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Profitability of hybrid aspen breeding in Latvia

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Abstract. Hybrid aspen (*Populus tremuloides* × *P. tremula*) has fast growth in climatic conditions of Northern Europe and relatively high wood quality. Therefore, breeding of it has been carried out in a number of Baltic Sea Region countries. Breeding requires notable financial investment; therefore, the aim of our study was to estimate the profitability of hybrid aspen breeding in Latvia and the factors affecting it. Financial analysis was based on the differential approach, that is, only the costs and benefits that differ between two compared alternatives – planting of hybrid aspen and natural regeneration of silver birch or common aspen – were compared. Differential gain in this case included additional monetary value of the above-ground parts of trees in planted hybrid aspen stands (values obtained from trials in Latvia); differential costs were the costs of tree breeding, plants, planting, cleaning and protection against browsing damages (repeated use of browser repellents or fencing). Profitability of hybrid aspen breeding was significantly affected by the size of the area planted annually, soil fertility (site index) and length of rotation period. The differential gain from investments in tree breeding and establishment and management of plantations (r = 3%), assuming that selected clones would be used for 15 years and 500 ha are planted annually, in comparison to natural regeneration of common aspen and to silver birch, was 662 EUR ha^{-1} and 1136 EUR ha^{-1}, respectively. In contrast, if only 50 ha are planted annually, the respective figures were 588 and 756 EUR ha^{-1}. If fencing was used for protection of the hybrid aspen plantation against browsing, the differential gain was positive only on the most fertile soils (site index Ia).

Key words: differential benefits, *Populus tremuloides* × *P. tremula*, site index.

INTRODUCTION

Short rotation plantations of forest stands is an important part of a risk reduction strategy for forest (land) owners since the frequency of different disturbances (mainly storms) is predicted to rise in Europe as a result of climatic changes (Seidl et al., 2014). Trees have inherited mechanisms to adapt to environmental stresses (Voronova et al., 2014), but adaptation has its limits (capacity) and direct impact of climatic changes (rise of temperature, shift in precipitation regime) is predicted to notably affect species composition and thus, substantially reduce the economic value of European forests (Hanewinkel et al., 2013).

Hybrid aspen (*Populus tremuloides* × *P. tremula*) is suitable for short-rotation management in Northern Europe (Liesebach et al., 1999; Beuker, 2000; Rytter, 2006; Tullus et al., 2009; Tullus et al., 2012). It exceeds growth of both of its parent species, as well as other forest tree species in the region, and in 20–25 year rotations in fertile sites, it has a mean annual increment of 20 m^3 ha^{-1} y^{-1} (Rytter & Stener, 2005), which is similar or slightly lower to that of other *Populus* hybrids (Jansons et al, 2014b). In addition, modelling of climate-growth relationships has revealed a potentially beneficial effect of predicted climatic changes on the productivity of hybrid aspen (Jansons et al., 2014a).

Wood of hybrid aspen is suitable for high-quality paper production (Sable et al., 2013) and a relatively large amount of logging residues for wood chip production can be obtained from such plantations, since the stem comprises 69% of total above-ground biomass (Jansons et al., 2015, submitted). Plantations also have a notable potential to contribute to the accomplishment of the CO_2 emission reduction targets of European Union via carbon sequestration.

Notable differences in the height and radial increment amongst clones of hybrid aspen have been detected and mainly attributed to differences in the length of the growth period (Yu et al., 2001): clones with the longest growth period produce the highest increment (Zeps et al., 2012). The most reliable approach to ensure a best fit between the growth period of a particular clone and the length of the period with climatic conditions suitable for tree growth is to test the clone's performance locally. Testing is logically linked to national breeding programs of hybrid aspen, creating crosses between plus trees of native common aspen and American aspen from appropriate regions, thus increasing the likelihood of best fit to climatic conditions. Breeding requires notable financial investment; therefore, the aim of our study was to estimate profitability of hybrid aspen breeding in Latvia and the factors affecting it.

MATERIALS AND METHODS

In Latvia, the goal is to have a breeding population of hybrid aspen that consists of 120 common aspen plus trees and 30 American aspen plus trees. Crossing within the population would be carried out according to factorial design and 120 full-sib families created. Selection between full-sib families (30 unrelated crosses) and within-family (40 candidates per family) were carried out at the age of 5 years. Each of the candidates from each family was propagated (40 ramets) and clonal tests established. Based on test results at the age of 8 years, clones for industrial propagation were selected and further tested to evaluate suitability for microclonal propagation. Before a final decision, full-sib family experiments were revisited to assess the presence of diseases (especially stem canker); if susceptibility was detected, candidates from that family were not recommended for large-scale propagation.

Financial analysis of the tree breeding work according to the above-described scheme was carried out using the differential approach. In this method, only costs and benefits that differ between two compared alternatives – planting of hybrid aspen and natural regeneration of silver birch (the most common tree species of natural afforestation of abandoned fields) or common aspen – were compared. Differential gain in this case included the additional monetary value of above-ground parts of trees in planted hybrid aspen stands; differential costs were the costs of tree breeding, plants, planting, cleaning and protection against browsing damages.

Yield of hybrid and common aspen and the parameters of trees were obtained from 9 experimental plantations in Latvia at the age of 11–41 years (unpublished data). Parameters of common aspen stands were obtained from the National Forest Inventory (NFI) database. Data from 126 sample trees did not reveal significant differences in stem form between hybrid and common aspen, therefore, an algorithm developed by Ozoliņš (2002) for common aspen was used to calculate the assortment structure of hybrid aspen. Proportion of branches in above-ground biomass were obtained using biomass equations, developed in Latvia (Jansons et al., 2015, submitted), and used to estimate the amount of wood for chipping. Mean prices of assortments and wood chips from the last 5 years, obtained from statistics collected at the Latvian State Forest Institute (Silava), were used to calculate the monetary value of the stands. Calculations did not include any premium for increased wood quality of hybrid aspen due to the lower percentage of rotten wood or any premium linked to carbon sequestration. Costs of breeding of hybrid aspen were obtained from the national tree breeding program in Latvia. Stand establishment costs included soil preparation, plants, planting, 6 cleanings (removal of competing vegetation, reducing risk of fire and vole damages) and treatment with repellents (10 applications) to deter browsing damages. The costs of these operations were obtained from JSC Latvijas valsts meži (Latvia's state forests company).

RESULTS AND DISCUSSION

Yield of hybrid aspen at the age of 20 years (325 m^3 ha^{-1}) was notably and significantly higher than that of common aspen at the same age in fertile forest types (according to the National Forest Inventory: 137 ± 29.2 m^3 ha^{-1}) and only slightly lower than that of common aspen at the age of 41 years (327 ± 54.4 m^3 ha^{-1}). Differential analysis was carried out to compare hybrid aspen at its recommended rotation age (20 years) and common aspen at the rotation age stated by legislation (41 years), assuming that the planting or natural regeneration would occur mostly on fertile sites (site index (*bonitate*) Ia) since currently, according to data of the National Forest Inventory, 55% of the total area of aspen stands are located in such conditions. With these assumptions, differential gain from investments in tree breeding and stand establishment and management with 3% interest rate was positive: 629 EUR ha^{-1}, if selected clones are used for 15 years to establish 100 ha of plantations annually, and 662 EUR ha^{-1}, if 500 ha of plantations are established annually.

Silver birch is the most common tree species in natural afforestation of abandoned agricultural lands or reforestation of forest lands on fertile soils. Its yield at the age of 71 years (cutting age stated by legislation) is 286 ± 48.5 m^3 ha^{-1} (data: NFI). Differential gain of hybrid aspen breeding and establishment of plantations, in comparison to natural regeneration of silver birch, was notably higher than that in comparison to natural regeneration of common aspen, assuming the same annual planting area. The result was affected by differences in the length of rotation period (20 years, when comparing hybrid aspen and common aspen, and 30 years, when comparing hybrid aspen and silver birch) and yield of common aspen and birch at the end of the rotation period. Differences between the two estimates increased with increasing soil fertility and increasing annual planting area. Differential gain for the comparison between breeding and planting of hybrid aspen and natural regeneration of silver birch changed in the same way: increased with increasing soil fertility and annual planting area (Table 1). If only 50 ha of hybrid aspen plantations were established annually (as it is currently done in Latvia), on soils with high and medium fertility (site index I and II, respectively), differential gain from investments in tree breeding and plantation establishment was negative. It reached 0 with an annual planting area 75 ha in site index I and 205 ha in site index II.

Table 1. Differential gain (EUR ha^{-1}) depending on site index and area planted annually. Interest rate 3%, clones from tree breeding cycle are used for establishment of plantations in 15 years long period

Area planted annually, ha	Site index (*bonitate*) Ia	I	II
50	470	-406	-924
100	1,084	208	-310
500	1,575	699	182
1,000	1,636	761	243
1,200	1,646	771	253

Potential clear-cut area in aspen stands (with no management restrictions, i.e. 92% from all stands) at the time of use of the clones from the proposed tree breeding program was 1,270 ha annually (data: NFI). Current legislation permits the planting of hybrid aspen on forest land, however, its rotation period has to be the same as for common aspen – 41 years. Replacing all common aspen with hybrid aspen would result in a differential gain 1209 EUR ha^{-1} (interest rate 3%), but using hybrid aspen in only 40% of this potential area (500 ha) would result in a differential gain of 1,136 EUR ha^{-1}. The Internal Rate of Return (IRR) from investments in tree breeding and plantation management, if 500 ha are planted annually, was 5.2% – which is relatively high in comparison to other alternatives in forestry. Plants for such sizes of plantations can be ensured by the current capacity of the commercial propagation facility in Latvia, owned by Latvijas valsts meži.

The differential gain from breeding of hybrid aspen is higher than that reported for breeding of silver birch in a similar annual planting area (Jansons et al., 2011). For silver birch, the plants are produced from seed orchards (not vegetatively), thus reducing the selection intensity and consequently, also genetic gain expected from a particular tree breeding cycle. Also, differences in length of rotation period between planted (selected) birch and naturally regenerated birch stands reached only 10 years, further reducing the monetary gain from birch breeding. Profitability of Norway spruce breeding in Latvia has been estimated based on equivalent annual annuity (Jansons et al., 2015), but financial gains were not as high as our estimates for that of hybrid aspen, mainly for the same reasons as that of silver birch breeding.

So far, the calculation of profitability of hybrid aspen breeding has included the use of repellents as a means of protection against browsing damages. However, moose population density is increasing rapidly in Latvia: according to data from State Forest Service, it has tripled since mid-1990s. Therefore, it might be that repellents cannot provide sufficient deterrence against browsing, and consequently, fencing is needed. For the average clearcut (approximately 2 ha, approximating a rectangular shape) it would increase costs of plant protection by 2.8 times. The Internal Rate of Return from investments in tree breeding and plantation management, with the inclusion of fencing and an area of 500 ha planted annually, was 3.5% in sites with mostly fertile soils (site index Ia), but below 3% in sites with lower soil fertility (2.6% and 1.9% in site index I and II, respectively). If only 50 ha were planted annually (as it is currently done), the differential gain was negative (internal rate of return of 2.3%) even for plantations on most fertile soils.

It is also important to note that the application of tree breeding results (i.e., establishment of plantations of faster-growing trees) to reforestation efforts can provide additional benefits which were not accounted for in the calculation:

a) increase of carbon sequestration;

b) release of the area for other uses (e.g. recreation, nature protection) without decreasing the total wood production from a particular forest massif.

CONCLUSIONS

Profitability of hybrid aspen breeding was significantly affected by the size of area planted annually, soil fertility (site index) and length of rotation period. Differential gain from investments in breeding of hybrid aspen, establishment and management of its plantations (interest rate 3%) was positive both in comparison to natural regeneration of common aspen and natural regeneration of birch (on forest land).

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