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Early growth of hybrid aspen (*Populus* × *wettsteinii* Hämet-Ahti) plantations on former agricultural lands in Estonia

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Abstract

Since 1999 hybrid aspen plantations have been established on former agricultural lands for production of pulpwood as a practice of short rotation plantation forestry in boreal Estonia. During the early growth period the dimensions of the trees have been highly variable. The main objective of the study was to explain the high variability in early growth speed of hybrid aspens by differences in physicochemical soil properties. A network of 51 experimental plots was created to study growth–soil interactions in 5-year-old plantations at various sites. The mean height of the trees was 2.7 ± 0.02 m, mean diameter at breast height was 1.9 ± 0.02 cm and mean current year height increment was 0.7 ± 0.01 m. Mean foliar concentrations of main mineral nutrients were estimated as follows: N 2.15%, P 0.20%, K 0.76%. Trees have grown faster on Arenosols, Albeluvisols and Planosols. Growth intensity has been poor on Luvisols, Cambisols and Gleysols. While evaluating site quality based on soil texture and drainage condition, we found, that in general, hydromorphic soils have been less favourable. At a young age, hybrid aspen grew faster on automorphic soils with loamy sand and on semihydromorphic soils with loam, silt loam and sandy loam texture. The study of height increment in 5-year-old hybrid aspen plantations allows us to predict that the modest growth rate during the first years after planting could improve at an older age. Preliminary impact hierarchy of site properties, especially soil moisture condition, may change during later growth stages, when light competition in the canopy layer of the stand and nutrient competition between the tree roots in the soil will become more decisive for the growth performance of the trees.

Keywords: Hybrid aspen; Early growth; Plantation forestry; Afforestation

1. Introduction

Fast-growing poplars and their hybrids are used in short-rotation forestry in many countries. Production plantations of poplars established with highly selected interspecific hybrid varieties and intensive agronomic-style tending practices are among the highest yielding crop trees in the temperate zone (Stanton, 2004). The only endemic *Populus* sp. in Estonia is European aspen (*P. tremula* L.). The share of forest land area with *P. tremula* as the dominant tree species is 5.4%. As a typical tree in mixed stands on fertile site types, it constitutes 8.1% of the growing stock of Estonian forests (Yearbook forest, 2004).

A cross between *P. tremula* L. and *P. tremuloides* Michx., known as hybrid aspen (*Populus* × *wettsteinii* Hämet-Ahti), was first described at the beginning of the 1920s in Germany (Wettstein, 1933). Presumably hybrid aspen exceeds its parental species in growth rate due to the phenomenon of heterosis. There are two leading hypotheses to explain the genetic basis of heterosis: dominance and overdominance. Li and Wu (1996) have found that in case of aspen hybrids heterosis might be due to overdominance interaction between two alleles, one from the *P. tremuloides* parent and the other from the *P. tremula* parent, at the same loci. The predicted rotation period for hybrid aspen in boreal conditions is 20–30 years for the production of pulpwood. Hybrid aspen has been grown and studied most intensively in Sweden, Finland and the Great Lakes Region in the USA (Benson and Einspahr, 1967; Li et al., 1998; Dickmann, 2001; Yu et al., 2001a; Karacic et al., 2003; Rytter and Stener, 2003, 2005).

In Estonia the first known experiment with a small number of hybrid aspens dates back to the 1980s. Larger scale cultivation for production of pulpwood started in 1999.

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Seven hundred hectares of hybrid aspen plantations had been established on former agricultural lands in Estonia by autumn 2005. Two experimental plantations have been established for afforestation of reclaimed oil-shale mining areas.

Seven hundred hectares is minute compared to the total area of forestland in Estonia (2.3 Mha) or compared to the approximate area of agricultural land that has been abandoned since the beginning of the 1990s (440 thousand ha). Nevertheless, it is the nation's largest project in short-rotation plantation forestry.

In the light of this, in 2002 a long-term research and monitoring programme was initiated in hybrid aspen plantations. The main research objective is to assess the general potential and feasibility of growing hybrid aspen in Estonian conditions. Investigation of relations between the growth of the trees and soil properties is the most important, but not the only part of the research programme. The scope of the programme includes the biodiversity of hybrid aspen plantations, determination of the best hybrid aspen clones, hybrid aspen wood properties, economic profitability and environmental impacts of short-rotation plantations (Tullus et al., 2005).

Most of the recent studies have focused on the clonal differences of physicochemical and phenotypical properties of hybrid aspen (e.g. Yu et al., 2001b; Rytter and Stener, 2003). Significant genotype × environment interaction on the growth of hybrid aspens has been observed (e.g. Li and Wu, 1997; Yu and Pulkkinen, 2003). The results have indicated that the selection of fast growing clones is essential for increasing the biomass production from short rotation aspen plantations. However, the expression of the hybrid vigour (heterosis) is highly dependent on the environment (Li and Wu, 1997; Yu et al., 2001a). In order to benefit from the genotype × environment effect we must also determine the optimal site conditions for the particular species in general.

In clonal forestry it is recommended to establish stands with a mixture of clones from a biodiversity and pest-control point of view (Roberds and Bishir, 1997; Weih, 2004). In the current study we focus on production plantations where the same principle has been followed in Estonia. Therefore, we have not included the clonal component while describing the growth-site relations.

The main hypothesis of our study was that the high variability in early growth speed of hybrid aspens can be explained by differences in physicochemical soil properties. We tried to investigate why the hybrid vigour had revealed itself in only a few cases, and to determine the combination of physicochemical soil properties in which hybrid aspen has displayed superior growth rate. The objectives of the present paper are (i) to describe the basic dendrometric characteristics in 5-year-old hybrid aspen plantations in Estonia; (ii) to describe interactions between tree growth and properties of the leaves and soil; (iii) to predict whether the modest growth rate will persist during the whole rotation, or whether the influence of factors that have suppressed growth will change.

2. Materials and methods

2.1. Plant material

For establishing the plantations, 1-year-old micropropagated hybrid aspens belonging to 27 clones had been used, on average 15 different clones per plantation. Plants of different clones were planted randomly. Planting material originated from Finland. According to the Finnish Plant Production Inspection Centre, these clones are marked as C05-99-8 until C05-99-34. The origin of the material can be traced back to the 1950s, when a large number of aspen hybrid families were produced from crosses between female *P. tremula* in Finland and male *P. tremuloides* in Canada and the northern part of the USA (Yu and Pulkkinen, 2003).

2.2. Plantations

The hybrid aspen plantations under investigation were established in 1999 and 2000. All the studied plantations have been established on previous agricultural lands.

The average spacing has been 2–2.5 × 3–3.5 m and planting density has varied in the range of 1200–1600 trees per ha. In the observed plantations the average planting density was 1300 trees per ha. In all plantations, 0.3–0.6 m biodegradable plastic tubes or 1.1 m net-like shelters have been used to prevent damage by rodents, hares (*Lepus* sp.) and roe-deer (*Capreolus capreolus* L.). None of the studied plantations have been fenced.

2.3. Experimental plots

From 2003 to 2004 a long-term network of 51 experimental plots was created for studying and monitoring the growth performance of hybrid aspen in Estonia at various site conditions. The experimental plots are located in 24 hybrid aspen plantations across the country (between 57°30′–59°30′N and 24°30′–27°30′E). Each plot is a circle with an area of 0.1 ha, on average 106 trees per plot. Dendrometric characteristics were measured in 5-year-old plantations after the end of the intensive vegetation period. Twenty plots were measured in the autumn of 2003 in 11 plantations that had been established in 1999, and 31 plots in the autumn of 2004 in 13 plantations that had been established in 2000.

Height (HT), diameter at breast height (DBH), height increment (*Z*), height of the beginning of the living crown (BLC), and maximum diameter of the crown (DC) were measured at the end of the fifth growing season. If the height of the tree was less than 1.3 m, DBH was not measured. Because of tree shelters, it was not possible to measure basal diameter or diameter at 55 cm. On the basis of HT and *Z* the relative height increment (Zr) was derived ($Zr = 100 \times Z/HT$).

2.4. Soil properties

Soil pits were hand dug in the centre of each experimental plot. Plots were located on microrelief that was typical for the