WOOD QUALITY OF BIRCH (*BETULA* SPP.) TREES DAMAGED BY MOOSE

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ABSTRACT: European white birch (*Betula pubescens*) and silver birch (*B. pendula*) are important tree species for Finnish pulp and wood-products industries. Moose (*Alces alces*) damage, however, reduces the quality of butt logs intended for high-quality plywood and saw logs. In addition to flaws in stem form, pith discoloration and color change outside the pith reduce quality and value of logs irrespective of their end use. Our objectives were to 1) analyze the external and internal quality of birch trees damaged by moose, 2) measure whether the severity, type, and occurrence of damage differed between silver birch and European white birch trees, and 3) evaluate visual criteria that would enable a forest-owner to assess damage and future value of moose-damaged birch trees prior to the first commercial thinning. We sampled 4 stands with a known history of moose damage; 18 trees per stand were classified by visual evaluation into 3 damage categories. The severity and type of damage lowering the internal quality of logs from sample trees were classified into 5 grades. The proportion of all visible color defects and/or decay was 74% in silver birch trees and 67% in white birch trees. Moose damage caused no visible color defect and/or decay in 35% of silver birch and 33% of white birch trees. The commercial quality and value of birch trees damaged by moose was reduced by the internal color defects and/or decay, even in certain trees without obvious external moose damage. Nevertheless, forest-owners can evaluate the internal quality of most birch trees in order to remove those of low-quality in the first commercial thinning by using external quality indicators of moose-damaged stems (e.g., stem form and clear curve at the point of stem breakage).

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European white birch (*Betula pubescens*) and silver birch (*B. pendula*) are the third and fourth most common tree species in Finland. The pulp industries and wood-products industries used about 14.5 and 1.5 Mill. m^3 of the production of 16 Mill. m^3 of birch roundwood in 2006. Birch species are considered as medium-preferred browse of moose (*Alces alces*) and a high proportion of their annual browse consumption consists of birch owing to its widespread availability (Bergström and Hjeljord 1987). This browsing may cause substantial damage and financial loss in young birch stands.

Moose population density has increased in Finland in recent decades (Torvelainen 2007). The post-harvest moose population peaked in 2001 when it was estimated at 139,000 (mean moose density of 3.3 moose/10 km^2). Concurrently, increasing moose damage (i.e., twig-browsing, stem breakage, and bark stripping) was raising increased concern amongst forest-owners and associated forest industries. Concern is based on the fact that, as a long-term consequence, moose damage reduces the quality of butt logs (i.e., merchantable timber that is intended as high-quality plywood or sawn timber), especially when main stems are broken (Heikkilä et al. 1993, Ingemarson et al. 2007, Lilja and Heikkilä 2007). In addition to flaws in stem form, pith discoloration and color change outside the pith reduce quality, hence

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the value of logs irrespective of their end use. As a consequence of damage risk from a high moose population, plantations of birch trees have declined markedly, especially in southern Finland in the last decade (Viiri 2007).

The objectives of this study were to: 1) analyze the external and internal quality of birch trees damaged by moose, 2) determine whether any difference in severity, type, and occurrence of damage exists between silver birch and European white birch, and 3) determine selection rules based on visual evaluation that would enable a forest-owner to decide whether to remove or retain moose-damaged birch trees in the course of the first commercial thinning.

MATERIAL AND METHODS

Data were collected in 2007 from 1 European white birch stand and 3 silver birch stands with a known history of moose browsing. All 4 stands were in central Finland (Kannonkoski, Saarijärvi, and Viitasaari municipalities, ca. 63˚N, 25–26˚E) and had reached the growth stage for the first commercial thinning (Table 1). All stands had been planted and suffered from severe moose browsing damage at the sapling stage. The randomly selected sample trees (18 per site) were classified by visual evaluation into 3 damage categories: 1) 6 trees with no visible moose damage (trees were known to have had previous moose damage, i.e., stem breakage), 2) 6 trees with slight moose damage (i.e., slightly visible curve at the point of stem breakage), and 3) 6 trees with moderate moose damage (i.e., moderately visible curve at the point of stem breakage). Consequently, this classification excluded birch with severe visible moose damage. We justified this approach because it is known that the inner quality of birch trees is reduced or lost when moose damage is highly visible (Heikkilä et al. 1993, Lilja and Heikkilä 2007).

Sample trees were felled and two, 2 m-long logs were cut from each sample tree, yielding a total of 144 logs. The stem form of each log was measured as a maximum deviation from the center line of the log. The logs were sawn into one, 20 cm-long bolt and six, 30 cm-long bolts. Next, each bolt was pith-centrally sawn into cants using a band saw. The severity and type of damage lowering the internal quality of log (i.e., color defects and/or decay) were classified into 5 grades: 1 = no damage (no visible color defects or decay); 2 = color defect in pith with a diameter <20 mm (slight color change); 3 = hard rot in pith with a diameter <20 mm (clear color change, usually as a result of chemical reaction or preliminary stage of decay); 4 = hard rot (the wood material dark but still hard, a condition caused by an infection related to a decaying fungus); 5 = soft rot (wood material is dark and soft, and wears away when scratched) (see Schatz et al. 2008). In addition, moose damage was separated from other damaging agents (i.e., insects, voles, and others) by visual evaluation. The spreading distance of the moose-caused color defects and/or decay in the stem wood was measured both vertically and horizontally. The maximum spreading distance was used in the calculations.

All statistical analyses were performed

Table 1. Stand characteristics of three silver birch stands and one white birch stand, central Finland, 2007.

Stand	Tree species	Planting year	Density (stems/ha)	Mean height (m)	Mean dbh[1](cm)
A	Silver birch	1991	1,725	15.8	12.0
B	Silver birch	1987	900	15.9	12.5
C	Silver birch	1987	1,450	14.0	11.1
D	White birch	1987	1,950	10.7	10.6

[1] Mean dbh = mean diameter at breast height (1.3 m).

with SPSS package. The parametric tests (ANOVA) were employed because the variables had normal distributions.

RESULTS

When combining all damage categories, the proportion of all visible color defects and/or decay was 74% in silver birch trees and 67% in white birch trees (Table 2). Moose damage alone did not cause any visible color defects and/or decay in 35% of silver birch and 33% of white birch trees (Table 3). In both species the most common damage type (>50%) was hard rot in pith with a diameter <20 mm; this exceeded or equaled the proportion of no damage (Tables 2 and 3). In practice, this means a clear color change is visible in the stem wood from a chemical reaction or preliminary stage of decay.

The moose-caused color defects and/or decay were spread both vertically and horizontally in damaged trees, as well as trees with no visible damage (Table 4). There was no difference in the vertical spreading distance of moose-caused color defects and/or decay in the stem wood among different damage categories of moose-damaged silver birch trees (F = 0.17, P >0.05). In white birch trees, the vertical spreading distance increased considerably (>50%) with increasing damage level, but no difference was found (F = 1.20, P >0.05). All horizontal spreading distances were <40 mm and were not different (P>0.05). Vertical spreading distance averaged 160 cm in the moderately damaged white birch trees. In silver birch trees, the maximum deviation from the center line of the log increased with increasing damage level (F = 5.38, P <0.01).

DISCUSSION

Our data indicate that wood discoloration caused by different damaging agents remains at a lower level in European white birch than silver birch (Table 2), although this difference was small. There was no moose-caused visible color defect and/or decay in 35% of silver birch and 33% of white birch trees based on the assessment of internal wood quality (Table 3). Thus, moose damage apparently does not always result in reduced wood quality because all trees were damaged by moose at some point. On the other hand, these data indicate that from a forest-owner perspective, the commercial quality and value of birch trees damaged by moose was substantially reduced due to internal color defects and/or decay. This was also the case for birch trees that were evaluated visually to have no external moose damage (Table 4), hence, there was no indication of the compromised internal quality. Importantly, these trees would normally be retained in the course of the first commercial thinning, therefore, visual assessments alone prior to the first commercial thinning will probably result in some low-quality birch trees being retained until maturity. Such timber at harvest will necessarily be pulpwood with only 30–50% value in comparison to saw or plywood logs. Nevertheless, for the worst

Table 2. The proportion (%) of damage type measured in logs cut from silver and white birch trees identified as damaged by moose browsing. Logs were graded to the damage type that most lowered the internal quality (e.g., log with soft rot may also contain hard rot, hard rot in pith, or color defect in pith). These data reflect pooling of moose and other damage agents.

Tree species	Damage type				
	No damage (%)	Color defect in pith (%)	Hard rot in pith (%)	Hard rot (%)	Soft rot (%)
Silver birch (n = 54)	25.9	11.1	35.2	18.5	9.3
White birch (n = 18)	33.3	5.6	44.4	5.6	11.1

Table 3. The proportion (%) of damage type measured in logs cut from silver and white birch trees identified as damaged by moose browsing. Logs were graded to the damage type that most lowered the internal quality (e.g., log with soft rot may also contain hard rot, hard rot in pith, or color defect in pith). Classification is based on the effect of moose damage; other damage agents were excluded but may have been present.

Tree species	Damage type				
	No damage (%)	Color defect in pith (%)	Hard rot in pith (%)	Hard rot (%)	Soft rot (%)
Silver birch (n = 54)	35.2	11.1	33.3	14.8	5.6
White birch (n = 18)	33.3	5.6	44.4	5.6	11.1

cases forest-owners can visually evaluate the internal quality of moose-damaged birch trees with external quality indicators (e.g., stem form, clear curve at the point of stem breakage), and be able to remove the lowest-quality trees in the first commercial thinning. If the first commercial thinning is carried out properly, potential damage and economic loss caused by moose browsing will be reduced.

The horizontal spreading distance of moose-caused color defects and/or decay was relatively limited in size (<40 mm in different damage categories), as reported previously (Heikkilä et al. 1993, Lilja and Heikkilä 2007). The vertical spreading distance of moose-caused color defects and/or decay was comparable to that measured by Lilja and Heikkilä (2007). The maximum deviations from the center line of the logs were relatively low in both birch species, and probably reflected the exclusion of sample trees with severe visible damage. This also indicates that the diameter of broken main stems at the sapling stage might have been relatively small in both species (cf., Heikkilä et al. 1993).

The internal quality of birch trees was reduced by factors other than moose (Table 2). It is known that insects (Annila 1979, Lilja and Heikkilä 2007) and voles (Henttonen et al. 1994) are potential damaging agents, and other related data and our observations suggest such also (S. Härkönen et al., Finnish Forest

Table 4. Damage categories, mean vertical and horizontal spreading distances of moose-caused color defects and/or decay in stem wood, and mean maximum deviation from the center line of the log in moose-damaged silver birch and white birch trees. The 3 damage categories were: None = trees with no visible moose damage, Slight = trees with slight moose damage, and Moderate = trees with moderate moose damage. Sample sizes are in parentheses; means (± SE) with the same letter are not different (ANOVA, P >0.05).

Tree species	Damage category	Vertical (cm)	Horizontal (mm)	Deviation (mm)
Silver birch	None (7)	143±16	17±4	29±5[a]
	Slight (13)	157±28	33±7	41±6[ab]
	Moderate (15)	142±14	37±5	60±7[b]
	F	0.17	2.07	5.38
	P	0.84	0.14	0.01
White birch	None (3)	39±17	16±4	28±5
	Slight (5)	95±39	13±2	40±11
	Moderate (4)	160±72	26±6	32±8
	F	1.21	2.54	0.45
	P	0.34	0.13	0.65

Research Institute, unpubl. data). In addition, pruning, sapping, and other wounds caused by careless thinning activities may also cause color defects in stem wood (Nevalainen 2006, Schatz et al. 2008). Hallaksela and Niemistö (1998) showed that planted silver birch trees may easily have stem discoloration from dead and broken branches, and that discoloration was connected with microbial invasion in 83% of their sample birch trees. We did not determine the microbes associated with damage, but different *basidiomycotina* and stain fungi species have been isolated in moose-damaged birch trees (Heikkilä et al. 1993).

It is evident that moose damage will lower the external and internal quality of birch trees. Thus, preventive measures may be required depending on the level of moose browsing and the desired timber product, and whether a forest-owner wants to ensure high quality birch trees at harvest. Various chemical repellents, visual and acoustic devices, and tree sheltering methods and devices have all been used to prevent moose damage in seedling and sapling birch stands. These methods are rather expensive, their effects are variable, and in many cases they have shown little promise for reducing moose damage on a large-scale or long-term basis. Thus, development of cost-effective mechanical and/or chemical preventive methods is still needed to reduce the risk of moose damage in young birch stands. Lower moose density may be the most cost-effective approach to reduce damage caused by moose, however, various moose-interest groups often have conflicting values and goals with respect to an ideal moose population density (Aarnio et al. 2008). We suggest that moderate moose population densities would provide for both sustainable and profitable forestry producing high-quality timber, as well as socio-economically acceptable management of moose.

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