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First-year Height Growth of Silver Birch in Farmland depending on Container Stock Morphological Traits

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Abstract

A trial was established to follow up the growth of silver birch container seedlings in the first year after planting out on abandoned farmland. Container seedlings were produced in the Rootrainer Sherwood container system (tray dimensions — 360 x 210 x 120 mm, cell volume 175 cm', growing density 423 cells m ^{2}). Simple linear regression was used to assess the first-year growth in height depending on the seedling initial morphological parameters. The low values of determination coefficients (0.033 — 0.147) indicated that a considerable proportion of variations in the growth could not be explained by seedlings morphology. The shoot:root and the diameter:height ratio of seedlings affected most significantly the growth in the first-year. Larger seedlings (higher values of shoot dry weight and shoot height) showed lower increment in height, indicating a higher transplanting stress. The experimental results are discussed in terms of raising the quality of birch container planting stock intended for farmland afforestation.

Key words: *Betula pendula,* afforestation, container seedlings, planting stock quality

Introduction

The land reform after Latvia regained sovereignty and the loss of export markets for food products have in recent decades reduced the area of cultivated farmlands. According to the 2003 land use data of the Ministry of Agriculture the area of abandoned agricultural lands was 340,400 ha (Agriculture and Rural... 2005). The government, by applying stimulating taxation policy and offering subsidies, promotes establishing forest on a portion of surplus lands. Creation of productive and vigorous forest stands on former agricultural lands is a new challenge for the Latvian forest scientists. A number of research projects are carried out to find the most appropriate methods for plantation cultivation of forest crops on one-time farmlands, including the weed control, the possibilities for summer planting, and comparing the growth of various tree species on diverse site types to study the fertilization effect for improving the performance of tree crops (Daugaviete 1999, 2000, 2001, 2002, Daugaviete and Krumina 2001, Liepins 2003).

The silver birch *(Betula pendula* Roth.) is one of the most popular species used for farmland afforestation in Latvia. According to the State Forest Service statistics, as of 01.01.2005 birch stands account for 42.7 % of the total area afforested (Forest statist... 2005). In Latvian forestry, for many decades the birch was neglected and considered a nuisance in well-managed forests. In the last decade the attitude has changed completely since the birch is a highly valuable raw material for the thriving domestic plywood industry. A comparison with other tree species allows concluding that plantation cultivation of silver birch is economically viable (Zudrags 2001, 2002).

In 2000, the leading Latvian plywood manufacturer JSC "Latvijas Finieris" concluded a long-term agreement with the LFRI "Silava" regarding the funding of research for the establishment and tending of birch plantations and optimising the birch container seedling technologies. Apart from the major objectives, the aim of the agreement is to popularise birch cultivation among the landowners and farmers to avoid shortage of birch-wood resources in the future.

In the boreal and boreo-nemoral forest zone the birch is a typical pioneer species whose ecological role is to convert non-forest lands into forest. A number of studies both in Latvia (Daugaviete and Krumina, 2001, Daugaviete *et al.* 2003) and elsewhere (Niemistö 1996, Karlsson *et al.* 1997, Vares *et al.* 2003) demonstrate an excellent performance of silver birch on the former agricultural lands. However, to ensure successful establishment of birch plantations on farmlands, the factors like choosing the most appropriate site, effective weed control, and the use of quality planting stock are essential. A disregard for these factors in establishing plantations results in completely failing or inadequately stocked stands. Although the silver birch is fast growing and easily adapts itself to a variety of ecological conditions, an opinion prevails that it performs best on well-drained light mineral soils (e.g. Cameron 1996, Saramäki and Hytönen 2004, Daugaviete *et al.* 2003). A number of studies were carried out in the Baltic and Scandinavian countries to find the most suitable methods for soil cultivation and weed control when establishing forest plantations on the former agricultural lands (Daugaviete and Krumina 2001, Hytönen and Jylhä 2005, Vares *et al.* 2001, Ferm *et al.* 1994, Siipilehto 2001). Several studies confirm the importance of planting stock quality for establishing silver birch plantations on former agricultural lands (Daugaviete and Krumina 2001, Brunvatne 1997).

In recent years in Latvia, the production of birch planting stock is increasing with advanced cultivation technologies introduced in tree nurseries to meet the growing demand. At present, a substantial portion of birch planting stock is produced as container seedlings. The poor field performance of certain container seedling types raised an issue about the quality requirements for planting stock used for farmland afforestation.

In current research projects regarding the major quality-determining factors for the container stock a limited consideration is given to the morphological traits. A variety of tests for assessing the physiological conditions of seedlings like xylem water potential, root growth potential, root and shoot electrolyte leakage, chlorophyll fluorescence etc. are applied both in nursery practices and experimental studies (eg. Poteri 2003, Menzies *et al.* 2001, O'Reilly and Keane 2002, Perks *et al.* 2004, Brunnum 2005, Bigras and Dumais 2005, Helenius *et al.* 2005). The effect of pre-planting nutritional status of the planting stock on field performance has also been studied (Fraysse and Crémicre 1998, Xu and Timmer 1999, Quoreshi and Timmer 2000, Idris *et al.* 2004, Puértolas *et al.* 2003, Rikala *et al.* 2004). The field performance of seedlings depending on their morphological traits and size has nevertheless been studied in a number of recent experiments (Rose and Haase 2005, South *et al.* 2005, Jacobs *et al.* 2005, Seemen and Jäärats 2005). An understanding how the morphological traits affect the field performance of the planting stock on former agricultural lands is of great importance for defining the target parameters for silver birch seedlings in container technologies.

The aim of this study is to identify the morphological traits, which ensure vigorous growth of birch container seedlings after planting out in the field, thus improving the overall performance of birch plantations.

Materials and methods

One-year silver birch seedlings grown in the "book" or "sleeve" Rootrainer Sherwood container type (Scotland) (tray dimensions — 360 x 210 x 120 mm, cell volume 175 cm^3 , growing density 423 cells m^{-2} (were used of the experiment and the planting stock was produced at the JSC "Latvijas Finieris" forest tree nursery "Zabaki". The routine of producing birch seed-lings at the nursery is as follows: in early spring the seeds are sown in boxes filled with peat (beginning of April) and placed in the greenhouse; after three weeks the saplings are transplanted to container trays filled with fertilized and limed peat (BKS-2, JSC Seda, Latvia) and grown in a plastic tunnel greenhouse until moving outdoors in June. Watering and fertilization are done with sprinklers on a travelling boom. In autumn the seedlings are packed and placed outdoors for wintering.

Planting out

The birch container seedlings were planted out in May 2004 on a site of abandoned farmland in the Dobele district (lat. 56°22.843 N, long. 23°09.196 E, alt. 74 m). The soil on the given site was loamy with occasional pebbles; the soil was of the humic podzol type. The soil characteristics are presented in Table 1. *Elytrigia repens, Dactylis glomerata,* and *Deschampsia cespitosa* dominated in the ground vegetation. The site was fallow for at least 5 years. In the autumn of 2003 the site was ploughed over and rotary-cultivated in April 2004. The planting was done in May 2004. In the year of planting, for weed control manual mowing down during the growing season of the competing vegetation around the crop trees was practiced.

Table 1. Major soil characteristics on the experimental plots

Depth, (cm)	Organic matter content, (%)	NH_4	NO_3	P_2O_5	K_2O	CaO	MgO	$pH(H_2O)$
		(mg $100g^{-1}$)						
0-33	4.2	0.8	7.1	<1.5	3.9	28.3	20.3	7.7
33-56	3,7	1.8	1.0	<1.5	2.7	35.2	25.4	8.0
56-76	2.2	5.0	<1.0	<1.5	2.4	28.1	20.2	8.0
76-100	1.9	1.6	<1.0	<1.5	2.5	28.1	25.2	7.8

Before planting out, the shoot height of seedlings was measured as the distance form the seedling top to the surface of the container media (accuracy 1 cm); the root collar diameter (RCD) was measured (accuracy 0.1 mm) right above the root ball, using the digital sliding calliper. The measurements accomplished, 500 seedlings were planted out in a random sequence, the planting density was 2,500 seedlings ha^{-1}; the distance between the rows and seedlings in a row was 2 metern. After planting out the shoot height above the ground was measured to obtain the data for height increment assessment. The stock planted out for the experiment was re-measured in October when the growing season was over.

Laboratory procedures

Totally 200 Rootrainer Sherwood container-grown birch seedlings from the same lot as those planted out were taken for laboratory analyses. The seedling root balls were carefully rinsed to remove the substrate. The shoot height and RCD were measured as described in the methodology for the experiment. Thereafter, the seedlings were dried for 48 h at the temperature +105°C to a constant weight (drying oven BMT Ecocell) and the dry weight (DW) of shoots and roots was obtained with an accuracy of 0.1 g (scales Precisa XB 220 A).

Statistics

Multiple linear regression models (SPSS for Windows 8.0.0 software) were used to predict the birch container seedlings root and shoot DW, using equations (1) and (2).

$$Y_i=(b_0+b_1X_1+b_2X_2)+\hat{a}_i \qquad (1)$$

where Y_i predicted shoot DW, b_1, b_2 are the estimated coefficients of predictors, and X_1 and X_2 stand for the shoot height and RCD.

$$Y_i=(b_0+b_1X_1+b_2X_2+\ b_3X_3)+\hat{a}_i \qquad (2)$$

where Y_i is predicted root DW, b_1, b_2 are the estimated coefficients of predictors X_1, X_2 and X_3 represent shoot height, RCD and shoot DW.

The proposed models are used to calculate the above-ground and the root mass for the stock planted out in the field. That is by knowing the values for RCD and shoot height, we can calculate the root and shoot mass for each plant

Seedlings with apical damages (animal or other damages) were excluded from further analyses.

A simple linear regression was used to determine the effect of morphological parameters (shoot height, RCD, shoot and root DW, diameter (mm): height (cm) ratio and shoot: root ratio (gDW per gDW) of silver birch container seedlings on the increment in height.

Results and discussion

Predicting shoot and root dry weight for birch container seedlings

When modelling the shoot and root DW for silver birch container seedlings, the multiple linear regression models produced higher R^1 values than single-variation equations. The model for shoot DW yielded a higher value of R^2 than that for root DW, i. e. 0.934 and 0.415, respectively. In the model for predicting the root DW there was a considerable proportion of unexplained variations. The container cell dimensions restrict the development of seedlings roots, and as a result the shoot parameters are less useful indicators for the root mass as compared with the bare root seedlings. The coefficients for the models are given in Table 2. The relatively random dispersal of points in standardized residual curves for both models (Figure 1) is an indicator for linearity and homogeneity of the data set (Field 2005).

Table 2. Coefficients for the shoot and root DW models with standard errors and statistical reliability

Term	Coefficients	Std. Error.	p
	Shoot DW		
Constant	-1.463	0.081	0.000
RCD	0.337	0.024	0.000
Shoot height	0.0324	0.001	0.000
	Root DW		
Constant	0.582	0.253	0.022
Shoot DW	0.516	0.108	0.000
RCD	0.255	0.067	0.000
Shoot height	0.0176	0.004	0.000

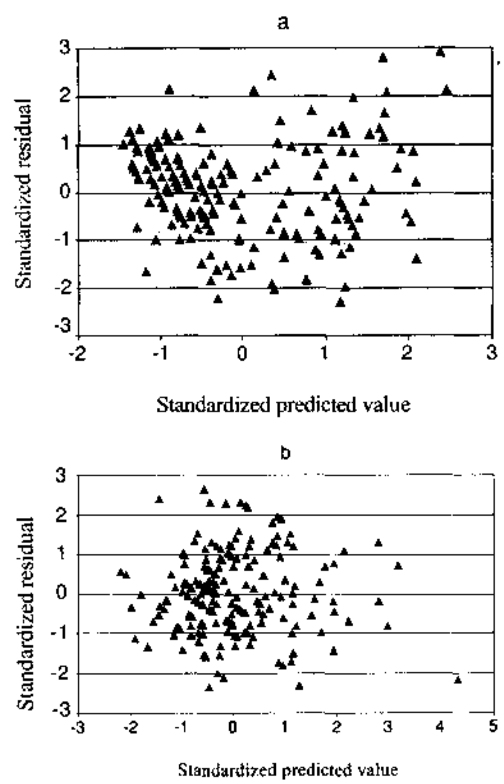

Figure 1. Plot of standardized residual for shoot DW (a) and root DW (b) against standardized predicted values

Interdependence between the morphological parameters and field performance

Although all the variables considered in the experiment had a significant effect ($p<0.05$) on the first-year growth in height, the coefficients describing the relationship between the morphological parameters of silver birch container seedlings and the first-year growth in height are relatively small (Table 3). It indicates that a considerable proportion of variations in the growth cannot be explained by seedling morphology only. Still, the experiment reveals the tendencies that could be taken into account in order to improve the field performance of birch container stock.

Table 3. Coefficients of determination for the first-year growth in height of the silver birch container seedlings

Variable	First-year height growth
Shoot height	0.139
RCD	0.036
Shoot DW	0.101
Root DW	0.033
Diameter:height ratio	0.107
Shoot:root ratio	0.145

Figure 2 illustrates the relationship between the first-year growth in height and some of the morphological parameters of seedlings. The growth in height of birch container seedlings decreases with increasing values for shoot:root ratio (R^2=0.1448). Conversely, the seedling growth in height reduces with increasing shoot height (R^2=0.1385) and shoot DW (R'=0.1008). Other authors, too, report on the effect of shoot:root ratio for the growth in height of both the bare-root and container seedlings after planting out (Andersen and Bentsen 2004, Rytter *et al.* 2003). Yet, the significance of this attribute for determining the quality of the container stock of conifers has been criticized (Bernier *et al.* 1995). In the given study, the shoot:root ratio of birch container stock had, as compared to other morphological attributes, the greatest effect on the first-year growth in height.

Proportionally developed root system of planting stock is proven to be of great importance in overcoming the planting stress. South and Zwolinski (1996) have introduced an indicator termed transplant stress index (TSI), which is defined as a deviation from the linear relationship between the shoot height at the beginning of the growth period and the height increment. The TSI concept implies that taller seedlings often experience stronger transplanting stress than shorter ones. Transplanting stress is usually attributable to water stress caused by poor root-soil contact and a limited amount of roots in relation to shoots (South and Zwolinski, 1996). This theory offers an explanation of the results of this study as well: the negative shoot:root ratio, shoot height and shoot DW to the height increment are obviously an evidence of increased transplanting stress.

The compacted root system in the containerised soil plug known as "rootbound" may be another explanation of reduced first-year growth in height of taller birch container seedlings. There are reports on the experiments with coniferous container seedlings, where seedlings with light-rooted plugs and juvenile, responsive rooting systems show better field performance (Salonius *et al.* 2000, Salonius 2002). Further research is needed to clarify the effect of this phenomenon on the root growth capacity of such a fast-growing broadleaved species as silver birch.

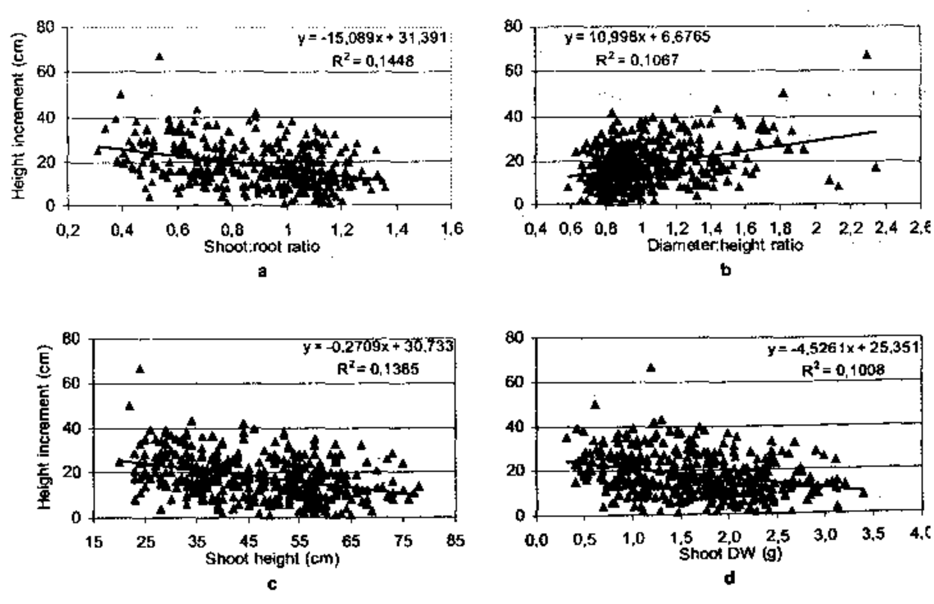

Figure 2. The relationship between the first year height increment of silver birch container seedlings and morphological parameters – shoot:root ratio (a), diameter:height ratio (b), shoot height (c) and shoot DW (d)

The diameter:height ratio of birch container seedlings or the index of sturdiness is often regarded as one of the major parameters for seedling quality (Mexal 1990, Mangalis 1996, O'Railey *et al. 2002).* In this study, the diameter:height ratio had a positive effect on the first-year height growth (R^2=0.1067). Other researchers, too, have pointed out the importance of this morphological attribute for enhanced post-planting growth of birch container seedlings. Brunvatne (1997) emphasizes that the diameter:height ratio of high quality birch container seedlings should be close to 1 or above, if we want to achieve that the seedlings delivered from the nurseries showed a balanced growth right from the planting out in the field.

The RCD integrates the entire morphological response of seedlings to the environment and its correlation with other attributes such as the shoot height, dry weight, and root morphology (Mexal 1990). The above mentioned indicator is often considered a highly important morphological predictor of the field performance of planting stock (Puértolas *et al.* 2003, Aphalo and Rikala 2003, South *et al.* 2001, South and Mitchell 1999, Mattsson 1997, Dobkowski 1996, Noland *et al.* 2001, South *et al.* 2005). In the given study we found a negligible effect of initial RCD on the first-year growth in height of silver birch container seedlings (R^2=0.036). It seems that a better balance of shoot:root and shoot diameter:height ratio is of greater importance for birch container seedlings grown in such relatively small containers as Rootrainer Sherwood.

The competition from herbaceous vegetation is considered the major obstacle for the development of silver birch seedlings on agricultural lands. Even complete soil preparation, making the area fully devoid of weeds before planting, is not adequate for ensuring the optimum development of seedlings (Hytönen and Jylhä 2005). In such conditions the preference of larger silver birch planting stock is evident. However, this study demonstrates the advantages of balanced morphological attributes of container seedlings. The container systems with bigger cavities and reduced growing densities should be used for producing improved quality birch planting stock. The growing density (cells per m^{-2}) is a determinant of seedling quality: in general, the container seedling quality increases with a corresponding decrease in the growing density (Landis 1990). Yet, this indicator is also of economical importance since it determines the quantity of planting stock produced per unit of the nursery area. For this reason many Latvian forest tree nurseries prefer to use smaller containers for silver birch seedlings although it results in poorer quality. There is evidence that silver birch seedlings grown in bigger container cavities and at lower densities have superior morphological traits: thicker stems, more branches, highest dry weight and the root/shoot ratio, ensuring improved field performance (Aphalo and Rikala 2003).

Conclusions

This study is limited only to a few morphological attributes of silver birch container planting stock, which affect the first-year growth in height when planted out in the field. However, some of tendencies found in this study can be taken into account in order to improve the seedling quality. Balanced shoot:root and shoot diameter:height ratio are the appropriate traits to be accounted for in order to produce high quality birch container stock. The use of container trays with bigger cell cavities and lower growing densities are preferable to produce vigorous and competitive birch container seedlings for afforestation instead of the system of Rootrainer Sherwood, HIKO V-120, which currently predominates in the majority of forest nurseries in Latvia. Further research on birch planting stock quality, including physiological status and nutrient load, is necessary to identify the factors, which affect the field performance.

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llPHPOCT B BbICOTY KOHTEIIHEPHbIX CAKEHIlEB bEPE3bI bOPOAABYATOII B llEPBOM TORY llOCJIE llOCARKH HA bbIBIIIHX CEJIbCKOXO3RHCTBEHHbIX 3EMJIRX B 3ABHCHMOCTH OT MOPOOJIOrHYECKHX llPH3H3HAKOB IIOCA^.jOYHOrO MATEPHAJIA

K. JIHenHHbIII

IlpoBeAeH aHann3 OIIbITHon nocaAKH KOHTeNHepHbIX cakeHueB 6epe3Þl 6opopaB aTon , 3anokeHHON Ha 6ÞmBluux cenbCKOX03RNCTBeHHbIX 3eMnBx, C IIenbIo OnpeiieneHHR npHpOCTa no BÞICOTe Ha nepBOM iOAy pOCTa B 3aBHCHMOCTH OT MOpOonOrHYecKHXNpH3HaKOBnocaAOqHOro MaTepHaiia, KOTOpÞIHBÞlpauteH HCIIOJIÞ3yR CHCTeMy KOHTeiHepoB ROOTRAINERS SHERWOOD (pa3MepÞi opHOF1 KOHTeHHepHoH RYen KH — 360x21 Ox 120 MM, eM10CTÞ RYenKH — 175 cm, ryCTOTa BÞlpaiuu aHHR — 423 R`IeeK M²). TIpHpOCT no BÞICOTe BÞIYHcneH HCnOnÞ3ymt MeTOA JIHHeapHOH perpeccIll. HH3KHe 3HaYHMOCTH K03OOMUHeHT OB JjeTepMHHaUHH (0,033-0,147) yIa3ÞlBalOT Ha TO, YTO cyutecTByeT RBHaR YaCTÞ H3MeH'IHBOCTH npH3HaKa, KOTOpÞIN He3aBHCHT OT MOpOOJIOCHYeCKHX OCO6eHHOCTeN nocaAO'HOro MBTepHana. YCTaHOBneHO, 4TO caMOe 6ollÞmoe BnHRHHe Ha npHPOCT aepeBueB B nepBOM ropy nocne SIX nocaAKH oKa3ÞIBaeT COOTHOIneHHe nOBepXHOCTHoro pOCTKa KOHTeHHepHorm cakeHqa H KOpHeBON MaccÞl, a TaKke AHaMeTpa KOpHeBON meHKH cakeHua H ero AUHHÞI. Y HaH6csrlee pocrn.IX KOHTeHHepHÞIX cakeHIjeB, y KOTOpMX Han60nÞIHaR Macca Ha1t3eMHON 4aCTH H HaH6oJmIuaR A nsHa no6era, npHpOCT no BÞICOTe MeHÞlue H3-3a cipecca, KOTOpwH Te nepekHJIH HpH nepecaAKe.

B CTaTÞe aHaJIH3HpOBaHÞI pe3ynÞTaTÞI npoaeAeHHÞIX HCCneAOBaHHN, a Taio a AaHM peKOMeHAaUHH no nOBÞIIDeHHIO KaYeCTBeHHÞix not a3arenen KOHTeHHepH1aX cakeHiteB 6epe3Þl.

Kntogeat to cnoBa: *Betula pendula,* 6epe3a 6opo2taBVaTaR, KOHTeHHepHÞle cakeHljÞl, Ka'eCTBO nocaAOYHOrO MaTepHaRa