CHARACTERISTICS OF DAMAGES IN NORWAY SPRUCE STANDS

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Abstract

Norway spruce (*Picea abies* (L.) Karst.) is economically important tree species, vulnerable to impact of different biotoc (cervids, bark beetle etc.) and abiotic (wind, wet snow etc.) factors and their combinations, expected to increase in frequency and/or magnitude in future due to climate changes. The aim of the study was to characterize occurrence damages in Norway spruce stands in Latvia. Data from 635 National forest inventory sample plots were used in the analysis, thus providing the information primarily on the non-lethal damages, since the dead trees in most of the cases would be removed from the stands in sanitary cuts. Damages were reported for $11.6 \pm 1.1\%$ of spruces from total basal area of spruces in the assessed pure and mixed stands. Admixture of other tree species or soil (group of forest types) had no significant effect on the proportion of damaged spruces. Also, no statistically significant differences in dimensions were observed between damaged and undamaged trees. The major cause of damages was browsing (three quarter of damaged spruces, in contrast to only one-quarter of the rest of the trees) and the highest proportion of damaged spruces were in stands in the age group 41 – 80 years, significantly differing from that in younger (up to 20 years) stands, demonstrating both the preferences of cervids to a certain dimensions of spruce as well as accumulation of damages over time.

Key words: browsing damages, wind damages, admixture, mixed stands.

Introduction

Increase of the increment of Norway spruce (Picea abies (L.) Karst.) has been found in different countries, explained both by climate change (Pretzsch *et al.*, 2014) as well as improved silvicultural practice. For example, Jansons et al. (2016a) found a rather long-lasting positive influence of initial fertilization to growth (radial increment) of Norway spruce. Nevertheless, following changes in climate might have unclear influence on trees both due to primary factors – limits of phenotypic plasticity to adapt in so rapidly changing climatic conditions (Schmidt-Vogt 1977) – as well as secondary factors, for example, improved conditions for spruce bark beetle, thus higher pressure to Norway spruce stands. Currently the major factors - climatic factors affecting the growth of trees had been analyzed and compared between tree species both in Latvia (Jansons *et al.*, 2016b) and elsewhere. However, the influence of specific climatic factors may shift over time (Jansons *et al.*, 2015b) due to climatic changes and such shifts are unpredictable without the specific studies. Also, the damages currently observed very seldom may appear in future climatic conditions e.g. drought crack (Zeltins *et al.*, 2016). Such damages might be linked to the growth of trees, however, their impact at least to some extent might be modified by selection of the right (most appropriate) genotypes. Finding productive and robust provenances for a particular area is in the aims of genetic adaptation of forestry to climatic changes (Keskitalo *et al.*, 2016; Rieksts-Riekstins *et al.*, 2014). Tree breeding has been long practiced for different species (Jansons,

Gailis, Donis, 2011), including Norway spruce, and the potential impact of climatic changes is considered in current tree breeding programs to an extent possible to still retain the activity financially viable (Jansons *et al.*, 2015a). Assessment of genotype x environment interaction (its scale, impact) is a key element in this approach (Jansons, 2008). Even so the Norway spruce regenerates surprisingly well also naturally not only in gaps, but also in larger-scale openings created e.g. by storm (Baders *et al.*, 2017a) or clear cutting, and is capable of dominating the areas to a large extent after a longer period of time (c.a. 40 years), still it is mainly planted. Frequent planting with Norway spruce, predominately by the plants grown from seed orchard seeds, suggests a possibility to enhance adaptability via tree improvement, and thus limit the potential risks for investments (Haapanen *et al.*, 2015; Dzerina *et al.*, 2016). Overall, the genetic gain of around 10% for volume increment by selecting a seed source can be achieved (Jansson *et al.*, 2013) increasing the above-ground biomass (Lībiete-Zālīte & Jansons, 2011; Lībiete *et al.*, 2017). Considering the above-mentioned, adding a transferred seed lots can be a tool to enhance adaptability (Lindner *et al.*, 2008).

Major factors causing damages in forests across Europe are fires, wind storms and bark beetles. Their impact is expected to increase in future (Seidl *et al.*, 2014). It may affect the tree species composition as well as cause notable economic losses. Norway spruce is vulnerable to all of these factors. Occurrence and severity of forest fires are affected by movements of

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large air masses (Kitenberga *et al.*, 2018) influenced by climatic changes. The major impact of drought conditions during summer on the occurrence of fires has been detected, but also other climatic variables have some influence. The actual cause of the fires currently can be linked to human activity, in the same way as the size of the fires (Donis *et al.*, 2017). Wind-storms have become increasingly more common during recent decades, causing significant damages for forestry as well as other sectors. Norway spruce has a shallow root system and therefore is not very wind-resistant, thus the ways to increase stability of the stands (for example, via different spacing, minimization of other damages e.g. root rot, different thinning regime) have been suggested. Bark beetle is often a secondary factor, affecting the spruces that have not been broken or uprooted by wind, but only damaged to some extent (weakened). Also, the conditions

of this dendrophagous insect have been improving e.g. the years, when it can form more than one generation per year have become increasingly more common (Šmits, personal communication). During the peak of its population density, it may affect also rather healthy spruce stands. Additionally, browsing damages may be an important factor affecting spruces. State forest service data suggests that population densities of cervids have almost doubled from the mid 1990th until now. Also, the monitoring of browsing damages demonstrates that the problem is significant. Browsing damage may cause a rot of the stem, deteriorating its economic value and potentially reducing the risk of wind damages. In order to understand the relative importance of the above-mentioned problem, the aim of the study was to characterize occurrence damages in Norway spruce stands in Latvia.

Table 1

MSI sample plots stands characteristics

Soil	Parameter	Mixed stands				Pure stands			
		A, years	D, cm	H, m	G, m² ha⁻¹	A, years	D, cm	H, m	G, m² ha⁻¹
Dry Mineral Soil	Mean	62.3	25.4	22.0	27.9	47.3	20.6	18.1	23.2
	StdDev	24.3	7.6	5.6	10.2	26.9	10.1	7.5	11.7
	Min	13	4.2	3.8	4.0	10	2.2	2.7	0.4
	Max	117	45.0	31.6	52.4	163	64.8	36.3	58.0
	Count	125	125	125	125	169	169	169	169
Wet Mineral Soil	Mean	67.5	24.6	20.7	26.9	42.0	16.9	15.2	20.8
	StdDev	29.9	7.0	4.8	9.2	22.9	7.1	5.9	11.5
	Min	13	4.0	3.6	1.3	12	3.3	2.9	0.3
	Max	171	40.2	31.7	44.6	170	47.8	28.6	44.7
	Count	114	114	114	114	147	147	147	147
Peat Soil	Mean	66.0	23.5	20.7	28.0	44.3	18.5	15.9	21.6
	StdDev	23.8	6.1	4.6	7.6	25.9	8.8	6.3	10.4
	Min	19	7.4	9.1	11.1	20	4.5	4.7	2.1
	Max	126	35.3	27.8	40.9	158	37.0	27.3	40.7
	Count	36	36	36	36	44	44	44	44

A – stand age, D – diameter at breast height, H – height, G – basel area.

Figure 1. Distribution of sampling plots in the territory of Latvia.

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Materials and Methods

Data from 635 sample plots of National Forest Inventory (NFI) (obtained in the years 2004 – 2009) sampling network (evenly distributed across the territory of Latvia (Fig. 1)) with spruce as dominant species in the first layer were analysed. Sample plots were not divided into distinct sectors suggesting that each sample plot was located within one stand. Pure stands (PS) were defined as stands, where at least 75% of the first layer trees were spruce; remaining stands where classified as mixed (MS). In total, 360 and 275 PS and MS were distinguished, respectively. In all stands the proportion of species was calculated according to the volume. However, the total count of trees was used for stands where the height or mean quadratic DBH of trees with mean quadratic DBH was below 12 m and 10 cm, respectively. According to soil types, PS were subdivided into another three distinct groups such as PS on dry mineral soils (DM), PS on waterlogged mineral soils (WM) and PS on peat soils (PT). The distribution of sample plots is representative (Table 1) allowing appropriate analysis of damages in spruce stands in Latvia.

Stands were divided into seven age groups with a step of 20 years (1-20; 21-40; 41-60; 61-80; 81-100; 101-120; above 121) to analyse the effect of age on the proportion of damaged trees. According to methodology of the NFI, damages were distinguished in distinct groups in respect to cause – 1 (wind tipping, wind breakage, snow breakage, snow bend), 2 (water logging), 3 (animal damage), 4 (fire), 5 (diseases), 6 (pests) and 7 (other). According to methodology of the NFI, damages found for live trees only were evaluated. Therefore, the potential cause of decline of dead trees found in sample plots was not determined. Damages from groups 1, 3 and 7 were analysed separately from the rest since the types of damages from other groups were notably less frequent in PS. However, to characterise the general resilience of forest stands, all types of damages were analysed together (Table 2). Data were prepared in MS Excel prior the analysis with SPSS for Windows with tools of linear mixed models.

Results and Discussion

Results show 10.4% damaged trees in total and 11.6% from all spruces. One third of all damaged trees had animal damages; however, this cause of damage for spruce was found for three quarters (Table 2).

In the stand level of PS, the mean proportion and mean basal area of damaged trees is $10.0 \pm 1.0\%$ and $10.4 \pm 1.0\%$, respectively. Nevertheless, for spruces these parameters reach $11.3 \pm 1.2\%$ and $11.6 \pm 1.1\%$, respectively. No statistically significant differences were found between the proportion of total count and basal area suggesting similar dimensions of both. Also, tree DBH/height ratio between damaged and undamaged trees did not differ significantly (Table 3). Considering that, only basal area was used in further analysis to characterize damages in PS.

Estimated marginal means of basal area in MS and PS is $9.0 \pm 1.3\%$ and $9.4 \pm 1.4\%$, respectively, from total basal area (Table 4). However, estimated marginal means of basal area of damaged spruces calculated from the total basal area of spruces is $10.4 \pm 1.5\%$ and $10.4 \pm 1.5\%$ in MS and PS, respectively. In DM the highest proportion of estimated marginal means of basal area of both all damaged trees ($10.9 \pm 1.0\%$) and damaged spruces ($11.5 \pm 1.2\%$) was observed. Lower values of this parameter were observed in WM ($8.4 \pm 1.2\%$ and $8.9 \pm 1.4\%$, respectively) and PT ($8.4 \pm 2.3\%$ and $9.4 \pm 2.8\%$, respectively).

Table 2

The count of trees according to the type of damages

Damages	All species			Spruce		
	count	proportion of all, %	proportion of damage, %	count	proportion of all, %	proportion of damage, %
Undamaged	17164	89.6	-	13162	88.4	-
Wind and Snow	175	0.9	8.8	132	0.9	7.7
Water logging	2	0.0	0.1	2	0.0	0.1
Animals	1324	6.9	66.5	1288	8.7	74.8
Fire	3	0.0	0.2	0	0.0	0.0
Diseases	93	0.5	4.7	30	0.2	1.7
Pests	78	0.4	3.9	57	0.4	3.3
Other	316	1.6	15.9	213	1.4	12.4
Damage Total	1991	10.4	100.0	1722	11.6	100.0
Grand Total	19155	100.0	-	14884	100.0	-

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Table 3

Differences in DBH and height between damaged and undamaged trees in PS

Species	Tree parameter	Damages	Mean	StdDev	Confidence α=0.05	Count	Countif >1.00
All	Diameter	All	1.014	0.343	0.031	469	232
		Wind and Snow	0.909	0.418	0.080	104	38
		Animals	0.980	0.304	0.032	349	164
		Forestry	1.015	0.432	0.061	190	81
	Height	All	0.996	0.229	0.021	469	245
		Wind and Snow	0.926	0.289	0.056	104	49
		Animals	0.973	0.214	0.022	349	172
		Forestry	1.010	0.302	0.043	190	97
Spruce	Diameter	All	1.010	0.329	0.031	438	225
		Wind and Snow	1.001	0.474	0.102	83	38
		Animals	0.990	0.297	0.032	340	163
		Forestry	0.987	0.372	0.061	143	61
	Height	All	1.005	0.247	0.023	438	238
		Wind and Snow	0.960	0.292	0.063	83	44
		Animals	0.978	0.210	0.022	340	170
		Forestry	0.974	0.295	0.048	143	72

Table 4

Estimated Marginal Means

Species	Variable	All damages		Wind and Snow		Animals		Other	
		Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
All species	Total	0.092	0.010	0.008	0.003	0.008	0.000	0.020	0.004
	DryMinSoils	0.109	0.010	0.007	0.004	0.059	0.008	0.020	0.004
	PeatSoils	0.084	0.023	0.006	0.008	0.046	0.018	0.019	0.009
	WetMinSoils	0.084	0.012	0.011	0.004	0.039	0.009	0.020	0.005
	Mixed	0.090	0.013	0.010	0.004	0.041	0.010	0.018	0.005
	Pure	0.094	0.014	0.006	0.005	0.054	0.011	0.021	0.005
	AgeGroup1	0.013	0.032	0.000	0.011	0.013	0.025	0.000	0.012
	AgeGroup2	0.074	0.011	0.008	0.004	0.047	0.009	0.011	0.004
	AgeGroup3	0.148	0.013	0.013	0.004	0.098	0.010	0.020	0.005
	AgeGroup4	0.131	0.013	0.005	0.004	0.084	0.010	0.026	0.005
	AgeGroup5	0.112	0.025	0.021	0.008	0.033	0.019	0.033	0.009
	AgeGroup6	0.091	0.033	0.009	0.011	0.036	0.026	0.010	0.012
	AgeGroup7	0.070	0.039	0.000	0.013	0.018	0.031	0.042	0.015
Spruce	Total	0.099	0.011	0.009	0.004	0.060	0.009	0.019	0.004
	DryMinSoils	0.115	0.012	0.009	0.004	0.068	0.010	0.020	0.005
	PeatSoils	0.094	0.028	0.007	0.010	0.063	0.023	0.018	0.010
	WetMinSoils	0.089	0.014	0.012	0.005	0.050	0.012	0.018	0.005
	Mixed	0.104	0.015	0.014	0.005	0.059	0.013	0.018	0.006
	Pure	0.094	0.017	0.005	0.006	0.061	0.014	0.019	0.006
	AgeGroup1	0.001	0.039	0.000	0.014	0.001	0.032	0.000	0.014
	AgeGroup2	0.081	0.013	0.010	0.005	0.060	0.011	0.010	0.005
Spruce	AgeGroup3	0.173	0.015	0.014	0.005	0.127	0.013	0.020	0.006
	AgeGroup4	0.148	0.016	0.006	0.006	0.112	0.013	0.023	0.006
	AgeGroup5	0.125	0.029	0.023	0.010	0.048	0.024	0.030	0.011
	AgeGroup6	0.084	0.039	0.010	0.014	0.047	0.032	0.007	0.014
	AgeGroup7	0.077	0.046	0.000	0.016	0.019	0.038	0.046	0.017

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Table 5

Type III Tests of Fixed Effects

Damages	Source	All species				Spruce			
		Nume-rator df	Denomi-nator df	F	Sig.	Nume-rator df	Denomi-nator df	F	Sig.
All	Intercept	1	594	85.818	0.000	1	594	70.148	0.000
	Soil	2	594	0.471	0.625	2	594	0.287	0.750
	Stand	1	594	0.220	0.639	1	594	0.020	0.888
	Age	6	594	5.368	0.000	6	594	5.961	0.000
	Soil*Stand	2	594	0.321	0.725	2	594	1.490	0.226
	Soil*Age	12	594	0.714	0.738	12	594	0.998	0.449
	Stand*Age	6	594	1.243	0.283	6	594	0.616	0.718
	Soil*Stand*Age	11	594	0.752	0.689	11	594	0.626	0.807
Wind and Snow	Intercept	1	594	6.052	0.014	1	594	5.071	0.025
	Soil	2	594	0.238	0.788	2	594	0.199	0.820
	Stand	1	594	0.394	0.531	1	594	0.971	0.325
	Age	6	594	0.800	0.570	6	594	0.593	0.736
	Soil*Stand	2	594	0.637	0.529	2	594	0.584	0.558
	Soil*Age	12	594	0.741	0.711	12	594	0.660	0.790
	Stand*Age	6	594	0.060	0.999	6	594	0.150	0.989
	Soil*Stand*Age	11	594	0.661	0.776	11	594	0.685	0.753
Animals	Intercept	1	594	37.052	0.000	1	594	37.779	0.000
	Soil	2	594	0.603	0.547	2	594	0.288	0.750
	Stand	1	594	1.116	0.291	1	594	0.134	0.714
	Age	6	594	4.890	0.000	6	594	5.883	0.000
	Soil*Stand	2	594	0.141	0.869	2	594	0.262	0.769
	Soil*Age	12	594	0.811	0.639	12	594	1.056	0.396
	Stand*Age	6	594	0.722	0.632	6	594	0.418	0.868
	Soil*Stand*Age	11	594	0.648	0.787	11	594	0.708	0.732
Forestry	Intercept	1	594	27.313	0.000	1	594	19.123	0.000
	Soil	2	594	0.048	0.953	2	594	0.002	0.998
	Stand	1	594	0.590	0.443	1	594	0.188	0.665
	Age	6	594	1.984	0.066	6	594	1.397	0.213
	Soil*Stand	2	594	0.140	0.870	2	594	0.380	0.684
	Soil*Age	12	594	0.863	0.585	12	594	1.027	0.422
	Stand*Age	6	594	1.003	0.422	6	594	0.628	0.708
	Soil*Stand*Age	11	594	0.550	0.869	11	594	0.579	0.847

The composition and soil type of stand did not have statistically significant influence on proportion of all damages of both all trees and spruces. Also, the frequency of distinct damage types was not affected significantly (Table 5). Significant effect on the proportion of both all damaged trees and animal damaged trees was observed for the stand age of I layer spruces. However, for both all trees and spruces

no significant effect of the rest of groups of damages was observed (Table 5).

The proportion of both all trees and spruces in middle-aged (41 – 80 years old) stands is significantly higher than in younger stands. More pronounced relations were observed for animal damages (Fig. 2)

Browsing damages to some extent might be linked to branch traits, affected also by genetics

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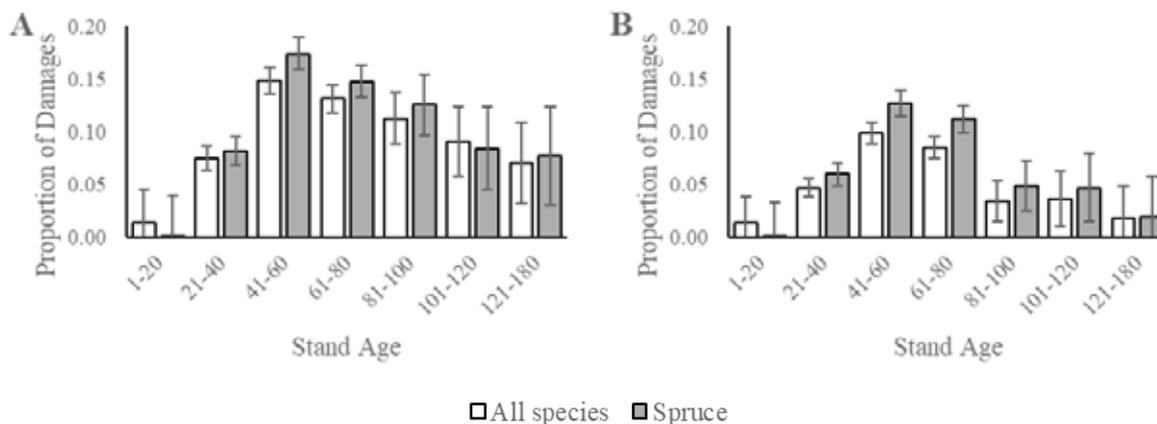CHARACTERISTICS OF DAMAGES
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Figure 1. The proportion of basal area of damaged trees in relation to the age group.
All damages (A), animal damages (B).

(Baders *et al.*, 2017b; Jansons *et al.*, 2006), but are primarily influenced by population densities of cervids. Moreover, they tend to accumulate over time, since the healing-over of a browsing scare takes a long time.

All age classes of all damaged trees and spruces, all damages and animal damages can be distinguished in two statistically significantly different groups–stands till age of 40 years and stands above 80 years.

Conclusions
1. The mean basal area of damaged trees is $10.4 \pm 1.0\%$ from the total basal area of stand. However, the basal area of damaged spruces is $11.6 \pm 1.1\%$ from the total basal area of spruces.
2. No statistically significant differences in dimensions between damaged and undamaged trees were observed. The proportion of damaged trees does not differ significantly between both PS and MS, and soil types.
3. Spruce is prone to browsing damages: one third of all damaged trees had animal damages; however, this cause of damage for spruce was found for three quarters. This is the major cause of damage that does not kill the tree; thus, its occurrence in the analyzed sample is not affected by the sanitary cuttings (salvage logging).
4. The highest proportion of damaged trees is in stands between the years 41 – 80, which is statistically significantly higher compared that with up to 20- year old stands.

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