The effect of auxinoid application on the planting stock root system

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ABSTRACT: The goal of the study was to verify the effect of growth substances from the group of auxinoids on the root system of European beech and Scots pine planting stock. The effect of growth substance application date (spring, summer dipping), the type of growth substance used (IBA, NAA), and the exposition to the growth substance (1, 2, 5 hours) were studied. The tests showed that the application of NAA and IBA did not stimulate the root system growth in Scots pine at any exposition of root systems to the growth substances. European beech exhibited a favourable effect of the 5-hour IBA exposition in the spring dipping. The summer dipping of European beech did not show a complex beneficial effect on the root system development at any of the expositions.

Keywords: root system; auxinoids; European beech; Scots pine; NAA; IBA

The technology of growing the planting stock in forest nurseries significantly affects the development of the root system in forest tree species. It is not only the general architecture of the root system that is affected but also the point of root setting and the number of developed roots, this indicating that not only the mechanical stability of trees is affected but also the physiological functionality of the root system. Impaired stability and physiological quality of the planting stock usually result from irreversible root system malformations. The issue of root system malformations was studied by Lokvenc (1979), Volná and Mauer (1981), Permingeat (1999).

Experts and the public at large agree that root system deformations should be prevented. A number of methods were used experimentally and in practice, focused on the elimination of root system malformations or at least on their minimized occurrence. It must be admitted, however, that none of them brought fully satisfactory results.

A promising method appears to be the elimination of the negative effect of root malformations and deviations by the application of growth substances of stimulating character based on phytohormones. These substances induce the establishment and growth of new roots that may gradually take over the function of the initially malformed roots. The application of cytokinins was tested (Bachelard, Stowen 1963) that were however mostly observed to inhibit the development of adventitious roots. The exogenous application of gibberellins GA_3 and $GA_{4/7}$ through the root system dipping was studied by Heidmann (1982), whose results only proved the positive influence of gibberellins on the shoot height growth while the growth of roots remained relatively unaffected.

Other authors studying the effect of growth substances – this time of synthetically prepared auxins (auxinoids) – were Selby and Seaby (1982), Simpson (1986), Baser et al. (1987), Cappiello and Kling (1987), Scagel and Linderman (2001), Liu et al. (2002), who mainly studied the effect of NAA (α-naphthylacetic acid), IBA (β-indolyl-γ-butyric acid), and IAA (indole-γ-acetic acid). Researched

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tree species were various oak species, Douglas fir and lodgepole pine. Results showed the auxinoids to influence the development of lateral roots in the researched tree species, with their effect being particularly pronounced at younger developmental stages. It was further demonstrated that an important factor for the achievement of good results is a choice of appropriate concentrations of the auxinoids used. The issue of the application of growth substances (NAA, IBA) to minimize mechanomorphoses in the planting stock was studied by Mauer and Palátová (1989), who studied the effect of growth substances on the planting stock of Norway spruce. A statement can be made based on their research results that there is a positive influence of the used auxinoids on the development of lateral roots with the magnitude of the effect depending on the type and concentration of the used auxinoid, on the developmental stage of the plant at the time of application, and on the exposure time to the effect of auxinoids.

It follows from the above facts that the use of auxinoids is a promising method to eliminate root system malformations and to enlarge the root system volume in general. With respect to the ever increasing trend of using the containerized planting stock – namely in beech and pine – the exogenous application of growth substances as a possibility to minimize the root system malformations in the planting stock of these tree species has become a theme of the day.

The goal of the study was to test the effect of growth substances from the group of auxinoids on the root system of the planting stock of European beech and Scots pine.

MATERIAL AND METHODS

Establishment of the experiments

The experiments were established in two series as follows:

- Spring treatment of root systems (24th March 2004) at the time of the first root system growing period;
- Late summer treatment (16th August 2004) at the time of the second root system growing period.

The planting stock used at all times in each of the experimental series was that of European beech (*Fagus sylvatica* L.) and Scots pine (*Pinus sylvestris* L.). The exogenous application was made by dipping the whole root systems of tested plants in the solutions of growth substances at concentrations of 1.10^{-4} M NAA and 1.10^{-3} M IBA for 1, 2 and 5 hours.

The material used in the first experimental series (spring dipping) was a two-year old planting stock of European beech (growing formula 1-1). The planting stock was trimmed by cutting – taproot and lateral roots pruned to 1/3 and 1/3 of total length, respectively – and the pruned root system was dipped in the solutions of NAA and IBA growth substances. The root system dipping time in each of the growth substances was 1, 2 and 5 hours – with the respective variants marked in the following text and tables as 1 IBA, 1 NAA, 2 IBA, 2 NAA, 5 IBA and 5 NAA. Control plants (referred to in the text below and in tables as Control) were only transplanted with no subsequent treatment after the root pruning. The plants treated with the growth substances and the control plants were transplanted into Quick pot QP 24 T containers with peat substrate obtained by blending sphagnum peat with perlite at 5:1, and with the controlled-release "Plantacote 6 M" full fertilizer at a dose of 3 g per 1 litre of substrate. After being placed in the containers, the transplants were transferred into a greenhouse being further grown and treated as a common planting stock. Plants in all experimental variants were treated in the same way.

The spring dipping of Scots pine was made with the containerized planting stock old 1 year (growing formula fk 1 + 0). Root balls were first subjected to a gentle removal of the substrate and then subsequently handled as a bare-rooted planting stock. The Scots pine root systems were not pruned prior to the dipping in the solutions of growth substances. Therefore another variant (Pruning) was added to the control variant untreated with the growth substances, in which the root system was pruned by 1/3 with the subsequent transplanting of the plants. The plants treated by dipping in NAA, IBA growth substances for 1, 2 and 5 hours and the untreated plants (Control, Pruning) were transplanted according to methodological procedures identical to those used in the variant with European beech. The plants in all experimental variants were further treated and grown in the same way.

The material used in the second experimental series (summer dipping) was the planting stock of European beech (growing formula fk 1.5 + 0) and Scots pine (growing formula fk 1.5 + 0). Root balls of both species were first subjected to a gentle removal of the substrate and then to a pruning of both taproots and lateral roots by 1/3. The treated plants were dipped in the solutions of growth substances (NAA and IBA) for 1, 2 and 5 hours and then transplanted. The control plants were transplanted immediately after the root system pruning. The transplanting, transport into the foil shelter, placement in the foil shelter and subsequent treatment of the planting stock were identical as in the planting stock of the previous series. Plants in all variants of the experiment were treated in the same way.

Each experimental variant included a total number of 80 treated and assessed plants.

Evaluation of the experiments

All plants (all variants, both tree species, both series) were lifted from the containers in November 2004 and analyzed after their root systems (RS) were thoroughly washed.

The terms used for the evaluation of the plants are as follows:

– Main root – the taproot growing vertically in the geotropic direction as a continuation of the original radix primarium or substitute taproots growing in the positive geotropic direction;
– Lateral roots – the roots longer than 1 mm shooting from the main root (lateral roots of the 1st order);
– Fine roots (FR) – the roots thinner than 1 mm in diameter;
– Large-diameter roots (LDR) – the roots thicker than 1 mm in diameter.

All plants were analyzed for the following characteristics:

(a) Shoot height (cm);
(b) Shoot increment in the last growing period (cm) was assessed only in plants from the first series (spring dipping);
(c) Root collar diameter (mm);
(d) Dry weight of fine roots (g);
(e) Dry weight of large-diameter roots (g);
(f) Dry weight of shoot (g);
(g) Number of large-diameter roots of the 1st order 2 cm below the root collar (LDR RC-2 cm);
(h) Number of fine roots of the 1st order 2 cm below the root collar (FR RC-2 cm);
(i) Number of large-diameter roots of the 1st order occurring in the first quarter of the main root length – from the root collar to the growing tip of the main root (LDR RC-1/4);
(j) Number of fine roots of the 1st order occurring in the first quarter of the main root length – from the root collar to the growing tip of the main root (FR RC-1/4);
(k) Number of large-diameter roots of the 1st order occurring in the second quarter of the main root length – from the root collar to the growing tip of the main root (LDR 1/4-1/2);
(l) Number of fine roots of the 1st order occurring in the second quarter of the main root length – from the root collar to the growing tip of the main root (FR 1/4-1/2);
(m) Number of large-diameter roots of the 1st order occurring in the third quarter of the main root length – from the root collar to the growing tip of the main root (LDR 1/2-3/4);
(n) Number of fine roots of the 1st order occurring in the third quarter of the taproot length – from the root collar to the growing tip of the main root (FR 1/2-3/4);
(o) Number of large-diameter roots of the 1st order occurring in the fourth quarter of the taproot length – from the root collar to the growing tip of the main root (LDR 3/4-4/4);
(p) Number of fine roots of the 1st order occurring in the fourth quarter of the taproot length – from the root collar to the growing tip of the main root (FR 3/4-4/4);
(q) Total number of large-diameter lateral roots of the 1st order (Total LDR);
(r) Total number of fine lateral roots of the 1st order (Total FR);
(s) Total number of all fine and large-diameter lateral roots of the 1st order (Total FR + LDR);
(t) Mortality expressed as a number of dead plants, unacceptable mortality is 17 plants, e.g. 20%.

The data sets were subjected to a statistical evaluation by the multidimensional analysis of variance (Manova) used in the Statistica 6.0 CZ programme. Tukey's HSD test was used to detect statistically significant differences between the variants and Dunnet's test was used to compare all experimental variants with the control in the respective series. Wilks' criterion was used for a general test of differences between the groups. The analysis of variance was preceded by a research analysis of data and verification was made of basic preconditions, namely the normal distribution and the tie of covariance matrices. Normality was evaluated by Shapiro-Wilks' test; the tie of covariance matrices was assessed by Box's test. The level of significance was 95% in all tests.

The results of surveys are presented in the form of tables. Data presented in the tables are arithmetic means, standard deviations and Dunnett's test results. Differences between the tests are illustrated by means of the following symbols:

ø indifferent effect (no significant difference between the control and the treated plants of the given variant was demonstrated),

* positive effect (a significant difference was demonstrated to the benefit of the given variant, i.e. treated plants were classified better in this parameter than the control plants),

Table 1. Scots pine (*Pinus sylvestris* L.) – spring dipping of root systems – biometrical parameters of shoot growth, dry weight of fine and large-diameter roots, mortality

Variant	Shoot height (cm)	Shoot increment (cm)	Root collar diameter (mm)	Dry weight of shoot (g/plant)	Dry weight of fine roots (g/plant)	Dry weight of large-diameter roots (g/plant)	Mortality (number of dead plants)
Control	27.1 ± 3.8	16.4 ± 3.8	4.5 ± 0.6	4.053 ± 1.056	0.994 ± 0.379	0.390 ± 0.130	0
1 NAA	23.1 ± 3.4$^{\times}$	13.5 ± 3.4$^{\times}$	4.2 ± 0.7$^{\times}$	3.304 ± 1.030$^{\times}$	0.639 ± 0.327$^{\times}$	0.270 ± 0.112$^{\times}$	1$^{\emptyset}$
2 NAA	23.2 ± 2.7$^{\times}$	13.5 ± 2.7$^{\times}$	4.6 ± 0.7$^{\emptyset}$	3.580 ± 1.069$^{\emptyset}$	0.841 ± 0.402$^{\emptyset}$	0.377 ± 0.148$^{\emptyset}$	3$^{\emptyset}$
5 NAA	23.6 ± 2.6$^{\times}$	13.8 ± 2.6$^{\times}$	4.4 ± 0.6$^{\times}$	3.329 ± 1.013$^{\times}$	0.720 ± 0.343$^{\times}$	0.316 ± 0.127$^{\times}$	3$^{\emptyset}$
1 IBA	26.0 ± 4.2$^{\emptyset}$	16.5 ± 4.2$^{\emptyset}$	4.7 ± 0.6$^{\emptyset}$	4.011 ± 1.070$^{\emptyset}$	0.829 ± 0.306$^{\emptyset}$	0.386 ± 0.113$^{\emptyset}$	0$^{\emptyset}$
2 IBA	24.6 ± 3.1$^{\times}$	15.0 ± 3.4$^{\emptyset}$	4.7 ± 0.6$^{\emptyset}$	4.018 ± 1.222$^{\emptyset}$	0.741 ± 0.351$^{\times}$	0.366 ± 0.135$^{\emptyset}$	2$^{\emptyset}$
5 IBA	24.0 ± 3.1$^{\times}$	14.3 ± 3.1$^{\times}$	5.0 ± 0.6°	3.768 ± 0.822$^{\emptyset}$	0.819 ± 0.295$^{\emptyset}$	0.434 ± 0.152°	2$^{\emptyset}$
Pruning	26.4 ± 3.8$^{\emptyset}$	15.7 ± 3.8$^{\emptyset}$	4.6 ± 0.5$^{\emptyset}$	4.006 ± 0.939$^{\emptyset}$	0.960 ± 0.392$^{\emptyset}$	0.383 ± 0.105$^{\emptyset}$	0$^{\emptyset}$

$^{\emptyset}$indifferent effect, $^{\times}$negative effect, $^{\circ}$positive effect

Table 2. European beech (*Fagus sylvatica* L.) – spring dipping of root systems – biometrical parameters of shoot growth, dry weight of fine and large-diameter roots, mortality

Variant	Shoot height (cm)	Shoot increment (cm)	Root collar diameter (mm)	Dry weight of shoot (g/plant)	Dry weight of fine roots (g/plant)	Dry weight of large-diameter roots (g/plant)	Mortality (number of dead plants)
Control	46.9 ± 8.6	19.9 ± 7.6	6.8 ± 0.8	6.271 ± 1.773	1.155 ± 0.541	6.003 ± 1.574	5
1 NAA	42.3 ± 10.4$^{\emptyset}$	20.0 ± 7.6$^{\emptyset}$	6.8 ± 0.9$^{\emptyset}$	4.868 ± 2.336$^{\emptyset}$	0.947 ± 0.552$^{\emptyset}$	4.617 ± 1.665$^{\times}$	5$^{\emptyset}$
2 NAA	49.9 ± 10.8$^{\emptyset}$	26.4 ± 9.8°	6.4 ± 0.8$^{\times}$	5.336 ± 2.105$^{\emptyset}$	0.720 ± 0.268$^{\times}$	3.642 ± 1.351$^{\times}$	3$^{\emptyset}$
5 NAA	52.5 ± 12.9$^{\emptyset}$	24.6 ± 10.1°	7.1 ± 1.1$^{\emptyset}$	6.552 ± 3.069$^{\emptyset}$	0.880 ± 0.495$^{\times}$	4.567 ± 2.016$^{\times}$	4$^{\emptyset}$
1 IBA	49.7 ± 10.1$^{\emptyset}$	27.5 ± 8.5°	7.3 ± 0.9$^{\emptyset}$	6.672 ± 2.202$^{\emptyset}$	1.239 ± 0.419$^{\emptyset}$	5.438 ± 1.682$^{\emptyset}$	7$^{\emptyset}$
2 IBA	55.6 ± 9.9°	28.5 ± 9.5°	7.1 ± 0.8$^{\emptyset}$	6.740 ± 2.038$^{\emptyset}$	1.206 ± 0.528$^{\emptyset}$	5.107 ± 1.432$^{\times}$	6$^{\emptyset}$
5 IBA	61.6 ± 13.3°	37.2 ± 11.0°	8.2 ± 1.2°	9.067 ± 3.628°	1.494 ± 0.647°	6.461 ± 2.504°	6$^{\emptyset}$

$^{\emptyset}$indifferent effect, $^{\times}$negative effect, $^{\circ}$positive effect x negative effect (a significant difference was demonstrated to the detriment of the given variant, i.e. treated plants were classified worse than the control plants).

RESULTS

Spring dipping

Scots pine

Results of the experimental spring dipping of Scots pine root systems were summarized into the following statements (Tables 1, 3):

– None of the experimental variants induced an unacceptable mortality; none of the experimental variants resulted in the impaired vitality of plants.
– None of the experimental variants exhibited a significant effect on the number of fine and large-diameter lateral roots of the 1st order in the respective sections of the main root length.
– The variants of Pruning and 1 IBA did not significantly affect any of the studied growth parameters.
– All variants with the application of NAA exhibited a stronger effect on the growth of aboveground parts and the dry weight of roots than the variants with IBA. The effect was significantly negative, though.
– The only significant positive effect of the whole experiment was observed in Variant 5 IBA and in the parameters of root collar diameter and large-diameter root dry weight. This variant however exhibited a significant negative effect in the parameter of shoot increment.
– None of the experimental variants showed a complex stimulation of the Scots pine root system development, the effect of NAA being rather negative (especially in variants 1 NAA and 5 NAA) and the effect of IBA being rather indifferent.

European beech

Results of the experimental spring dipping of European beech root systems were summarized into the following statements (Tables 2, 4):

– None of the experimental variants induced an unacceptable mortality; none of the experimental variants resulted in the impaired vitality of plants.
– None of the experimental variants exhibited a significant effect on the number of fine or large-diameter lateral roots of the 1st order in the zone of RC-2 cm. With the exception of Variant 1 IBA in the zone of RC-1/4, none of the experimental vari-

Table 3. Scots pine (*Pinus sylvestris* L.) – spring dipping of root systems – fine and large-diameter roots in the respective zones of measurement

Variant	Number of lateral roots of the 1st order in the respective zones of measurement												Total
	RC – 2cm		RC – 1/4		1/4–1/2		1/2–3/4		3/4–4/4		Total		
	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	FR + LDR
Control	0.8 ± 1.1	0.9 ± 1.6	0.9 ± 1.3	2.9 ±1.7	1.8 ± 1.1	2.3 ± 1.2	1.1 ± 1.0	3.4 ± 1.5	0.0 ± 0.3	3.7 ± 1.1	3.8 ± 2.0	12.3 ± 2.9	16.1 ± 3.2
1 NAA	0.2 ± 0.8$^{\varnothing}$	1.9 ± 1.0$^{\varnothing}$	0.8 ± 1.0$^{\varnothing}$	2.4 ± 1.3$^{\varnothing}$	1.9 ± 1.0$^{\varnothing}$	4.1 ± 1.6$^{\varnothing}$	0.3 ± 0.0$^{\varnothing}$	3.6 ± 0.7$^{\varnothing}$	0.2 ± 0.0$^{\varnothing}$	4.5 ± 1.2$^{\varnothing}$	3.2 ± 1.6$^{\varnothing}$	14.2 ± 3.8$^{\varnothing}$	17.4 ± 3.6$^{\varnothing}$
2 NAA	0.8 ± 1.0$^{\varnothing}$	1.0 ± 1.5$^{\varnothing}$	1.9 ± 1.0$^{\varnothing}$	2.1 ± 1.6$^{\varnothing}$	1.6 ± 0.9$^{\varnothing}$	2.6 ± 0.7$^{\varnothing}$	0.6 ± 0.5$^{\varnothing}$	3.8 ± 0.7$^{\varnothing}$	0.3 ± 0.4$^{\varnothing}$	3.8 ± 1.3$^{\varnothing}$	4.4 ± 1.2$^{\varnothing}$	12.3 ± 2.8$^{\varnothing}$	16.7 ± 3.3$^{\varnothing}$
5 NAA	1.1 ± 1.4$^{\varnothing}$	1.4 ± 1.1$^{\varnothing}$	1.1 ± 1.3$^{\varnothing}$	1.2 ± 1.5$^{\varnothing}$	1.7 ± 1.0$^{\varnothing}$	3.4 ± 1.4$^{\varnothing}$	0.9 ± 0.7$^{\varnothing}$	4.2 ± 1.6$^{\varnothing}$	0.3 ± 0.4$^{\varnothing}$	5.3 ± 1.0$^{\varnothing}$	4.0 ± 1.5$^{\varnothing}$	14.2 ± 1.6$^{\varnothing}$	18.2 ± 1.7$^{\varnothing}$
1 IBA	0.7 ± 0.0$^{\varnothing}$	0.9 ± 1.3$^{\varnothing}$	1.0 ± 0.5$^{\varnothing}$	2.0 ± 2.0$^{\varnothing}$	2.1 ± 0.4$^{\varnothing}$	3.3 ± 1.4$^{\varnothing}$	0.7 ± 0.8$^{\varnothing}$	3.1 ± 1.4$^{\varnothing}$	0.0 ± 0.5$^{\varnothing}$	4.6 ± 2.3$^{\varnothing}$	3.8 ± 2.0$^{\varnothing}$	13.0 ± 2.5$^{\varnothing}$	16.8 ± 3.4$^{\varnothing}$
2 IBA	0.4 ± 0.8$^{\varnothing}$	0.8 ± 1.7$^{\varnothing}$	1.2 ± 0.9$^{\varnothing}$	2.5 ± 1.6$^{\varnothing}$	2.0 ± 1.1$^{\varnothing}$	3.9 ± 1.3$^{\varnothing}$	0.4 ± 0.5$^{\varnothing}$	4.4 ± 1.0$^{\varnothing}$	0.2 ± 0.3$^{\varnothing}$	4.6 ± 0.9$^{\varnothing}$	3.8 ± 2.4$^{\varnothing}$	15.4 ± 2.2$^{\varnothing}$	19.2 ± 3.9$^{\varnothing}$
5 IBA	1.3 ± 1.4$^{\varnothing}$	1.7 ± 1.3$^{\varnothing}$	0.9 ± 1.3$^{\varnothing}$	1.4 ± 1.6$^{\varnothing}$	1.2 ± 1.3$^{\varnothing}$	3.7 ± 2.8$^{\varnothing}$	0.7 ± 0.9$^{\varnothing}$	3.6 ± 1.9$^{\varnothing}$	0.2 ± 0.3$^{\varnothing}$	4.8 ± 1.1$^{\varnothing}$	3.0 ± 1.4$^{\varnothing}$	13.5 ± 3.2$^{\varnothing}$	16.5 ± 3.9$^{\varnothing}$
Pruning	0.7 ± 1.2$^{\varnothing}$	1.4 ± 1.6$^{\varnothing}$	1.4 ± 1.3$^{\varnothing}$	1.3 ± 1.8$^{\varnothing}$	1.6 ± 1.1$^{\varnothing}$	3.7 ± 2.3$^{\varnothing}$	0.6 ± 0.9$^{\varnothing}$	3.2 ± 1.5$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	5.4 ± 2.5$^{\varnothing}$	3.6 ± 1.5$^{\varnothing}$	13.6 ± 3.9$^{\varnothing}$	17.2 ± 4.2$^{\varnothing}$

$^{\varnothing}$indifferent effect, ^{x}negative effect, *positive effect

Table 4. European beech (*Fagus sylvatica* L.) – spring dipping of root systems – fine and large-diameter roots in the respective zones of measurement

	Number of lateral roots of the 1st order in the respective zones of measurement												
	RC – 2cm		RC – 1/4		1/4–1/2		1/2–3/4		3/4–4/4		Total		Total
Variant	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	FR + LDR
Control	0.5 ± 1.1	2.3 ± 2.2	0.7 ± 1.3	3.1 ± 2.4	1.0 ± 1.2	3.5 ± 1.5	1.2 ± 0.8	4.8 ± 1.4	1.4 ± 1.3	5.3 ± 1.5	4.3 ± 2.2	16.7 ± 5.3	21.0 ± 5.2
1 NAA	0.7 ± 0.8$^{\emptyset}$	3.2 ± 2.6$^{\emptyset}$	1.5 ± 1.0$^{\emptyset}$	5.2 ± 2.9$^{\emptyset}$	1.6 ± 1.1$^{\emptyset}$	6.3 ± 1.6*	0.5 ± 1.1$^{\emptyset}$	6.2 ± 1.4$^{\emptyset}$	0.5 ± 0.7$^{\emptyset}$	7.3 ± 1.5$^{\emptyset}$	4.1 ± 2.6$^{\emptyset}$	25.0 ± 5.3$^{\emptyset}$	29.1 ± 5.5$^{\emptyset}$
2 NAA	0.6 ± 0.8$^{\emptyset}$	4.0 ± 4.0$^{\emptyset}$	0.7 ± 0.8$^{\emptyset}$	5.6 ± 4.7$^{\emptyset}$	0.5 ± 0.5$^{\emptyset}$	4.3 ± 1.6$^{\emptyset}$	1.0 ± 1.1$^{\emptyset}$	5.3 ± 1.8$^{\emptyset}$	1.1 ± 1.1$^{\emptyset}$	5.5 ± 1.6$^{\emptyset}$	3.3 ± 1.3$^{\emptyset}$	20.7 ± 8.6$^{\emptyset}$	24.0 ± 9.0$^{\emptyset}$
5 NAA	0.3 ± 0.7$^{\emptyset}$	4.3 ± 3.6$^{\emptyset}$	0.5 ± 0.7$^{\emptyset}$	6.5 ± 3.9$^{\emptyset}$	0.8 ± 0.9$^{\emptyset}$	6.5 ± 1.6*	0.5 ± 0.7$^{\emptyset}$	7.0 ± 2.0$^{\emptyset}$	0.9 ± 1.1$^{\emptyset}$	8.0 ± 1.8$^{\emptyset}$	2.7 ± 1.9$^{\emptyset}$	28.0 ± 7.1*	30.7 ± 6.0*
1 IBA	1.1 ± 0.6$^{\emptyset}$	7.0 ± 4.0$^{\emptyset}$	2.1 ± 1.1*	9.9 ± 4.9*	1.4 ± 1.3$^{\emptyset}$	7.6 ± 1.9*	0.4 ± 0.7$^{\emptyset}$	9.3 ± 2.4*	1.0 ± 0.9$^{\emptyset}$	15.6 ± 4.5*	4.9 ± 2.3$^{\emptyset}$	42.4 ± 9.9*	47.3 ± 10.6*
2 IBA	0.6 ± 0.8$^{\emptyset}$	4.2 ± 3.8$^{\emptyset}$	0.9 ± 0.9$^{\emptyset}$	6.7 ± 4.7$^{\emptyset}$	1.2 ± 1.7$^{\emptyset}$	6.2 ± 4.3$^{\emptyset}$	0.8 ± 1.5$^{\emptyset}$	5.4 ± 2.7$^{\emptyset}$	1.1 ± 1.4$^{\emptyset}$	15.3 ± 4.1*	4.0 ± 2.5$^{\emptyset}$	33.6 ± 10.0*	37.6 ± 9.7*
5 IBA	1.2 ± 1.0$^{\emptyset}$	4.5 ± 3.7$^{\emptyset}$	1.6 ± 1.1$^{\emptyset}$	7.1 ± 3.6$^{\emptyset}$	0.5 ± 0.8$^{\emptyset}$	7.6 ± 2.8*	1.1 ± 1.5$^{\emptyset}$	7.7 ± 2.0*	2.4 ± 1.4$^{\emptyset}$	15.5 ± 3.3*	5.6 ± 2.3$^{\emptyset}$	37.9 ± 9.5*	43.5 ± 9.6*

$^{\emptyset}$indifferent effect, $^{\times}$negative effect, *positive effect

ants affected the number of large-diameter lateral roots of the 1st order. All variants with the applied IBA significantly increased the number of fine lateral roots of the 1st order in the 3/4–4/4 zone (ca. 3×) and the number of total fine lateral roots of the 1st order (more than 2×). In Variants 1 IBA and 5 IBA, a significant increase of the number of lateral fine roots was also observed in the 1/4–1/2 and 1/2–3/4 zones (ca 2×). With the exception of Variants 1 NAA and 5 NAA in the 1/4–1/2 zone of measurement, none of the experimental NAA variants was observed to have a significant effect on the number of fine lateral roots of the 1st order; the increase recorded in Variant 5 NAA also showed in a significant increase in the total number of fine lateral roots of the 1st order.

– Variant 5 IBA was the only variant that significantly stimulated the development of beech in all studied parameters of shoot growth and root system dry weight. Although the effect of Variant 1 IBA on the increased shoot increment was significant, the variant was observed to have an indifferent effect on other parameters. All other variants (1 NAA, 2 NAA, 5 NAA, 2 IBA) exhibited a significant inhibition of large-diameter root dry weight at all times, and also a significant inhibition of fine root dry weight (2 NAA and 5 NAA) despite the stimulating or indifferent effects on the growth of the aboveground part of the plant.
– None of the experimental NAA variants showed a complex stimulation of development of the European beech root system. Variant 5 IBA induced the complex stimulation of root system development and also the stimulation of shoot development. The effects of this variant were similar to those of Variant 1 IBA, in which a significant increase in lateral roots of the 1st order was recorded (i.e. the basis for the root system development in the coming period), and a stimulating (in the parameter of shoot increment) or an indifferent effect (in the parameter of root collar diameter and shoot dry weight) on the development of aboveground parts, and an indifferent effect on the biomass of fine and large-diameter roots.

Summer dipping

Scots pine

Results of the experimental summer dipping of Scots pine root systems were summarized into the following statements (Tables 5, 7):

– None of the experimental variants induced an unacceptable mortality; none of the experimen-

Table 5. Scots pine (*Pinus sylvestris* L.) – summer dipping of root systems – biometrical parameters of shoot growth, dry weight of fine and large-diameter roots, mortality

Variant	Shoot height (cm)	Root collar diameter (mm)	Dry weight of shoot (g/plant)	Dry weight of fine roots (g/plant)	Dry weight of large-diameter roots (g/plant)	Mortality (number of dead plants)
Control	37.8 ± 3.7	4.9 ± 0.6	4.455 ± 1.097	0.526 ± 0.213	0.573 ± 0.179	1
1 NAA	39.0 ± 4.3$^{\varnothing}$	4.6 ± 0.5$^{\varnothing}$	4.473 ± 1.127$^{\varnothing}$	0.318 ± 0.132$^{\times}$	0.500 ± 0.145$^{\varnothing}$	0$^{\varnothing}$
2 NAA	37.9 ± 3.4$^{\varnothing}$	4.8 ± 0.6$^{\varnothing}$	4.533 ± 1.158$^{\varnothing}$	0.354 ± 0.170$^{\times}$	0.547 ± 0.197$^{\varnothing}$	2$^{\varnothing}$
5 NAA	39.1 ± 4.0$^{\varnothing}$	5.0 ± 0.6$^{\varnothing}$	5.032 ± 1.370$^{\varnothing}$	0.361 ± 0.166$^{\times}$	0.567 ± 0.175$^{\varnothing}$	2$^{\varnothing}$
1 IBA	37.5 ± 3.1$^{\varnothing}$	4.8 ± 0.6$^{\varnothing}$	4.196 ± 1.062$^{\varnothing}$	0.487 ± 0.218$^{\varnothing}$	0.509 ± 0.173$^{\varnothing}$	4$^{\varnothing}$
2 IBA	38.2 ± 5.0$^{\varnothing}$	4.9 ± 0.6$^{\varnothing}$	4.627 ± 1.369$^{\varnothing}$	0.340 ± 0.122$^{\times}$	0.574 ± 0.224$^{\varnothing}$	1$^{\varnothing}$
5 IBA	38.6 ± 3.6$^{\varnothing}$	5.0 ± 0.7$^{\varnothing}$	4.475 ± 1.261$^{\varnothing}$	0.317 ± 0.155$^{\times}$	0.545 ± 0.194$^{\varnothing}$	1$^{\varnothing}$

$^{\varnothing}$indifferent effect, $^{\times}$negative effect, *positive effect

Table 6. European beech (*Fagus sylvatica* L.) – summer dipping of root systems – biometrical parameters of shoot growth, dry weight of fine and large-diameter roots, mortality

Variant	Shoot height (cm)	Root collar diameter (mm)	Dry weight of shoot (g/plant)	Dry weight of fine roots (g/plant)	Dry weight of large-diameter roots (g/plant)	Mortality (number of dead plants)
Control	36.1 ± 3.7	5.9 ± 0.6	2.709 ± 0.744	0.457 ± 0.209	2.452 ± 0.813	2
1 NAA	35.9 ± 3.7$^{\varnothing}$	5.6 ± 0.6$^{\varnothing}$	2.195 ± 0.683$^{\times}$	0.319 ± 0.150$^{\times}$	1.876 ± 0.603$^{\times}$	1$^{\varnothing}$
2 NAA	36.3 ± 3.2$^{\varnothing}$	5.9 ± 0.6$^{\varnothing}$	2.365 ± 0.614$^{\varnothing}$	0.388 ± 0.147$^{\varnothing}$	1.911 ± 0.542$^{\times}$	1$^{\varnothing}$
5 NAA	37.7 ± 4.1$^{\varnothing}$	5.9 ± 0.6$^{\varnothing}$	2.885 ± 0.730$^{\varnothing}$	0.460 ± 0.248$^{\varnothing}$	2.332 ± 0.863$^{\varnothing}$	2$^{\varnothing}$
1 IBA	36.1 ± 3.0$^{\varnothing}$	6.0 ± 0.6$^{\varnothing}$	2.562 ± 0.815$^{\varnothing}$	0.463 ± 0.199$^{\varnothing}$	1.963 ± 0.741$^{\times}$	1$^{\varnothing}$
2 IBA	36.1 ± 3.5$^{\varnothing}$	5.9 ± 0.8$^{\varnothing}$	2.491 ± 0.724$^{\varnothing}$	0.582 ± 0.203*	2.142 ± 0.802$^{\times}$	3$^{\varnothing}$
5 IBA	35.3 ± 3.1$^{\varnothing}$	5.8 ± 0.7$^{\varnothing}$	2.394 ± 0.708$^{\varnothing}$	0.546 ± 0.241$^{\varnothing}$	2.024 ± 0.773$^{\times}$	2$^{\varnothing}$

$^{\varnothing}$indifferent effect, $^{\times}$negative effect, *positive effect

tal variants resulted in the impaired vitality of plants.
- None of the experimental variants exhibited a significant effect on the number of fine and large-diameter lateral roots of the 1st order in the respective sections of the main root length.
- Variant 1 IBA did not significantly affect any of the studied growth parameters.
- Although none of the experimental variants was observed to have significantly affected the shoot growth and the dry weight of large-diameter roots, with the exception of Variant 1 IBA all other variants showed a significant and a very marked reduction of fine root dry weight.
- None of the experimental variant had a positive effect on the development of Scots pine root system.

European beech

Results of the experimental summer dipping of European beech root systems were summarized into the following statements (Tables 6, 8):
- None of the experimental variants induced an unacceptable mortality; none of the experimental variants resulted in the impaired vitality of plants.
- None of the experimental variants exhibited a significant effect on the number of fine or large-diameter lateral roots of the 1st order in the RC-2 cm zone. None of the experimental variants affected the number of large-diameter roots of the 1st order in the respective studied sections of the main root length. All IBA variants significantly increased the number of fine lateral roots in the 3/4–4/4 zone, Variant 2 IBA increased the number of fine lateral roots also in the RC-1/4, 1/4–1/2 and 1/2–3/4 zones, and Variant 5 IBA increased the number of fine lateral roots also in the 1/4–1/2, 1/2–3/4 zones. The significant effect on the development of fine lateral roots in Variants 2 IBA and 5 IBA was reflected in a more than doubled increase of the total number of fine roots shooting from the main root. None of NAA variants had a significant effect on the number of fine roots.
- None of the experimental variants significantly stimulated the development of aboveground parts, and with the exception of the shoot dry weight parameter in Variant 1 NAA where the effect was negative, their effect was found indifferent in all cases. Apart from Variant 5 NAA where

Table 7. Scots pine (*Pinus sylvestris* L.) – summer dipping of root systems – fine and large-diameter roots in the respective zones of measurement

	Number of lateral roots of the 1st order in the respective zones of measurement												
	RC – 2cm		RC – 1/4		1/4–1/2		1/2–3/4		3/4–4/4		Total		Total
Variant	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	FR + LDR
Control	0.9 ± 1.1	1.6 ± 1.6	1.4 ± 1.3	2.5 ± 1.7	1.4 ± 1.1	3.7 ± 1.2	0.6 ± 1.0	3.7 ± 1.5	0.1 ± 0.3	4.5 ± 1.1	3.5 ± 2.2	14.4 ± 3.5	17.9 ± 2.3
1 NAA	0.7 ± 0.8$^{\varnothing}$	1.5 ± 1.0$^{\varnothing}$	1.2 ± 1.0$^{\varnothing}$	2.5 ± 1.3$^{\varnothing}$	1.2 ± 1.0$^{\varnothing}$	2.7 ± 1.6$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	3.9 ± 0.7$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	3.1 ± 1.2$^{\varnothing}$	2.4 ± 1.2$^{\varnothing}$	12.2 ± 2.6$^{\varnothing}$	14.6 ± 2.7$^{\varnothing}$
2 NAA	0.8 ± 1.0$^{\varnothing}$	1.1 ± 1.5$^{\varnothing}$	0.9 ± 1.0$^{\varnothing}$	1.8 ± 1.6$^{\varnothing}$	1.1 ± 0.9$^{\varnothing}$	3.9 ± 0.7$^{\varnothing}$	0.5 ± 0.5$^{\varnothing}$	4.1 ± 0.7$^{\varnothing}$	0.2 ± 0.4$^{\varnothing}$	3.8 ± 1.3$^{\varnothing}$	2.7 ± 1.7$^{\varnothing}$	13.6 ± 3.2$^{\varnothing}$	16.3 ± 3.3$^{\varnothing}$
5 NAA	1.1 ± 1.5$^{\varnothing}$	0.7 ± 1.1$^{\varnothing}$	1.6 ± 1.3$^{\varnothing}$	1.8 ± 1.5$^{\varnothing}$	1.9 ± 1.1$^{\varnothing}$	3.3 ± 1.4$^{\varnothing}$	1.2 ± 0.7$^{\varnothing}$	3.3 ± 1.6$^{\varnothing}$	0.2 ± 0.4$^{\varnothing}$	4.2 ± 1.0$^{\varnothing}$	4.9 ± 2.6$^{\varnothing}$	12.7 ± 2.7$^{\varnothing}$	17.6 ± 3.3$^{\varnothing}$
1 IBA	0.6 ± 0.0$^{\varnothing}$	1.0 ± 1.3$^{\varnothing}$	0.9 ± 0.5$^{\varnothing}$	1.9 ± 2.0$^{\varnothing}$	1.7 ± 0.4$^{\varnothing}$	2.6 ± 1.4$^{\varnothing}$	0.6 ± 0.8$^{\varnothing}$	3.6 ± 1.4$^{\varnothing}$	0.1 ± 0.5$^{\varnothing}$	4.5 ± 2.3$^{\varnothing}$	5.4 ± 0.8$^{\varnothing}$	13.0 ± 3.6$^{\varnothing}$	18.4 ± 4.1$^{\varnothing}$
2 IBA	0.6 ± 0.8$^{\varnothing}$	1.8 ± 1.8$^{\varnothing}$	0.8 ± 0.9$^{\varnothing}$	2.6 ± 1.6$^{\varnothing}$	1.4 ± 1.1$^{\varnothing}$	4.0 ± 1.3$^{\varnothing}$	0.3 ± 0.5$^{\varnothing}$	3.6 ± 1.0$^{\varnothing}$	0.1 ± 0.3$^{\varnothing}$	4.3 ± 0.9$^{\varnothing}$	2.6 ± 1.0$^{\varnothing}$	14.5 ± 2.0$^{\varnothing}$	17.1 ± 2.3$^{\varnothing}$
5 IBA	1.5 ± 1.4$^{\varnothing}$	1.1 ± 1.3$^{\varnothing}$	1.9 ± 1.3$^{\varnothing}$	1.7 ± 1.6$^{\varnothing}$	1.9 ± 1.3$^{\varnothing}$	3.0 ± 2.8$^{\varnothing}$	0.8 ± 0.9$^{\varnothing}$	4.1 ± 1.9$^{\varnothing}$	0.1 ± 0.3$^{\varnothing}$	5.1 ± 1.1$^{\varnothing}$	4.7 ± 2.2$^{\varnothing}$	13.5 ± 5.6$^{\varnothing}$	18.2 ± 5.2$^{\varnothing}$

$^{\varnothing}$indifferent effect, $^{\times}$negative effect, *positive effect

Table 8. European beech (*Fagus sylvatica* L.) – summer dipping of root systems – fine and large-diameter roots in the respective zones of measurement

	Number of lateral roots of the 1st order in the respective zones of measurement												
	RC – 2cm	RC – 1/4		1/4–1/2		1/2–3/4		3/4–4/4		Total		Total	
Variant	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	LDR	FR	FR + LDR
Control	0.2 ± 0.4	3.4 ± 2.4	0.9 ± 1.4	7.9 ± 2.0	0.6 ± 1.1	7.5 ± 2.8	0.1 ± 0.3	8.6 ± 1.5	0.7 ± 1.3	8.5 ± 2.7	2.3 ± 3.1	32.5 ± 4.8	34.8 ± 5.6
1 NAA	0.1 ± 0.3$^{\varnothing}$	3.4 ± 2.1$^{\varnothing}$	0.3 ± 0.7$^{\varnothing}$	6.4 ± 2.2$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	7.1 ± 1.5$^{\varnothing}$	0.2 ± 0.4$^{\varnothing}$	8.3 ± 1.8$^{\varnothing}$	0.2 ± 0.4$^{\varnothing}$	9.3 ± 2.7$^{\varnothing}$	0.7 ± 0.7$^{\varnothing}$	31.1 ± 6.0$^{\varnothing}$	31.8 ± 6.0$^{\varnothing}$
2 NAA	0.1 ± 0.3$^{\varnothing}$	3.7 ± 4.3$^{\varnothing}$	0.1 ± 0.3$^{\varnothing}$	7.9 ± 4.0$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	7.1 ± 3.9$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	8.6 ± 1.6$^{\varnothing}$	0.0 ± 0.0$^{\varnothing}$	10.7 ± 2.2$^{\varnothing}$	0.0 ± 0.3$^{\varnothing}$	36.3 ± 8.3$^{\varnothing}$	36.4 ± 8.1$^{\varnothing}$
5 NAA	0.2 ± 0.4$^{\varnothing}$	3.5 ± 2.5$^{\varnothing}$	0.2 ± 0.4$^{\varnothing}$	8.0 ± 4.4$^{\varnothing}$	0.4 ± 0.7$^{\varnothing}$	9.0 ± 2.5$^{\varnothing}$	0.6 ± 1.0$^{\varnothing}$	9.1 ± 2.5$^{\varnothing}$	0.5 ± 1.0$^{\varnothing}$	10.7 ± 2.3$^{\varnothing}$	1.7 ± 2.1$^{\varnothing}$	36.8 ± 7.7$^{\varnothing}$	38.5 ± 7.0$^{\varnothing}$
1 IBA	0.1 ± 0.3$^{\varnothing}$	3.7 ± 2.8$^{\varnothing}$	0.4 ± 1.0$^{\varnothing}$	8.5 ± 2.2$^{\varnothing}$	0.4 ± 0.7$^{\varnothing}$	9.0 ± 2.4$^{\varnothing}$	0.5 ± 0.7$^{\varnothing}$	10.4 ± 2.0$^{\varnothing}$	0.5 ± 0.8$^{\varnothing}$	18.7 ± 5.0*	1.8 ± 1.8$^{\varnothing}$	46.6 ± 9.0*	48.4 ± 8.9*
2 IBA	0.3 ± 0.5$^{\varnothing}$	5.0± 2.5$^{\varnothing}$	0.4 ± 1.0$^{\varnothing}$	12.0 ± 4.2*	0.2 ± 0.6$^{\varnothing}$	14.2 ± 2.3*	0.1 ± 0.3$^{\varnothing}$	17.2 ± 2.9*	0.3 ± 0.5$^{\varnothing}$	26.8 ± 9.2*	1.0 ± 1.2$^{\varnothing}$	70.2 ± 10.9*	71.2 ± 10.5*
5 IBA	0.2 ± 0.4$^{\varnothing}$	3.0 ± 2.4$^{\varnothing}$	0.3 ± 0.5$^{\varnothing}$	6.4 ± 2.9$^{\varnothing}$	0.2 ± 0.4$^{\varnothing}$	12.1 ± 4.3*	0.1 ± 0.3$^{\varnothing}$	22.0 ± 9.0*	0.2 ± 0.4$^{\varnothing}$	32.8 ± 10.7*	0.8 ± 0.9$^{\varnothing}$	73.3 ± 20.6*	74.1 ± 20.6*

$^{\varnothing}$indifferent effect, $^{\times}$negative effect, *positive effect the effect was indifferent, all other experimental variants exhibited a significantly negative effect on the dry weight of large-diameter roots.

– None of the experimental NAA variants was found to have a positive effect on the development of the European beech root system. None of the experimental IBA variants showed a complex positive effect on the development of the European beech root system. Although the 2 IBA and 5 IBA Variants exerted a pronounced positive effect on the number of fine roots (namely in the lower half of the main root), both variants also had a significant negative effect on the biomass of large-diameter roots.

DISCUSSION

Our experiments demonstrated only a partial positive effect of the dipping of European beech and Scots pine root systems in the solutions of NAA and IBA growth substances on the development of the root system. A conclusion can be drawn that the responses of plants to the treatment depended on the tree species, on the type of auxinoid and on the time of its application.

The different responses of the two species – Scots pine and European beech – to the treatment of their root systems with the NAA and IBA growth substances corroborate the findings of Procházka and Šebánek (1997) and Kamínek (2002), who claimed the response of the tree species to growth substances in general to be species-specific. Our experimental results are also in good agreement with those published by Audus (1959), who demonstrated the response of Scots pine to the treatment with growth substances to be lower than that of European beech. Scots pine exhibited the lower response to the treatment of root systems than European beech in both cases of the spring and the summer dipping, with the effect of the treatment on the development of lateral roots of the 1st order not being demonstrated. On the other hand, the response of European beech plants to dipping in the solutions of growth substances by developing fine lateral roots of the 1st order was demonstrated unambiguously, some of the variants exhibiting however a general reduction of the dry weight of fine roots. This corresponds well with the findings of Mauer and Palátová (1989), who concluded that a production loss was incurred in spite of the marked stimulation of the development of lateral roots – both in terms of root system biomass production and in the production of the aboveground part. These conclusions were also drawn by Baser et al. (1978), who informed that the number of lateral roots was initiated by the application of the growth substances but the dry weight of the root system was generally lower than in the control.

In assessing the experiments it was found out that – in contrast to the findings of Selby and Seaby (1982), Simpson (1986) and Mauer and Palátová (1989), who demonstrated the NAA efficiency to be higher than that of IBA in the tested planting stock – Scots pine did not respond to NAA and IBA by developing new lateral roots of the 1st order and that European beech – although exhibiting the stimulation of the development of new lateral roots of the 1st order – responded to IBA more than to NAA. This is likely to have to do with the species-specific reaction as some authors (e.g. Liu et al. 2002) found the efficiency of IBA in stimulating the development of adventitious roots in *Puearia lobata* (Wild.) higher than with the applications of NAA and IAA, which is also in good agreement with our findings. The species-specific reaction is reflected not only in the response to the type and concentration of the used auxinoid but also in the exposure time. In our experiments, the 5-hour dipping in the IBA solution performed best when influencing the root system development in European beech. However, Mauer and Palátová (1989) found that the best exposure time in the dipping of Norway spruce root system in the same growth substance and its concentration was two hours while the 5-hour exposition showed an inhibitory effect.

In agreement with Selby and Seaby (1982), who failed to induce the development of lateral roots in the basal part of the primary root by both dipping and powdering the planting stock root systems in/with the growth substances, we failed to demonstrate the effect of root system dipping in growth substances on the development of lateral roots in the basal zone and/or in the zone of 2 cm below the root collar in a single experimental variant although the rudimentary physiological publications such as Luxová (1974) claim that the exogenous application of growth substances affects the development of adventitious roots namely in the vicinity of the root collar, on the hypocotyl and on the aboveground parts of the plant. In all our experiments the development of new lateral roots of the 1st order was initiated in the lower part of the root system, perhaps due to the fact that the root systems were pruned (mechanically trimmed) before being placed into the containers. A sound mechanical treatment of the root system by pruning would induce the development of new roots at the cutting point or closely above it nearly at all times.

As compared with the control, the treatment of plants with the growth substances at expositions of 1, 2 and 5 hours did not induce an increased mortality. The same results were obtained by Mauer and Palátová (1989), in whose experiment the high mortality was induced only by a 12-hour exposition with the expositions of two and five hours not having increased the mortality. Identical conclusions can also be deduced from the paper of Baser et al. (1978) where the unacceptable mortality was induced only after using several times higher concentrations of the growth substances.

CONCLUSION

Results obtained from the assessment of the experiments can be summarized in the following conclusions:

– None of the experimental variants induced an unacceptable mortality in any of the two species.
– In the case of Scots pine, none of the experimental variants induced a significant effect on the number of fine and large-diameter lateral roots of the 1st order in the respective length sections of the main root. Since the growth substances of NAA and IBA did not unambiguously improve the quality of the Scots pine planting stock with the used concentrations and methods of application, the use of these growth substances cannot be recommended for growing the planting stock of this species.
– In the case of European beech, the spring dipping of the root systems in IBA for 5 hours exhibited an unambiguously beneficial and complex effect on the planting stock quality, inducing an increased shoot increment and biomass dry weight, increased root collar diameter, increased dry weight biomass of fine and large-diameter roots and at the same time a pronounced multiplication of the number of lateral fine roots of the 1st order. The given method can therefore be recommended for the practical use in forest nurseries.
– In the case of European beech, the summer dipping of the root systems in NAA did not exert a beneficial effect on the development of the root system of the planting stock in any of the experimental variants and the summer dipping in IBA did not have a beneficial effect on the development of the root system of the planting stock of this species in any of the experimental variants either. Although the variants with 2- and 5-hour IBA exposition were observed to have a pronounced beneficial effect on the number of lateral fine roots, their significant negative effect on the biomass of large-diameter roots was found at the same time. With respect to this fact, we cannot recommend the NAA and IBA growth substances in the used concentrations and application methods for growing the planting stock of European beech by the summer dipping of root systems.

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Vliv aplikace auxinoidů na kořenový systém sadebního materiálu

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ABSTRAKT: Cílem práce bylo ověřit vliv růstových látek skupiny auxinoidů na kořenový systém sadebního materiálu buku lesního a borovice lesní. Byl sledován vliv termínu aplikace růstových látek (jarní, letní máčení), druhu použité růstové látky (IBA, NAA) a doby expozice v růstové látce (1, 2, 5 hodin). Ověřování prokázalo, že aplikace NAA i IBA nestimulovala růst kořenového systému borovice lesní při žádné expozici kořenových systémů v růstových látkách. U buku lesního měla při jarním máčení pozitivní účinek pětihodinová expozice v IBA. U letního máčení buku lesního nebyl u žádné expozice zjištěn komplexní pozitivní vliv na vývin kořenového systému.

Klíčová slova: kořenový systém; auxinoidy; buk lesní; borovice lesní; NAA; IBA

V práci byla ověřována reakce buku lesního (*Fagus sylvatica* L.) a borovice lesní (*Pinus sylvestris* L.) na exogenní aplikaci růstových látek NAA a IBA v koncentraci NAA 1.10^{-4} M, IBA 1.10^{-3} M. Exogenní aplikace růstových látek byla realizována máčením kořenových systémů v období první a druhé periody růstu kořenového systému (jarní a letní máčení). Kořenové systémy byly v daných růstových látkách máčeny vždy 1, 2 a 5 hodin. V každé variantě bylo vždy hodnoceno 80 rostlin, u kterých byla měřena výška nadzemní části, tloušťka kořenového krčku, biomasa sušiny nadzemní části, biomasa sušiny jemných a hrubých kořenů a počet bočních kořenů I. řádu v jednotlivých délkových sekcích kořene hlavního. Poznatky získané založením a vyhodnocením experimentů lze shrnout do následujících závěrů:

– Žádná z variant experimentů u žádné z dřevin nevyvolala nepřijatelnou mortalitu.
– U borovice lesní v jarním a letním máčení žádná z variant experimentů nevyvolala statisticky průkazný vliv na počet jemných a hrubých bočních kořenů I. řádu v jednotlivých sledovaných sekcích délky hlavního kořene. Protože růstové látky NAA i IBA v použitých koncentracích a způsobech aplikace jednoznačně nezvýšily kvalitu sadebního materiálu borovice lesní, nelze zatím jejich využití doporučit při pěstování sadebního materiálu této dřeviny.
– U buku lesního při jarním máčení bylo prokázáno, že jednoznačně pozitivní a komplexní účinek na kvalitu sadebního materiálu mělo pětihodinové máčení kořenového systému v IBA. Toto ošetření vyvolalo zvýšení přírůstu a biomasy sušiny nadzemní části, zvýšení tloušťky kořenového krčku, zvýšení biomasy sušiny jemných a hrubých kořenů a současně vyvolalo výrazné zmnožení počtu bočních jemných kořenů I. řádu. Proto lze daný způsob pěstování doporučit i provozní školkařské praxi.
– U buku lesního při letním máčení nebyl u žádné z variant aplikované NAA zjištěn pozitivní vliv na vývin kořenového systému buku. U žádné z variant aplikované IBA nebyl zjištěn komplexní pozitivní vliv na vývin kořenového systému buku. Varianty s dvouhodinovou a pětihodinovou expozicí IBA měly sice výrazný pozitivní vliv na počet bočních jemných kořenů, současně byl však zjištěn signifikantní negativní vliv na biomasu hrubých kořenů. Vzhledem k této skutečnosti nelze zatím (při použitých koncentracích a způsobech aplikace) NAA a IBA doporučit při pěstování sadebního materiálu buku lesního formou letního máčení kořenových systémů.

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