sustainability

MDPI

Article

Growth of *Fagus sylvatica* L. and *Picea abies* (L.) Karst. Seedlings Grown in Hiko Containers in the First Year after Planting

Jacek Banach [1,*], Stanisław Małek [1], Mariusz Kormanek [2] and Grzegorz Durło [3]

[1] Department of Ecology and Silviculture, Faculty of Forestry, University of Agriculture in Krakow, Al. 29 Listopada 46, 31-425 Kraków, Poland; rlmalek@cyf-kr.edu.pl

[2] Department of Forest Utilization, Engineering and Forest Techniques, Faculty of Forestry, University of Agriculture in Krakow, Al. 29 Listopada 46, 31-425 Kraków, Poland; rlkorma@cyf-kr.edu.pl

[3] NaviGate LLC, Wadowicka 8a, 30-415 Kraków, Poland; rldurlo@cyf-kr.edu.pl

* Correspondence: rlbanach@cyf-kr.edu.pl; Tel.: +48-12-662-51-25

Received: 3 August 2020; Accepted: 30 August 2020; Published: 2 September 2020

Abstract: In forest management in Poland, there are no standards for the quality and suitability for planting seedlings produced in nursery containers; therefore, research contributing to the development of such guidelines is important. We investigated the growth reaction of European beech and Norway spruce seedlings growing in container technology one year after planting on an experimental forest plantation. The seedlings used in the study were three experimental variants grown in a container nursery differing in fertilization. Two heights of seedlings were measured, i.e., after the first growing season on the experimental plantation and the initial (obtained in the forest nursery), and the annual (AHI, cm) and relative height increments (RHI, %) were calculated. The regression of the RHI of seedlings to their initial height was calculated, and the equations obtained were used to determine the optimal range of seedling height at the stage of nursery growth at which they will achieve the maximum increment in the first year of growth on the plantation. The change from foliar fertilization to a mixed one affected beech and spruce seedling parameters; however, it did not affect the diversity of their survival on the experimental plantation. Higher seedlings planted on the experimental plantation were characterized by a smaller RHI. The optimal range for the height of seedlings obtained at the nursery stage of growing, which determined the maximum value of the AHI after the first year of growth after planting, was 18–36 cm for beech and 14–25 cm for spruce.

Keywords: European beech; Norway spruce; seedling height; relative height increment; survival; container seedling; field performance

1. Introduction

Changes caused by technological progress and changing demand for seedlings have been observed in Polish nurseries. In the 1950s and 60s, production was carried out in many small, temporary ground nurseries. Currently, such nurseries are less numerous, are larger and more technologically advanced, and in many of them a part of the production is carried out in the so-called container modules. There are also 17 large container nurseries, where only seedlings with a covered root system are produced. Since the beginning of the 21st century, the total annual production of seedlings in Poland has not exceeded 1000 million, and in 2016, about 12% came from specialist production (containers, Dünemann's seedbeds, greenhouses) [1].

The use of containerized seedlings allows elimination of root damage and the reduction of planting mistakes [2], which results in good adaptation of the seedlings on the forest plantations. Compared to ground seedlings, container seedlings survive and grow better on the cultivations [3], regardless of the altitude [4]. This is due to the improved overcoming of post-planting stress, which is partly related to the higher tolerance of container seedlings to drought [5]. The quality of the planting material depends on a number of factors, including the type and characteristics of the soil or nursery substrate [6–9], soil compaction [10–14], irrigation [15–18], light [19], and fertilization [20–22].

Soil or substrate fertilization, especially in container nurseries, is an element of seedling cultivation strictly controlled by the nursery staff. In ground nurseries, the primary source of mineral nutrients is soil, along with periodically applied organic fertilizers in the form of green manure or compost. Foliar fertilizer is also applied sometimes, especially when initial fertility is insufficient [23]. In container nurseries, fertilization is carried out mainly in liquid form combined with watering, and is the basic source of nutrients for the seedlings [24]. Sometimes foliar fertilization is preceded by a small amount of long-acting starter fertilizer. Studies on the cultivation of *Acer mono* seedlings showed that nitrogen and phosphorus, when used in a 10:8 ratio, resulted in maximum height and root collar diameter [25]. Thus, fertilization can be used to shape the growth parameters of seedlings, and the seedling size can be used to determine their suitability for planting and adaptation on forest plantations [26–28]. Results of different research shows that the fertilization procedure used in the nursery has an influence on better growth parameters of seedlings; however, there is not always a connection with their better survival and growth after outplanting [20,29–31]. This dissimilar adaptive effect may be due to the different heights of the seedlings.

The aim of the study was to evaluate the growth of European beech and Norway spruce seedlings in the first year after planting them on the experimental forest plantation, depending on the experimental variant determined by different methods of fertilization (starter and foliar) applied at the production stage in the container nursery. The occurrence of the so-called post-planting shock was evaluated and the optimal range of the height of the planting material, at which the planted seedlings will have the maximum height increments, was determined. Two research hypotheses were made: (1) a change in the fertilization method during seedling production will have a positive effect on their post-planting adaptation, and (2) the seedling height obtained at the production stage in the nursery does not affect its growth on forest plantations.

2. Materials and Methods

European beech and Norway spruce seedlings were produced in a nursery farm in Nędza (Rudy Raciborskie Forest District) on a 1-year cycle, using peat substrate with the addition of perlite (10%). The Hiko V265 container with a cell capacity of 265 cm^3 was used for beech, while the Hiko V120SS container with a cell capacity of 120 cm^3 was used for spruce. The seedlings of each species were grown in three different fertilization variants. In the control variant (V_{CON}), fertilization was carried out in accordance with the developed practice for the cultivation of either species. Beech seedlings were fertilized only in a foliar manner with Floralesad fertilizer at 11.35 $dm^3 \cdot ar^{-1}$, while for spruce it was 21.25 $dm^3 \cdot ar^{-1}$. Additionally, starter fertilization with Osmocote bloom fertilizer, with a long nutrient release period (2–3 months), was applied at 2.5 kg per 1 m^3 of substrate. In both modified variants (V_{GRO}, V_{LAI}), Osmocote bloom fertilizer (2.5 $kg \cdot m^{-3}$) and foliar fertilization with Floralesad fertilizer were applied initially. In the V_{GRO} variant, foliar fertilization was discontinued after obtaining the desired share of class seedlings (beech—70%; spruce—90%), determined on the basis of plant height and root collar diameter given in the PN-R-67025 standard [32]. In the V_{LAI} variant, foliar fertilization was discontinued after reaching the desired value of the leaf area index (LAI), which was 8.120 for beech and 3.225 for spruce [33]. For the V_{CON} variant, fertilization was discontinued at the end of August. The V_{GRO} and V_{LAI} variants used 3.85 $dm^3 \cdot ar^{-1}$ of Floralesad fertilizer for spruce and 3.11 $dm^3 \cdot ar^{-1}$ for beech. In all variants, the substrate bulk moisture content was controlled using a semi-automatic measuring and control system consisting of TDR (time domain reflectometer) probes and an MPI DN (multi point interface) recorder, which indicated the production field substrate moisture content in 32 points [18,34]. Only when the value of humidity approached the warning level (80%), the person operating the sprinkler system, depending on the weather conditions, made a decision about the need for irrigation. In 2016, humidity conditions were similar to the climatological standard and favorable for the growth of the seedlings. The precipitation abundance index (*W*) [35] was 42%, which meant that water had to be supplied to the production fields only on an ad hoc basis, and substrate humidity was maintained at 85% (±4%).

Beech seedlings bred in the container nursery were outplanted in autumn 2016 and spruce in spring 2017. They were grown for one vegetation season before the measurements were carried out. Both experimental plots were located in the Rudy Raciborskie Forest District in subdivision 247ac in Rudy forest range (50°10′19″ N; 18°24′52″ E). The experimental plantations were established in a fresh mixed-forest habitat in the strongly fresh moisture variant. For both, in division 247 and in the neighboring divisions, the dominant species is the Scots pine, mostly in the near-cutting or cutting phase. The Beech experimental plantation was established on a clear-cutting gap of about 20 acres, cut in a 120-year-old pine stand (subdivision 247c), and the spruce plantation in a clear-cutting area made in a similar pine stand (subdivision 247a). Both experimental plantations were prepared in this same time and protected with a forest net against the damage from game. The preparation of the soil consisted of uncovering the mineral layer by plowing out about 0.7 m wide furrows.

An experimental plantation with 9 variant plots, distributed according to the Latin square scheme (3 variants × 3 repetitions), was established for each species. Each plot was marked, and the outer seedlings were labeled with a description of the experimental variant. One hundred seedlings (10 × 10 seedlings) were planted on one plot at a spacing of 1.5 × 1.0 m (distance between strips × distance of seedlings on the strip). A total of 900 seedlings were planted for one species—300 for each fertilization variant.

Samples of mineral soil from depth 0–25 cm were collected on each variant plot and its chemical properties were analyzed separately, as shown in Table 1. Soil samples were air-dried and sieved (2 mm mesh). The following characteristics were determined in soil samples: electrical conductivity (EC) measured conductometrically and pH measured potentiometrically at 21 °C; soil organic carbon (SOC) and total nitrogen (Nt), using a LECO TruMac CNS analyzer. Base cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) were extracted in 1 M CH_3COONH_4 (pH = 7). The concentrations of Na^+, K^+, Ca^{2+}, and Mg^{2+} in the extracts were measured using atomic absorption spectrometry by an ICP-OES (iCAP™ 6000 Series). All laboratory analyses were carried out at the certified Laboratory of Geochemistry of Forest Environment and Lands Intended for Reclamation of the Department of Ecology and Silviculture of the University of Agriculture in Krakow (Polish Centre for Accreditation No AB 1656). According to Polish Soil Systematic [36], soil on the experimental plantation, such as a Brunic Arenosols, were determined.

Table 1. Mean values ± standard error (SE) of soil basic chemical properties on the experimental plot.

	Soil Parameter	Mean ± SE
	pH in KCl	3.37 ± 0.01
	pH in H_2O	4.24 ± 0.01
	Hydrolytic acidity (me·100 g^{-1})	7.156 ± 0.111
	EC (μS·cm^{-1})	28.3 ± 0.4
Nutrient content	Total nitrogen (%)	0.052 ± 0.001
	Soil Organic Carbon (%)	1.309 ± 0.031
	Calcium—Ca^{2+} (me·100 g^{-1})	0.177 ± 0.005
	Potassium—K^+ (me·100 g^{-1})	0.051 ± 0.001
	Magnesium—Mg^{2+} (me·100 g^{-1})	0.066 ± 0.002
	Sodium—Na^+ (me·100 g^{-1})	0.025 ± 0.000
	Phosphorus—P_2O_5 (me·100 g^{-1})	0.541 ± 0.022
	Content of exchangeable cations—SH (me·100 g^{-1})	0.319 ± 0.007
	Cation exchange capacity—TH = HH + SH (me·100 g^{-1})	7.475 ± 0.117
	Share of exchangeable cations—VH = SH/TH·100 (%)	4.198 ± 0.052

The height of the seedling after planting (after growing in the nursery) and the height after the first growth season were measured, and the number of seedlings lost, the number of live seedlings with and without annual height increment, and the number of seedlings damaged during maintenance works carried out on the experimental area were recorded. Only those trees on which no damage was observed were included in the assessment. The average height before and after the first growing season, annual height increment (AHI) and relative height increment (RHI) of seedlings for each species, and experimental variant were calculated. RHI was calculated as the quotient of the seedling annual growth increment to its initial height (after outplanting). Differences between the variants were evaluated using a single-way analysis of variance (fixed model) and homogeneous groups were determined using Tukey's test. The analyses were carried out with Statistica 12 software [37].

For each species, for all experimental variants in total, the diagrams of relationship of the RHI of seedlings after the first year of growth on the experimental plantation and the height obtained at the stage of production in the nursery were prepared. A logarithmic function was used to describe this relationship. The obtained regression equations were used to calculate RHI values for different initial heights of seedlings, which were then used to determine the absolute height increment. An optimal range for the initial height of the seedlings at which a large AHI can be expected, which determined the limit of the maximum value of AHI reduced by 5%, was proposed.

3. Results

The survival rate of beech on the plantation was 99.3%, of which 3.1% of the seedlings did not demonstrate an annual increment and 0.2% were mechanically damaged during maintenance work. A slightly lower survival rate (93.9%) was obtained for spruce. Lack of growth was seen in 2.1% of seedlings, while 19.5% of the spruce seedlings were damaged during maintenance. In most of the damaged spruce seedlings, only an annual increment was broken, while some of them were completely cut out, as shown in Table 2.

Table 2. Summary of seedling parameter statistics for different experimental variants; seedlings: A—with annual height increment; B—without annual height increment; C—with mechanical damage; D—dead (a, b, c—homogeneous groups for $p < 0.05$; Tukey's test).

Species	Experimental Variant	Number of Planted Seedlings (pcs.)	Survival ± SE (%)	Seedlings Share (%)			
				A	B	C	D
European beech	V_{CON}	300	100.0 ± 0.0 ^{a}	97.0	3.0	0.0	0.0
	V_{GRO}	300	98.0 ± 0.8 ^{b}	97.0	1.0	0.0	2.0
	V_{LAI}	300	100.0 ± 0.0 ^{a}	94.1	5.3	0.6	0.0
	Total	900	99.3	96.0	3.1	0.2	0.7
Norway spruce	V_{CON}	300	90.4 ± 1.7 ^{b}	72.7	1.7	16.0	9.6
	V_{GRO}	300	95.7 ± 1.2 ^{a}	73.4	1.3	21.0	4.3
	V_{LAI}	300	95.7 ± 1.2 ^{a}	71.8	2.3	21.6	4.3
	Total	900	93.9	72.3	2.1	19.5	6.1

Beech seedlings clearly differed in height obtained at the nursery growth stage (2016). The lowest were those from the control variant (24.2 cm), i.e., with only foliar fertilization. The seedlings from the V_{GRO} variant (36.5 cm) and the V_{LAI} variant (40.7 cm), i.e., with mixed fertilization, were definitely taller. However, the lowest seedlings in the nursery stage showed the highest increment in the first year after planting, both in absolute and relative terms, which for the V_{CON} variant amounted to 32.9%, with 17.2% and 13.7% for the V_{GRO} and V_{LAI} variants, respectively. A significant effect of the experimental variant was demonstrated for each of the analyzed features, as shown in Table 3.

The height of spruce obtained at the nursery cultivation stage was completely different. Contrary to beech, the tallest seedlings were from the control variant (27.2 cm), with a slightly shorter V_{GRO} variant (24.8 cm), followed by the V_{LAI} variant (22.2 cm), which was the shortest. After the first year of growth, the disproportion between the height of spruce trees from individual variants increased even further, as the maximum growth was observed for the tallest spruce trees, and the minimum for the shortest. The relative growth was, however, similar in all experimental variants (29.3–31.1%) and no significant impact of the variant was obtained only for this feature, as shown in Table 3. The differing result for spruce may have been influenced by the lack of growth in the large number of seedlings mechanically damaged during maintenance works (19.5%).

Table 3. Mean values (±SE) of the analyzed features of container seedlings of European beech and Norway spruce of different experimental variants (a, b, c—homogeneous groups for $p < 0.05$; Tukey's test).

Trait	Average Value ± SE in the Variant			*F* Test	Significance Level (*p*)
	V_{CON}	V_{GRO}	V_{LAI}		
European beech					
Height in 2016 (cm)	24.2 ± 0.4 [c]	36.5 ± 0.4 [b]	40.7 ± 0.5 [a]	435.65	<0.001
Height in 2017 (cm)	31.3 ± 0.5 [c]	42.6 ± 0.5 [b]	46.2 ± 0.5 [a]	257.71	<0.001
Absolute height increment (cm)—AHI	7.1 ± 0.3 [b]	6.1 ± 0.2 [a]	5.4 ± 0.2 [a]	14.07	<0.001
Relative height increment (%)—RHI	32.9 ± 1.6 [a]	17.2 ± 0.6 [b]	13.7 ±0.6 [b]	95.27	<0.001
Norway spruce					
Height in 2016 (cm)	27.2 ± 0.4 [a]	24.8 ± 0.3 [b]	22.2 ± 0.2 [c]	68.17	<0.001
Height in 2017 (cm)	34.9 ± 0.4 [a]	32.1 ± 0.3 [b]	28.5 ± 0.3 [c]	103.45	<0.001
AHI (cm)	7.7 ± 0.2 [a]	7.3 ± 0.2 [a]	6.3 ±0.2 [b]	13.74	<0.001
RHI (%)	30.0 ± 1.1 [a]	31.1 ± 1.1 [a]	29.3± 0.9 [a]	0.63	0.511

A clear relationship was observed when comparing the height of individual beech and spruce seedlings and their RHI. An increase in the height of the seedlings used to establish the cultivation was accompanied by a decrease in RHI, and the change could be described by a regression equation, based on the natural logarithm, as shown in Figure 1.

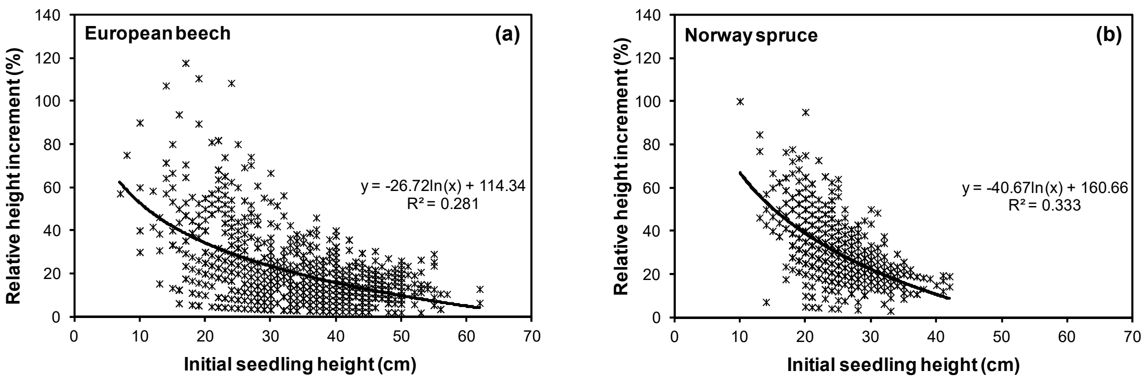

Figure 1. Relationship between the initial height of the seedlings of European beech (**a**) and Norway spruce (**b**) used to establish the experimental plantation and their relative height increment after the first year of growth.

Using the obtained regression equations, an attempt was made to determine the optimal range for the initial height of the seedlings, at which the maximum increment would be observed. For European beech, the optimal initial height of the seedlings was in the range 18 to 36 cm, while for Norway spruce, shorter seedlings in the height range 14–25 cm turned out to be better, as shown in Figure 2.

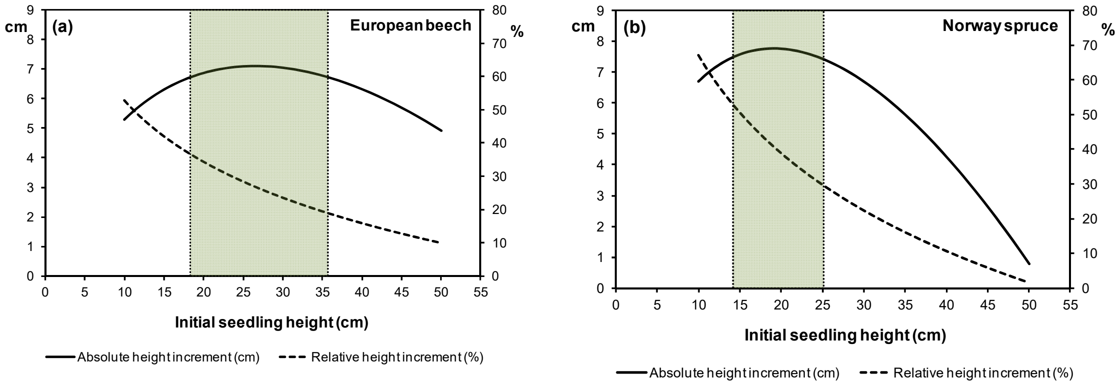

Figure 2. Forecasted height increment of seedlings of European beech (**a**) and Norway spruce (**b**) in the first year of growth on the experimental plantation depending on their initial height; vertical dotted lines define the proposed range of optimal height.

4. Discussion

The adaptive success of the seedlings being planted on the forest plantation, especially in areas exposed to seasonal droughts, depends on the characteristics of the seedlings, which may develop due to the external conditions, e.g., fertilization during the growing season [20]. The seedlings of both investigated species, i.e., European beech and Norway spruce, differed in the analyzed features depending on the method of fertilization during the production period in the container nursery. This was most visible in beech, where the maximum average height was found in the V_{LAI} variant seedlings, and the minimum in the V_{CON} variant. The Norway spruce showed opposite results, with the maximum average height in the V_{CON} variant and the minimum in the V_{LAI} variant. Beech responded positively to the application of starter fertilization in combination with foliar fertilization, achieving a higher average height than with foliar fertilization alone. Starter fertilization and foliar fertilization discontinuation after reaching the desired share of class seedlings (V_{GRO} variant) and after reaching the desired LAI index (V_{LAI} variant), resulted in a weaker spruce growth, which attained the maximum average height in the control variant. For the same fertilization (starter + foliar) in each of the variants, the differences in growth resulted from longer foliar fertilization (10 cycles of 0.77 $dm^3 \cdot ar^{-1}$). The amount of fertilizer supplied to the seedlings during the production process is very important and is shown by research carried out for *Quercus suber*, where nutrient deficiency caused a lower total biomass of the seedlings (which was probably related to a lower value of the sturdiness quotient), but this did not affect their adaptation to the cultivation [20]. Similarly, Jackson et al. [31] showed no correlation between the level of nitrogen fertilization and subsequent adaptation in the forest plantation of container seedlings of *Pinus palustris*, however, at the production stage in the nursery they observed significant differences resulting from the applied dose of fertilizer. Slightly different results were obtained by McAlister and Timmer [29], analyzing the effect of increased nitrogen fertilization in the production of *Picea glauca* in a ground nursery. High nutrient content in seedlings at the end of the 3-year production period resulted in an increase in the seedling biomass in the first year after planting, and the highest increments were observed in the variant with more intensive nitrogen fertilization. According to these authors, it was the effect of re-translocation of nutrient reserves accumulated at the stage of cultivation in the nursery to growth zones. The suggestion is consistent with the result obtained for spruce seedlings from the control variant, which were the tallest at the nursery cultivation stage and grew the most in absolute terms in the first year after planting on the forest plantation. A similar relationship was observed for *Betula pubescens* and *Picea sitchensis* seedlings grown in containers [28].

The root system may have had an influence on better adaptation of beech in cultivation. This is indicated by the relationship between root volume and water absorption efficiency observed for different species. Seedlings with a larger root system volume avoided moisture stress better, especially during periods with less water availability, which favored their better adaptation even to a few years after planting on the forest plantation [21,38–40]. According to Hobbs [41], the structure of the root system of the seedlings, which should have a fibrous structure and be characterized by the presence of multiple root ends, is also an important factor.

In the earlier nursery practice, the effect of production was evaluated in accordance with the requirements of the PN-R-67025 standard [32], however, in the case of container seedlings, it is not very useful. It is not possible to classify seedlings according to the length of the root system, because their growth is limited by the height of the container. A good indicator of the suitability of seedlings for establishing cultivations is the proportion of their height to the root collar diameter, the size of which determines the structure of the seedlings (stocky or spindly) and at the same time indicates greater resistance to abiotic damage. This proportion is particularly important for the production of container seedlings, where high and undesirable values can appear [26,42]. According to Roller [43], a sturdiness quotient (SQ) value of more than 60 resulted in significant damage to *Picea mariana* seedlings in the cultivation due to wind, drought, and frost. All spruce seedlings grown in 2016 in the container nursery were characterized by an excessively high above-ground part and the SQ ratio was above 70. This index was particularly high in the V_{CON} variant (SQ > 100), which probably resulted in more than double the higher number of dead seedlings after the first year of growth on the experimental plantation compared to the other two variants. This is confirmed by the results of analyses carried out by Vaario et al. [44], in which the low value of roots to shoots dry mass ratio resulted in poor adaptation and growth in spruce seedlings on a forest plantation. The obtained results suggest that shorter seedlings after planting on the cultivation grow relatively faster and after some time may equal the initially taller individuals, which grow weaker. This result is consistent with the results obtained by Ivetić et al. [45]. However, shorter seedlings with fast weed infestation in the experimental plantation are more likely to be damaged by careless maintenance. Such a case was observed for spruce, where a large number of damaged (mostly short) seedlings could result in a different absolute increment relationship compared to beech. In both species, the highest relative increment occurred in the shortest seedlings, while the tallest seedlings at the stage of cultivation in the container nursery grew the least in the first year after establishment of the forest plantation. However, the survival rate for both species was satisfactory, with a small number of seedlings characterized by a lack of height increment. A slightly higher share of seedlings without increment (5.3%) was observed only in the V_{LAI} variant for beech, i.e., in the variant with the initial tallest seedlings. It is therefore necessary to find a compromise between the height of the seedlings obtained in nursery production and their viability and growth on the plantation. For this purpose, it is possible to use regression equations (of the relative increment and height of seedlings after the nursery cultivation stage), which enable the indication of the optimal seedling height range, at which the seedlings will obtain the maximum height increments on the forest plantation. The optimal height of seedlings proposed for beech is 18–36 cm, and for spruce 14–25 cm. It can thus be concluded that usually very tall spruce seedlings are produced in current nursery practice, and they grow poorly on the forest plantation and do not make full use of the incremental potential of this species.

5. Conclusions

- The change of foliar fertilization to a mixed one at the stage of production in the container nursery affected the parameters of beech and spruce seedlings; however, it did not affect the diversity of their survival on the experimental forest plantation.
- Taller seedlings planted on the forest plantation were characterized by a lesser RHI after the first year of their establishment, and its dependence on the height of seedlings obtained in the container nursery was described well by logarithmic regression equations.
- For spruce and beech, the highest annual height increment (AHI) was recorded in the V_{CON} variant, and the lowest in the V_{LAI} variant. However, a difference was obtained in the relative height increment (RHI) in both species. This is due to the different height of seedlings after

production in a container nursery, which is most likely the result of a different amount of fertilizers used in individual experimental variants.

- The optimal range for the height of seedlings obtained at the stage of nursery cultivation, which determined the maximum value of the AHI after the first year of growth on the forest plantation, was 18–36 cm for beech and 14–25 cm for spruce.

Author Contributions: Conceptualization, J.B., S.M., and M.K.; methodology, J.B. and M.K.; software, J.B.; validation, M.K. and S.M.; formal analysis, J.B.; investigation, J.B., M.K., S.M., and G.D.; resources, J.B.; data curation, J.B.; writing—original draft preparation, J.B., M.K., S.M., and G.D.; writing—review and editing, J.B., M.K., S.M., and G.D.; visualization, J.B.; supervision, J.B. and S.M.; project administration, S.M.; funding acquisition, S.M. All authors have read and agreed to the published version of the manuscript.

Funding: Experimental plantations were established with the seedlings grown during the project ER-2717–4/14 "Optimizing the production of seedlings with covered root system in the selected container nurseries", funded by the Directorate General of State Forests in Warsaw (Poland). Article was financed by a subvention from the Ministry of Science and Higher Education of the Republic of Poland for the University of Agriculture in Krakow for 2020 (SUB/040012/D019 and SUB/040014/D019).

Acknowledgments: The authors would like to thank the employees of Rudy Raciborskie Forest District and Eng. Łukasz Fajkis for help in field measurements.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Banach, J.; Skrzyszewska, K.; Skrzyszewski, J. Reforestation in Poland: History, Current Practice and Future Perspectives. *Reforesta* **2017**, *3*, 185–195. [CrossRef]
2. Buraczyk, W.; Szeligowski, H. The impact of soil's textural group and moisture on the growth of Scots pine (*Pinus sylvestris* L.) seedlings with containerized root system. *For. Res. Pap.* **2008**, *69*, 291–297.
3. Repáč, I.; Tučeková, A.; Sarvašová, I.; Vencurik, J. Survival and growth of outplanted seedlingsof selected tree species on the High Tatra Mts. windthrow area after the first growing season. *J. For. Sci.* **2011**, *57*, 349–358. [CrossRef]
4. McDonald, P.M. Container seedlings outperform barefoot stock: Survival and growth after 10 years. *New For.* **1991**, *5*, 147–156. [CrossRef]
5. Grossnickle, S.C.; El-Kassaby, Y.A. Bareroot versus container stocktypes: A performance comparison. *New For.* **2016**, *47*, 1–51. [CrossRef]
6. Zou, C.; Penfold, C.; Sands, R.; Misra, R.K.; Hudson, I. Effects of soil air-filled porosity, soil matric potential and soil strength on primary root growth of radiata pine seedlings. *Plant Soil* **2001**, *236*, 105–115. [CrossRef]
7. Jordan, D.; Ponder, F.; Hubbard, V.C. Effects of soil compaction, forest leaf litter and nitrogen fertilizer on two oak species and microbial activity. *Appl. Soil Ecol.* **2003**, *23*, 33–41. [CrossRef]
8. Banach, J.; Skrzyszewska, K.; Świeboda, Ł. Substrate influences the height of one- and two-year-old seedlings of silver fir and European beech growing in polystyrene containers. *For. Res. Pap.* **2013**, *74*, 117–125. [CrossRef]
9. Olivo, V.B.; Buduba, C.G. Influencia de seis sustratos en el crecimiento de Pinus ponderosa producido en contenedores bajo condiciones de invernáculo. *Bosque* **2006**, *27*, 267–271. [CrossRef]
10. Kozlowski, T.T. Soil Compaction and Growth of Woody Plants. *Scand. J. For. Res.* **1999**, *14*, 596–619. [CrossRef]
11. Brais, S. Persistence of Soil Compaction and Effects on Seedling Growth in Northwestern Quebec. *Soil Sci. Soc. Am. J.* **2001**, *65*, 1263–1271. [CrossRef]
12. Fleming, R.; Powers, R.; Foster, N.; Kranabetter, J.; Scott, A.; Ponder, F., Jr.; Berch, S.; Chapman, W.; Kabzems, R.; Ludovici, K.; et al. Effects of organic matter removal, soil compaction, and vegetation control on 5-year seedling performance: A regional comparison of Long-Term Soil Productivity sites. *Can. J. For. Res.* **2006**, *36*, 529–550. [CrossRef]
13. Kormanek, M.; Banach, J.; Ryba, M. Influence of substrate compaction in nursery containers on the growth of Scots pine (*Pinus sylvestris* L.) seedlings. *For. Res. Pap.* **2013**, *74*, 307–314. [CrossRef]
14. Kormanek, M.; Banach, J.; Sowa, P. Effect of soil bulk density on forest tree seedlings. *Int. Agrophys.* **2015**, *29*, 67–74. [CrossRef]

15. Fare, D.C.; Gilliam, C.H.; Keever, G.J. Monitoring Irrigation at Container Nurseries. *HortTechnology* **1992**, *2*, 75–78. [CrossRef]
16. Beeson, R.C. Relationship of Plant Growth and Actual Evapotranspiration to Irrigation Frequency Based on Management Allowed Deficits for Container Nursery Stock. *J. Am. Soc. Hortic. Sci.* **2006**, *131*, 140–148. [CrossRef]
17. Zida, D.; Tigabu, M.; Sawadogo, L.; Odén, P.C. Initial seedling morphological characteristics and field performance of two Sudanian savanna species in relation to nursery production period and watering regimes. *For. Ecol. Manag.* **2008**, *255*, 2151–2162. [CrossRef]
18. Durło, G.; Jagiełło-Leńczuk, K.; Kormanek, M.; Małek, S.; Banach, J. Supplementary irrigation at container nursery. *For. Res. Pap.* **2018**, *79*, 13–21. [CrossRef]
19. Ruano, I.; Pando, V.; Bravo, F. How do light and water influence (*Pinus pinaster* Ait.) germination and early seedling development? *For. Ecol. Manag.* **2009**, *258*, 2647–2653. [CrossRef]
20. Trubat, R.; Cortina, J.; Vilagrosa, A. Nursery fertilization affects seedling traits but not field performance in Quercus suber L. *J. Arid Environ.* **2010**, *74*, 491–497. [CrossRef]
21. Luis, V.C.; Puértolas, J.; Climent, J.; Peters, J.; González-Rodríguez, Á.M.; Morales, D.; Jiménez, M.S. Nursery fertilization enhances survival and physiological status in Canary Island pine (*Pinus canariensis*) seedlings planted in a semiarid environment. *Eur. J. For. Res.* **2009**, *128*, 221–229. [CrossRef]
22. Wang, J.; Li, G.; Pinto, J.; Liu, J.; Shi, W.; Liu, Y. Both nursery and field performance determine suitable nitrogen supply of nursery-grown, exponentially fertilized Chinese pine. *Silva Fenn.* **2015**, *49*. [CrossRef]
23. Szołtyk, G.; Zajączkowski, P. Nawożenie doglebowe. In *Szkółkarstwo Leśne od A do Z: Praca Zbiorowa*; Wesoły, W., Hauke, M., Eds.; Centrum Informacyjne Lasów Państwowych: Warszawa, Poland, 2009; pp. 233–241, ISBN 978-83-89744-81-4.
24. Wesoły, W.; Hauke, M.; Sienkiewicz, A. Nawożenie dolistne oraz stosowanie nawozów wieloskładnikowych o długim okresie działania, w szkółkach kontenerowych i otwartych. In *Szkółkarstwo Leśne od A do Z: Praca Zbiorowa*; Wesoły, W., Hauke, M., Eds.; Centrum Informacyjne Lasów Państwowych: Warszawa, Poland, 2009; pp. 241–254, ISBN 978-83-89744-81-4.
25. Razaq, M.; Zhang, P.; Shen, H. Salahuddin Influence of nitrogen and phosphorous on the growth and root morphology of Acer mono. *PLoS ONE* **2017**, *12*, e0171321. [CrossRef] [PubMed]
26. Thompson, B.E. Seedling morphological evaluation—What you can tell by looking. In *Evaluating Seedling Quality: Principles, Procedures, and Predictive Abilities of Major Tests: Proceedings of the Workshop Held 16–18 October 1984*; Dureya, M.L., Ed.; Forest Research Laboratory, Oregon State University: Corvallis, OR, USA, 1985; pp. 59–71, ISBN 0-87437-000-0.
27. Haase, D. Morphological and Physiological Evaluations of Seedling Quality. In *National Proceedings: Forest and Conservation Nursery Associations—2006; Proc. RMRS-P-50*; USDA Forest Service: Fort Collins, CO, USA, 2007; pp. 3–8.
28. Grossnickle, S.C. Why seedlings survive: Influence of plant attributes. *New For.* **2012**, *43*, 711–738. [CrossRef]
29. McAlister, J.A.; Timmer, V.R. Nutrient enrichment of white spruce seedlings during nursery culture and initial plantation establishment. *Tree Physiol.* **1998**, *18*, 195–202. [CrossRef]
30. Óskarsson, H.; Brynleyfsdóttir, S.J. The interaction of fertilization in nursery and field on survival, growth and the frost heaving of birch and spruce. *Icel. Agric. Sci.* **2009**, *22*, 59–68.
31. Jackson, P.D.; Dumroese, K.R.; Barnett, J.P. Nursery response of container Pinus palustris seedlings to nitrogen supply and subsequent effects on outplanting performance. *For. Ecol. Manag.* **2012**, *265*, 1–12. [CrossRef]
32. *PN-R-67025 Sadzonki drzew i krzewów do upraw leśnych i na plantacje*; Polski Komitet Normalizacyjny: Warszawa, Poland, 1999; ISBN 978-83-236-2771-5.
33. Durło, G.; Jagiełło-Leńczuk, K.; Kormanek, M.; Małek, S.; Banach, J.; Pająk, K. Using unmanned aerial vehicle (UAV) to monitor the physiological condition of plants in a nursery. In *Výskum Rezných Mechanizmov v Procese Spracovania Drevnej Hmoty*; Krilek, J., Ed.; TU Zvolen Mongraph; Technická univerzita vo Zvolene: Zvolen, Slovakia, 2016; pp. 17–27, ISBN 978-80-228-2920-5.
34. Kormanek, M.; Durło, G.B.; Małek, S.; Banach, J. Modyfikacja pola zraszania rampy deszczującej na przykładzie rozwiązania zastosowanego w urządzeniu HAB T-1 BCC w szkółce leśnej w Nędzy. In *Użytkowanie Maszyn Rolniczych i Leśnych—Badania Naukowe i Dydaktyczne*; Tylek, P., Owoc, D., Eds.; Przemysłowy Instytut Maszyn Rolniczych: Poznań, Poland, 2018; pp. 63–70, ISBN 978-83-940788-9-8.

35. Radzka, E.; Rymuza, K. Statistical and geostatistical analysis of spatial variation of precipitation periodicity in the growing season. *Időjárás* **2020**, *124*, 129–141. [CrossRef]
36. Marcinek, J.; Komisarek, J. Systematyka gleb Polski. In *Gleboznawstwo*; Mocek, A., Ed.; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2015; pp. 281–364, ISBN 978-83-01-17994-6.
37. STATISTICA (data analysis software system). StatSoft Inc.: Tulsa, OK, USA, 2014.
38. Carlson, W.C. Root System Considerations in the Quality of Loblolly Pine Seedlings. *South. J. Appl. For.* **1986**, *10*, 87–92. [CrossRef]
39. Rose, R.; Atkinson, M.; Gleason, J.; Sabin, T. Root volume as a grading criterion to improve field performance of Douglas-fir seedlings. *New For.* **1991**, *5*, 195–209. [CrossRef]
40. Hasse, D.L.; Rose, R. Soil Moisture Stress Induces Transplant Shock in Stored and Unstored 2 + 0 Douglas-Fir Seedlings of Varying Root Volumes. *For. Sci.* **1993**, *39*, 275–294.
41. Hobbs, S.D. The Influence of Species and Stocktype Selection on Stand Establishment: An Ecophysiological Perspective. In *Seedling Physiology and Reforestation Success*; Duryea, M.L., Brown, G.N., Eds.; Forestry Sciences; Springer Netherlands: Dordrecht, The Netherlands, 1984; Volume 14, pp. 179–224, ISBN 978-94-009-6139-5.
42. Ivetić, V.; Skorić, M. The impact of seeds provenance and nursery production method on Austrian pine (*Pinus nigra* Arn.) seedlings quality. *Ann. For. Res.* **2013**, *56*, 297–305.
43. Roller, K.J. *Suggested Minimum Standards for Containerized Seedlings in Nova Scotia*; Information Report M-X-69; Maritimes Forest Research Centre: Fredericton, NB, Canada, 1977; pp. 1–18.
44. Vaario, L.-M.; Tervonen, A.; Haukioja, K.; Haukioja, M.; Pennanen, T.; Timonen, S. The effect of nursery substrate and fertilization on the growth and ectomycorrhizal status of containerized and outplanted seedlings of *Picea abies*. *Can. J. For. Res.* **2009**, *39*, 64–75. [CrossRef]
45. Ivetić, V.; Devetaković, J.; Maksimović, Z. Initial height and diameter are equally related to survival and growth of hardwood seedlings in first year after field planting. *Reforesta* **2016**, *1*, 6–21. [CrossRef]