right up to the depth of 40 cm.

According to Bakker et al. (2001), in floodplain forests the depth of the root system is limited by soil porosity. Almost all parameters that characterize the biomass and the production of fine roots are declining with decreasing soil porosity. The authors also reported that 74% of fine roots (up to 3 mm in diameter) were located in the upper 15 cm of soil in oak mixed forests.

The anthropogenic modification of the soil environment, particularly sulphur and nitrogen deposition that is connected with the influence on the molar ratio of Al^{3+}/Ca^{2+}, causes considerable changes in fine root allocation. According to Murach (1984) and Puhe (1994), the fine roots of Norway spruce occur almost exclusively in A-horizon under these conditions. Mauer and Palátová (2002) presented similar results for young and also older individuals of rowan (*Sorbus aucuparia* L.), while they proved a considerable influence of the soil type.

However, the fine roots can reach a considerable soil depth. Köstler et al. (1968) reported the depth of approximately 5 m for the vertical roots of oak on the limestone soil, but they did not specify the diameter of the roots.

The fine root biomass is an important component of the stand total biomass. Its quantification is very time-consuming and therefore the effort to find a relationship between the fine root biomass and some of the stand characteristics that are easier to measure (e.g. stand basal area) is understandable (Kurz et al. 1996). However, Chen et al. (2004) found no correlation between these two parameters ($r^2 = 0.1$) after the analysis of extensive literary databases made by Vogt et al. (1996). Regarding the strict separation of the functions of the different root diameter categories, it is not possible to derive the fine root biomass from the total root biomass either.

Similarly, the efforts to derive the biomass or the other fine root features from some abiotic and biotic characteristics (e.g. soil grain, content of macroelements in litterfall, temperature, precipitation etc.) collide with the high variability of fine root biomass and thereby a weak relationship between given variables (Ostonen et al. 2007).

European beech is considered to be an exceptionally competitively strong tree species, which is particularly represented by its ability to eliminate most of our main tree species from the stand canopy under optimal conditions as well as by its adaptation to the wide range of environmental conditions. Ellenberg (1996) stated that dominance in the crown canopy was the primary factor for the existence of large homogeneous beech forests in Central Europe. The ability to occupy various sites is conditioned mainly by the specific attributes of the fine root system according to Köstler et al. (1968) and Hertel (1999). Hertel (1999) reported similar expansivity like that observed for the crowns also during the development of the fine root system. This conclusion was based on the results from the study of root competition between beech and sessile oak. The study confirms that the beech occupies the areas with thicker humus layer or soil space with increased nutrient supply more intensively than oak.

Tilman (1987) presented a hypothesis that strong competition in the root space reduces competition in the crown canopy. He assumed that the competitors invested too much of the organic matter into root competition, which was then missing during the growth of the aboveground parts. That may be one of the reasons why the root competition on the soils with good nutrient supply is weaker than on the poor sites. According to Ellenberg (1996) the competitive power of the beech root system, as the dominant tree species on the vast areas, is likely the same on the very different sites.

The goal of this study is to quantify the fine root biomass in an intermediate forest, to describe its basic morphological features and to derive the relevant relationships between them.

MATERIAL AND METHODS

The Badín virgin forest belongs to the oldest virgin forest reserves in Slovakia. It was declared in 1913 according to the list of natural heritage with the character of virgin forest. The forests of the enlarged protection zone were managed by common methods and therefore the requirement for their consecutive modification (forest stand reconstruction) towards an increase in the stability, i.e. towards the natural tree species composition and structure, emerged (Rybár 2001).

From the total area of the reserve (30.7 ha), the calamity area that is currently in the stage of intermediate forest comprises 6.1 ha. The virgin forest is situated in the south-eastern part of the Kremnické vrchy Mts. and belongs to the forest management unit Badín (forest district Staré Hory, forest enterprise Slovenská Ľupča). The average annual temperature is 5.5–6.0°C and the average annual precipitation amounts to 850–900 mm. The geologic bedrock is built of tuffs, andesitic agglomerates and compact andesite. Deep, eutric Cambisols are a dominant soil type. The humus is represented by the mull and favourable moder forms. The physiological soil depth is limited (40–45 cm) and the root system of trees (beech and fir) does not occupy heavy tuff layers, which can be a reason for uprooting the part of the virgin forest in 1947 according to Šály (1980).

The vast majority of the plant communities in Badín virgin forest (60–70% of the area) belong to the 4th forest vegetation zone, mesotrophic group B and the forest typology unit *Fagetum typicum* (Križová 2000).

At the end of May 1947 almost the whole inner part of the NNR Badín virgin forest (6.1 ha), was uprooted and left to the natural succession (Korpeľ 1995). Before the windthrow 80% of the uprooted area had a strongly homogeneous vertical structure that is typical of the optimum stage. The stand consisted of 75% beech and 25% fir and the average growing stock amounted to 800–850 m^3/ha.

In 1957, i.e. 10 years after the windthrow, the area was continuously covered by a thicket that consisted of 89% goat willow, 6% beech, 3% fir and 2% other pioneer tree species (birch, aspen, black elder). Korpeľ (1989) considered the natural succession on the windthrow area quite fast. In spring 1957 the mean density of goat willow in the pioneer forest reached 6,300 individuals per 1 hectare, with the average height of 2–3 m.

In 1967 the stand already had the character of the intermediate forest with the irregular mixture of climax tree species (beech, fir, maple) in understorey. Korpeľ (1995) reported the goat willow proportion decreased down to 77% and its stems were almost absolutely concentrated in the overstorey. The proportion of beech increased to 18%, while the other pioneer tree species made up less than 1%. During the measurements in 1987 an average density of natural regeneration of 301 individuals per hectare was recorded. The natural regeneration consisted of beech (36.5%), fir (28.6%), maple (22.3%), goat willow (8.5%) and other tree species (4.1%) and thus the continuous presence of the seedlings of all main tree species was ensured (Korpeľ 1995).

Saniga (1998) recorded a significant mortality of goat willow stems, which was expressed by a decrease in its growing stock and an increase in its dead wood ratio. In 1996 goat willow made up 28.9% of the total stem number and the proportion of beech was 68.2%. According to Richter and Saniga (2006) the proportion of goat willow decreased to 26.3% and that of beech increased to 70.2% in 2005, which confirmed a successive decline of goat willow from the stand. Presently the stand is in the final phase of the intermediate forest stage. An important role for the relatively fast emergence of the intermediate stage forest was played by the presence of the natural regeneration of climax tree species already under the canopy of the mature stand as reported from other virgin or managed forests (Saniga, Klimaš 2004; Klimaš, Smolek 2004; Barna 2008).

In the windthrow area we established 5 circular sample plots 22.6 m in diameter and 400 m^2 in size. On these plots all living trees according to the tree species were registered. We measured dbh (cm) for each stem and subsequently the stand basal area was calculated. The basic characteristics of the sample plots are presented in Table 1 (Jaloviar et al. 2008). The results confirm the high spatial heterogeneity of stem density that is caused mainly by beech. The higher beech proportion also leads to an increase in the total stand basal area, whereby the increase in its basal area is overproportionally higher than the decrease in the goat willow basal area, i.e. the beech increases its basal area not only as a result of the replacement of goat willow from the growing space.

The samples of fine roots were taken from 7 points that were set up in the centre of each sample plot. For the sampling we used a regular hexagon scheme with the side length of 1.5 m. The sample points

Table 1. The basic dendrometric characteristics of sample plots

Plot	Number of trees per 1 ha				Basal area				Basal area total	Mean dbh	
	beech		goat willow		beech		goat willow			beech	goat willow
	n	(%)	*n*	(%)	(m^2/ha)	(%)	(m^2)	(%)	(m^2/ha)	(cm)	(cm)
Plot 1	775	68.9	350	31.1	10.2	29.4	24.7	70.6	34.9	11.1	27.1
Plot 2	775	66.0	400	34.0	11.8	31.6	25.4	68.4	37.2	11.4	27.3
Plot 3	1,050	76.4	325	23.6	27.4	63.2	15.9	36.6	43.3	15.3	23.5
Plot 4	475	65.5	250	34.5	14.1	40.5	20.7	59.5	34.8	15.5	31.5
Plot 5	1,550	78.5	425	21.5	18.6	41.6	26.1	58.4	44.7	10.3	26.3

were located at the vertices of the hexagon and at its centre, which was identical with the centre of the sample plot.

For the determination of the fine root quantitative morphological characteristics we used a direct destructive method. The root samples were taken with a hollow drill of the inner diameter 80 mm and the length of the hollow part 200 mm in two steps, 0–20 cm and 20–40 cm. The depth of the samples depended on the skeleton fraction and ranged from minimum 20 to maximum 40 cm. The cylindrical soil cores with the parameters 80 × 200 mm were divided into the sections that corresponded to the layers 0–5 cm, 5–10 cm, 10–20 cm, 20–30 cm and 30–40 cm. The humus horizon was analyzed as a whole and separately.

In the laboratory the fine roots were separated from the soil cores and the humus layer, respectively, and categorized as vital or dead. The dead roots were not the subject of subsequent analysis and all presented results relate to vital fine roots. Despite the harvesting of comparative root samples for both species (beech, goat willow) many morphologically similar roots were observed during the analysis and it was not possible to exactly distinguish between the tree species merely according to the macroscopic features. Therefore we have to give up the analysis regarding the quantification of the fine root biomass according to the particular tree species. The image of vital fine roots was digitized using a high-resolution scanner (1,200 dpi) and subsequently the roots were dried for 72 hours at the temperature of 60°C and weighed to the nearest 0.1 mg.

The values of root length and number of root tips were determined using the software WinRhizo 2004a™. The biomass of vital fine roots was calculated by the program Fewubiom working under MS Excel. The output of the program is the fine root weight calculated per 1 ha, weights per hectare for each sample point and also the data on the fine root concentration in 100 ml of fine-grained soil (including the basic measures of variability).

RESULTS AND DISCUSSION

The values of total biomass of vital fine roots show a high variability in the investigated soil profile. The average value of the fine root biomass calculated as an arithmetic mean of all plots reaches 3,229 kg/ha. As expected, the majority of fine roots is concentrated in the layer from 0 to 10 cm (1,348.1 kg/ha), which represents 41.7% of all vital roots with the diameter less than 2 mm. The absolute values of fine root biomass (up) and their proportion from the total biomass in the investigated profile (down) according to separate soil layers are shown in Fig. 1. The high variability of individual values around the mean on each of the 35 sample plots is evident from the lines that represent standard deviations. The variability within the particular plots is lower; nevertheless, it remains on a high level with the coefficient of variation 89.9% (35.5–264.5%). The highest variability of

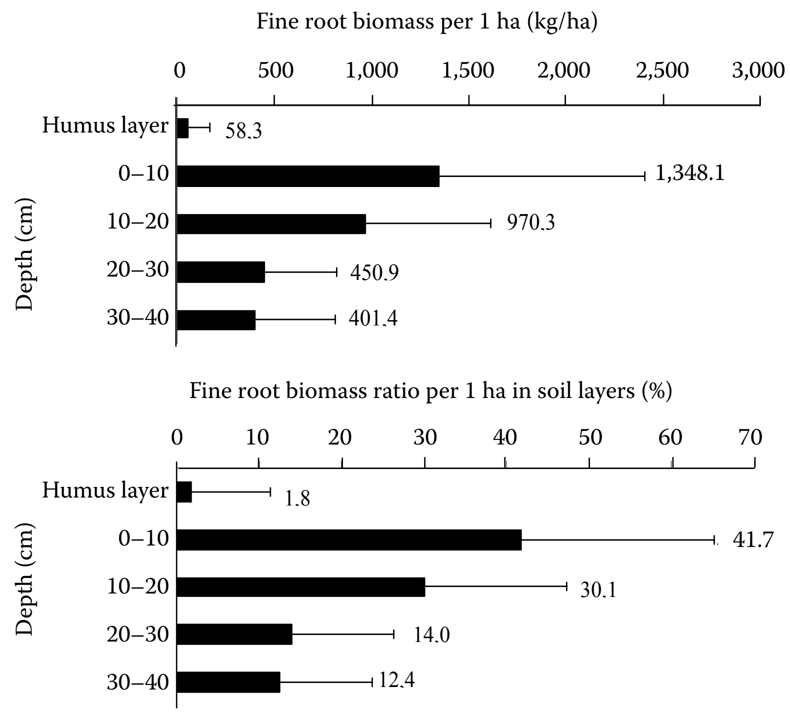

Fig. 1. Means and standard deviations of fine root dry matter weight in kg per 1 ha (up) and the proportions of root weights in particular soil layers (down) from fine root biomass in the whole soil profile (up to 40 cm depth)

Table 2. Fine root length in meters and weight of fine root dry matter in grams calculated per 1 m^2 area and 1 cm thick soil layer

Layer	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Average	
	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Length in m per 1 m^2 and 1 cm thick soil layer												
Humus	282.1	509.4	160.9	169.5	38.7	33.0	140.8	156.7	115.6	43.5	156.1	254.0
0–5 cm	204.3	136.6	228.3	153.2	461.9	283.7	697.7	700.9	165.0	83.2	361.6	397.8
5–10 cm	202.1	153.3	313.9	118.9	377.8	159.2	692.8	658.7	258.5	105.3	373.9	349.6
10–20 cm	195.3	82.3	129.3	85.7	205.1	113.8	174.6	153.1	173.8	128.9	175.6	112.0
20–30 cm	70.6	46.9	51.3	31.7	56.1	26.3	21.9	9.4	51.1	33.7	50.3	33.6
30–40 cm	98.8	73.4	28.9	25.6	80.6	24.9	16.4	18.6	61.5	43.5	58.8	51.3
Weight in g per 1 m^2 and 1 cm thick layer												
Humus	10.08	9.36	9.30	1.78	–	–	9.34	7.52	5.09	2.24	8.01	6.08
0–5 cm	12.94	12.40	16.30	21.52	26.50	11.56	23.70	28.96	8.18	2.91	17.73	17.53
5–10 cm	7.92	5.52	19.37	15.73	23.96	9.95	34.84	15.05	19.71	8.12	20.14	13.21
10–20 cm	7.15	3.95	5.60	4.36	16.13	7.37	12.92	6.13	9.93	5.66	10.11	6.55
20–30 cm	4.85	5.05	3.31	3.63	4.75	3.26	3.23	1.82	5.16	4.67	4.43	3.75
30–40 cm	3.45	2.94	1.06	0.60	9.71	8.65	1.24	1.72	8.37	5.04	5.05	5.62

the fine root biomass was found in the humus layer. Cairns et al. (1997) presented the values of root biomass and its allocation in different world regions. For the temperate zone they reported the values of total root biomass from 35 to 99 tonnes per 1 hectare, whereas the proportion of roots 5 mm in diameter accounted for 1–23%. According to Kodrík and Barna (2002) the ratio of the roots with diameter up to 5 mm represents 7–10% of the total root biomass of selected beech samples. Hertel (1999) presented the average fine root biomass around 100–600 g of dry matter per 1 m^2 (i.e. 1,000–6,000 kg/ha) for forest stands of the temperate zone. The fine root dry matter reaches 270 g per 1 m^2 in broadleaved stands and 300 g per 1 m^2 in coniferous stands. If we assume that the results refer to entire rhizosphere and to similar stratification of the biomass like in our research, then the total fine root biomass for the whole 40 cm profile (3,229 kg/ha, i.e. 322.9 g/m^2) determined in our study is by 20% higher. Nevertheless, it still remains close to the mean value of the above-mentioned range.

The total length of fine roots was analyzed according to individual sample plots and soil layers. All values of the length were calculated per 1 cm thick soil or humus layer respectively, and per 1 m^2 area. The highest variability of the fine root length was recorded in the humus layer. The fine root length distribution also corresponds to the average fine root biomass distribution (Fig. 1, Table 2). On each

Table 3. Parameters of linear and exponential regression between total fine root length and soil depth

Plot	$y = a + bx$			$y = a + e^{b+cx}$			
	a	b	r^2	a	b	c	r^2
Plot 1	233.3	–4.55	0.241	–109.2	5.87	–0.018	0.244
Plot 2	290.1	–8.69	0.532	–6.1	5.99	0.073	0.587
Plot 3	437.4	–12.80	0.531	20.3	6.44	–0.088	0.610
Plot 4	677.6	–22.90	0.350	–7.0	7.24	–0.138	0.447
Plot 5	237.9	–5.74	0.375	–144.8	5.99	–0.021	0.380

Table 4. Total fine root length distribution according to diameter classes in meters calculated per 1 m^2 area and 1 cm thick soil layer

Plot	Diameter class (mm)									
	0.01–0.50		0.51–1.00		1.01–1.50		1.51–2.00		2.01–2.50	
	(m)	(%)	(m)	(%)	(m)	(%)	(m)	(%)	(m)	(%)
Soil layer 0–5 cm										
Plot 1	186.8	91.5	15.0	7.3	1.0	0.5	1.30	0.6	0.04	0.03
Plot 2	215.0	94.2	11.6	5.1	0.7	0.3	0.20	0.1	0.67	0.03
Plot 3	413.9	89.7	35.4	7.7	9.4	2.0	2.70	0.6	0.16	0.03
Plot 4	675.5	96.9	14.6	2.1	3.6	0.5	3.00	0.4	0.42	0.06
Plot 5	148.3	89.9	14.7	8.9	1.5	0.9	0.30	0.2	0.01	0.01
Soil layer 5–10 cm										
Plot 1	182.7	90.5	15.7	7.8	3.1	1.5	0.30	0.1	0.07	0.03
Plot 2	288.9	92.1	18.9	6.0	5.2	1.6	0.70	0.2	0.01	0.01
Plot 3	332.2	88.1	34.1	9.1	5.9	1.5	3.30	0.9	1.57	0.40
Plot 4	631.7	91.3	40.1	5.8	14.2	2.1	4.10	0.6	1.73	0.25
Plot 5	226.9	87.9	21.5	8.3	6.2	2.4	2.70	1.0	0.85	0.30
Soil layer 30–40 cm										
Plot 1	89.1	90.2	7.3	7.4	1.8	1.8	0.52	0.5	0.00	0.00
Plot 2	22.8	78.9	5.7	19.7	0.4	1.4	0.00	0.0	0.00	0.00
Plot 3	65.5	81.3	11.6	14.4	2.6	3.2	0.84	1.0	0.00	0.00
Plot 4	13.5	81.8	2.6	15.7	0.4	2.4	0.01	0.1	0.00	0.00
Plot 5	48.9	80.4	8.9	14.6	1.8	2.9	0.16	0.3	1.00	1.70

plot the highest values of the fine root length were recorded in the first mineral soil layer (0–10 cm). The maximum lengths were found in the soil layer 0–5 cm on sample plots 1, 3 and 4, and in the soil layer 5–10 cm on sample plots 2 and 5. The value of the total root length decreased with the increasing soil depth. There is a weak but significant relationship between the fine root length and the soil depth and it has almost a linear character in the mineral soil. The comparison of the amounts of explained variance (r^2) and the parameters of the linear and nonlinear (exponential) regression shows that the replacement of linear equation with exponential function will not significantly increase the accuracy of the estimate for the given weak relationship. The r^2-values (Table 3) confirm the explained variance increased at most on sample plot 4, anyway this increase was less than 10%.

The distribution of total fine root length according to diameter classes was evaluated only for the layers 0–5 cm, 5–10 cm and 30–40 cm. According to previous results, the highest proportions of fine root biomass from the whole investigated profile are located in the first two soil layers. The soil layer 30–40 cm is the deepest investigated one. The differences in the absolute values of the length between the sample plots are the largest in the first diameter class (Table 4). The proportions of this diameter class are decreasing slightly with the soil depth, whereas the proportion of the subsequent diameter classes is increasing. From the diameter of 1.5 mm a significant decrease in the proportion of the total length can be observed again.

The total fine root length recorded by Hendricks and Bianchi (1995) in beech stands reached 184.10^6 m/ha and for Douglas fir they reported the value of 67.10^6 m/ha. In the mixed stand of both tree species even higher total values were recorded. The authors consider this as a sign for the competition between beech and Douglas fir, whereas the tree species occupy different soil layers.

The number of root tips is an important indicator of the fine root physiological activity. The root tip is followed by a zone of root hairs, i.e. of prolonged

Table 5. Parameters of linear regression between the number of fine root tips and the soil depth

Plot	*a*	*b*	*r*	r^2	*p* (for *a*)	*p* (for *b*)
Plot 1	85,573	–1,544.9	0.406	0.165	0.001	0.002
Plot 2	126,695	–3,636.3	0.611	0.374	0.001	0.001
Plot 3	185,155	–5,776.3	0.651	0.424	0.001	0.001
Plot 4	331,888	–11,357.3	0.531	0.282	0.001	0.001
Plot 5	126,176	–3,013.3	0.473	0.223	0.001	0.001

epidermal cells with the dominant function of water and minerals supply. The ratio between the fine root length and the number of root tips is an indicator of the intensity of the fine root forking.

A direct comparison of root tip number between the soil layers and sample plots is possible, but the number by itself depends on the other quantitative characteristics of fine roots, particularly on their length. With the increasing value of the fine root length the number of root tips increases as well. Therefore the highest frequency of root tips was recorded in the uppermost mineral soil layer, as expected. The proportion of the first two fine root diameter classes in the root length decreases slightly with the soil depth (Table 4). These finest roots bear a dominant amount of root tips and therefore the decrease in the root tip number with increasing soil depth is faster than in the case of root length. Hertel (1999) recorded a fast decrease in the root tip number with soil depth, whereas according to his results the decrease in the root tip number is faster than the decrease in the fine root biomass. His finding supports an assumption that the production and lifetime period of fine roots are affected by the availability of nutrients, especially of nitrogen. As soil nitrogen is almost exclusively the product of the organic matter decomposition, the fast decrease in the root tips with soil depth is an expected natural phenomenon. Despite this fast decrease a more or less linear relationship between the soil depth and the root tip number is maintained. The application of exponential function does not increase the accuracy of the estimation. Therefore the relationship between the root tip number (calculated per 1 cm thick soil layer and 1 m^2 area) and the soil depth was fitted by a regression line with the parameters reported in Table 5.

A more suitable comparative variable is the specific density of root tips, i.e. the number of root tips per 1 cm of root length. The occurrence of root tips is concentrated in the finest diameter class of fine roots. On the roots over 0.5 mm in diameter the root tips are very scarce and limited only to the endings originated on the dead parts of fine roots. The analysis confirmed that there is no correlation, or only a very weak one, between the specific density of root tips in the finest diameter class of fine roots and the soil depth. The decrease in the root tip number is caused rather by the increasing root

Table 6. Mean and variability of the root tip number per 1 cm of root length in the first three diameter classes

Soil layer	Diameter class					
	0.0–0.25 mm		0.26–0.50 mm		0.51–0.75 mm	
	mean*	SD	mean*	SD	mean*	SD
Humus	5.74	1.67	1.41	0.68	1.23	2.71
0–5 cm	5.86	0.92	1.49	0.49	0.69	0.41
5–10 cm	5.99	1.08	1.51	0.40	0.73	0.41
10–20 cm	5.84	1.04	1.42	0.68	0.69	0.75
20–30 cm	6.23	1.15	1.58	0.74	0.84	0.97
30–40 cm	6.37	1.33	1.30	0.41	0.45	0.28

*Tips per cm

diameter and by the proportion of the given diameter class in the total length (or weight) than by the soil depth (Table 6). Fritz (1999) considered the number of root tips per 1 cm as one of the basic indicators of the soil environment changes. According to our results the trees respond to the low nutrient supply in the lower soil horizons rather by the reduction of the finest root length than by the reduction of root tips density.

CONCLUSIONS

The research of fine roots in the intermediate stage of a beech virgin forest confirmed that the major portion of root biomass was concentrated in the uppermost mineral soil layer. The humus layer, which usually shows the highest root density in coniferous virgin forests, plays no significant role in the conditions of the 4th forest vegetation altitudinal zone. The values of the total fine root biomass in the intermediate forest correspond to the data presented by other authors.

The distribution of the total fine root length in the soil profile corresponds to the distribution of their biomass. The proportion of the finest roots (diameter class 0–0.5 mm) decreases slightly with the increasing soil depth.

The number of root tips is the highest in the uppermost mineral soil layer. Anyway, the decline of the root tip number is faster than the root length decline. We found no relationship between the number of root tips in the finest diameter class and the soil depth. Therefore it can be assumed that the reason for the fast decrease in the root tip number is the higher proportion of roots from the larger diameter classes together with the decline of the root length in the finest diameter class.

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Kvantitatívne charakteristiky a distribúcia biomasy jemných koreňov v prechodnom lese v NPR Badínsky prales

ABSTRAKT: Biomasa jemných koreňov v prechodnej etape prírodného bukového lesa s rôznou prímesou rakyty predstavuje 3 372 kg/ha, pričom najväčší podiel tejto biomasy je sústredený v najvyššie položenej vrstve minerálnej pôdy 0–10 cm. Variabilita biomasy jemných koreňov vypočítaná z 35 odberných miest predstavuje približne 90 % priemernej hodnoty a najväčšia je v prostredí nadložného humusu. Celková dĺžka jemných koreňov v skúmaných 10 cm hrubých vrstvách pôdy klesá smerom do hĺbky pôdy. Závislosť dĺžky jemných koreňov (prepočítaná na 1 cm hrubú vrstvu a 1 m^2 porastovej plochy) a hĺbky v pôde má lineárny charakter, ale len nízku tesnosť korelácie. Početnosť koreňových špičiek klesá v smere do hĺbky v pôde rýchlejšie ako dĺžka koreňov. Dôvodom je predovšetkým klesajúci podiel najtenšej triedy jemných koreňov s hrúbkou do 0,5 mm na celkovej dĺžke jemných koreňov v danej vrstve, keďže početnosť špičiek pripadajúca na 1 cm dĺžky koreňov zostáva v tejto hrúbkovej triede bez významných rozdielov v rôznych hrúbkových triedach.

Kľúčové slová: jemné korene; buk lesný; vŕba rakyta; Badínsky prales; koreňové špičky

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