Relationships between the parameters of aboveground parts and the parameters of root plates in Norway spruce with respect to soil drainage

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ABSTRACT: The aboveground parameters and the parameters of root plates in uprooted Norway spruce trees (*Picea abies* [L.] Karst.) were measured in the Hnilé Blatá locality (the High Tatras Mts.) (waterlogged sites) and in the Zemská locality (Low Tatras Mts.) (well-drained sites). The methods of linear correlation and regression analysis were used to quantify the relationships between the aboveground and belowground parameters. In waterlogged sites, a significant correlation (r = 0.60) was found between the stem diameters and the horizontal width of root plate, calculated average width of root plate, theoretical surface of root plate and visible surface of root plate. A medium correlation was found out between the stem diameters, tree height and the vertical radius of root plate. Similarly, a medium correlation was also determined between the tree height, width and length of crown and the horizontal width of root plate, average calculated width of root plate, theoretical surface of root plate and visible surface of root plate in spruce trees growing in waterlogged sites. In well-drained sites, was found out a medium correlation between the stem diameters and the horizontal width of root plate, partial vertical radius of root plate, average calculated width of root plate, theoretical surface of root plate and visible surface of root plate. A somewhat lower correlation was observed between the tree height and the vertical radius of root plate, average calculated width of root plate and theoretical surface of root plate in spruce trees growing in well-drained sites. In both sites, was found out a slight correlation between the aboveground parameters and the thickness of root plates; and no correlation was determined between the crown proportion index and root plate parameters.

Keywords: *Picea abies*; root plate; waterlogged sites

Norway spruce forms a typical shallow root system with large horizontal lateral roots extending just below the soil surface. From them, small roots branch down vertically. However, the environment (especially soil conditions) can influence the root system features considerably (Coutts 1987). The root development can be influenced by soil texture, structure, compaction and aeration, and the availability of moisture and nutrients. Similarly, Kodrík and Kodrík (1996) declared that although the root system formation is naturally controlled by the plant genetic and species-specific properties, it can be modified by environmental influences to a large extent. They stated that in general there is a close correlation between the root system structure and soil properties. Especially, a high groundwater table can reduce the maximum depth of root penetration. Kodrík (1998) reported that the groundwater level has the strongest influence on the root system formation. According to Crow (2005), waterlogged soils have a poor gas exchange, which depletes the soil of oxygen and leads to anaerobic

Supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences – VEGA, Grant. No. 1/4397/07.

conditions and root death. Soils with permanently high water tables typically cause the trees to develop very shallow, widespread rooting systems. According to Konôpka (2003), the roots do not need or cannot penetrate through deeper soil horizons, and as a result, shallow and unstable root systems are formed at waterlogged sites.

The question of relationships between the aboveground parts and the woody root system of trees was studied by Drexhage and Gruber (1992), Rastin and Mintenig (1992), Weber and Mattheck (2005), Gruber and Lee (2005), Di Iorio et al. (2005) and Nicoll et al. (2006). In Slovakia, an extensive research on these relationships was conducted by Kodrík (1983) and Konôpka (2001, 2002, 2003, 2006). However, the relationships between the aboveground and the belowground parts of trees can be influenced by soil properties, especially by the level of groundwater. The groundwater level strongly modifies the root system parameters and consequently, there arises a question how it influences the relationships between the aboveground and the belowground parts of trees. The aim of this study is to compare the relationships between the aboveground parts and the parameters of root plates in adult Norway spruce trees growing in waterlogged and well-drained sites.

MATERIAL AND METHODS

The aboveground and belowground parameters were measured in Norway spruce (*Picea abies* [L.] Karst.) in the Hnilé Blatá locality (the High Tatra Mts.) (waterlogged site) and in the Zemská locality (the Low Tatra Mts.) (well-drained site). Forest stand 396A (waterlogged) is uneven-aged, with the dominant stand layer 90 years old, south aspect, 5–10% slope, altitude about 950 m a.s.l. The stand consists of three forest biotopes (Table 1). The properties of soil are given in Table 2. Norway spruce is a dominant woody plant at the site, but the birch and alder are also quite abundant. The soil is rather waterlogged, with a low incidence of peat.

Forest stand 47A (well-drained site) is 80 years old, north aspect, 40% slope, at an altitude of about 950 m a.s.l. The stand consists of one forest biotope (Table 1). The soil properties are given in Table 2. Forest stand 47A consists of Norway spruce at a 100% proportion.

Using random sampling, 94 uprooted spruce trees in the waterlogged site and 39 uprooted spruce trees in the well-drained site were selected. These uprooted spruce trees were scattered across the stand. For the aboveground biomass, the following parameters were measured: stem diameter at the ground level ($d_{0.0}$), stem diameter 20 cm above the ground level ($d_{0.2}$), diameter at breast height (dbh) measured at 130 cm from the ground level, tree height (h), crown length (CL) and crown width (CW). The crown proportion index $C_{pi} = CL/h \times 100$ was calculated. For the belowground biomass, the following root plate parameters were measured: horizontal width of root plate (W_{rp}), vertical radius of root plate (R_{rp}), partial vertical radius of root plate (PR_{rp}), and thickness of root plate (T_{rp}) (Fig. 1). The average width of root plate (AW_{rp}) was calculated according to the formula: $AW_{\mathrm{rp}} = (W_{\mathrm{rp}} + 2R_{\mathrm{rp}})/2$. The theoretical surface of root plate was calculated according to the formula: $S_{\mathrm{t}} = \pi(AW_{\mathrm{rp}}/2)^2$ and the visible root plate surface – above the level of soil surface (above the hinge point) was calculated according to the formula: $S_{\mathrm{v}} = (\pi(AW_{\mathrm{rp}}/2)^2)/2 + W_{\mathrm{rp}} \times PR_{\mathrm{rp}}$. The mean values of all aboveground and belowground parameters were calculated.

Table 1. Habitat classification of analyzed stands (according to Stanová, Valachovič 2002)

Stand	Stand area (%)	Forest type according to Slovak forest typology		CORINE[1]		EUNIS[2]	
		code	name	code	name	code	name
396A (waterlogged)	50	0023	peaty fir-spruce	44.A4	*Sphagnum* spruce woods	G3.E6	nemoral bog *Picea* woods
	40	0012	birch-alder on a fluvioglacial substrate	44.21	montane grey alder galleries	G1.121	montane *Alnus incana* galleries
	10	6124	bilberry-spruce with fir	42.1	fir forests	G3.1	*Abies* and *Pinus* woodland
47A (well-drained)	100	6232	nutritive spruce-firs of higher degree	42.1	fir forests	G3.1	*Abies* and *Pinus* woodland

[1]According to the classification of the Commission of European Communities, [2]According to the EUNIS Habitat classification

Table 2. Soil characteristics of analyzed forest stand

Stand	Soil type[1]	Soil skeleton/average size (cm)	Proportion of skeleton (%)
396A (waterlogged)	Haplic Stagnosols	Stony/20	20
47A (well-drained)	Dystric Cambisols	Gravelly/4	50

[1]According to the classification of WRB (World Reference Base for Soil Resources 1994)

The relationships between the aboveground and belowground parameters were analyzed statistically, using linear correlation and regression analysis. STATISTICA 7.0 (StatSoft) was used for data analysis. The values of partial correlation coefficients were calculated. These partial correlation coefficients expressed the degree of correlation between the individual aboveground parameters and the individual root plate parameters. The forward stepwise method of multiple linear regression was used with the aim to find optimal regression equations calculated in order to estimate the values of root plate parameters (dependent variable) on the basis of the aboveground parameters (independent variables).

RESULTS

The mean values of aboveground parameters of the analysed spruce trees are given in Table 3. We found out differences in the aboveground parameters of the analysed spruce trees between the waterlogged and the well-drained sites. In waterlogged sites, the mean value for dbh was 32 cm, for $d_{0.2}$ 41 cm, for $d_{0.0}$ 50 cm, and for tree height it was 22.8 m. However, we obtained higher mean values in stem measurement in well-drained sites. In this locality, the mean value for dbh was 42 cm, for $d_{0.2}$ 55 cm, for $d_{0.0}$ 77 cm, and for tree height it was 31.5 m. Higher mean values of crown width and crown length were found out in spruce trees growing in well-drained sites. A relatively high mean value (72.2%) of the crown proportion index was found out in trees growing in waterlogged sites. The mean value of C_{pi} was 58% in the case of spruce trees growing in well-drained sites.

The mean values of root plate parameters of the analyzed spruce trees are given in Table 3. We have found out differences in root plate parameters between the Norway spruce trees growing in the waterlogged and in the well-drained sites. The mean value of W_{rp} was 500 cm in trees growing in waterlogged sites, but it was only 419 cm in Norway spruce trees growing in well-drained sites. Interestingly, on the other hand, in waterlogged sites, the mean value of R_{rp} was 159 cm only, but it was 211 cm in trees growing in well-drained sites. Therefore, we have not found out any large differences in the calculated mean values of AW_{rp}, S_t and S_v between the trees growing in the waterlogged and those in the well-drained sites. The mean value for PR_{rp} was 73 cm in spruce trees growing in waterlogged sites and 45 cm in those growing in well-drained sites. We observed considerable differences in the thickness of root plates between the

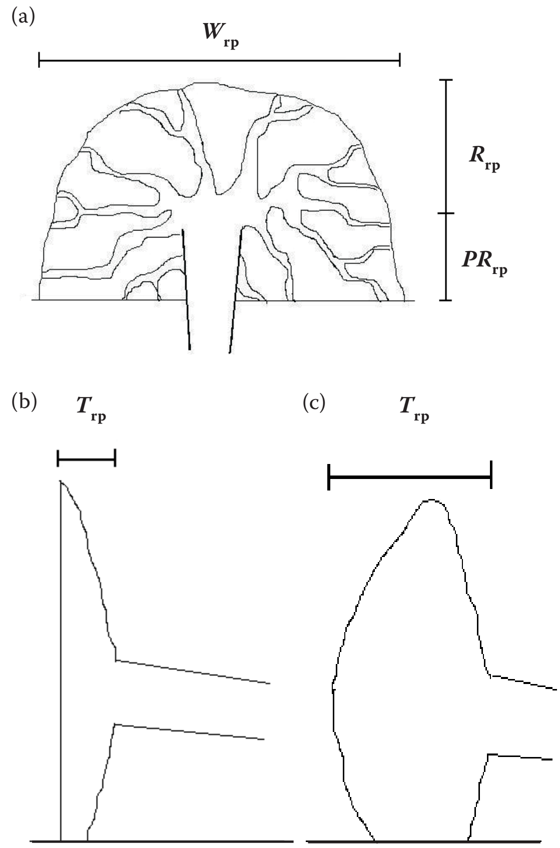

Fig. 1. Measurement of the root plate: width of root plate (W_{rp}), distance from the stem centre to the windward edge (R_{rp}), distance from the stem centre to the hinge (PR_{rp}) (a), thickness across the plate (T_{rp}) in spruce trees growing in waterlogged sites (b), thickness across the plate (T_{rp}) in spruce trees growing in well-drained sites (c)

Table 3. Mean values of aboveground and roots parameters of analyzed Norway spruce trees (± SD)

Site/Number of measured trees	Stem diameter (cm)			Tree height (h)	Crown (m)		Crown proportion index C_{pi} (%)
	dbh	$d_{0.2}$	$d_{0.0}$		width (CW)	length (CL)	
Aboveground							
Waterlogged/94	31.98 ± 7.68	41.20 ± 10.72	50.18 ± 14.29	22.79 ± 2.77	5.13 ± 1.40	16.46 ± 2.98	72.23 ± 9.71
Well-drained/39	42.32 ± 8.09	54.90 ± 10.47	76.61 ± 16.10	31.49 ± 2.68	6.48 ± 1.58	18.32 ± 3.25	58.17 ± 9.37
	Horizontal width(W_{rp}) (cm)	Vertical radius (R_{rp}) (cm)	Partial vertical radius (PR_{rp}) (cm)	Thickness (T_{rp}) (cm)	Average width (AW_{rp}) (cm)	Theoretical surface (S_t) (m^2)	Visible surface (S_v) (m^2)
Roots							
Waterlogged/94	499.68 ± 126.60	159.20 ± 67.69	72.50 ± 33.33	30.53 ± 5.07	409.04 ± 111.46	14.10 ± 7.75	10.77 ± 5.03
Well-drained/39	418.68 ± 94.35	211.18 ± 53.19	44.87 ± 17.14	122.37 ± 27.58	420.53 ± 84.36	14.43 ± 6.00	9.15 ± 3.65

dbh – diameter at breast height

spruce trees growing in the waterlogged and in the well-drained sites. The mean value of T_{rp} was only 31 cm in spruce trees growing in waterlogged sites, but the mean value of T_{rp} was four times higher in spruce trees growing in well-drained sites.

The values of partial correlation coefficients between the aboveground parameters and the parameters of root plates are given in Table 4. The regression equations calculated to estimate the values of root plate parameters on the basis of the

Table 4. Values of correlation coefficients between the aboveground parameters and the parameters of root plates in analyzed Norway spruce trees

Parameter	Site	dbh	$d_{0.2}$	$d_{0.0}$	h	CW	CL	C_{pi}
W_{rp}	waterlogged	0.62*	0.60*	0.58*	0.47*	0.56*	0.39*	0.11
	well-drained	0.51*	0.44*	0.45*	0.25	0.32*	0.22	0.15
R_{rp}	waterlogged	0.42*	0.44*	0.45*	0.41*	0.33*	0.38*	0.13
	well-drained	0.31	0.26	0.15	0.39*	0.13	0.22	0.05
PR_{rp}	waterlogged	0.20	0.22*	0.22*	0.12	0.08	0.09	0.00
	well-drained	0.32*	0.42*	0.40*	0.05	0.23	0.21	0.22
T_{rp}	waterlogged	0.18	0.16	0.16	0.17	0.05	0.08	–0.06
	well-drained	0.27	0.16	0.10	0.26	0.23	0.18	0.09
AW_{rp}	waterlogged	0.61*	0.61*	0.60*	0.51*	0.52*	0.45*	0.14
	well-drained	0.48*	0.41*	0.34*	0.39*	0.26	0.27	0.11
S_t	waterlogged	0.57*	0.57*	0.57*	0.48*	0.49*	0.44*	0.15
	well-drained	0.49*	0.41*	0.33*	0.38*	0.29	0.27	0.11
S_v	waterlogged	0.62*	0.63*	0.62*	0.50*	0.52*	0.44*	0.14
	well-drained	0.52*	0.46*	0.40*	0.34*	0.32*	0.29	0.16

*Statistically significant correlation coefficient (α = 5% significance level), dbh – diameter at breast height measured at 130 cm from the ground level, $d_{0.2}$ – stem diameter 20 cm above the ground level, $d_{0.0}$ – stem diameter at the ground level, h – tree height, CW – crown width, CL – crown length, C_{pi} – crown proportion index, W_{rp} – horizontal width of root plate, R_{rp} – vertical radius of root plate, PR_{rp} – partial vertical radius of root plate, T_{rp} – thickness of root plate, AW_{rp} – average width of root plate, S_t – theoretical surface of root plate, S_v – visible root plate surface – above the level of soil surface (above the hinge point) aboveground parameters are given in Table 5. In general, we have found out a higher correlation between the aboveground parameters and the root plate parameters in spruce trees growing in waterlogged sites. The highest degree of correlation was obtained between the particular stem diameters and the horizontal width of root plates, AW_{rp}, S_t and S_v. In waterlogged sites, a medium correlation was found out between the particular aboveground parameters (expect for C_{pi}) and the vertical radius of root plate. Interestingly, the values of correlation coefficients between the particular stem diameters and the partial radius of root plates were higher in spruce trees growing in well-drained sites. According to our results, there was only a slight correlation between the particular aboveground parameters and the thickness of root plates in both sites. A medium-strong correlation was found out between the tree height and the root plate parameters (except for PR_{rp} and T_{rp}), and this correlation was lower in spruce trees growing in well-drained sites. Similarly, a medium-strong correlation existed between the crown width and the belowground parameters (except for PR_{rp} and T_{rp}), but only in spruce trees growing in waterlogged sites. Norway spruce trees growing in well-drained sites showed a lower degree of correlation between the crown width and the parameters of root plates. Similarly, a lower degree of correlation was found out between the crown length and the particular root plate parameters (expect for PR_{rp} and T_{rp}) in spruce trees in waterlogged sites. Moreover, this correlation was even lower in the case of spruce trees growing in well-drained sites. Interestingly, in either of the localities no correlation was determined between the crown proportion index and the root plate parameters.

Similarly, based on the results of correlation analysis, the forward stepwise method of multiple linear regression selected particularly the individual stem diameter variables into the models. These variables were mostly statistically significant. In the case of computing the variable T_{rp}, the regression equations were statistically insignificant, and only a low share of dependence (R^2 = 0.05 and 0.07) could be explained by these regression models. Therefore, it seems that the greatest problem is to estimate the thickness of root plates, because no correlation be-

Table 5. Statistically optimal regression equations of root plate parameters

Estimated parameter	Site	Regression equation	R	R^2	P-level
W_{rp}	waterlogged	$y = 204.837^* + 8.623\text{dbh}^* + 22.101CW - 5.734CL$	0.64	0.41	0.000
	well-drained	$y = 209.721^* + 7.440\text{dbh}^* - 5.781CL$	0.53	0.28	0.003
R_{rp}	waterlogged	$y = -14.054 + 1.506d_{0.0}^* + 4.288h$	0.46	0.21	0.000
	well-drained	$y = -35.040 + 7.820h^*$	0.39	0.16	0.014
PR_{rp}	waterlogged	$y = 49.289^* + 1.137d_{0.2}^* - 4.609CW$	0.26	0.07	0.046
	well-drained	$y = 36.847 + 0.824d_{0.2}^* - 1.182h$	0.45	0.20	0.021
T_{rp}	waterlogged	$y = 27.212^* + 0.232\text{dbh}^* - 0.797CW$	0.23	0.05	0.087
	well-drained	$y = 83.939^* + 0.908\text{dbh}$	0.27	0.07	0.106
AW_{rp}	waterlogged	$y = 135.155^* + 5.082d_{0.2}^* - 12.570CW$	0.62	0.38	0.000
	well-drained	$y = 208.291^* + 5.016\text{dbh}^*$	0.48	0.23	0.002
S_t	waterlogged	$y = -4.033 + 0.328\text{dbh} + 0.152d_{0.0}$	0.59	0.34	0.000
	well-drained	$y = -0.813 + 0.360\text{dbh}^*$	0.49	0.24	0.002
S_v	waterlogged	$y = -2.055 - 0.010d_{0.2} + 0.226\text{dbh} + 0.119d_{0.0}$	0.64	0.41	0.000
	well-drained	$y = -0.740 + 0.234\text{dbh}^*$	0.52	0.27	0.001

*Statistically significant absolute and regression coefficient (α = 5% significance level), dbh – diameter at breast height measured at 130 cm from the ground level, $d_{0.2}$ – stem diameter 20 cm above the ground level, $d_{0.0}$ – stem diameter at the ground level, h – tree height, CW – crown width, CL – crown length, W_{rp} – horizontal width of root plate, R_{rp} – vertical radius of root plate, PR_{rp} – partial vertical radius of root plate, T_{rp} – thickness of root plate, AW_{rp} – average width of root plate, S_t – theoretical surface of root plate, S_v – visible root plate surface – above the level of soil surface (above the hinge point), R – multiple correlation coefficient, R^2 – multiple coefficient of determination tween the aboveground parameters and the thickness of root plates was found in the two localities.

DISCUSSION

We have found out considerable differences in the root plate parameters of Norway spruce trees growing in two sites with different water regimes. Konôpka (2001, 2002) compared the parameters of root plates between Norway spruce trees growing in waterlogged and in well-drained sites. He found out that the mean value of root plate depth was 45 cm in spruce trees growing in poorly drained sites and 100 cm in the trees growing in well-drained sites. However, according to our results, the mean values of the thickness of root plates were almost four times lower in spruce trees growing in waterlogged sites (mean value only 30 cm). This may point out to more extreme soil conditions under which we conducted our research. Konôpka (2002) obtained lower mean values of root plate width in spruce trees growing in poorly drained sites (315 cm) in comparison with our results according to which the mean value of W_{rp} was 499 cm in spruce trees growing in waterlogged sites. Konôpka (2002) found out that the mean value of root plate width was only 248 cm in spruce trees growing in well-drained sites. This is a considerably lower mean value in comparison with our results (in our case, in well-drained sites, the mean value of W_{rp} was 418 cm). Our results more correspond to the results of Kodrík (1983), who found out that the root systems of Norway spruce trees growing in loamy-sandy soils had the values of root system thickness from 0.7 to 1.4 m (averaged 0.9 m), and the values of root system width from 3.1 to 6.4 m (averaged 4.8 m). In medium-deep soils with the physiological depth of about 1.3 m, this author found out that the roots reached a rooting soil depth of only 0.7–1.1 m, but the root system width was 4.0–6.4 m. Similarly, Crow (2005) reported that Norway spruce trees growing in intermediate loamy soils could reach a rooting depth of up to 1.5 m.

Interestingly, in well-drained sites, the mean value of the vertical radius of root plate (R_{rp}) reached approximately a half mean value of the horizontal width of root plates (W_{rp}). It reveals that in well-drained sites, the horizontal widths and vertical widths of root plates were almost the same (in contrast to waterlogged sites). Based on this finding, it seems that Norway spruce trees growing in well-drained sites form more symmetrical root plates in comparison with the spruce trees growing in waterlogged sites. Therefore, the mean value of the theoretical surface of root plates was higher in spruce trees growing in well-drained sites.

In both localities, the mean value of crown width was higher than the mean value of the horizontal width of root plate (W_{rp}) (measured in the same horizontal direction), although this difference was not so distinct in spruce trees growing in waterlogged sites (in this case, the mean value of *CW* was only by 13 cm higher in comparison with the mean value of W_{rp}). Kodrík (1983) found out that the root system of Norway spruce trees growing in well-drained sites exceeded the circumference of the crown. This author reported that the width of spruce root systems in the Hronec locality was wider by 94 cm than the width of the crown. On the other hand, Konôpka (2002) found out the lower values (roughly half values) of root system widths than the values of crown widths in spruce trees growing in well-drained sites. On the contrary, this author found out that the values of root plate widths were higher than the values of crown widths in spruce trees growing in poorly drained sites. He stated that the root systems of spruce trees growing in poorly drained sites were broader by one-third than those in well-drained sites. Kodrík and Kodrík (1996) mentioned that the values of crown widths were higher than the values of root system widths in Silver fir trees growing in well-drained sites.

Based on our results, the closest correlation was found out between the stem diameters and the root plate parameters. Therefore, it seems that the stem diameters may be the best predictors of root plate parameters. Similarly, Gruber and Lee (2005) found out a high degree of correlation (r^2 = 0.96) between the diameter at breast height and the total dry weight of coarse roots in Norway spruce. For example, Nicoll et al. (2006) found out a positive linear correlation between the coarse root volume and the stem volume in *Picea sitchensis*. Similarly, analyzing the root system architecture of *Quercus pubescens* Di Iorio et al. (2005) found out that the diameter at breast height was the best predictor of root volume but without any correlation to the length and number of roots.

Konôpka (2001) evaluated the depth and width of root systems in Norway spruce, Silver fir, European beech, European larch and Scots pine and compared the interspecific differences in root system parameters. He found out a closer correlation between the root plate width and the dbh than between the root plate depth and the dbh. His results partially correspond to our results because we have not found out any correlation between the stem diameters and the thickness of root plates in Norway spruce trees growing in the two localities. Konôpka (2002) found out a statistically significant correlation between the aboveground parameters ($d_{0.2}$, dbh, tree height, width and length of crown, slenderness ratio) and the width of root plates in Norway spruce trees growing in well-drained sites. However, we observed only a weak correlation between the width and length of the crown and the root plate parameters in spruce trees growing in well-drained sites. Similarly, Kodrík (1983) found out a strong correlation between the crown width and the root plate width in Norway spruce trees growing in well-drained sites. That does not correspond to our results. It seems possible that the author conducted his research in different growing conditions, because the root plate width of spruce trees (analyzed by Kodrík) exceeded the circumference of the tree crown. On the other hand, our spruce trees had a considerably higher mean value of crown width (averaged 6.5 m) in comparison with the mean value of the horizontal width of root plate (averaged 4.2 m).

Konôpka (2002) found out a statistically significant correlation between the crown length and the root plate width in Norway spruce trees growing in poorly drained sites but also in most of the well-drained sites. However, we found out a statistically significant correlation between these two parameters only in the case of spruce trees growing in waterlogged sites. In well-drained sites, we determined only a weak and statistically insignificant correlation between the *CL* and the root plate width. Konôpka (2002) came to equivocal results concerning the correlation between the C_{pi} and the root plate width. He reported these two variables being in correlation in the both types of the studied localities; however, the correlation was significant in a half of them only. According to our results, a weak correlation exists between the C_{pi} and the root plate parameters.

Konôpka (2002) found out statistically significant correlations between the aboveground parameters ($d_{0.2}$, dbh, crown width, slenderness ratio) and the depth of root plates in Norway spruce trees growing in poorly drained and well-drained sites. The correlation between the tree height and root plate depth was significant only in a half of the localities. For most of his localities, this author observed an insignificant correlation between the root plate depth and the crown length and C_{pi}. His results are in contradiction with our results because we have not found out any correlation between the aboveground parameters and the thickness of root plates in the two localities. In general, it can be supposed that there is a correlation between the aboveground parts and the rooting depth in trees growing in well-drained sites – because of deeper vertical root penetration. In contrast, no such a correlation is supposed in the case of waterlogged sites because the high groundwater level strictly obstructs the trees to develop deep roots. Therefore, there arises a question why Konôpka (2002) found out a statistically significant correlation between the aboveground parameters and the depth of root plates in spruce trees growing both in waterlogged and in well-drained sites. According to our results, it seems that the roots of Norway spruce reach the final rooting depth at an early age and that the rooting depth does not increase in adult trees. This phenomenon can be caused by the surface root system typical of Norway spruce. Similarly, Köstler et al. (1968) reported that Norway spruce develops an intensive vertical rooting growth in the first decades of its life and it reaches the final rooting depth at an age of 30–40 years. Later, the roots hardly penetrate into deeper soil horizons while the vertical root system is densified by other root branches that grow from the main roots. Kodrík (1983) concluded that the growth ability of roots fades away since the age of 80 years; and that the root systems of trees at the age of 80 years were the same as those 120 years old. According to our results, the correlation between the aboveground parameters and the thickness of root plate was stronger in spruce trees growing in well-drained sites than the correlation in spruce trees growing in waterlogged sites; however, in comparison with the results of Konôpka (2002), it was statistically insignificant. For example, Nicoll and Ray (1996) observed that the spread of the root system of *Picea sitchensis* trees and the ratio of root mass to shoot mass (root/shoot ratio) were both negatively related to the root plate depth in soil.

CONCLUSION

We have not found out any strong correlation between the aboveground parameters and the root plate parameters in either of the localities. Generally, this correlation was stronger in Norway spruce trees growing in water-logged sites, and the highest degree of correlation was observed between the particular stem diameters and the root plate parameters. Our results allow us to recommend the dbh – the most frequently measured parameter in forestry practice – as a predictor of the root plate width in Norway spruce trees, but without a correlation to the root plate depth. Therefore, the main problem seems to be the estimation of the thickness of root plates in Norway spruce trees, and it is probable that there does not exist any relationship between the aboveground parts and the rooting depth in adult spruce trees.

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Received for publication November 2, 2009
Accepted after corrections January 12, 2010

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