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Productivity and thinning effects in hybrid aspen root sucker stands

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ABSTRACT

The Nordic countries have a vision to become carbon neutral by 2050. One way to approach this vision is to cultivate and harvest fast-growing tree species as bioenergy.

In three study parts, this paper investigated how hybrid aspen performs in the second generation of root suckers. The three studies investigated; (1) initial growth, (2) growth effects following three early thinning strategies, and (3) individual tree development after the three early thinning strategies in study 2 and an intensive low thinning. In study 1, root suckers between 1- and 4-years-old were studied at four sites. Studies 2 and 3 followed growth dynamics for 12 years at one site.

After 2 years, the four sites in study 1 had a mean stand density of 63,500 living root sucker stems ha^{-1} (ranged 46,800–72,900 stems ha^{-1}) and the mean standing biomass (including living and dead stems) was 14.5 Mg dry weight ha^{-1} (ranged 9.1–21.7 Mg dry weight ha^{-1}). Differences between sites were observed.

Even though significant amounts of biomass had been harvested after 2 years in two of the treatments in study 2, the density of living stems did no longer differ between the treatments at the end of the 12-year period. The stem diameter was largest for cross-corridor thinning, while the height development was not affected by thinning strategy. During the 12-year period, the obtainable biomass (included living, dead and harvested biomass) did not differ significantly among the thinning treatments and after 12 years the mean annual increment was 9.8 Mg dry weight ha^{-1} yr^{-1} and had started to decrease.

Results following the second thinning in study 3 showed that early biomass harvest had a large influence on the development of individual stems. Unthinned strategy resulted in smaller stem diameters and green crowns, while cross-corridor thinning showed the largest stem dimensions and green crowns. Green crowns became of similar size for the various thinning strategies, but the difference in stem diameter remained and the mean annual increment continued to diverge.

This paper showed that the second generation of hybrid aspen can contribute significantly to the biomass supply, and that the strength of early thinning has a large effect on the continuing growth. The importance of early thinning, when striving for large fast-growing trees, is highlighted.

1. Introduction

The Nordic countries have a vision to become carbon neutral by 2050 (Nordenergi, 2010; IEA, 2013). One major way to approach this vision is by using woody biomass for energy, and efforts have been made to increase the production and availability of bioenergy. Hence, trees with a high growth potential, e.g. hybrid aspen (*Populus* × *wettsteinii* Hämet-Ahti = *P. tremula* L. × *P. tremuloides* Michx.), is of interest in this approach.

Hybrid aspen has been tested in southern Sweden for about 70 years (e.g. Johnsson, 1953, 1976; Ilstedt and Gullberg, 1993; Stener and Karlsson, 2004; Stener, 2010; Rytter et al., 2011) and commercial stands have been established since the 1990s (Hugosson et al., 2004; Rytter et al., 2011). Knowledge and experience of growth and management effects in the first generation of planted trees must be considered good (Jakobsen, 1976; Einspahr and Wyckoff, 1978; Einspahr, 1984; Telenius, 1999; Rytter, 2002; Karačić et al., 2003; Tullus et al., 2009, 2012; Johansson, 2013; Rytter and Stener, 2014).

In the first generation, hybrid aspen can reach a mean annual increment (MAI) of between 20 and 25 m^3 stem wood ha^{-1} year^{-1}, or approximately 8–10 Mg dry weight ha^{-1} (DW) of above ground woody biomass ha^{-1} year^{-1} (Liesebach et al., 1999; Karačić et al.,

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2003; Stener and Karlsson, 2004; Tullus et al., 2012; Johansson, 2013; Rytter and Stener, 2014). After final harvest, hybrid aspen usually produces over 50,000 root suckers ha^{-1} (Liesebach et al., 1999; Rytter, 2006; Rytter and Stener, 2010, 2014). Root suckers use the already existing root system of the parent tree, which results in an initial fast establishment and growth (Sandberg and Schneider, 1953). The harvest should be done during the dormant season, if the most vigorous root suckers are preferred (Peterson and Peterson, 1992).

In a Nordic perspective, research and knowledge on management of hybrid aspen established by root suckers is scarce (Rytter, 2006; Rytter and Stener, 2010). However, root sucker stands may give more flexible possibilities than planted stands, since they can be treated both for high biomass production in dense spacing or treated towards more conventional forestry with sparser stand density but larger trees. It is also possible to harvest biomass through thinnings in the latter case. Therefore, it is of importance to gain knowledge about the productivity as well as the management options in these second generation stands. Depending on future goals for root sucker stands, strategies for early thinning are probably of great importance due to the high stem number and intra-specific competition.

An advantage with root suckers instead of replanting is the establishment cost. Planting is expensive due to the costly plant material, which must be produced by either micro propagation, rooting of woody or greenwood cuttings, or cuts from root segments (Zsuffa et al., 1993; Louis and Eils, 1997; Haapala et al., 2004). Root suckers will appear free of costs, but will most likely need early management. In addition, a planted stand must be protected against browsing and fraying (Johansson, 2010; Edenius et al., 2011). The numerous amounts of root suckers may provide the option to leave the second generation unfenced, since there are many stems to select future crop trees from and the faster initial growth will earlier lead to a browsing safe height (Myking et al., 2011). Thus, the option of using root suckers instead of replanting after a harvest operation may be very interesting (Rytter, 2006).

This study was carried out in four clear-felled hybrid aspen stands in southern Sweden where the early production of hybrid aspen root suckers was evaluated. In addition, at one of the sites, the effect on biomass production after different strategies of early biomass harvests was studied, as well as the effect on retained crop trees after an intensive low thinning. The main hypotheses were; (1) root suckers will be successful in establishing harvested sites with a high number of root suckers and a high initial biomass production, (2) less intensive initial thinning strategies will lead to a higher degree of self-thinning and smaller stem diameters, and (3) the strength of the first thinning will be essential for the development of the individual crowns and hence also the stem diameter of the remaining trees after an intensive low thinning.

2. Material and methods

2.1. Sites

The study was conducted at four sites on former agriculture land in southern Sweden. The sites were originally established with 1-year-old containerized rooted cuttings spaced 3 × 3 m (1100 stems ha^{-1}). The stands (Table 1) were established after clear-felling in winter. At the time of harvest, the stands were of different ages and border rows were surrounding all experimental sites. The soil type at the site Maltesholm was a sandy sediment, while the soil type at the other sites was clayey moraine.

2.2. Measurements

2.2.1. Initial growth (study 1)

The four sites (Table 1) were studied for initial growth in unthinned stands up to the age of 4 years. Only trees taller than breast height (130 cm) were included in the study. The stem diameter at breast height and number of stems were measured in 3–12 10 m^2 circular plots per block. The size of a block was indicative for determining the number of sample plots. Depending on stand density, heights were measured on every fifth or tenth tree. For each treatment and site, trees that were only measured for stem diameter were allocated heights based on the relationship between diameter and height estimated from sample trees (Section 2.3.1).

From each site, 20–60 trees of different diameter ranges were selected for dry weight measurements. The dry weight was measured through drying of whole shoots (1- and 2-year-old shoots), or drying of disks from every second meter of the stem (4-year-old shoots and older) starting at stump height (10 cm). The disks or whole shoots (including branches) were first weighted for fresh weight and finally dried at 85 °C until constant weight. Additionally, the disks were measured for volume through the water displacement method (Olesen, 1971) before they were dried. This was used to calculate basic density (Olesen, 1971) and further estimate dry weights of whole stems ⩾4 years old. All branches were collected from the sample trees and weighed fresh. The same dry weight percentage that were found for the top disk of the trees were used to estimate the dry weight of branches.

The stem diameter, tree height, number of stems and biomass production were measured at stand ages 1, 2 and 4 years, except at Jordkull year 1 and Ekebo year 4.

Table 1
Characteristics of the four sites in southern Sweden. The last year of the study was 2012.

Site characteristics	Sites			
	Jordkull	Maltesholm	Snogeholm	Ekebo
No. of clones[a]	4	47	8	35
Age of parent stand at harvest (years)	11	21	12	22
Mean stand density prior to harvest (stems ha^{-1})	750	740	950	530
Age of 2nd generation at the end of study (years)	12	4	4	2
Stand size (ha)	0.7	0.5	3.5	0.2
No. of blocks	4	1	4	1
Study parts[b]	1, 2 and 3	1	1	1
Sample plots per block and treatment	3–6	12	6	8
Coordinates	55°59′N, 13°02′E	55°55′N, 14°00′E	55°33′N, 13°43′E	55°57′N, 13°06′E
Altitude (m.a.s.l.)	80	40	45	88

[a] Number of clones at harvest of the parent stand.
[b] Study parts: (1) initial growth, (2) thinning effects on biomass production (three treatments after 2 years: no thinning, corridor thinning (2/3 harvest), and cross-corridor thinning (8/9 harvest)), and (3) development of retained trees after second thinning (1100 stems ha^{-1}) performed 2 years after treatments in study part 2.