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SHORT COMMUNICATIONS

Are there any differences in the root branch architecture of Norway spruce trees growing on two sites with different water regime?

Peter Štofko[1,2] ✉, *Milan Kodrík*[3]

[1] Neulogy, Pribinova 25, 811 09 Bratislava, Slovakia, phone: +421 254 414 100, e-mail: stofko@neulogy.eu,
[2] Slovak Organization for Research and Development Activities, Pribinova 25, 811 09 Bratislava, Slovakia, phone: +421 918 378 550, e-mail: stofko@sovva.sk
[3] Technical University in Zvolen, Faculty of Forestry, T. G. Masaryka 24, 960 53 Zvolen, Slovakia, phone: +421 455 206 273, e-mail: kodrik@vsld.tuzvo.sk

In case of undisturbed development, the spruce forms a typical shallow root system. In this surface root system, large, horizontal, lateral roots extend just below the soil surface with small roots branching down vertically. However, the environment (especially soil conditions) can influence root system features considerably (Coutts 1987). A high groundwater table can reduce maximum depth of root penetration. Kodrík (1998) mentions that the level of water table has the strongest influence on the formation of root system. Köstler *et al*. (1968) point out that the spruce forms extreme shallow root system on poorly drained sites. According to Konôpka (2003), the roots do not need to or cannot penetrate through deeper soil horizons, thus shallow and unstable root systems are formed on waterlogged sites. Crow (2005) states that soil water logging results in poor gas exchange, which depletes soil of oxygen and leads to anaerobic conditions and subsequent root death. Soils with permanently high water tables typically cause trees to develop very shallow, widespread root systems.

The main problem in research on belowground biomass is equivalent to the basic problem – how to obtain roots from the soil substrate or how to get to their nearest proximity in the soil substrate. Only overcoming this obstacle enables proper studies. For rough tree roots research, the excavation method is most common, hence roots are obtained from soil by digging. Using trees which are naturally uprooted, e.g. by wind or by a winch, is also effective.

The aim of this study is to compare the diameter and length structure of root branches of spruce trees growing on waterlogged and well-drained sites.

The structure of root branches of the Norway spruce (*Picea abies* [L.] Karst.) was measured in the locality Hnilé Blatá (20°03´E, 49°06´N) (High Tatra Mts.) (waterlogged site) and the locality Zemská (20°04´E, 49°01´N) (Low Tatra Mts.) (well-drained site). The forest stand waterlogged is uneven-aged, with the dominant tree layer 90 years old, south orientation, 5–10% slope, altitude is about 950 m a.s.l. The spruce is the dominant woody plant on the site and the birch (Betula sp.) and alder (Alnus sp.) are the admixture. Mean value of DBH is 31 cm and the average tree height equals 22 m. Soil is rather waterlogged, with low contents of peat in top horizons. The soil type is haplic stagnosols, stony soil skeleton with the percentage of stone 20%, with the average size of stones about 20 cm.

The forest stand on well-drained site is uneven-aged, with the over storey 80 years old, north orientation, 40% slope, altitude is about 950 m a.s.l. The forest stand is built only of the Norway spruce. The mean value of DBH of analysed spruce trees is 46 cm and the mean value of tree height is 32 m. The soil type is dystric cambisols, gravely soil skeleton with the percent-

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age of stones about 50% with the average size of stones about 4 cm.

Using random sampling, 22 uprooted spruce trees on the waterlogged site and 9 uprooted spruce trees on the well-drained site were selected. The uprooted spruces were scattered across the stands. The root plates of measured spruce trees were cleared from soil, by using hand tools (mattock, pick and shovel). The root plates were unsoiled up to the soil surface. It means that we did not excavate the whole root plates. We only cleared visible surface of root plates up to the hinge. After cleaning the root plates, the parameters of root branches were measured. The number, length and diameter of individual root branches were measured. The individual root branch is defined as the most vigorous continual root branch forking into other, smaller individual root branches. The length of the individual root branch was measured as the actual distance from its forking point up to the tip of its thickest (strongest) sub-branch. The individual root branches were classified to eleven diameter classes according to their diameter measured in the middle of root branch length: 1.1–2.0 cm, 2.1–3.0 cm, 3.1–4.0 cm, 4.1–5.0 cm, 5.1–6.0 cm, 6.1–9.0 cm, 9.1–12.0 cm, 12.1–15.0 cm, 15.1–20.0 cm, 20.1–25.0 cm and 25.1–30.0 cm. Mean values of the number and length of root branches were calculated for each root-diameter class.

Mean values of frequency and length of root branches according to the individual root-diameter classes are presented in Figures 1, 2 and 3. We found differences in the diameter and length structure of root branches between spruce trees growing on the waterlogged and well-drained sites. Average values of the absolute frequency of root branches in the first seven root-diameter classes (1.1–12.0 cm) were higher for spruce trees growing on well-drained sites. Moreover, these values were more than two times higher in the first three root-diameter classes. On the contrary, in the last four root-diameter classes (12.1–30.0 cm), we found lower mean values of the absolute frequencies of root branches in spruce trees growing on well-drained sites (Fig 1).

The results obtained showed that the frequency of roots in the first (thinner) root-diameter classes was higher in spruce trees growing on well-drained sites. Interestingly, the frequency of root branches in the coarsest root-diameter classes was higher in the

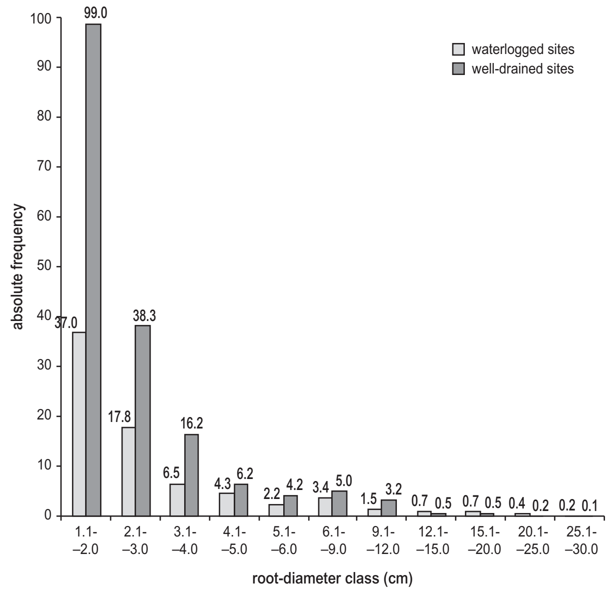

Fig. 1. Mean values of root-branches frequency in individual root-diameter classes in *Picea abies*

spruce trees growing on waterlogged sites. On the other hand, Konôpka (2005) found larger quantities of roots, especially those with the medium diameter as well as thin ones, on poorly drained sites than on well-drained sites. According to his results, the root systems were extremely long on poorly drained sites, so they had very abundant thinner roots. Kodrík and Hlaváč (1994) analysed the root architecture of the Norway spruce on well-drained sites. They found that the relative frequency of roots with the diameter smaller than 2 cm was about 50%, the relative frequency in the diameter class 2.1–7.0 cm was around 30% and the rest belonged to the diameter class 7.1 cm and higher. After re-calculation of our data, we found that the relative frequency of root branches up to 2 cm diameter was slightly higher (57% on well-drained sites) in comparison to the results of Kodrík and Hlaváč (1994). Kodrík (2002) analysed the frequency and thickness of root branches with the diameter exceeding 1cm in spruce trees growing on well-drained sites. He reported that the relative amount of roots with the diameter not larger than 3 cm was 59.5%, for roots with the diameter 3.1–9.0 cm it was 28% and roots with the diameter exceeding 10 cm consttuted only 12.5% of the total root number of wind thrown spruce trees. However, a different situation was observed by this author for standing spruce trees. In this case, the relative amount of roots with the diameter under 3 cm was 46.6%, with the diameter 3.1–9.0 cm it was 32.5% and with the diameter over 10 cm it was 20.9%. We found higher amounts of root branches in the first and the second root-diameter classes (together 79.2% in the two classes) in spruce trees growing on well-drained sites when compared to the results of Kodrík (2002).

We found considerably higher mean values of the length of root branches in all root-diameter classes in spruce trees growing on waterlogged sites (Fig 2). The values obtained were approximately two times higher in the first seven root-diameter classes of spruce trees growing on waterlogged sites. Mean values of the total length of root branches were noticeably higher in the last four root-diameter classes (12.1–30.0 cm) on waterlogged sites (Fig 3). Interestingly, we found that the mean value of the total length of root branches was two times higher in the root-diameter class 3.1–4.0 cm in spruce trees growing on well-drained sites.

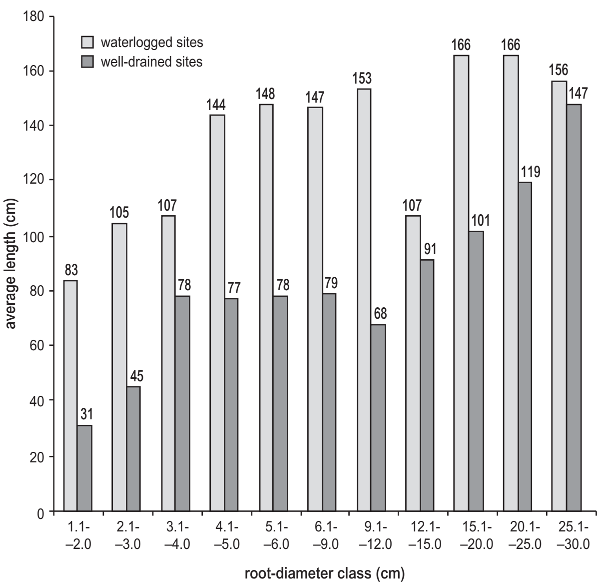

Fig. 2. Average length of root branches in individual root-diameter classes in *Picea abies*

We found the lowest values of the average length of root branches in the first (thinner) root-diameter classes. On the contrary, in these root-diameter classes the average values of the total root branch length were the highest. Similarly, Konôpka (1997) observed the highest value of the total length of root branches in the first root diameter class (1.0–3.0 cm) in spruce trees growing on well-drained sites. After re-calculation of his data, we found out that the relative value of the total length of root branches with the diameter 1.0–3.0 cm was 57.8% of all root branches together. Similarly, after another re-calculation of our data, we found out that the relative value of the total length of root branches with diameter 1.1–3.0 cm was 65.0% of all root branches together on waterlogged sites. In spruce trees growing on well-drained sites it was 63.5%. This difference is not big, so it seems that between waterlogged and well-drained sites there are not substantial differences in the total relative length of root branches in these root diameter classes.

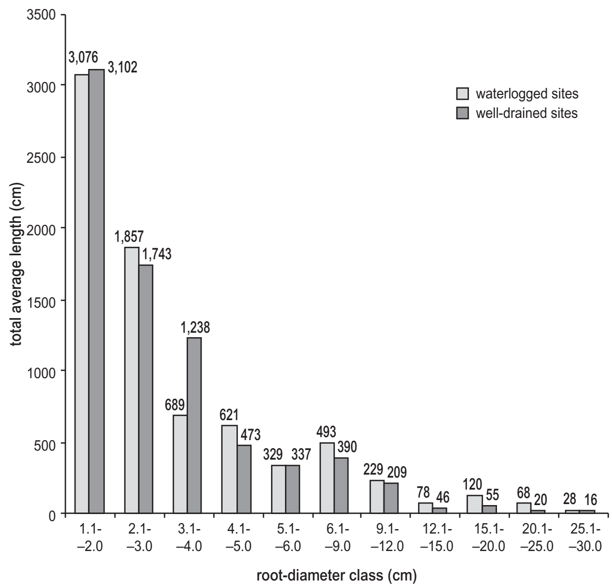

Fig. 3. Total average length of root branches in individual root-diameter classes in *Picea abies*

Konôpka (2005) made a detailed comparison of the root system architecture between spruces growing in well-drained and poorly drained sites. He found big differences in the total length of roots between spruces growing in poorly drained and well-drained sites. He reports that the mean value of the total root length was 58 m on waterlogged sites and 33 m on well-drained sites (trees with stem diameters 20 cm at the ground level ($D_{0.2}$) – from 6.5 cm to 49.0 cm). This author points out that the average total length of root branches in the root-diameter class 1.0–2.5 cm was 33.3 m (after re-calculation it is 63.4% of all root-diameter classes together) in spruce trees growing on well-drained sites and 72.4 m (after re-calculation it is 71.1% of all root-diameter classes together) in spruces growing on waterlogged sites (selected trees with $D_{0.2}$, from 25.1 cm to 35.0 cm). However, we found out that the mean value of the total length of root branches in all root-diameter classes together was almost the same on waterlogged (after re-calculation it is 75.9 m) and well-drained sites (after re-calculation it is 76.3 m). Similarly, after re-calculation, we found out that the mean value of the total length of root branches in the root-diameter classes 1.1–3.0 cm was 48.5 m (after re-calculation it is 63.5% of all root-diameter classes together) in spruce trees growing on well-drained sites and it was 49.3 m (after re-calculation it is 65.0% of all root diameter classes together) on waterlogged sites.

Based on these results it seems that the total mean length of root branches (all root-diameter classes together) with the diameter exceeding 1cm is almost the same for spruce trees growing on waterlogged and well-drained sites. Rastin and Mintenig (1992) found that in the Norway spruce horizontal roots at the distance of 40 cm, and especially at 80 cm from the centre of the rootstocks, were thicker on waterlogged soil types than on brown forest soil (well-drained). Spruce trees growing on brown forest soil also developed shorter and thinner horizontal roots than those growing on waterlogged soil types. Similarly, according to our results, spruce trees growing on well-drained sites form shorter root branches in the case of thinner root-diameter classes, but the frequency of these root branches is higher in comparison with spruce trees growing on waterlogged sites. Therefore, the total length of root branches (with the diameter exceeding 1 cm) of spruce trees growing in waterlogged and well-drained sites is almost the same.

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