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Possibilities of influencing the rooting quality of Norway spruce (*Picea abies* [L.] Karst.) cuttings

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ABSTRACT: The influence of the date of cutting collection and cutting position in the crown on rooting quality was evaluated in cuttings taken from seven-year ortets. The evaluation of various dates of cutting collection in spring demonstrated a possibility of successful propagation by cuttings during a relatively long period from full bud dormancy to flushing onset. The relationship between the development of aboveground parts (flushing, shoot and bud formation) and rooting quality was not established. The exposure of cuttings in the crown of parent tree with respect to the cardinal points did not influence rooting percentage and quality. A somewhat higher rooting ability was observed in cuttings from lower parts of the crown in comparison with cuttings taken from the highest whorls. Differences were more perceivable in generally weak-rooting clones. The comparison of rooting quality in cuttings from seven- and eight-year mother plantations with cuttings from a sixteen-year mother plantation confirmed that not only the rooting of cuttings collected from older mother plantations is weaker but also their growth is slower and their plagiotropic growth continues for a longer time.

Keywords: Norway spruce; *Picea abies* (L.) Karst.; vegetative propagation; cuttings; cutting date; position of cuttings in crown; mother plantation age; rooting quality; rooting ability

The technology of production of Norway spruce cuttings is a well-tried method of vegetative propagation of forest tree species. Information is available about the influence of cutting size and treatment, age of parent trees, collection dates, position of cutting collection in the crown and other aspects of propagation on rooting ability and further development of rooted cuttings.

Rooting quality is influenced by genetic dispositions, physiological condition of cuttings at the time of their collection and environment in propagation houses. There may exist large differences in rooting ability between different clones of the same population.

An extensive clone material of Norway spruce that is currently at disposal in the model area of the Krkonoše Mts. made it possible to study the above-mentioned problem in great detail in relation to particular clones. Attention was mainly focused on the influence of the date of winter cutting collection and on the influence of cutting exposure in the crown on the number of rooted cuttings and their quality. Our investigations were supported by Grant QD1274 of National Agency for Agricultural Research.

Present state

Copious literary data on qualitative biological and biometrical requirements for the original material for spruce propagation by cuttings are available. ROULUND (1971), KLEINSCHMIT and SCHMIDT (1977), ZAVADIL (1979, 1982), BÄRTERLS (1982), RADOSTA (1987), SPETHMANN (1997) and many other authors presented complex findings. VOLNÁ et al. (1982) elaborated a summary review of literature providing enough information on the given problem.

The physiological condition of a cutting at the time of collection largely influences rooting quality. Besides the ortet age and environmental conditions it is affected by collection date and cutting position in the crown of the parent tree. ZAVADIL (1979) expressed an opinion that differences in rooting, frequently considered as genetically conditioned, could partly be caused by the physiological condition of the parent plant. SPETHMANN (1997) also stated that genetically fixed characteristics could be modified by the ortet physiological condition.

A general finding is that rooting ability decreases with increasing *age of parent plants* (ROULUND 1975, 1979; CHALUPA 1982a; RAUTER 1982; ZAVADIL 1982; ŽĎÁRSKÁ 1983; HARTIG 1986; KLÍMA 1986, 1987; HAUCK 1987; JANSON 1989; RADOSTA 1990b). The authors reported not only a decrease in the total number of rooted cuttings but also a slowdown of the rooting process – the time for the formation of a new root system becomes longer (DOLGOLIKOV 1984). A root to shoot ratio gets

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worse by reducing the growth of roots, especially of fine ones (SCHACHLER, MATSCHKE 1984). The age of parent plant influences not only rooting percentage but also the growth rate and morphology of rooted cuttings (MAUER, PALÁTOVÁ 1994). The older the ortet, the longer the time until ramets start growing straight upwards. It is to expect that the younger the ortet, the easier the rejuvenation because it is not necessary to turn about such an amount of ontogenetic development (WÜHLISCH 1984). SPETHMANN (1997) concluded that only rooted cuttings from young plants or their parts could develop into high-quality plants. Besides the deterioration of growth characteristics, the vitality of cuttings and their adaptability to environmental factors (frost, stress) also get worse with increasing age of parent plants. Surviving plants are physiologically unstable and the quality of rooted cuttings is worse than that in mother plantations. The weaker the rooting of a tree species in general, the higher the influence of the parent plant age (GENEVE 1994).

The juvenile phase for cutting collection is not strictly delimited either within a species or within a population, and is clone-dependent (SCHNECK 1980; SPETHMANN 1997). According to ZAVADIL (1984) the propagation of seedlings and plants by cuttings to the age of about 5 years (80–90%) is very successful, at the age of 10 years on average above 50%.

Some aspects that seem negligible in young mother plantations become increasingly important with the growing age of parent trees. These are e.g. differences between clones (RADOSTA 1990b) or the influence of cutting position in the crown (GIROUARD 1974; FOJTÍK 1979a,b; DUCHÁČ 1981; KLEINSCHMIT 1974; VOLNÁ 1982).

For instance CHALUPA (1982b) observed great differences in rooting ability *between clones* when in identical conditions the rooting percentage of some clones was only 30–40% while of others even 100%. Various clones can respond differently to the application of growth hormones (WISE, CALDWELL 1993). TERASMAA (1985) reported differences in rooting ability in four-year spruce plants and CHALUPA (1982b) found out large clone differences in six-year parent trees. RADOSTA (1990b) reported that at the age of 6 years clone variability accounted on average for maximally 5% of the total rooting percentage, two years later in the same (eight-year) mother plantation the difference in rooting between the best and the worst rooting clone amounted to 70%. TOMKOVÁ and CHLEPKO (TOMKOVÁ et al. 1987; CHLEPKO, TOMKOVÁ 1990) also recorded differences between clones not only in rooting percentage but also in rooting quality (number and length of formed roots). Clones with the higher percentage of rooting cuttings produced the root system of higher quality.

The *influence of the position of cutting collection in the crown* also becomes more important with the age of parent trees. While in young trees the differences between cuttings from various positions are negligible, in older trees they are more perceivable (GIROUARD 1974; KLEINSCHMIT 1974; FOJTÍK 1979b,c; DUCHÁČ 1981; VOLNÁ 1982, etc.). The influence of the position in the crown is more marked in tree species with bad rooting than in good-rooting ones (GENEVE 1995). In young (eight-year) spruce trees there was no difference in rooting between the cuttings from axial parts or from lateral branches (HAUCK, VOLNÁ 1989). SPETHMANN (1997) concluded that the importance of the position of cutting collection in the crown increased with the height of the tree. He recommended to collect cuttings in the closest proximity to the stem because they responded as the most juvenile ones in this position. In general, it is recommended to collect cuttings preferentially from well-sunlit shoots in the lower half of parent tree (VOLNÁ 1982; SCHACHLER et al. 1987). ROULUND (1975) reported an average improvement of rooting by 2.5% per whorl from top to lower parts. On the contrary, HAUCK and VOLNÁ (1989, 1990), who examined in detail the influence of the collection position on rooting quality in eight-year spruce trees, found the part between the 3rd and 6th whorl to be the most important position for cutting collection, i.e. the part where three orders of branches already developed. On condition that the purposefully grown young mother plantation is used in optimum conditions, the position of cutting collection on the parent tree is an unimportant factor. Neither can it be taken into account in forest operations for economic reasons because the collection of a maximum number of cuttings is required. These conclusions also hold good when the *cutting position is examined from the aspect of cardinal points* (DUCHÁČ 1981) and order of branches from which cuttings were collected (HAUCK 1987). DUCHÁČ (1981) found out that the influence of cardinal points on rooting percentage was insignificant while the influence of the whorl position was much more important.

Date of collection largely depends on climatic conditions of the mother plantation locality, climatic conditions of the year of propagation, and on individual and population phenological differences in propagated planting stock (RADOSTA 1990a). Although the opinions and experience of the time of spruce cutting collection considerably vary among the authors, the collection of cuttings in spring before flushing is currently preferred in propagation operations. This time of collection is a compromise between biological and economic aspects. With the high native rooting ability especially the power consumption for the heating of propagation houses is reduced (RADOSTA 1990a). Cuttings that started flushing are not suitable for rooting (FOJTÍK 1982). On the other hand, DUCHÁČ (1981) reported that the time of collection January–May did not have a large influence on rooting percentage in spruce. Rooting percentage was not influenced by the time of parent tree flushing either.

MATERIAL AND METHODS

Rooting quality may be influenced by the physiological condition of cuttings at the time of their collection. Besides the ortet age and environmental conditions it depends mainly on the date of collection and on the position of cutting in the crown of the parent tree.

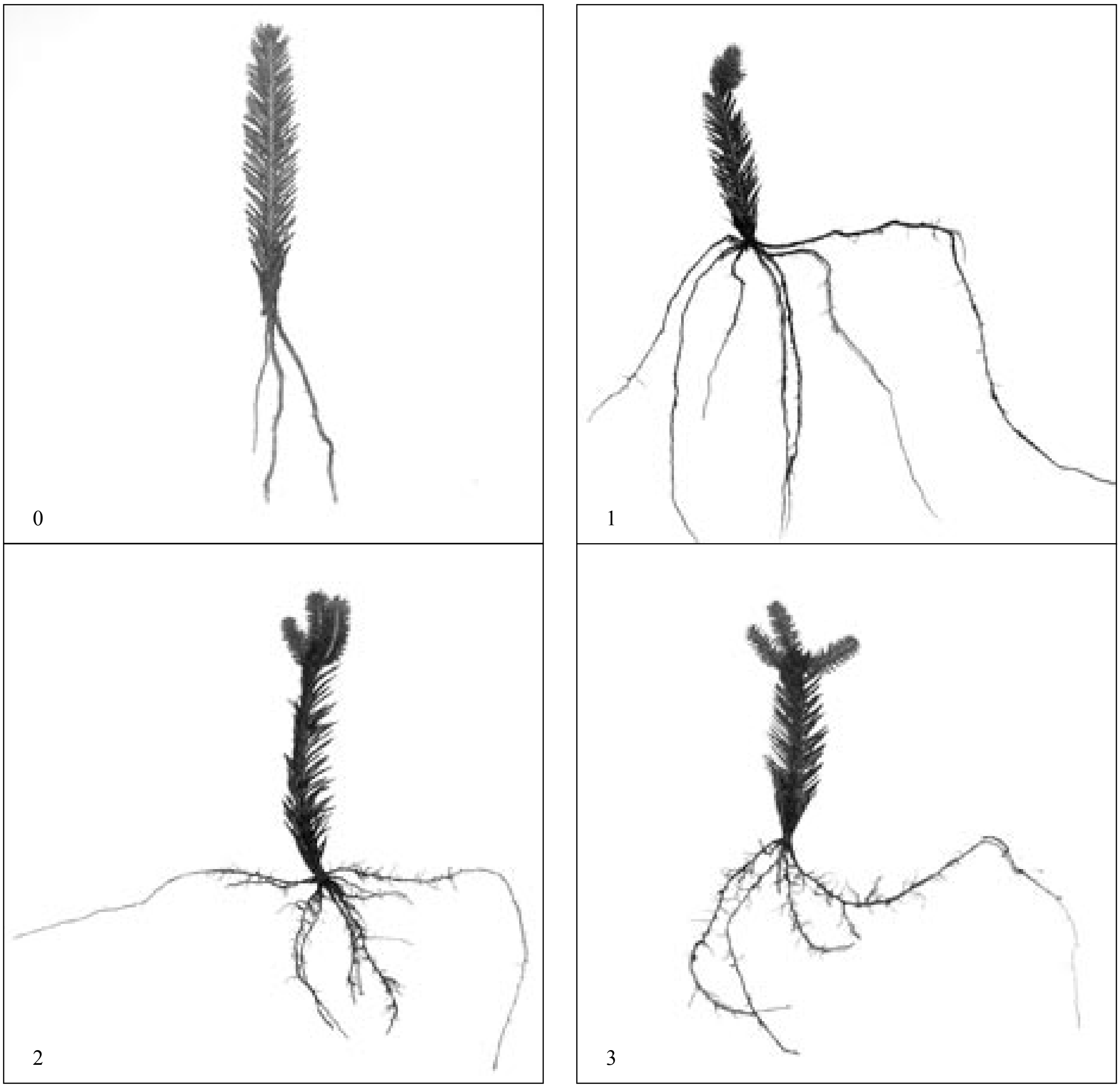

Fig. 1. Indexes of richness of root branching

To study these partial aspects of the technology of vegetative propagation by cuttings a clone material was used that was produced under the programme of the conservation of genetic resources of valuable Krkonoše populations of Norway spruce. Collection of cuttings from the particular precisely registered clones made it possible to distinguish between genetically conditioned variability and variability caused by the technology and environment.

To evaluate the above-mentioned influences an experiment was established with selected clones in 2002 to examine:

– the influence of the date of cutting collection,
– the influence of cutting position in the crown on either northern or southern exposure,
– the influence of cutting collection from different whorls,
– the influence of the age of mother plantation.

The original material was spruce trees from a seven-year clone planting at Benecko locality (750 m above sea level). Rooted plants to establish this clone planting were grown from cuttings collected in 1993 and 1994 in mother plantations at Trutnov and at Lesní Bouda locality in the Krkonoše Mts. They are the offspring of selected valuable, usually autochthonous populations from various localities in the Krkonoše Mts.

Rooting of cuttings took place in a plastic greenhouse using the double-foil technology. It is a technology when cuttings inside plastic greenhouses are placed in tunnels covered with a special milk foil. Unlike the common technique of cutting rooting in plastic greenhouses it is easy to maintain high air humidity in tunnels and plastic greenhouses can be efficiently ventilated in warm weather. Watering and checks of the cutting condition are carried out once or twice a week when the tunnels are uncovered for a short time. A potting substrate of sand and peat (3:2) was used for rooting.

For particular stages of experiments cuttings were collected from different parts of the crown of parent trees (from different whorls or from either northern or southern exposure) and on different dates in the spring season.

Flushing of cuttings and bud formation in the particular clones were evaluated during the rooting process. Rooted cuttings were lifted at the end of the vegetation period and their basic morphological traits were determined: shoot number, root number, length of the longest root and richness of root branching. Based on the frequency of higher-order roots (branching richness) roots were attributed the following indexes (Fig. 1):

0 = skeletal roots only,
1 = weak branching,
2 = medium branching,
3 = rich branching.

Dry weight of original cuttings, newly formed shoots and roots was evaluated by the weight analysis.

Differences between the evaluated variants were tested by common statistical methods (*t*-test, evaluation of correlations). The most interesting results of the analyses are presented in graphs or tables.

RESULTS

Influence of date of cutting collection

To evaluate the influence of cutting collection date on their rooting cuttings from the Benecko clone planting were collected in spring 2002 on 3 dates: 1st date – cuttings with dormant buds (collection 11. 4. – inserting of cuttings 15. 4.), 2nd date – cuttings in the stage of the onset of bud swelling, hereinafter denoted as "woken up" buds (collection 30. 4. – inserting 6. 5.), and 3rd date – cuttings in the stage of the onset of flushing, denoted as "flushed" ones (collection 12. 5 – inserting 16. 5. 2002). Table 1 shows the collection scheme.

Course of flushing

Not all rooted cuttings form new shoots in the year of propagation. These shoots usually grow from lateral buds and do not have any positive influence on further growth of the aboveground parts. Fine tissues of shoots are rather susceptible to mould infection from the technological aspect. They also cause bad form or plagiotropic growth in the first years.

In relation to the date of cutting collection bud flushing was evaluated as a proportion of flushing cuttings in the particular clones and variants. Fig. 2 shows average values according to the dates of cutting collection, either in relation to the actual date or in relation to the number of days that elapsed since inserting of cuttings.

The flushing of cuttings collected in the stage of dormancy in mid-April was relatively fast, and almost all of them formed new shoots. Most cuttings also formed new shoots if they were collected in mid-May. Flushed cuttings were usually collected on this date. Flushing was the slowest with the lowest proportion of cuttings forming new shoots in the year of propagation if the cuttings were collected at the end of April when buds broke dormancy,

Table 1. Numbers of cuttings collected on various dates from Benecko clone planting. Graphical representation of flushing time in parent trees: no highlighting – late flushing ramets, hatching – ramets with medium-late flushing, grey highlighting – early flushing ramets

Date of cutting collection	Progeny	Mother plantation Lesní bouda, clone plantation Benecko, progeny Labský důl 14				
	Clone	120		123	127	145
	Plant (ramet)	**177**	**179**	**187**	**192**	**228**
11. 4. 2002	Dormant	20	20	20	20	20
30. 4. 2002	Woken up	10	10	10	10	10
14. 5. 2002	Flushing	10	10	10	10	11
Date of cutting collection	Progeny	Mother plantation Trutnov, clone plantation Benecko, progeny Labský důl 14				
	Clone	533				535
	Plant (ramet)	**1495**	**1508**	**1509**	**1515**	**1522**
11. 4. 2002	Dormant	20	20	20	20	20
30. 4. 2002	Woken up	20	20	20	20	20
Date of cutting collection	Progeny	Mother plantation Trutnov, clone plantation Benecko, progeny Labský důl 14				
	Clone	533		537	540	
	Plant (ramet)	**1496**	**1516**	**1527**	**1553**	**1562**
30. 4. 2002	Woken up	20	20	20	20	20
14. 5. 2002	Flushing	20	20	20	20	20

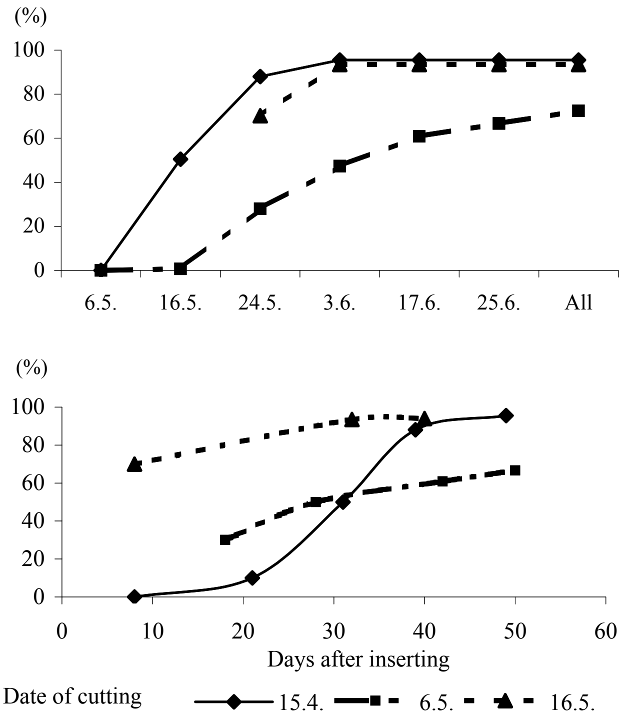

Fig. 2. Process of the flushing of cuttings collected on various dates: left – relation to the actual date, right – relation to the number of days after insertion into a substrate

started swelling but they did not flush yet. As more than 70% of cuttings formed new shoots in this case, we can state that practically the date of cutting collection did not have a significant influence on the reduction of shoot formation in the phase of rooting.

Some shoots formed terminal buds relatively soon. Out of cuttings from the first date of collection 7% of individuals formed buds at the end of June, after the 2nd collection 3.7% of individuals formed buds, and 3% of individuals out of cuttings collected in mid-May (3rd date). But bud formation was markedly different according to the origin (ramets).

Rooting percentage and quality

The proportion of rooted individuals (Fig. 3) and quality of their rooting are more important aspects to evaluate the influence of cutting collection date. Fig. 4 shows biometrical and weight characteristics. The results are average values for the total number of rooted cuttings.

The best results of rooting were recorded in cuttings collected at the stage of bud swelling (i.e. end of April) while flushed cuttings (collected in mid-May) showed the worst results. But more than 60% of cuttings took roots in the latter case.

Fig. 4 documents rooting quality, representing morphological traits of roots and the results of weight analysis as average values of all studied clones. The characteristics of shoots formed in the year of propagation are also shown.

The average values of all collected clones document that cuttings collected just before the onset of flushing (end of April) formed the highest number of roots and the strongest shoots. The longest roots and richest branching were formed in cuttings collected in the stage of dormancy (mid-April). The differences in all traits of rooting quality and in shoot development were statistically highly significant.

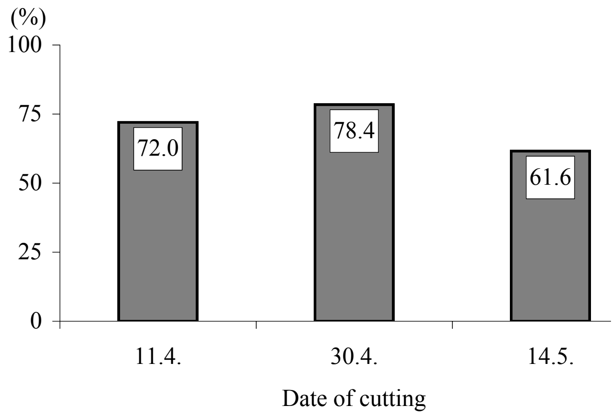

Fig. 3. Influence of the date of cutting collection on rooting percentage

As rooting ability is also influenced genetically, the influence of cutting collection date on rooting quality was evaluated separately according to particular clones and ramets. The results are summarised in Table 2. The data do not indicate a single trend of rooting quality in relation to the date of rooting collection.

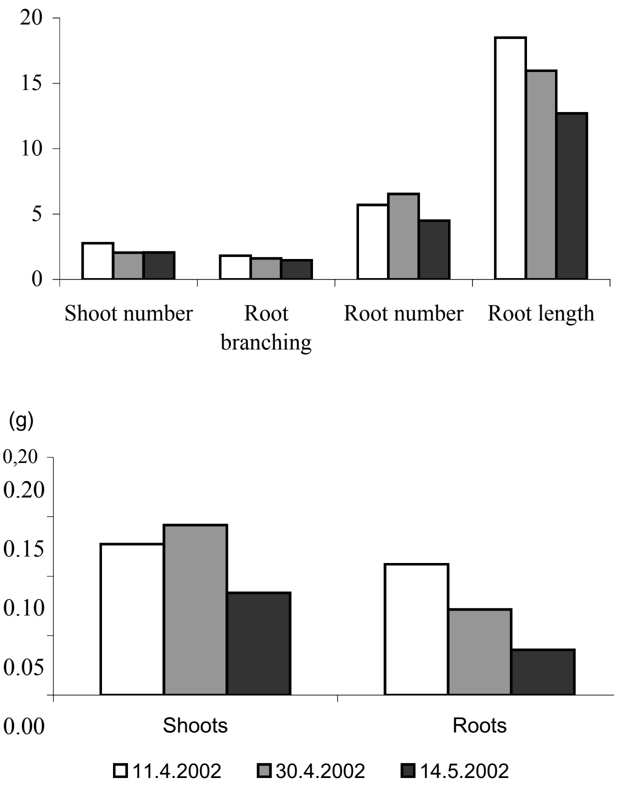

Fig. 4. Influence of the date of cutting collection on shoot growth and rooting quality (above – shoot and root morphology, below – shoot and root dry weight)

Table 2. Influence of the date of cutting collection on rooting quality (the numbers in table headings denote particular ramets – the details see Table 1). Hatching distinguishes the ramets according to the earliness of flushing of parent trees

	177	179	187	192	228	1495	1508	1509	1515	1522	1496	1516	1527	1553	1562
Rooting percentage															
1	55	55	60	90	40	75	100	100	75	70					
2	60	40	80	80	70	95	85	75	100	35	95	90	70	85	85
3	80	60	50	20	45						55	65	50	85	80
Average number of roots															
1	4.2	4.0	5.8	5.9	4.0	5.8	7.0	6.1	6.0	6.0					
2	4.3	3.3	5.8	3.8	4.4	6.6	7.8	8.5	6.6	3.6	8.4	7.3	6.1	6.1	6.6
3	5.3	5.2	1.8	1.5	3.4						3.6	5.0	4.3	4.9	5.3
Index of branching richness															
1	1.8	1.5	2.4	2.3	1.5	1.7	1.9	1.8	1.5	1.7					
2	2.0	1.8	1.9	1.5	1.9	1.4	1.4	1.4	1.5	0.7	1.7	1.7	1.3	2.1	1.9
3	1.3	1.7	0.6	1.0	2.0						1.2	1.7	1.2	1.8	1.5
Length of the longest root (cm)															
1	14.5	8.5	15.5	15.1	9.3	19.4	25.0	27.1	21.7	15.9					
2	17.7	14.8	15.8	17.9	15.9	15.8	19.6	16.3	15.3	6.6	20.9	18.5	10.7	12.6	12.4
3	11.5	14.5	10.8	7.0	9.6						14.4	15.1	10.1	13.8	16.1
Number of shoots															
1	2.5	1.1	4.1	2.9	2.3	2.7	3.6	2.6	3.9	1.4					
2	2.3	1.3	0.6	0.6	2.6	2.1	1.9	1.5	2.0	0.1	2.2	2.3	0.9	4.5	2.8
3	2.0	1.2	1.6	4.5	2.8						2.5	2.8	3.0	1.4	1.3
Dry weight of cutting (g)															
1	0.533	0.497	1.043	0.994	0.503	0.983	0.816	0.589	0.764	0.792					
2	0.597	0.490	0.872	1.058	1.055	0.821	0.879	0.892	0.713	0.800	0.821	0.737	0.673	0.653	0.699
3	0.314	0.430	0.397	0.491	0.572						0.786	0.558	0.446	0.474	0.611
Dry weight of shoots (g)															
1	0.129	0.075	0.176	0.114	0.088	0.137	0.158	0.127	0.139	0.081					
2	0.101	0.090	0.090	0.099	0.093	0.113	0.131	0.153	0.141	0.058	0.221	0.137	0.128	0.152	0.188
3	0.068	0.058	0.095	0.157	0.095						0.075	0.091	0.091	0.084	0.098
Dry weight of roots (g)															
1	0.072	0.055	0.116	0.165	0.053	0.107	0.133	0.118	0.091	0.124					
2	0.062	0.046	0.150	0.067	0.074	0.051	0.072	0.074	0.050	0.029	0.086	0.118	0.050	0.047	0.086
3	0.037	0.054	0.024	0.076	0.029						0.032	0.049	0.029	0.033	0.039

Flushing time: late medium-late early

The results document that in spite of some differences in rooting percentage and quality the rooting of cuttings collected in spring in a relatively long period from full dormancy to flushing onset can be successful.

Influence of position in the crown – exposure on the northern and southern side of the crown

Northern or southern exposure of cuttings in the crown of parent tree influences the light enjoyment and heat bal-

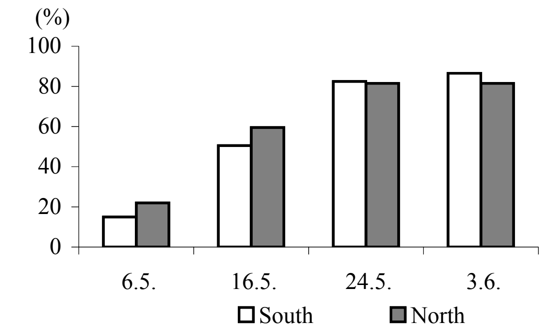

Fig. 5. Process of the flushing of cuttings collected from the northern and southern exposure of the crown (cutting collection 30. 4. 2002)

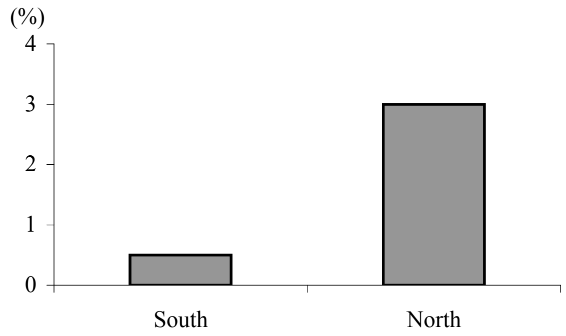

Fig. 6. Proportion of cuttings with early bud formation (in June 2002)

ance of cuttings. It can have impacts on growth activity and hormone level. A potential influence of exposure on the rooting ability of cuttings was investigated in ramets of several clones in spring 2002. Clones of the same origin (half-sister progeny of tree 14 from Labský důl – ld14) were selected from mother plantations at Trutnov 1 and Lesní Bouda 1 located in the Benecko clone planting (750 m a.s.l.). Twenty cuttings from each individual were collected on 11. 4. 2002, and they were inserted in the substrate on 15. 4. 2002.

Partial results indicated that at the beginning (within the first month after cutting propagation) the flushing of cuttings from the northern exposure of the crown was faster compared to the southern exposure. This trend was similar in most ramets. Later on, the differences in flushing equalised (Fig. 5). Early bud formation was associated with the particular ramets. We found out differences between ramets within the same clones. Higher bud formation was observed in cuttings collected from the northern side of the crown compared to the southern side (Fig. 6).

Tables 3 and 4 show the results of biometrical and weight analysis of rooted cuttings collected from the northern and southern exposure of the crown. Statistical significance of differences in biometrical traits between the northern and southern exposure of cuttings within the particular ramets and the whole set is shown in Table 3. Weight analyses were carried out in total for the whole ramet. The differences in weight traits within the evaluated set are not statistically significant.

Even though there were some differences in flushing and bud formation in the experiment, the data on rooting document that the exposure of cuttings in the crown of the parent tree did not influence the percentage and quality of rooting in relation to the cardinal points.

Influence of cutting collection from different whorls

To evaluate the influence of cutting position in whorls cuttings were collected in Benecko seven-year clone

Table 3. Biometrical analysis of rooted cuttings collected from the northern and southern exposure of the crown in Benecko locality (n = 20)

Clone	Ramet	Number of shoots			Number of roots			Length of the longest root (cm)			Index of branching richness		
		north	south	N/S[1]	north	south	N/S[1]	north	south	N/S[1]	north	south	N/S[1]
113	174	3.1	2.8	–	6.0	5.7	–	11.7	11.7	–	1.3	1.5	–
115	176	2.1	2.5	–	8.5	7.8	–	15.7	13.5	–	2.0	2.1	–
124	188	3.2	4.3	–	4.8	4.5	–	14.8	12.4	–	1.8	1.6	–
140	215	0.8	1.3	–	2.7	3.9	–	11.5	11.4	–	1.5	2.4	**
140	216	1.6	0.5	–	2.4	4.4	–	9.2	9.9	–	1.4	1.5	–
530	1481	1.0	1.3	–	3.7	3.4	–	16.8	12.6	–	1.9	2.0	–
530	1482	1.0	1.4	–	2.9	3.3	–	12.5	10.6	–	2.0	2.0	–
532	1493	1.8	2.5	–	4.7	3.5	–	18.2	10.5	–	1.6	1.5	–
532	1494	3.4	2.0	*	3.6	3.5	–	17.6	11.4	–	1.6	1.0	–
537	1532	2.5	2.9	–	4.4	5.1	–	14.6	13.9	–	1.7	2.6	**
Average		2.2	2.2	–	4.7	4.7	–	14.6	11.9	**	1.7	1.8	–

[1]Statistical significance of differences between the northern and southern exposure (– not significant, * significant on the 5% level, ** significant on the 1% level)

Table 4. Weight analysis of rooted cuttings collected from the northern and southern exposure of the crown in Benecko locality

Clone	Ramet	Rooting (%)		Dry weight of cuttings (g)		Dry weight of shoots (g)		Dry weight of roots (g)	
		north	south	north	south	north	south	north	south
113	174	90	100	0.66	0.77	0.13	0.12	0.06	0.10
115	176	100	100	0.74	0.64	0.08	0.12	0.12	0.12
124	188	90	60	0.91	0.52	0.14	0.09	0.11	0.05
140	215	50	40	1.08	0.72	0.04	0.04	0.08	0.06
140	216	25	55	0.38	1.64	0.02	0.04	0.02	0.10
530	1481	70	85	0.40	0.97	0.04	0.08	0.08	0.09
530	1482	85	80	0.48	0.63	0.04	0.06	0.06	0.06
532	1493	60	55	0.34	0.64	0.06	0.09	0.06	0.04
532	1494	70	60	0.77	0.52	0.14	0.06	0.07	0.04
537	1532	80	70	0.60	0.53	0.09	0.08	0.09	0.08
Average		72	70.5	0.63	0.76	0.08	0.08	0.08	0.07

planting on two dates in spring 2002. Table 5 shows a detailed description of the variants. Cuttings collected from the highest whorl and cuttings growing on the stem in the upper part of the crown are designated as whorl I in this experiment. Cuttings collected from the 2nd and 3rd whorl denote whorl II and III, whorl IV is taken to denote cuttings collected in the lower part of the crown (whorl IV and lower) (Fig. 7). Each time 10 cuttings from each whorl were collected. As it was necessary to collect a higher number of cuttings from one tree, vigorously growing trees with a sufficient number of branches in all whorls were selected.

Fig. 7. Scheme of the collection of cuttings from different whorls (Benecko clone planting)

Rooting percentage and quality

There were large differences between the clones and between the ramets within the particular clones in successful root formation (rooting percentage) and quality of root systems.

Fig. 8 shows the influence of the cutting position in the crown – in different whorls – on rooting ability. Cuttings collected on 11. 4. 2002 (progenies Černohorská rašelina 7 – cr7 and Malá Kotelní jáma 2 – mkj2 separately) and those collected on 30. 4. 2002 (from progenies Černohorská rašelina 8 – cr8 and Labský důl 11 – ld11) were evaluated separately. A total of 200 cuttings from the 1st collection date (100 individuals from progeny cr7 and 100 individuals from progeny mkj2) and 50 cuttings from the 2nd collection date were evaluated from each whorl.

In all cases the rooting percentage was highest in cuttings collected from the lower part of the crown (whorls III and IV). The lowest rooting percentage was observed

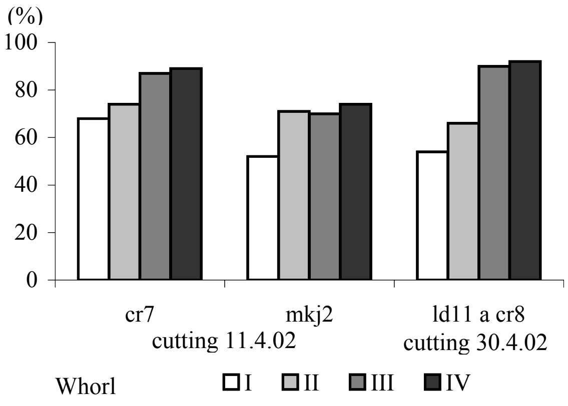

Fig. 8. Rooting percentage in cuttings collected from different whorls of spruce from a seven-year clone planting Benecko

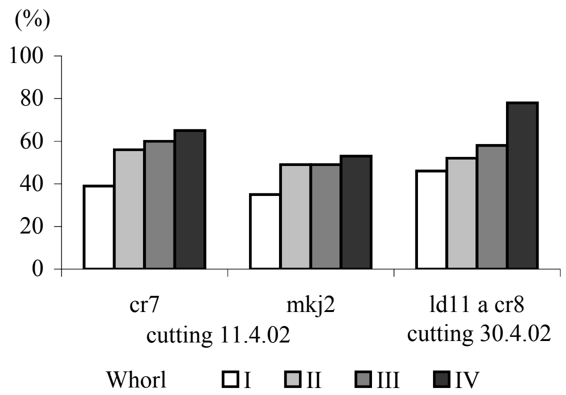

Fig. 9. Percentage of cuttings with shoot formation in the first year after collection in relation to the cutting position in the crown of parent tree

in cuttings collected from the highest whorl and from the stem in the upper part of the crown (I). The flushing of these cuttings was also the lowest and they formed least shoots in the year of rooting (Fig. 9).

Large differences between the clones and ramets were determined not only in the intensity of flushing and bud formation but also in the length of shoots and bud character (Fig. 10). Sometimes buds were formed on very short shoots immediately after flushing, sometimes long shoots were produced with early or very late bud formation.

As variability between clones and between ramets within the clones was high, statistical significance of differences in rooting quality was determined by *t*-test. The results are illustrated in Fig. 11, where the perpendicular bars drawn from the columns indicate standard deviations of sampling and the letters under the columns show statistical significance. The same letters denote insignificant differences while different letters mark significant differences on 5% significance level.

The results document that cuttings collected from the highest part of the crown formed on average a lower number of roots, with poorer branching of higher orders. The dry matter of formed roots was also significantly lower. On the contrary, there were not any statistically significant differences in the average length of the longest root.

When evaluating the influence of the position of cuttings in the crown on their further development we also examined whether there were any differences between good-rooting and weak-rooting clones. For this purpose the clones with rooting percentage higher than 70% and the weak-rooting clones with the proportion of rooted cuttings lower than 60% were evaluated separately.

The results represented in Fig. 12 confirmed the above assumption. A markedly lower rooting percentage in weak-rooting clones was observed in cuttings collected from the highest whorl. These differences were much smaller in good-rooting clones.

Influence of mother plantation age on cutting rooting and growth

In a forest nursery detailed measurements of morphological characteristics were carried out in three-year rooted cuttings, in clones of the progeny from Malá Kotelní jáma locality (mkj2). Because these rooted cuttings come from both the older generative mother plantation and the younger clone planting, we could examine the influence of mother plantation age on the clone level. Growth was compared in rooted cuttings from generative mother plantation Lesní Bouda 1 (age at the time of cutting collection 16 years) and from clone plantings Benecko A (age at the time of cutting collection 8 years) and Benecko B (age 7 years).

The results represented in Fig. 13 confirmed a well-known fact that the rooting of cuttings collected from older mother plantations was weak and their growth was slow. On the contrary, the differences between good- and weak-rooting clones in older mother plantations were not proved to increase.

Differences in the continuation of plagiotropic growth were also marked; it was observed in all rooted cuttings originating from 16-year generative mother plantation

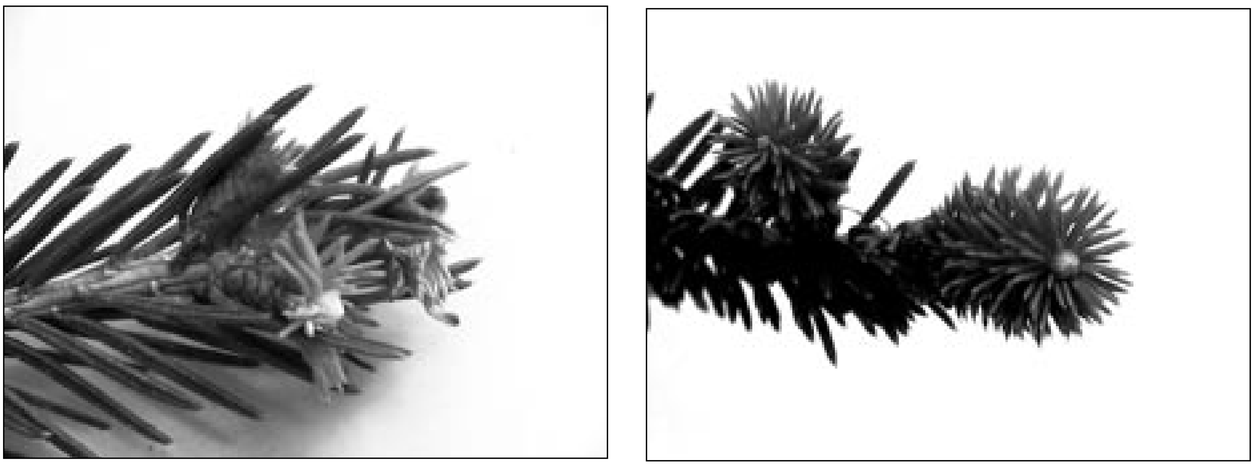

Fig. 10. Different character of shoot and bud formation in cuttings propagated in 2002

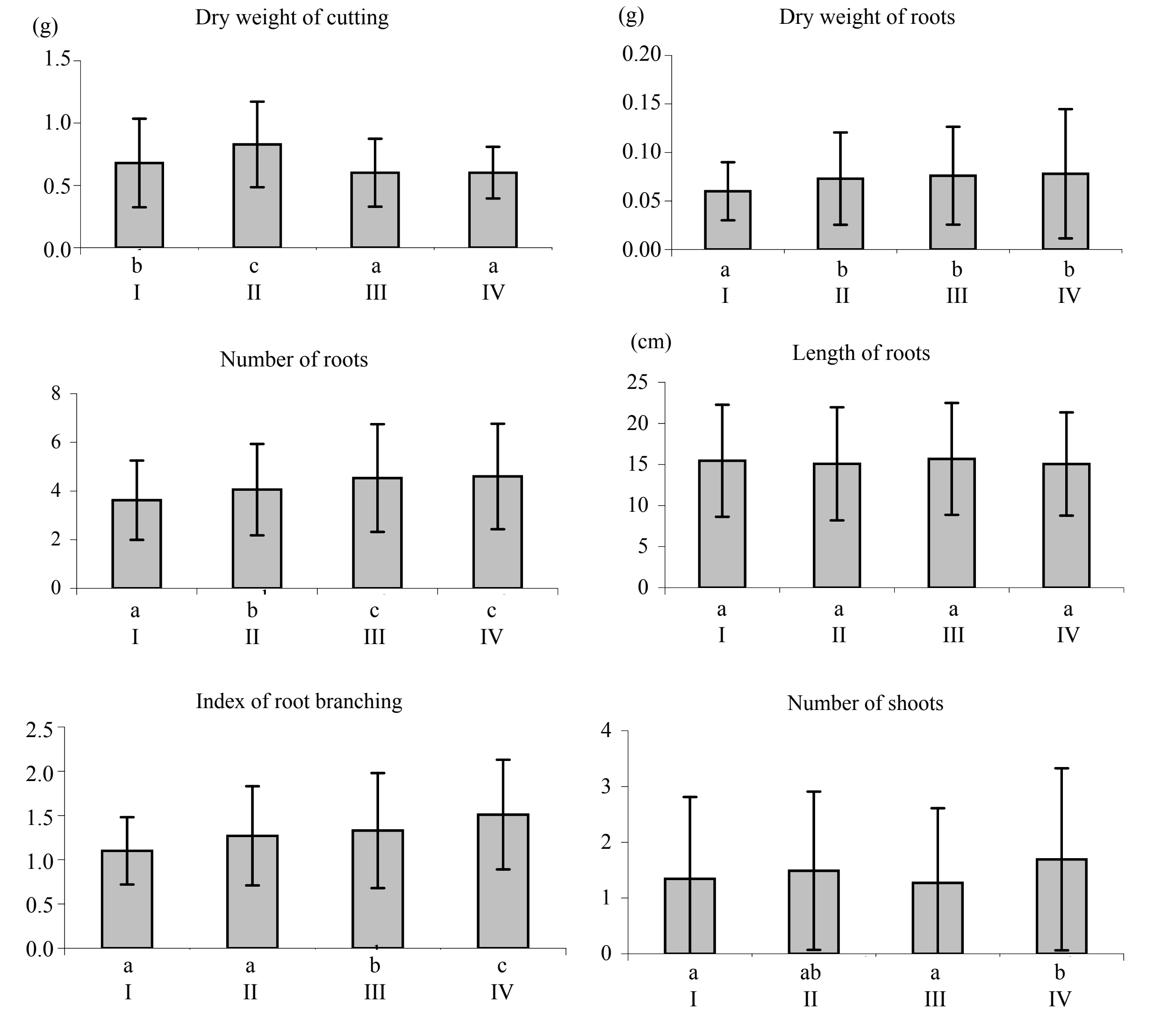

Fig. 11. Rooting quality and shoot number in cuttings collected from different whorls. The whiskers show standard deviations of sampling. The same letters under the columns denote differences below 5% significance level

LB1 while in rooted cuttings from younger mother plantations (Benecko – age 7 and 8 years) it occurred only in 40–50% of individuals.

DISCUSSION

Date of collection

The average values of the sets of cuttings collected on spring dates from mid-April to mid-May documented good rooting ability. A comparison of cuttings collected in various stages of spring activity (dormancy – collection in mid-April, break of dormancy, just before the flushing onset – end of April and bursting – mid-May) indicated that the stage of collection influenced the process of flushing and shoot growth. Flushing was the slowest and with the lowest number of shoots in cuttings collected just before the flushing onset (in the conditions of Benecko mother plantation it was at the end of April). The collection of flushed cuttings in mid-May resulted in a moderate but statistically significant decrease in rooting percentage and quality. The highest number of roots and strongest shoots were formed in cuttings collected just before the flushing onset at the end of April while dormant cuttings collected in mid-April formed the longest roots and richest branching. But the detailed evaluation of rooting quality within the particular ramets did not confirm the above-mentioned trends in many cases.

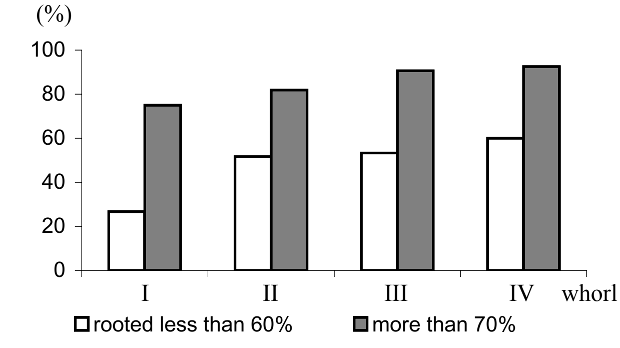

Fig. 12. Influence of cutting position in the crown on rooting percentage in good- and weak-rooting clones

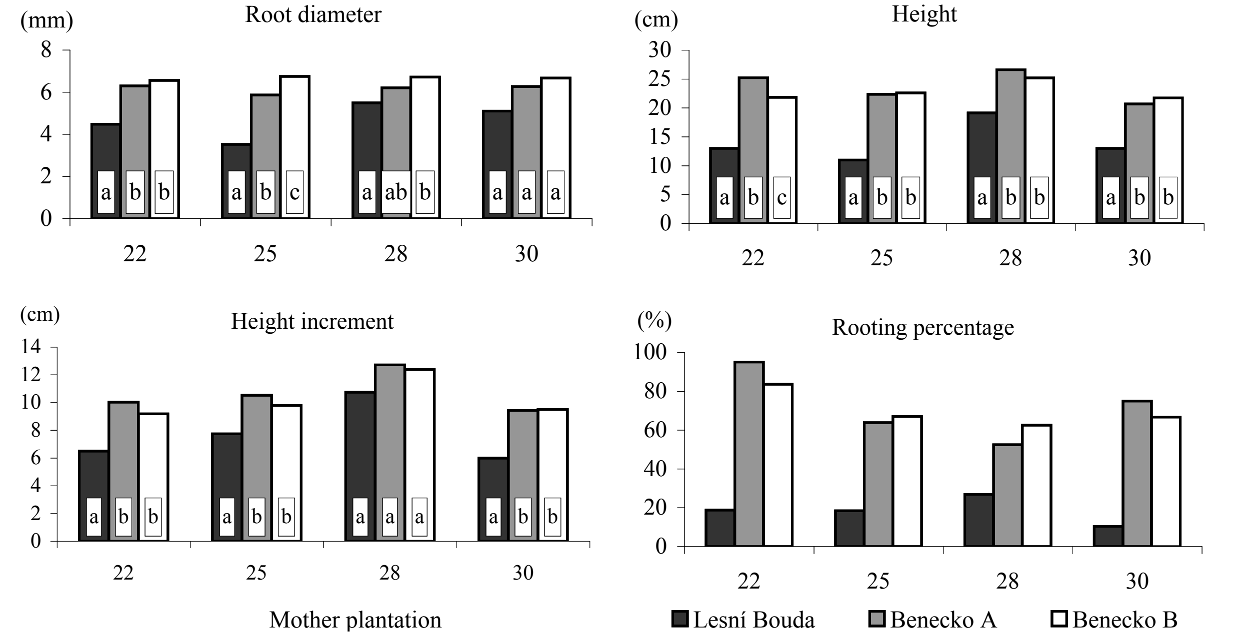

Fig. 13. Rooting percentage and morphological parameters of rooted cuttings coming from mother plantations of different age (the same letters in the adjacent columns denote differences below 5% significance level) – numbers 22, 25, 28, 30 mean marks of the clones

Our results agree with the data on a large amplitude of time segments suitable for cutting collection (DUCHÁČ 1981; VOLNÁ 1982). They are also in agreement with the data of ZAVADIL (1984) on precocious flushing during the collection of flushed cuttings. But our experiments did not unambiguously prove a marked decrease in rooting percentage when flushed cuttings were collected ZAVADIL (1984).

We did not find out a relationship between the development of aboveground parts (flushing, shoot and bud formation) and rooting quality. Similarly, TOMKOVÁ and her co-authors (TOMKOVÁ et al. 1987) reported that shoots were formed in cuttings with both the good and the weaker rooting ability.

Exposure of cuttings in the crown

In spite of some differences observed during the flushing of propagated cuttings and in bud formation the exposure of cuttings in the crown of parent tree in relation to the cardinal points did not have a larger influence on rooting percentage and quality. DUCHÁČ (1981) presented similar results concluding that the influence of the whorl position was far more important.

The results of the rooting of cuttings collected from various whorls confirmed general data indicating that rooting is better in cuttings from the lower part of the crown (VOLNÁ 1982; SCHACHLER et al. 1987; SPETHMANN 1997). Cuttings collected from the highest whorls formed on average

Table 5. An overview of clones used to evaluate the rooting of cuttings from different whorls

Date of cutting	11. 4. 2002			30. 4. 2002	
Progeny: Malá Kotelní jáma 2		Černohorská rašelina 7		Labský důl 11	
Clone	plant	clone	plant	clone	plant
780	1,006	727	847	202	351
780	1,007	727	849	202	352
790	1,018	727	850	202	354
790	1,019	730	859	202	356
790	1,022	730	861	Černohorská rašelina 8	
790	1,024	730	862		
791	1,025	731	867	176	324
791	1,028	731	868		
794	1,035	731	869		
796	1,046	734	877		

a lower number of roots and these roots had the poorer branching of higher orders. The dry matter of formed roots was significantly lower. On the contrary, there were no statistically significant differences in the average length of the longest root. HAUCK and VOLNÁ (1989, 1990) drew rather different conclusions when they reported that neither position of cutting collection nor cutting length influenced the number of formed roots but the average root length increased from whorl 2 to whorl 5 and the proportion of order 3 roots decreased from whorl 3 to whorl 5.

When good-rooting and weak-rooting clones were compared, the influence of cutting position in the crown was markedly higher in weak-rooting sets. It was reflected mainly in the lower rooting percentage of cuttings collected from the highest whorl compared to cuttings from the other parts of the crown. These results are consistent with general data indicating that the influence of position in the crown is higher in weak-rooting tree species than in good-rooting ones (GENEVE 1995).

Influence of mother plantation age

The results of experiments confirmed a well-known fact that the rooting of cuttings collected from older mother plantations was rather weak and their growth was also slower (VOLNÁ et al. 1982; KLEINSCHMIT, SVOLBA 1988; KRÜSSMANN 1997). On the contrary, the increase in differences between good-rooting and weak-rooting clones in older mother plantations was not confirmed (RADOSTA 1990a).

Differences in the continuation of plagiotropic growth were also marked; it was observed in all rooted cuttings originating from the 16-year generative mother plantation while it occurred only in 40–50% of individuals from the seven- and eight-year mother plantation. Similar findings were reported by VOLNÁ et al. (1982) and CHALUPA (1979a,b).

CONCLUSION

Based on the results of evaluating the condition of cuttings collected from a seven-year clone planting of spruce these conclusions were drawn:

- The evaluation of spring dates of cutting collection in various stages of activity demonstrated a possibility of successful propagation by cuttings over a relatively long period from full dormancy of buds to flushing onset. It was a period from mid-April to mid-May in conditions of the given mother plantation and year.
- The relationship between the development of aboveground parts (flushing, shoot and bud formation) and rooting quality was not established.
- The cutting position in the crown of parent tree (whorl, northern or southern exposure) did not have a greater influence on rooting intensity and quality. Somewhat better rooting ability was observed in cuttings from lower parts of the crown. Differences were statistically significant, but not very perceivable from the practical aspect. They were larger in weak-rooting clones. Cuttings from lower branches should be handled more carefully, especially when inserted into the substrate because their mechanical strength is lower.

The comparison of rooting quality of cuttings from seven- and eight-year mother plantations with cuttings from a 16-year mother plantation confirmed a well-known fact that the rooting of cuttings collected from older mother plantations is weak, their growth is slower and their plagiotropic growth continues for a longer time.

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Možnosti ovlivnění kvality zakořenění řízků smrku ztepilého (*Picea abies* [L.] Karst.)

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ABSTRAKT: U řízků smrku ztepilého ze sedmileté klonové výsadby byl sledován vliv termínu řízkování a umístění řízků v koruně na kvalitu zakořenění. Posouzení vlivu termínů odběru řízků v různém stadiu aktivity na jaře prokázalo možnost úspěšného řízkování během poměrně dlouhého období od plné dormance pupenů až po začátek rašení. Nebyl zjištěn vztah mezi vývojem nadzemních částí (rašení, tvorba výhonů a pupenů) a kvalitou zakořenění. Expozice řízků v koruně rodičovského stromu vzhledem ke světovým stranám neměla vliv na úspěšnost a kvalitu zakořenění. Poněkud lepší zakořeňovací schopnost byla pozorována u řízků ze spodních částí koruny v porovnání s řízky z nejvyšších přeslenů. Rozdíly byly výraznější u obtížně kořenících klonů. Porovnání kvality zakořenění řízků ze sedmileté a osmileté matečnice s řízky ze 16leté matečnice potvrdilo skutečnost, že řízky odebírané ze starších matečnic nejen obtížněji koření, ale také pomaleji rostou a podrží si po delší dobu plagiotropní růst.

Klíčová slova: smrk ztepilý; vegetativní množení; řízky; termín řízkování; pozice řízků v koruně; stáří matečnice; kvalita zakořenění; schopnost zakořenit

Kvalita zakořenění smrkových řízků je ovlivňována genetickými dispozicemi, fyziologickým stavem řízků v době jejich odběru a prostředím v množárnách. Značné rozdíly ve schopnosti zakořeňovat existují i mezi různými klony téže populace.

Pro sledování těchto dílčích aspektů technologie vegetativního množení řízkováním byl využit klonový materiál získaný v rámci programu záchrany genofondu cenných krkonošských populací smrku ztepilého. Odběr řízků z jednotlivých přesně evidovaných klonů umožnil rozlišení geneticky podmíněné variability a variability způsobené použitou technologií a prostředím.

Pro hodnocení popsaných vlivů byl v roce 2002 založen pokus sledující u vybraných klonů:
– vliv termínu odběru řízků,
– vliv umístění řízků v koruně na severní nebo jižní straně,
– vliv odběru řízků z různých přeslenů.

Z výsledků hodnocení vlivu stavu řízků odebraných ze sedmileté klonové výsadby smrku na jejich schopnost zakořenění vyplynuly následující závěry:
– Posouzení různých termínů odběru řízků v různém stadiu aktivity na jaře prokázalo možnost úspěšného řízkování během poměrně dlouhého období od plné dormance pupenů až po začátek rašení. Řízky odebrané těsně před začátkem rašení (na konci dubna) vytvořily nejvíce kořenů a nejmohutnější výhony. Nejdelší a nejvíce větvené kořeny vytvořily řízky odebrané ve fázi vegetačního klidu (v polovině dubna). Přestože rozdíly průměrných hodnot ve všech znacích kvality zakořenění a většinou i ve vývoji nadzemních částí byly statisticky vysoce průkazné, při podrobném hodnocení podle jednotlivých klonů nebyl patrný žádný jednotný trend kvality zakořenění ve vztahu k termínu odběru řízků.
– Nebyl zjištěn vztah mezi vývojem nadzemních částí (rašení, tvorba výhonů a pupenů) a kvalitou zakořenění.
– Expozice řízků v koruně rodičovského stromu vzhledem ke světovým stranám neměla vliv na úspěšnost a kvalitu zakořenění.
– Umístění řízku v různých přeslenech v koruně matečného jedince neovlivnilo výraznějším způsobem intenzitu a kvalitu zakořenění. Poněkud lepší zakořeňovací schopnost byla pozorována u řízků ze spodních částí koruny. Rozdíly jsou sice statisticky průkazné, z praktického hlediska však nejsou příliš výrazné. Patrnější jsou u klonů, které obecně koření obtížněji. Řízky ze spodních větví přitom zpravidla vyžadují větší pozornost při manipulaci a vlastním zapichování vzhledem ke své menší mechanické pevnosti.

Porovnání kvality zakořenění řízků ze sedmileté a osmileté matečnice s řízky ze 16leté matečnice potvrdilo známou skutečnost, že řízky odebírané ze starších matečnic nejen obtížněji koření, ale také pomaleji rostou a podržují si po delší dobu plagiotropní růst.

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