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Influence of nitrogen fertilisation on biometric features of two-year-old seedlings of pedunculate oak subjected for root pruning

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Abstract

Pruning is one of the important cultural treatments that have potential to influence hardwood seedling morphology. The aim of the study was to compare the growth of pedunculate oak seedlings, performed pruning roots, in the second growing season, fertilised full and reduced dose of nitrogen.

A total of 24 experimental plots, each with an the area of 0.04 ha, were designated. The roots pruning were made at the end of February 2014 using root pruning machine EGEDAL. The fertilisation, for all seedlings, was performed using ammonium nitrate in an amount of 25 kg ha^{-1} of nitrogen. The second fertilisation was performed only for variants 2 and 4. For these variants, urea was used in an amount of 25 kg ha^{-1}. At the end of the growing season, the root collar diameter and the height of seedlings were measured.

A dose of nitrogen affects the height of pruned seedlings. The effect of the full dose of nitrogen on the height of the pruned seedlings was a statistically significant ($p \leq 0.05$). There was no statistical difference in the height of the seedlings without pruning, fertilised with different dose of nitrogen.

Analysis of root collar diameter showed the significant differences between the variants. The Tukey test, at the significance level of $p \leq 0.05$, showed a significant impact on the root collar diameter of pruned seedlings but no proven effect of nitrogen fertilisation. To conclude, we found that it is reasonable to reduce the doses of nitrogen fertilisation to half of recommended amount (25 kg ha^{-1}) if the root system is not pruned during the second growth year. Seedlings that has received pruning should be fertilised using the recommended doses of nitrogen.

Key words

Quercus robur L., forest nursery, bare-root seedlings, nitrogen, fertilization

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Introduction

Root pruning is used in nurseries since the end of the 19th century (Racey and Racey 1988). The procedure was described for the first time in the bulletin Nursery Practice on the National Forests, chapter entitled 'Root pruning' (Tillotson 1917) and in principle, has not been changed for 100 years. This is one of the more important growing procedures affecting the morphology of deciduous seedlings, favouring proper conformation of the root system. Pruning is performed in order to reduce the primary root increasing the number of fine roots above the site of cutting. A large number of fine roots have a positive effect on shoot growth, compared to the seedlings with a poor number of fine roots (Schultz and Thompson 1996). It is believed that the greater the value of seedlings, the larger is the ratio between the mass of the root system and the mass of the above-ground part. McKay et al. (1999) showed that the survival rate of pruned seedlings of beech in the cultivation is higher compared to seedlings that were not pruned.

Fertilisation is the main source of nutrients for seedlings. The strategy of plant fertilisation in nurseries is based on the knowledge on the nutritional requirements of particular plant species, test results of soil and plants along with visual inspection. The greatest requirements of plants apply to nitrogen, whose amount is usually not enough in the soil. Nitrogen is necessary as a building material of proteins and nucleic acids. It is also a component of vitamins, nucleotides, alkaloids and chlorophyll. It determines the proper development of plants and stimulates the growth of the underground and above-ground parts of plants, ensuring an intense green colour. Rational fertilisation of seedlings with nitrogen in nurseries leads to the production of a high-quality planting material, with sufficient reserves of stored nutrients and carbohydrates allowing survival in unfavourable growing conditions of forest habitat (Ingestad 1979; Imo and Timmer 1992). During pruning procedure, as well as ploughing of seedlings, a part of the root system is lost along with nutrients' storage, which should be supplemented by fertilisation.

The objective of the study was to compare biometric features of pedunculate oak (*Quercus robur* L.) seedlings in the second growing season, fertilised with full and reduced dose of nitrogen, subjected for roots' pruning.

Material and methods

The experiment was established in February 2014 in a forest nursery Muchów (51°01′09″N 16°01′17″E), Jawor Forest District, before the beginning of the second growth year of pedunculate oak seedlings. Acorns for experiment establishment were collected in October 2013, in the production seed stand, located in the seed micro-region Dbs50 (Lower Silesia). The amount of seed sown was 56.2 kg ha^{-1}.

Before starting the experiments, soil analyses were performed in the Laboratory of Environmental Chemistry (Forest Research Institute, Poland). The recommendation was limited to the application of a dose of pure nitrogen in the amount of 50 kg N ha^{-1} in two doses, each of 25 kg N ha^{-1} for deciduous species in the first year of growth and 60 kg N ha^{-1} in two doses, each of 30 kg N ha^{-1} for deciduous species in the second year of growth. In the experiment, the amount of nitrogen was reduced to 50 kg ha^{-1} as resulted from earlier observations and publications (Kasprzyk et al., 2015), indicating the possibility to reduce the total dose of nitrogen for pedunculate oak seedlings up to the level of 48 kg ha^{-1}.

On 0.04-ha fragment of area covered with sowing, 24 experimental plots of length of 11 m were determined. On those areas the following 2×2 factorial experimental scheme in 6 replicate each, was applied:

1. Seedlings root pruned and fertilised with 25 kg ha^{-1} of nitrogen (50% of the recommended dose of nitrogen);
2. Seedlings root pruned and fertilised with 50 kg ha^{-1} of nitrogen (100% of the recommended dose of nitrogen);
3. Seedlings without root pruning, fertilisation 25 kg ha^{-1} of nitrogen (50% of the recommended dose of nitrogen);
4. Seedlings without root pruning, fertilisation 50 kg ha^{-1} of nitrogen (100% of the recommended dose of nitrogen).

Root pruning was performed at the end of February 2014 because of favourable weather conditions occurring in this period (lack of snow cover, temperature oscillating within the range 12–15°C) using a pruning machine type BRS (EGEDAL) allowing for the horizontal cutting.

On 12 May 2014, fertilisation using ammonium nitrate in the amount of 25 kg ha^{-1} of nitrogen was performed for pruned and control seedlings. The second fertilisation procedure was conducted on 20 June 2014 before the beginning of regrowth of the seedlings only for variants 2 and 4. For these variants, we used urea in the amount of 25 kg ha^{-1} when calculated per nitrogen. At the end of the growing season, seedlings were removed, one measured the diameter of the root collar (RCD) and the height of seedlings. For each seedling, the sturdiness quotient was calculated (height/RCD). A total of 368 seedlings were measured, at least 14 seedlings were taken in replicate. Data obtained were further used for statistical analysis based on a two-factor analysis of variance with interaction term (Dobek and Szwaczkowski 2003). The groups of homogeneous means were designated with the use of Tukey's HSD test. The calculations were made in Statistica 6.0 program (Statsoft Inc. 2006).

Results

The average height of seedlings, depending on nitrogen fertilisation, was 27.06 cm (50% of N dose) and 33.67 cm (100% of N dose) for root pruned seedlings as well as 57 cm and 60.47 cm (Fig. 1) for control seedlings (not pruned).

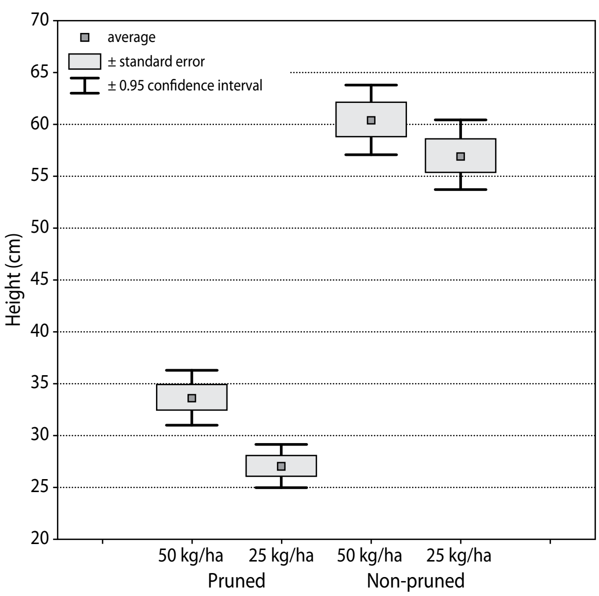

Figure 1. Average height of seedlings for different silvicultural treatment

The analysis of variance demonstrated statistically significant differences in the height of seedlings (Tab. 1), depending on the lack/presence of root development ($p < 0.001$). Moreover, a significant result was obtained for nitrogen dose ($p < 0.001$). No significant interaction was reported between the effect of these two factors. Tukey's test demonstrated differences between particular groups (Tab. 2). Nitrogen dose affects the height of the seedlings for which roots were subjected for pruning. Seedlings pruned and fertilised with a full dose of nitrogen were higher in comparison to seedlings that were pruned and fertilised with half of the recommended nitrogen dose.

Table 1. Analysis of variance for seedlings height

	Sum of squares	Degrees of freedom	Mean square	F	*p*
Treatment	73,656.8	1	73,656.8	359.654	<0.001
Doze (N * ha^{-1})	2,329.7	1	2,329.7	11.376	<0.001
Treatment * Doze of N	224.3	1	224.3	1.095	0.296
Error	74,751.5	365	204.8		

Table 2. Tukey's test for analysed features. Means with the same letter are not significantly different at $p \leq 0.05$

Treatment	Doze of N (kg ha^{-1})	Height (cm)	Root-collar diameter (mm)	Sturdiness quotient
Pruned	25	27.0 a	5.3 a	5.4 a
	50	33.6 b	6.1 a	4.9 b
Without pruning	25	57.0 c	7.4 b	7.8 c
	50	60.4 c	7.9 b	7.8 c

Analysis of variance for the diameter of the root collar showed the significant impact of fertilisation and pruning (Tab. 3). Root pruning significantly affects the diameter of the root collar of seedlings ($p < 0.001$); moreover, a fertilizer dose is also significant ($p = 0.006$). No interaction was reported between the effect of treatment and the level of fertilisation on the diameter of the root collar. Tukey's test at the significance level of $p \leq 0.05$ showed a significant impact of seedlings' pruning on the diameter of the root collar; however, no effect of nitrogen fertilisation was shown. The diameter of the root collar was 5.39 mm (25 kg ha^{-1} N) and 6.15 mm (50 kg ha^{-1} N), while in the group of the pruned and control seedlings, it was 7.47 and 7.93 mm, respectively (Fig. 2).

Table 3. Analysis of variance for root collar diameter

	Sum of squares	Degrees of freedom	Mean square	F	*p*
Treatment	343.6	1	343.6	79.3	<0.001
Doze (N * ha^{-1})	32.9	1	32.9	7.5	0.006
Treatment * Doze of N	2.3	1	2.3	0.5	0.463
Error	1581.8	365	4.3		

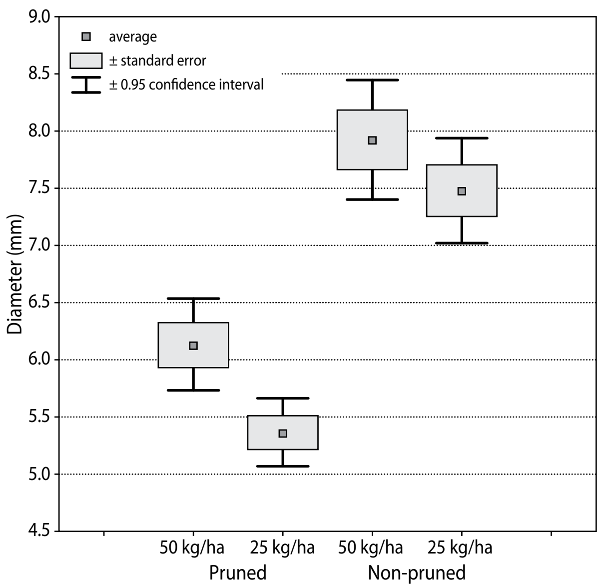

Figure 2. Average root-collar diameter of seedlings for different silvicultural treatment

An important element in seedlings production is the assessment of the quality of the planted specimens, performed based on the measuring of biometric features as set forth in the Polish Standard PN-R-67025. Ninety percent of seedlings pruned and fertilised with a full nitrogen dose was classified into class 1. After reducing the nitrogen dose by half, 85% of seedlings met the requirements of class 1. In the case of non-pruned seedlings, a share of class 1 cuttings was 99% (50 kg ha^{-1} N) and 97% (25 kg ha^{-1} N).

Sturdiness quotient (SQ) is the height–diameter relationship of the root collar and is very similar to the diameter of the root collar as an indicator because of its capacity to predict growth and survival. A small quotient indicates a sturdy plant with a higher expected chance of survival (Jaenicke 1999). On the basis of an analysis of variance for SQ, a difference between the variants was shown. Tukey's test carried out at a level of significance of $p \leq 0.05$ revealed a considerable influence of pruned seedlings on SQ (Tab. 2). For pruned seedlings, the nitrogen dose had a considerable influence on SQ, such a diversity was not observed for non-pruned seedlings.

Discussion

The primary objective of nursery production is to grow high-quality seedlings, which ensures a high quality of forest stands. Properly balanced mineral fertilisation, in addition to the organic fertilisation, still remains one of the fastest and most commonly used methods of seedlings' production of specific parameters, assessed currently via the height of the above-ground part and the diameter in the root collar, by which one determines the usefulness of planting material for reforestation and afforestation.

In the present study, we observed no effect of reduction in the nitrogen fertilisation on biometric features of two-year-old pedunculate oak seedlings, which were not subjected for roots' development. Seedlings fertilised with a full dose of nitrogen had an average height of 60.4 cm, whilst the seedlings treated with the half dose had an average height of 57 cm. Kasprzyk and Jastrzębowski (2016) showed no effect of the full and reduced dose of nitrogen on biometric features of the not-pruned two-year-old beech seedlings. The above-mentioned studies suggest that nitrogen fertilisation for non-pruned pedunculate oak seedlings can be reduced by half. On the other hand, it should be noted that excessive reduction of nitrogen fertilisation may have a negative impact on the survival and growth of oak seedlings during cultivation (Villar-Salvador et al. 2004; Cuesta et al. 2010).

The results obtained clearly indicate the impact of pruning on seedlings' features. Pruned seedlings in comparison to non-pruned ones differently react to doses of nitrogen. As a result of pruning, a part of the root system is removed, and consequently, a plant loses large amounts of nutrients. Coker (1984) reports that during pruning, pine seedlings lose approximately 22% of the root system and, consequently, 15% of nitrogen. The nitrogen is a mobile element in a plant. After pruning of roots, the amount of nitrogen in roots increases, whilst its amount in the above-ground part decreases. A reduction in the amount of nitrogen in needles and shoots was determined at the level of 20–25% within 5 days after treatment. At the same time, increase in the amount of nitrogen in roots was about 5% (Coker 1984). In case of oak seedlings, the amount of nitrogen loss may be much greater than that in the pine, as in deciduous seedlings which loose leaves, the amount of nitrogen stored in the roots is considerably greater in comparison to coniferous seedlings (Villar-Salvador et al. 2015).

In the study presented, pruning of roots was done before the start of the growing season. In the spring, nitrogen that is derived from the tissue reserves is necessary to develop leaves (Millard and Thomson 1989; Berger and Glatzel 2001). In Norway spruce, the most pronounced regeneration of roots occurs at a temperature of about 20°C (Stupendick and Shepherd 1979). Probably, because of the above-mentioned reasons, pruned seedlings are characterised by a decreased height in comparison to seedling that were not subjected for roots' development. Buraczyk (2011) observed that shortening of spruce roots reduced the growth of the above-ground part; however, it simultaneously intensified the regeneration of the root systems proportionally to the size of roots' reduction.

Another parameter describing the seedling is the diameter of the root collar. The diameter of the root collar reflects the size of the root system, which affects the survival rate of seedlings during cultivation (Duryea and Dougherty 1991). The thicker the diameter of the root collar of seedling, the greater is the size of the root (Ritchie 1984). Larger root mass is an indicator of their ability to absorb water and increases the possibility to reduce the stress associated with planting. Studies have shown the impact of pruning or its lack on the diameter of the root collar. For pruned roots, no effect of different doses of nitrogen fertilisation was observed. The size of the root system has a sustainable impact on further growth of seedlings. In 10-year-old excavated Douglas firs, it was observed that the initial size of the root system was correlated with an increase in breast height diameter and root biomass (Sundström and Keane 1999).

Conclusions

1. The level of nitrogen fertilisation affects the height of pruned seedlings; however, no effect of nitrogen fertilisation on the diameter of the root collar was observed.
2. Studies indicate the possibility of reducing nitrogen fertilisation for non-pruned seedlings; however, further studies should be carried out after their planting.

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