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Production potential of 36 poplar clones grown at medium length rotation in Denmark

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ABSTRACT

The importance of choosing suitable clones for production of timber and biomass has long been recognized. The aims of this study were to describe the genetic variation and production potential among 36 poplar clones grown in a rotation of 5–13 years and evaluate the different species and hybrid group's potential for use in Northern Europe and comparable growth conditions. Based on two trials with randomized block designs, 36 clones from 4 species and 5 groups of species hybrids, measurements of height and diameter were used for estimating biomass production for rotation lengths of 5 and 13 years. The estimated mean annual increment of above ground biomass ranged from 1 to 9 Mg ha^{-1} yr^{-1} at age 13 years. A hybrid clone O.P. 42 (synonyms Hybrid 275, NE 42) *Populus maximowiczii* × *trichocarpa*, performed best, but also clones of the species *Populus trichocarpa* had a high biomass production. In general the hybrids using *P. maximowiczii* as a parent were well performing. Lowest production had pure species *Populus nigra* and *Populus deltoides* as well as their hybrids. The choice of species hybrid combination had a very strong impact on biomass production, but less influence on quality and health traits like dead shoot tips, leaf density and stem form.

1. Introduction

Today, Denmark has a rather unique and widespread use of cooperative highly energy-efficient district heating facilities with combined heat and power supply for even relatively small communities. The heat-and-power plants have been encouraged to use biomass as energy source through low taxes on biomass vs. fossil fuels. Together with the widespread single household use of firewood for heating, woody biomass already plays an important role in Denmark. The consumption of wood for energy (chips, pellets and firewood) increased by 58% from 2005 to 2010 and is at present covering approximately 41% of the renewable energy consumption or 8% of the total energy consumption [1]. However, current supply of biomass is insufficient to meet the demand and the increase in wood fuel consumption the last three years is mainly due to import of wood pellets. Encouraged by ambitious targets both at EU and national Danish levels aiming at 20 and 30% shares of renewables in the total energy consumption, respectively [2–4], the demand for woody biomass is predicted to increase even more.

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Table 1 – Description of climate and soil conditions for the two test sites on former farm land. Climatic data is estimates from LocClim [59].

Site	Latitude–longitude	Annual mean temperature (°C)	Length of growing season[a] (days)	Degrees days above 5 °C[b]	Annual precipitation (mm)	Soil-type	Specific notes:
Toftlund (1375)	55.2 N 9.02 E	7.4	216	1431	831	Sandy coarse loam	Trees can rather easily reach groundwater in approx. 2 m dept.
Skave (1376)	56.38 N 8.8 E	7.4	214	1455	787	Sandy coarse loam	More dry soil.

[a] Number of days with a mean temperature above 5 °C.
[b] Number of days times temperature above 5 °C.

Historically poplars have played a minor role in Danish forestry, *Populus tremula* (L.) being the only native species from the *Populus* family. During the 20th century, the occasional planting of poplar hybrids for forestry purposes was focused on black poplars (*P.* × *euramericana*) and hybrid aspen (*P. tremula* × *tremoloides*) for the match industry [5].

Since the 1980s an increased interest has appeared for short rotation forestry (SRF) and short rotation coppice (SRC) on farm land to meet increasing demands for biomass. Particularly Sweden and Great Britain have invested in research and energy crop establishment mainly based on SRC willow [6–8]. In Denmark some interest emerged for the fast growing hybrid poplars in the 1980s as a potential biomass crop on low-productive farm land. Part of this trend was rooted in EU subsidy regulations of farming to reduce the surplus agricultural production by laying farmland fallow or supporting afforestation. Following the turn for the millennium the EU farming subsidies are now supporting short rotation (<10 years) high density crops (>2000 trees ha^{-1}) equally with many farm crops which have considerably increased farmers interests [9]. Additionally, the advantage of the short rotation crops is a payback period of the investment that is more in line with what a farmer is familiar with compared to the rotation periods usually considered in temperate forestry.

A key feature comparing the different short rotation systems, SRF with a 5–15 year rotation and SRC with 1–4 year rotation crops, is the annual production of biomass per unit area compared to annual input to produce the biomass. However, to the author's knowledge, designed field studies comparing such a wide span of rotation ages do not exist. In recent Danish SRC willow trials, average annual biomass production ranged between 5.0 and 13.4 Mg ha^{-1} yr^{-1} and large differences were observed between different clones [10,11]. In UK and German studies, production of SRC ranged between 4.1 and 17.8 Mg ha^{-1} yr^{-1} [12–15] and 2.4–14.0 Mg ha^{-1} yr^{-1} [16], respectively.

In an SRF study on abandoned farm land sites in southern Sweden (latitude 55° and 59°) including *Populus trichocarpa*, *Populus maximowiczii* × *P. trichocarpa* (O.P. 42) and hybrid aspen and a range of stocking densities (410–2500 plants ha^{-1}) mean annual biomass production was 3–10 Mg ha^{-1} yr^{-1} for a rotation length of 9–19 years [17]. In a comparable study of several aspen clones, biomass production ranged from 6.8 to 9.5 Mg ha^{-1} yr^{-1} [18,19] and with large genetic variation in production [20].

Substantial growth, phenological and health differences between *Populus* species and species hybrid cultivars have been recognized in numerous studies [21–30]. The large clonal variation in biomass production as well as the effect of site and clone interaction stresses the need for further knowledge on the selection of adequate clones for increasing overall biomass production based on designed field trial comparisons – also for medium length rotations. This is essential to overcome the confounding effect of clone and site in single clone-production plots and to gain further knowledge of poplar clone performance on different sites and the potential genotype–clone interactions [30].

The aims of the present study were to evaluate the production potential of different poplar clones grown in medium length rotation, i.e. to i) predict clone values for survival, height and diameter growth, vitality and estimated biomass production, ii) compare the performance of clones with respect to the species and species hybrids involved, and iii) discuss obtained results in the perspective of poplar biomass production in medium length rotation.

2. Materials and methods

2.1. Sites

Two forest plantations were established in the spring 1992 on former farm land both located in the western part of Denmark (Table 1). A randomised complete block design was used with 5 blocks and 16 plants in a 4 by 4 plot, and a spacing of 2.5 × 2.5 m yielding a total of 80 rooted cuttings (ramets) per clone and site.

2.2. Clones

The 36 clones selected for this study originate from four *Populus* species: *P. maximowiczii* (m), *P. trichocarpa* (t), *Populus deltoides* (d), and *Populus nigra* (n) and include five parental groups