# PROFITABILITY OF SILVER BIRCH (*BETULA PENDULA* ROTH.) BREEDING IN LATVIA

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**Abstract**

Economic importance of Silver birch in Latvia has been increasing in last decade, triggering scientific research, dedicated to improvement of this species, including tree breeding. Bulk of progeny trials will reach the evaluation time in next few years; therefore, decisions for further tree breeding activities have to be made. The aim of our study is to evaluate profitability of silver birch breeding, based on current situation in the year 2010 and circumstances in Latvia and assess the factors that might notably influence the result. Analysis considers all available breeding material and links between tree breeding, seed orchards and end product – forest stand, regenerated with improved plants in order to evaluate profitability of different alternatives based on differential approach. Results reveal that differential benefits from forest regeneration with selected birch material in comparison to natural regeneration, in areas with highest site indexes (Ia-II) with 3% interest rate and at least part of the stands managed in order to maximize yield of large diameter trees at age of final felling, are positive. The highest profitability can be reached if selection of best individuals is done based on clonal testing, genetic gain is maximized and combined with proper silvicultural praxis and annual planting area (utilization of seeds from selected trees) are maximized.

**Key words**: differential benefits, birch improvement, selection.

## Introduction

Silver birch is one of the birch species (*Betula pendula* Roth. and *Betula pubescens* Ehrh.) that in forest inventories are not distinguished from each other and together occupy 28.2% of forest area, being the second most widespread after Scots pine (Anonymous, 2008). During the 20$^{th}$ century birch in most of the forest areas was treated as a species of secondary importance that needs to be removed in thinnings in favor of coniferous trees. Economic value of birch has not been fully recognized until few decades ago. Birch is used now in plywood production that accounts for more than 10% of total export value of forest sector products (Anonymous, 2008) and also plays an important role in furniture production. Birch wood is used also in production of sown goods, ship boards.

After the collapse of the Soviet Union, large areas of agricultural lands are abandoned. Natural afforestation of these lands mainly is with birch. Birch is used also as one of the main species (38% of area) for afforestation of former agricultural lands. That has triggered plant production (nursery industry): in recent years on average around 4 million birch seedlings are produced annually and only minor portion of it (30%) used in forest regeneration on forest lands.

The advancement in recognition of birch value and use has triggered significant research activity in fields of plant production and afforestation technique (Liepiņš, 2003, 2004), thinning of birch stands (Zālītis and Zālītis, 2002) and tree breeding activities of this species. A large number of forest stands has been inventoried across Latvia, plus trees and phenotypically valuable trees selected altogether in 37 stands. Seeds from trees of theses stands have been used to establish open-pollinated progeny trials in 3 contracting sites in Latvia, altogether occupying 60 ha. This material forms a basis for further tree breeding activities.

As the demand for birch plants was growing, plus-trees were phenotypically selected and joint-stock company (JSC) 'Latvia's State Forests' established birch seed orchard in plastic greenhouse for production of improved seed material. That, in turn, triggered further interest in selection of new set of clones with even higher genetic value that would serve as a parent trees for new generation of planted forest stands. Bulk of the birch progeny tests is close to the evaluation and selection age i.e. close to the point of beginning of the second breeding cycle. Therefore, it is important to analyze the alternatives for further breeding activities in order to select the most economically efficient one.

Numerous theoretical studies have addressed the issue of the efficiency of and comparison among the breeding strategies (Danusevicius and Lindgren, 2002a, b, 2005) recently. Excel-based calculation tools have been developed to optimize the necessary amount of breeding material at different stages, scale the genetic diversity vs. genetic gain and compare breeding strategies (Danusevicius and Lindgren, 2002a, b). However, the studies have not been used for practical analysis in Latvia and have a number of limitations (like – no considerations of genotype-environment interaction, very limited available knowledge in values of some of the parameters etc.) for stand-alone practical application. Theoretical approaches of economic evaluation of profitability of tree breeding have been analysed by A. Ahtikoski (2000). It also included practical analysis of Scots pine and Silver birch seed orchards in Finland; however, the basis for optimization of tree breeding activities was not presented.

In order to maximize the gain from use of selected material, a detailed economic analysis for relative weights of different traits in selection index has been carried out mainly with species used in short rotation plantations (Lowe et al., 1999; Dinus and Welt, 1995), but recently also for Scots pine in Sweden (Berlin et al., 2009). This approach, however, requires detailed data on genetic parameters of traits and their importance in particular production process that are not available in our case.

The aim of the study is to evaluate profitability of silver birch breeding based on current situation and circumstances in Latvia and assess the factors that might notably influence the result.

## Materials and Methods

All available breeding material of silver birch in Latvia can be divided in 2 groups:

1) open-pollinated progenies of 921 phenotypically selected plus tree or superior stand tree that have reached the age of 10 years in 2010 when this study was done;
2) progenies of 360 controlled crosses of 100 untested (phenotypically selected) clones in seed orchard that have reached the age of 4 years.

Both groups of available material can be integrated at the end of the second breeding cycle of the first group; therefore, it is chosen as a time horizon for the analysis.

For the bulk of material (first group) it is planned to establish 2 breeding populations, based on delineated provenance regions (eastern and western), and using altogether 150 trees – phenotypically selected progenies from the most productive and qualitative open-pollinated families, since the mother trees are not available any more. Among the members of the breeding population, double-pair mating will be performed. For further activities 3 different alternatives are compared: 1) phenotypic (FEN) selection of the best individuals within a family; 2) clonally (VEG - vegetative) testing, where the selection of candidates within a family and their vegetative propagation is performed, followed by the establishment of clonal progeny trials and backward selection of the two best candidates from each family; 3) progeny (GEN - generative) testing, where phenotypic selection of candidates within a family and their flowering stimulation to obtain seeds is done, followed by the establishment of open-pollinated progeny trials and backward selection of the two best candidates from each family. Planned activities, that are not explicitly analyzed in the study, but costs are added to each of the alternatives:

1) for the first group of material, before the beginning of the second breeding cycle: repeated measuring of part of the trials, selection of individual trees within superior families;
2) for the second group of material: tending work in progeny trials, measurements, selection of individual trees within superior families.

The comparison of alternatives is based and differential approach is used, i.e., only positions of benefits and costs, which differ between 2 regeneration methods – natural and planting of selected material – are considered (Ahtikoski, 2000). In the analysis differential costs are based on prices of the year 2010 and represented by:

1) costs of tree breeding activities, obtained from practical experience in the Latvian State Forest Research Institute 'Silava' according to activities needed to carry out each of the alternatives (FEN, VEG, GEN);
2) costs of seed orchard establishment and maintenance, obtained from the JSC 'Latvia's State Forests', that owns the productive birch seed orchards in Latvia;
3) costs of regeneration: plants, soil preparation, planting, and two extra cleanings, information from the results of the tenders of the JSC 'Latvia's State Forests'.

The differential benefit is represented by additional yield and shorter rotation time (cutting by target diameter, if possible) of the stands regenerated by the selected reproductive material. Values of genetic gain for each of alternatives, scale and timing of tree breeding works were partly assessed using the 'Breeding Cycle Analyser' (Danusevicius and Lindgren, 2002a, b) with genetic gain per unit of time as the target to be maximized (Table 1).

Genetic gain of an improved stand expressed relative to diameter and height growth of an unimproved stand was calculated based on constant proportional advantage approach (Ahtikoski, 2000).

Growth models for traditional (high initial density, delayed, low intensity thinnings) and targeted (aimed to maximize the mean diameter and total volume of trees at the final felling age, and characterized by low initial stand density) silvicultural systems and thinning regimes, the same for naturally regenerated and planted (improved) stand were chosen, based on recommendation of P. Zālītis and J. Jansons (2009). The assortment structure in thinning and final felling was calculated according to the algorithm developed by R. Ozolins (Ozoliņš, 2002). The assortment prices for the years 2006 - 2010 were obtained from Central Statistical Bureau and JSC 'Latvia's State Forest'. Assortments were set as follows: first grade logs (top diameter exceeds 25.9 cm, length 4.9 m), second grade (18 - 25.9 cm, 4.9 m), third grade (14 - 17.9 cm, 4.9 m), pulpwood (6 - 13.9 cm, 3 m), firewood (3.0 - 5.9 cm, 2 m).

Area of seed orchard was based on minimal number of clones to ensure genetic diversity as well as predicted seed needs, assuming that all birch stands on fertile soils would be clear-felled and replanted with improved material. Selected set of clones is set to be used for 24 years, since none of the alternatives could switch to new set of clones of higher genetic quality faster than that.

Table 1

**Scale and timing of tree breeding works based on different alternatives used in analysis**

| Size of breeding material and duration of different phases | | Tree breeding alternative | | |
|---|---|---|---|---|
| | | FEN | VEG | GEN |
| Duration of activity, years | Recombination | 6 | 6 | 6 |
| | Time before | 2 | 4 | 2 |
| | Testing of progenies | 25 | 12 | 14 |
| | Time after | - | - | 5 |
| | Time before | - | - | 2 |
| | Testing of candidates | - | - | 12 |
| | Total time | 33 | 22 | 41 |
| Size of breeding material | Number of families | 150 | 150 | 150 |
| | Number of trees per family | 300 | 100 | 120 |
| | Number of candidates | - | 40 | 25 |
| | Number of progenies/ramets per candidate | - | 40 | 35 |

To ensure unbiased comparison between regeneration methods and breeding alternatives, net present value (NPV) was calculated with the interest rate 3%.

## Results and Discussion

Results reveal that NPV of tree breeding costs are highest in VEG alternative, followed by GEN (60% of VEG costs) and FEN (40%). Genetic gain of FEN alternative is approximately 79% of the other alternatives that is according to theory (Falconer and Mackay, 2004) and reflects increased precision of selection, based on progeny testing. In the current situation (prices and costs of the year 2010, on average a bit below 500 ha $y^{-1}$ birch planting used, predictions of genetic gain for height and diameter 14% for FEN and 18% for VEG and GEN, targeted and traditional silviculture applied in equal proportions of area) highest differential benefit is achieved with VEG alternative (88 LVL $ha^{-1}$), followed by GEN (51 LVL $ha^{-1}$) and FEN (34 LVL $ha^{-1}$). Influence of amplitude of different genetic gains is presented in Figure 1.

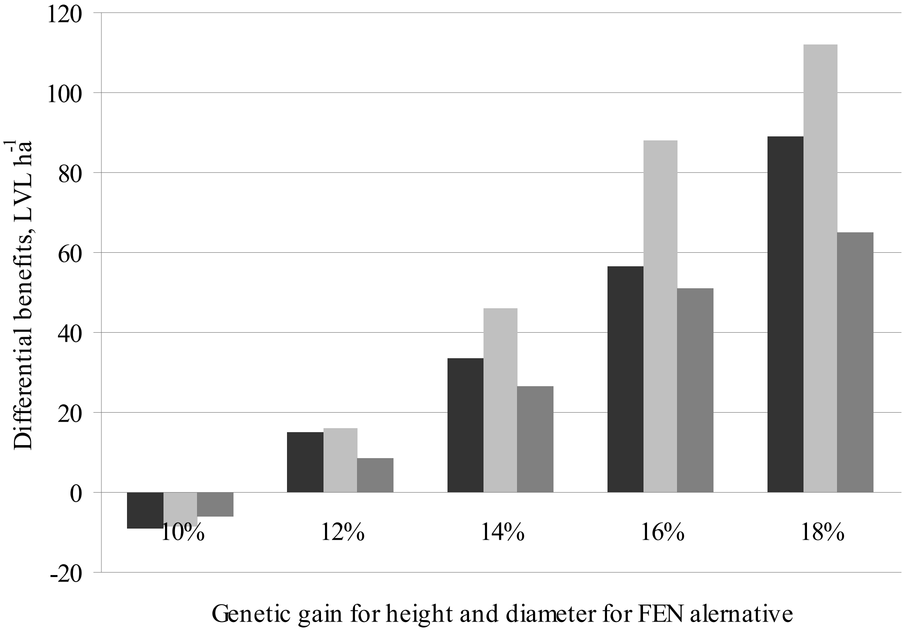


Figure 1. Comparison of differential benefits from selection alternatives:
FEN VEG GEN

Genetic gain for other alternatives calculated proportionally to that of FEN selection alternative
Assumed, that birch planting will be carried out 500 ha $y^{-1}$ and targeted and traditional silviculture applied in equal proportions of area.

Results reveal that superiority of selection based on clonal testing (VEG) remains across the range of genetic gain levels, that exceed 10%, and is increasing in absolute value, as higher the genetic gain is. It is in line with conclusions of L.-G. Stener and G. Jansson (2005) that also noted superiority of vegetative (clonal) testing.

Figures of genetic gain used in this study are in line with other published estimates: at the age of 10 years, 10% gain in height and 18% in diameter has been found for silver birch (Stener and Jansson, 2005). Other studies report no notable difference in genetic gain at the age of 10 and 20 - 36 years, the absolute value being 29% for yield (Hagqvist and Hahl, 1998) that would roughly correspond with 14% increase in height and diameter. Genetic gain 10% - 25% at age 21 - 32 years are estimated (for height) and 20% predicted for yield at mature age for Scots pine (Jansson, 2007; Andersson et al., 2006; Ståhl and Jansson, 2002) for the first breeding cycle. Considerable decrease in genetic variation have been found between wild population and selected plus trees, but the next steps of selection, based on progeny testing corresponds to only marginal changes in genetic variation (Bouffier et al., 2008). Therefore, it can be assumed that the possibility of further improvement in next breeding cycle remains the same as in the first one.

Value of differential benefits is influenced not only by genetic gain, but also by annual planting area and fluctuation in assortment prices (Table 2).

Table 2

**Differential benefits from selection alternatives, LVL ha$^{-1}$**

| Assortment prices as in year | Annual planting area and selection alternative | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 500 ha y$^{-1}$ | | | 5000 ha y$^{-1}$ | | | 7500 ha y$^{-1}$ | | |
| | FEN | VEG | GEN | FEN | VEG | GEN | FEN | VEG | GEN |
| 2010 | 34 | 88 | 51 | 71 | 162 | 95 | 72 | 165 | 97 |
| 2009 | 24 | 73 | 42 | 62 | 147 | 86 | 63 | 150 | 88 |
| 2008 | 143 | 280 | 164 | 181 | 354 | 208 | 182 | 357 | 210 |
| 2007 | 169 | 327 | 191 | 206 | 401 | 235 | 208 | 404 | 237 |
| 2006 | 85 | 181 | 105 | 122 | 255 | 150 | 124 | 258 | 151 |

Genetic gain for height and diameter 14% for FEN and 18% for VEG and GEN alternatives
Assumed that and targeted and traditional silviculture applied in equal proportions of area

Annual planting area has a profound effect on value of differential benefits: as it increases from 500 ha year$^{-1}$, planted during the last decade on average, up to 5000 ha year$^{-1}$ the differential benefits increases by 60% on average, ranging from 25% to more than doubling. It is related to constant costs involved in equation – the more the area increases, the lower are the costs of seed orchard establishment and maintenance per one hectare planted with material grown from selected seeds. Tight link between economic value of tree breeding process and the size of the area, where selected forest reproductive material is utilized, is also noted by other authors (Ledig and Porterfield, 1982).

Fluctuation of wood prices has remarkable influence on the value of differential benefits: difference between the lowest and highest estimate for the same alternative and annual area of planting varies 2.4 – 5.0 times. That indicates the importance of selection of proper final harvest time, based on market conditions in order to reap highest benefits from the use of selected material in forest regeneration. Results also demonstrate that rather conservative genetic gain estimate ensures positive differential benefits from tree breeding and use of selected material, even with the least beneficial alternative and in years with the lowest wood prices.

Silvicultural system has a notable influence on stand parameters. Results demonstrate that stands with 'targeted' management regime, involving only one commercial thinning ensures notably higher differential benefits than stands with 'traditional' one regardless of selection alternative or wood price conditions (Figure 2). Main cause of it is faster diameter increment in 'targeted' management, providing opportunity to shorten rotation period as well as to obtain higher proportion of most valuable assortments. In the study we were not able to address aspects of genotype-silvicultural system (like initial spacing, intensity of pre-commercial thinning etc.). Only few studies of this aspect have been carried out in the region based on very limited Scots pine material. They indicate that genotype – initial spacing interaction might have a practical importance (Roth et al., 2007; Persson, 1994). Selection of assortments in our study is based only on dimensions, and quality is not considered. However, studies demonstrate that up to 90% of proportion of veneer logs from tree is determined by branch quality (Hagqvist, 2001). Genetics is even more important than the silviculture in determining quality traits of birch, like natural pruning (Zālītis and Zālītis, 2002), branch diameter and angle (Hagqvist and Hahl, 1998), wood quality (Koski and Rousi, 2005). Genetics has significant effect even on slenderness of trees (Kroon et al., 2008). Therefore, increased quality and proportion of the most valuable assortments could be an important part of differential benefit from use of selected material and shall be addressed in further studies, as soon as there is sufficient data from National forest inventory and older birch trials. Average proportion of elite-grade logs could be determined also by equations, developed by P. Zalitis and colleagues (Zālītis et al., 2002), but it does not allow to consider the additional gain from quality improvement. Constant proportional advantage, adding the genetic gain to parameters of unimproved stand at any age, is used in our study. However, genetic gain could be different at different age, and thinning regime could be optimized to reap highest benefits from the use of selected material.

Considering the above mentioned – thinning regime not optimized, quality traits not estimated and elite veneer assortment not assessed – as well as probability, that no extra cleanings might be needed for planted stand in comparison to naturally regenerated. It can be stated that the results of our study are close to the lowest limit of estimates of differential benefits from the use of selected material.

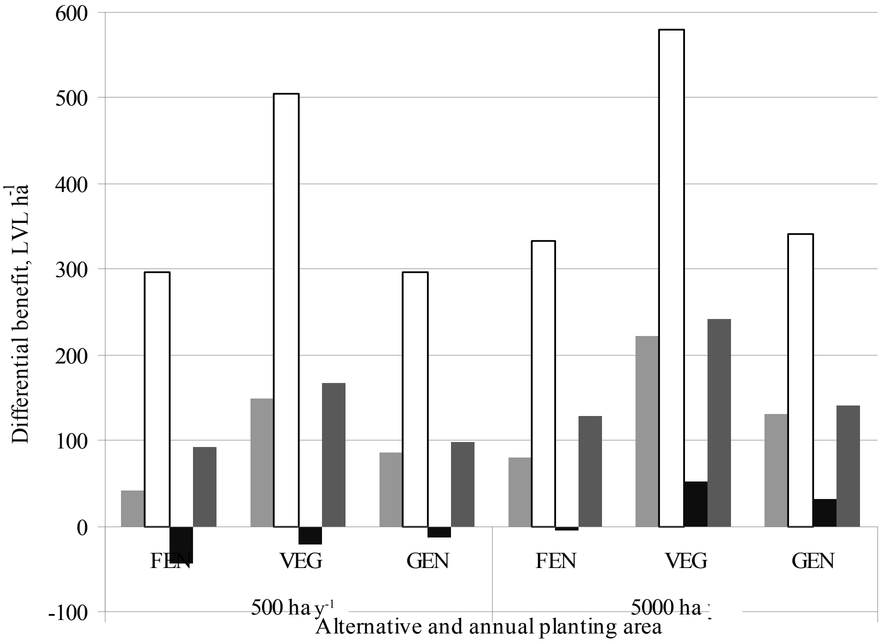


Figure 2. Influence of silvicultural system applied on the differential benefits from forestry in the year of high (2007) and low (2009) wood prices:
2007 traditional 2007 targeted 2009 traditional 2009 targeted
Genetic gain for height and diameter 14% for FEN and 18% for VEG and GEN alternatives.

Interest rate used in the study – 3% – might seem rather low, but it is in line with values usually used in economic analysis in forestry (Pentinten, 1999; Pesonen and Hirvelä, 1992).

## Conclusions

1. Differential benefits from forest regeneration with selected birch material in comparison to natural regeneration, in areas with the highest site indexes (Ia-II) with 3% interest rate and at least part of the stands managed in order to maximize radial increment, is positive
2. Selection of best individuals based on clonal testing is the most expensive, least time consuming alternative that ensures highest differential benefits across the range of genetic gain levels, that exceed 10%, and is increasing in absolute value, as higher the genetic gain becomes
3. Factors like annual planting area, silvicultural system used for management of planted stand, and fluctuation of wood prices have a profound effect on value of differential benefits, therefore need to be considered in order to maximize it.

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