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Stem damages caused by heart rot and large poplar borer on hybrid and European aspen

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Abstract. Solid wood production of hybrid aspen requires relative longer rotation periods, thus increasing risk of wood damages by pests and diseases. We compared damages by heart rot and poplar borer of 48 years old hybrid (*Populus tremuloides* Michx. × *P. tremula* L.) and European aspen in a progeny trial located in Eastern part of Latvia. Trees were harvested and rot patches and galleries were recorded and measured at a stump level. The number of galleries had positive relation on number of patches and total area of rot. The susceptibility of the rot and poplar borer was similar for both hybrid and European aspen. Yet, some differences among families were detected. No effect of pathogens damage was observed on the tree growth. Larger trees had smaller proportion and incidence of rot and galleries per unit of area as well as wider outer rot-free wood layer.

Key words: *Populus tremula*, *Populus tremuloides* × *P. tremula*, wood damages, heart rot, *Saperda carcharias*.

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Introduction

Since the end of the 20th century, main production goal for fast-growing hybrid aspen (*Populus tremuloides* Michx. × *P. tremula* L.) has been energy wood (Rytter & Stener, 2005). However, growth characteristics of hybrid aspen allow flexibility in rotation period and solid wood can be produced.

The use of resistant clones may not be necessity for biomass production (Steenackers *et al*., 1996) where short rotations allow avoiding diseases and pest caused wood damages and high quality (mechanical strength) of wood is not needed. However, rotation period for solid wood production is 20–30 years (Hynynen *et al*., 2004; Rytter & Stener, 2005) and risk of wood damages and reduced growth due to diseases and pests increases. For instance, reduction of height growth has been observed due to the large poplar borer *Saperda carcharias* L. damage and rot associated with it (Cramer, 1954; Välimäki & Heliövaara, 2007). Damaged trees become less vigorous, and trees fall behind in growth (Mattson *et al*., 1988). In addition, maintaining resistance interferes with growth (Osier & Lindroth, 2006): productive trees allocate more resources for the growth, thus they may be more susceptible to pests and diseases (Osier & Lindroth, 2006). Additionally, the large poplar borer is most abundant in well-lit, low-density stands on vigorous trees (Šrot, 1962), thus may cause more damage in plantations. Due to mechanical damage by poplar borer, trees are more prone to wind (DeBell *et al*., 1997) and poplar borer might introduce the

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rot into the tree. *Phellinus tremulae* (Bond.) Bond. et Boriss. is unusually aggressive rot, specialized for both trembling and European aspen, and cause more wood volume loss than other diseases (Newcombe *et al.*, 2001). Moreover, decay and discoloration can be major defects limiting the end use of timber (Eckstein *et al.*, 1979).

Tree breeding has mainly focused on superiority in terms of growth and stem quality paying less attention to resistance to diseases (Steenackers *et al.*, 1996). *Populus* hybrids, including hybrid aspen, with remote origin of parent trees are reported to be prone to diseases (Ilstedt & Gullberg, 1993). Resistance to diseases for *Populus* is highly heritable (Newcombe & Bradshaw, 1996), including these for decay and discoloration traits (Eckstein *et al.*, 1979). Yet, main focus has been on *Hypoxylon* and *Melampsora* caused diseases (DeBell *et al.*, 2002). In the recent past a few studies have been done in relation to pest and disease resistance for hybrid aspen (Tullus *et al.*, 2012), among which Välimäki & Heliövaara (2007) have focused on rot and poplar borer damages in Finland.

The aim of this study was to assess susceptibility of hybrid aspen to rot and poplar borer in comparison to European aspen. We hypothesized that hybrid aspen is more prone to both rot and poplar borer due to faster growth.

Material and Methods

This study was based on a progeny trial located in Eastern part of Latvia, near Kalsnava (56°40′ N, 25°58′ E). The stand was established on a former agricultural land on sod-podzolic mineral soil with normal moisture regime, corresponding to *Oxalidosa* forest type. In 1966, three-year old saplings of seven provenances of native European aspen *P. tremula* and seven families of hybrid aspen *P. tremuloides* × *P. tremula* were planted at a 3 × 3 m grid. All hybrid aspen families were progenies of the same mother-tree growing in botanical garden in central part of Latvia (no information on its origin is available) and seven local plus trees from different regions of Latvia. In the winter 2013/2014, height and the diameter at breast height (DBH) was measured for each tree. A year later, the stand was harvested by clearcut at age of 48 years. In total, 43 aspen and 129 hybrid aspen trees from five families, representing DBH distribution (ranging from 18 cm to 43 cm) of the trial for respective families, were sampled. On stumps, aspen heart rot (patches located both in central and periphery part of the stump), caused by fungus *P. tremulae* and galleries, created by poplar borer *S. carcharias* (part of them was enclosed by the rot), were found. To measure the defects, a polythene film was mounted on the selected stump. Perimeter of stump, rot patches and galleries were projected on a film with a black marker. In the laboratory, area of stump, central and peripheral rot, and galleries were measured from film using planimeter (PLANIX 10S, Tamaya Inc., Japan). Total number of galleries and those enclosed by rot were counted. The distance from bark to the outermost gallery and rotten patch was measured.

Normality of data was assessed by Shapiro-Wilkinson test. ANOVA was used to assess the effect of "species" and family on the height. The effect of "species", family and DBH group as independent variables on the response parameters other than tree height was assessed using non-parametric Kruskal-Wallis test. The differences between groups were tested using Dunn's multiple comparison. *P*-values were adjusted using the Bonferroni transformation (Sokal & Rohlf, 1995). Spearman rank correlation was used to assess the relationships between the measured variables. All tests were performed at $\alpha = 0.05$. All calculations were done in R 3.4.0. (R Core Team, 2016).

Table 1. Mean values of stem parameters and wood damages (± confidence interval).

Group	Mean DBH, cm	Mean height, m	Mean area of rot per stump, cm^2	Mean proportion of rot per stump, %	Number of rot patches per stump	Number of galleries per stump	Number of galleries enclosed by rot per stump
Family A	29.8±2.2^{bc}	30.2±1.1^{a}	221.1±86.9^{a}	19.6±7.9^{ab}	2.4±0.8^{ab}	6.1±2.0^{a}	3.3±1.9^{a}
Family B	31.3±2.5^{bc}	31.0±1.4^{a}	156.7±73.6^{a}	11.4±5.6^{b}	4.1±1.4^{b}	6.8±1.9^{a}	4.2±2.0^{a}
Family H64	31.4±2.1^{bc}	29.0±1.4^{a}	269.5±75.8^{a}	21.8±7.0^{ab}	2.6±0.8^{ab}	5.8±1.7^{a}	3.2±1.2^{a}
Family J	29.2±2.0^{abc}	29.1±1.1^{a}	327.4±105.8^{ab}	32.2±11.7^{a}	1.8±0.8^{a}	5.9±2.4^{a}	5.0±2.4^{a}
Family M	31.9±1.6^{bc}	30.0±0.7^{a}	438.0±90.0^{b}	29.0±6.2^{a}	2.7±0.8^{ab}	8.0±1.7^{a}	4.6±1.3^{a}
Hybrid aspen in total	30.8±0.9^{A}	29.8±0.5^{A}	294.5±40.9^{A}	23.4±3.5^{A}	2.7±0.4^{A}	6.5±0.8^{A}	4.0±0.7^{A}
European aspen	26.0±1.6^{Ba}	26.2±0.8^{Ba}	258.7±69.9^{Aa}	27.2±5.9^{Aa}	2.0±0.4^{Aa}	5.8±2.0^{Aa}	4.6±2.0^{Aa}

DBH – diameter at breast height.
Different capital letters indicate significant differences in mean values between hybrid aspen and European aspen.
Different small letters indicate significant differences between specific pairs of families at $\alpha = 0.05$.

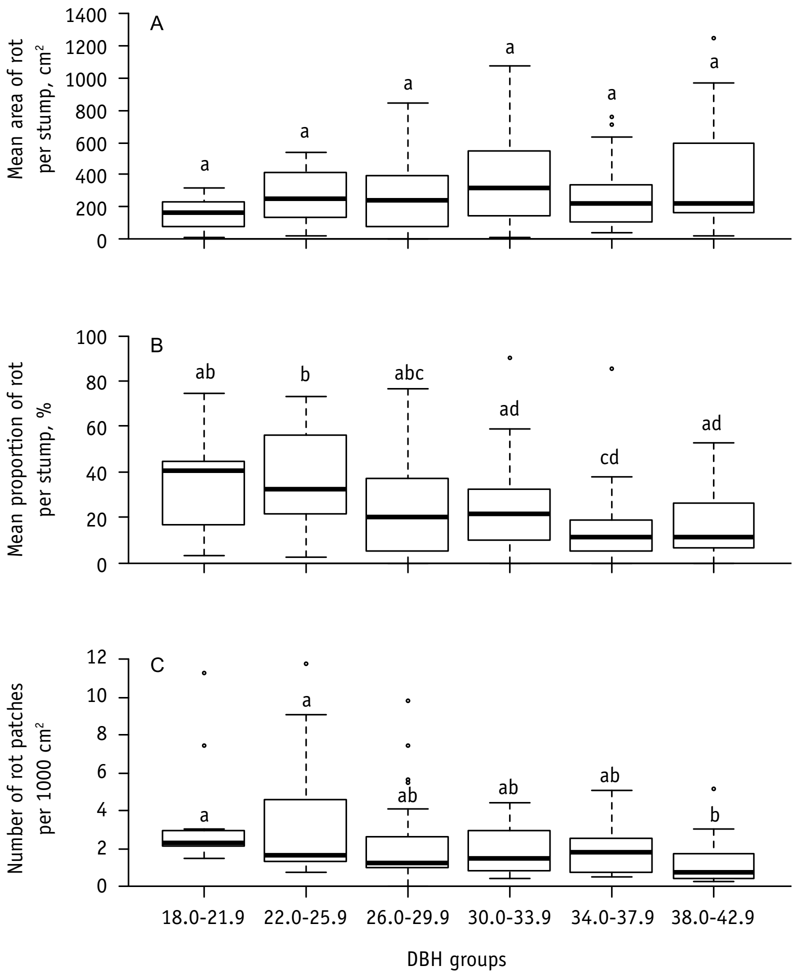

Figure 1. Mean area (A) and proportion (B) of rot per stump, and number of rot patches per 1000 cm^2 (C) depending on DBH (diameter at breast height) of a tree (hybrid and European aspen together). Different letters indicate significant differences between specific pairs at $\alpha = 0.05$.

Results

The mean diameter of hybrid aspen significantly exceeded that of European aspen (Table 1). Regardless of the vigorous look of the stand, the heart rot and poplar borer galleries were abundant since they were found on 170 and 157 stumps out of the sampled 171, respectively.

The mean area and the proportion of rot was similar for both hybrid and European aspen ($p = 0.35$ and 0.08, respectively) (Table 1). Nevertheless, the mean area of rot differed ($p = 0.02$) among the families, and the family M exceeded families A, B and H64, as well as European aspen (Table 1). Trees with larger DBH tended to have larger total rot area, but significantly ($p < 0.01$) smaller proportion of rot (Figure 1 A and B). In addition, family had significant effect on the proportion of rot ($p < 0.01$) (Table 1).

The main part of rot was located in the centre of the stump and the peripheral rot area formed 9.2% of the total rot area. In total, 56.9% of the galleries were enclosed by the rot. The rot transferred exclusively by poplar borer damage (located around its galleries and not connected to other patches of rot on the stem cross-cut) was detected on 11 stumps (6.4% of trees).

The number of galleries was similar for both hybrid and European aspen and also among families of hybrid aspen (Table 1). No significant correlation between damage by *S. carcharias* (number of galleries) nor rot (area of rot) and DBH (*rho* = 0.01, $p = 0.88$ and *rho* = 0.11, $p = 0.13$, respectively) nor height (*rho* = 0.01, $p = 0.85$ and *rho* = –0.01, $p = 0.86$, respectively) was found.

As expected, the number of galleries and number of rot patches correlated significantly (*rho* = 0.33, $p < 0.01$). Significant correlation was also observed between the number of galleries and the total rot area (*rho* = 0.31, $p < 0.01$).

Significant differences in number of rot patches were found among the families of hybrid aspen ($p = 0.02$) (Table 1). The family B had significantly higher number of rot patches than the family J and European aspen (Table 1). Irrespectively of family, faster growing (greater DBH) trees had less rot patches per unit of area (*rho* < –0.27, $p = 0.01$) (Figure 1C).

In total, rot occupied 24.3% of stump area, but area of galleries was negligible (0.8%). However, damages were scattered and located close to the bark. The outermost rot and gallery was located at the 2.7 and 1.6 cm distance from the bark, respectively. Nonetheless, rot-free layer of sapwood was significantly ($p = 0.04$) wider for trees with larger DBH (Figure 2).

Discussion

Resistance to diseases may be interfered by hybridization in various ways. In our study, no significant differences of susceptibility of rot and poplar borer were found between hybrid and European aspen (Table 1). It is in accordance with Cheng *et al.* (2011) stating, that in most cases, hybrids are as resistant as or more susceptible than parental species.

No effect of rot area or number of galleries to the growth of trees was observed as suggested by non-significant correlation, although a negative effect of poplar borer damage on height growth has been reported by Cramer (1954) and Välimäki & Heliövaara (2007). Reduction of growth might be a result of maintenance of high concentration of phenolic glycoside (Osier & Lindroth, 2006), that has strong negative impact on herbivore growth, development time and fecundity (Osier & Lindroth, 2001). Contrary, we found significant negative relationship between tree DBH and proportion and incidence of rot and galleries per unit of area (Figure 1C). Additionally, larger trees had wider rot-free layer from the bark (Figure 2). This could be explained by constant growth rate of rot regardless of tree size (Etheridge, 1961). However, Witt (2010) found positive relationship for tree DBH and both incidence and volume of

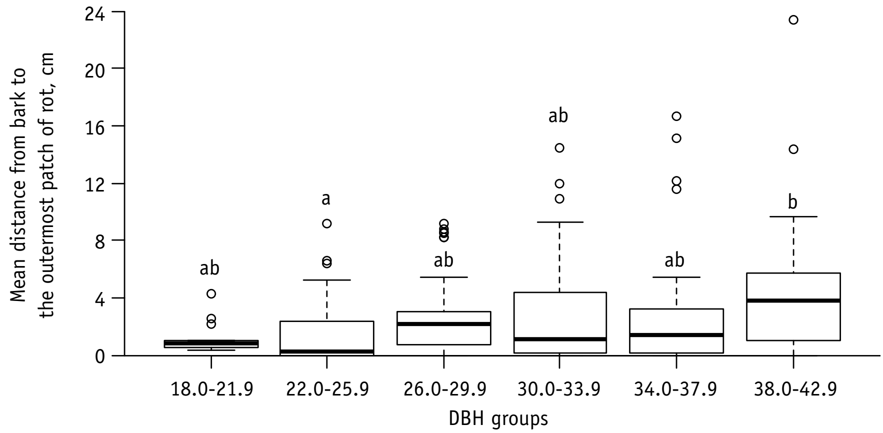

Figure 2. Mean distance from bark to the outermost patch of rot depending on DBH (diameter at breast height) of a tree (hybrid and European aspen together). Different letters indicate significant differences between specific pairs at α = 0.05.

infection. Alternatively, higher infestation of smaller trees by the poplar borer can be explained by its preference of young and small dimension trees (Nuorteva *et al.*, 1981; Brandt *et al.*, 2003).

Significant differences of damages were observed among hybrid aspen families (Table 1). This might be explained by genetically determined production of defence substances (Osier & Lindroth, 2006). Alternatively, susceptibility against the rot might be explained by vessel features (wall-lumen ratio and size) that are partly genetically controlled and affect development of fungus (Eckstein *et al.*, 1979). Poplar borer galleries might have similar effect, i.e. affecting aeration and loss of moisture, facilitating development of rot (Eckstein *et al.*, 1979).

More intense infection of rot has been observed in stands damaged by boring insects (Newcombe *et al.*, 2001). Hence, the number of galleries had significant effect on the number of patches and total area of rot. Although, the poplar borer is believed to damage young trees (Nuorteva *et al.*, 1981), occurrence of galleries in sapwood suggested that this pest did not avoid also the older trees as observed by Välimäki & Heliövaara (2007). The pest lives only within living wood, and hence it avoids heartwood rot by relocating closer to bark (Nuorteva *et al.*, 1981). It explains the observed distribution of galleries in sapwood. Incidence of rot increases with the age of the tree (Witt, 2010) hence, at the age of 48 years rot was detected on > 99% of trees, regardless of their vigour.

Conclusions

Our hypothesis was not confirmed, and no significant difference of susceptibility between hybrid and European aspen was found. Alternatively, susceptibility to rot differed among the hybrid aspen families, hence hybrid aspen families as resistant to rot as European aspen might be selected.

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