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SANITARY STATE OF NATURALLY AND ARTIFICIALLY REGENERATED *PICEA ABIES* (L.) H.KARST YOUNG STANDS IN *OXALIDOSA*

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Abstract
In Latvia, *P.abies* (L.) H. Karst stands occupy about 18% of the total forest area (3.01 million) forming pure and mixed stands. Regardless of the main goals, productivity of the future forest stands must be preserved; therefore, it is very important for forest management to identify risk factors. *P.abies* often suffers from various risk factors. The aim of the research was – to assess the sanitary state of *Picea abies* (L.) H. Karst in *Oxalidosa,* where the area of forest stands has been restored both anthropogenically and naturally. Selected young stands are located in Limbazi district of Latvia. Empirical data was collected in 5 spruce stands with the total area of 9.2 ha in *Oxalidosa*. In total, 67 sample plots were installed with radius of 3.99 m, measuring 799 trees. Diameter was measured for all trees in the sample plot. For sanitary state of *P.abies* young stands characterization damage caused by biotic factors was assessed visually after four-point scale: health tree (0), minor damage to 25% (1), moderately damaged 26 – 50% (2), severely damaged or dried – from 51% (3). Damage caused by *P.abietina* and browsing was found in several stands, while damage produced by *P.abietina* larvae was detected only in one pure stand. Occurrence of browsing damage is 10 – 28%, while damage intensity – 7.7 – 21.8%. There are significant differences between occurrence of browsing damage (p=0.001) and also between damaged tree damage intensity (p=0.003). Nature of browsing damage depends on the size of pure and mixed stand area, the location in forest massif and adjoining territory.
Key words: pure, mixed stand, *Pristiphora abietina, Betula* spp., browsing.

Introduction

P.abies is a tree species who has entered the territory of Latvia from the east side and in this part it has always been more widespread. Even in the most favorable periods of growth, *P.abies* occurrence in the western part of the country was small, not exceeding a quarter or fifth of the total forest area (Prieditis, 1999). Spruce is shade tolerant and wind fragile species which also suffers from many pests (Miezite *et al.*, 2017). In investigated stands larvae damage of little spruce sawfly *Pristiphora abietina* Christ was detected, gnawing the young shoots of spruce needles, as a result shoots wither (Ozols, 1985; Miezite, 2015). Spruce suffers from insects, but the needles and even shoots - from late spring frosts. *P.abies* grows in slightly acidic sandy clay soils. It suffers from prolonged soil drought, is not resistant to pests and diseases, especially suffering from root rot (Miezite *et al.*, 2013; Ruba, Miezīte, & Luguza, 2014; Žemaitis & Stakenas, 2016). In future the availability of water, which is a significant parameter of tree growth, will become increasingly more critical with longer and more frequent drought periods (Leuschner, 2009; Allen *et al.*, 2010). Czech scientists have found that over the past two decades there has been a massive decline of spruce stands, which is expressed as yellowing, defoliation and tree death at all stages of the age. Occurrence of damage of various risk factors in *P.abies* stands, possibly, unsatisfactory state of forest soils due to past pollution, precipitation and high temperatures in the growing season associated with global climate change (Nilsson *et al.*, 2010; Jansons *et al.*, 2016; Zeltiņš *et al.*, 2016). Many authors have studied spruce ability to adapt to climate change (Kapeller *et al.*, 2012; *Nilsson, Elfving, & Karlsson,* 2012; Ulbrichová *et al.*, 2015), but the level of knowledge about the potential for adaptation of spruce stands is still not sufficient.

In Latvia, spruce stands occupy about 18% of the total forest area (3.01 million) forming pure and mixed stands, mainly with pine (*Pinus sylvestris* L.), birch (*Betula* spp.) and aspen (*Populus tremula* L.) (State Forest Service, 2016). The economic significance is very high, although the mechanical properties of wood are smaller than *P. sylvestris*. *P.abies* is used in greenery in rural areas, it is also suitable for high hedges. Spruce bark is used for tanning, while the essential oils are obtained from the needles as well as manufacturing medical preparations, vitamin-based pastes and needle flour for animal feed (Maurins & Zvirgzds, 2006). Well aerated, clay and acidic soil is optimal for spruce growth, and on such soil forest stands with site index I and Ia are formed (Zalitis, 2008). Forests on normally wet mineral soil grow in well aerated mineral soil (Liepa, 2003). The soil is rich, typical podzolic or soddy podzolic, loamy soil, sandy loam, less clay or fine sand; also, brown soilin, which takes place in intense circulation of substances occurs. In *Oxalidosa, P.abies* pure and mixed stands with the site index I and Ia (Liepa, 2003) grow. Therefore, the aim of the research was to assess the sanitary state of *Picea abies* (L.) H. Karst in *Oxalidosa,* where the area of forest stands has been restored both artificially (in pure stands) and naturally (in spruce stands with birch admixture 20 – 40%).

Table 1

Young stands of *Picea abies* in *Oxalidosa* (Vr)

Block/parcel	Coordinates	Type of regeneration	Tree species composition and age	Area, ha	Number of sample plot in parcel
55/5	X 540038.50; Y 6378420.00	artificial	10E8	0.8	7
40/4	X 532702.01; Y 3877730.02	artificial	10E8	4.5	32
397/2	X 551313.10; Y 6374378.91	natural	8E2B11	1.0	7
845/3	X 536158.32; Y 6363814.22	natural	7E3B11	2.0	14
636/22	X 543160.82; Y 6362868.31	natural	6E4B11	0.9	7

Legend: E – *P.abies*; B – *Betula* spp.

Materials and Methods

Selected young stands are located in Limbazi district of Latvia. The empirical data was collected, measured and analyzed in 5 spruce stands with a total area of 9.2 hectares in *Oxalidosa* (hereinafter Vr) (Table 1). Both 8-year-old spruce pure stands were regenerated anthropogenically, while three 11-year-old spruce stands with birch admixture were regenerated from spruce regrowth and birch sprouts (Table 1). Tree height measurements were made using 5 m long lath (accuracy 1 cm); electronic caliper – for the tree diameter at 1.3 m above the root collar measuring (accuracy 0.1 mm). Sample plots (hereinafter SP) with a radius of 3.99 m (area of 50 m^2) were established. In each forest stand SP was placed on the longest diagonal of the area. In total 67 SP were installed. Diameter measurements were made for all trees in SP, as well as the sanitary state for total of 799 trees was evaluated. In each forest plot total height of 30 trees was measured for calculating the average height of the stand.

Cadastral map and stand description were obtained from National Forest Service program ArcPad, with the help of this program in the researched spruce young stands SP distances and coordinates of each parcel were determined.

There was a little undegrowth in all investigated *P.abies* young stands. In undergrowth the following species were found: *European mountain-ash* (*Sorbus aucuparia* L.), European hazelnut (*Corylus avellana* L.) and bird cherry (*Padus avium* Mill.). In turn, in ground vegetation: bracken fern (*Pteridium aquilium* (L.) Kuhn), wood anemone (*Anemone nemorosa* L.), wood sorrel (*Oxalis acetosella* L.), may-lily (*Maianthenum bifolium* (L.) F.W. Schmidt), wood *horsetail* (*Equisetum sylvaticum* L.) and others (Bušs, 1981).

For sanitary state of *P.abies* young stands characterization damage caused by biotic factors was assessed visually after four-point scale: health tree (0), minor damage to 25% (1), moderately damaged 26 – 50% (2), severely damaged or dried – from 51% (3).

Dendrometric indicators for sanitary state characterization in *Oxalidosa* were calculated using formulas 1 – 3. The number of trees per hectare (*N*, pieces ha^{-1}) was calculated according to formula 1:

$$N = \frac{N_p}{L} . 100 , \quad (1)$$

where *Np* – the number of trees in the current sample plot (pcs.) and *L* – area of current sample plot (m^2). Damage occurrence (P, %) was calculated using formula 2:

$$P = \frac{n . 100}{N} , \quad (2)$$

Where *P* – occurrence of damaged trees (%), *n* – the number of damaged trees (pcs. ha^{-1}). Damaged tree damage intensity was calculated according to formula 3:

$$R = \frac{\sum_{i=1}^{4} n_i . b_i}{N . k} . 100 , \quad (3)$$

where *R* – damaged tree damage intensity (%), n_i – the number of damaged trees (pcs. ha^{-1}), b_i – damage degree (points), *N* – total number of listed trees (pcs. ha^{-1}) and *k* – the highest degree of damage (points) (Miezite *et al.*, 2013; Ruba *et al.*, 2013).

Regression and dispersion analysis was used for sanitary state and tree damage significance evaluation. Standard error of average values was determined (± SE) (Arhipova & Bāliņa, 2003).

Results and Discussion

Sanitary state of forests stands affects not only location in the forest massif (Ruba, Miezīte, & Luguza, 2014), but also dendrometric indicators such as average tree diameter, height, stands thickness etc. The average diameter of tree (1.9 ± 0.13 cm) in 8-year-old artificially regenerated pure stand 40/4 with the largest number of trees per hectare (3100 ± 155 pieces ha^{-1}) is lower than in the stand 55/5 with a smaller number of

Table 2

Dendrometric indicators of *Picea abies* young stands in *Oxalidosa*

Block/parcel	Tree species composition and age	$D_{vid.}$ ± SE, cm	$H_{vid.}$ ± SE, m	N ± SE, pcs. ha^{-1}
55/5	$10E_8$	2.1 ± 0.09	2.9 ± 0.08	3100 ± 155
40/4	$10E_8$	1.9 ± 0.13	3.0 ± 0.13	2620 ± 131
397/2	$8E2B_{11}$	3.2 ± 0.22	3.1 ± 0.14	4200 ± 210
845/3	$7E3B_{11}$	3.1 ± 0.12	3.1 ± 0.11	3760 ± 188
636/22	$6E4B_{11}$	3.1 ± 0.09	3.1 ± 0.10	2470 ± 124

Legend: Dvid. ± SE – average tree diameter, cm; SE – standard error; Hvid. – average tree height, m; N ± SE – number of trees or stand thickness, pcs. ha^{-1}.

trees per ha (2.1 ± 0.09 cm), while the average height of tree is upside down (table 2). It shows that pure stand 55/5 has a large thickness because of which trees have begun to spindle, also affecting the size of crown thus reducing resistance to abiotic factors (Peltola, Nykänen, & Kellomäki, 1997) in Latvia, especially against the wind damage (Jansons, 2015).

The average tree diameter in naturally regenerated 11-year-old mixed stand of spruce is larger (3.2 ± 0.22 cm) with the highest stand thickness (4200 ± 210 pcs. ha^{-1}) and smallest birch admixture (20%), but slightly smaller in young stands with larger birch admixture of 30% and 40% (Table 2). Thus, increasing admixture of birch in spruce stands, the average tree diameter and height will decrease; also Zālītis (2008) in his studies has found that admixture affects the productivity of dominant species. Average tree diameter and height reduction between mixed stands is not significant ($p>0.05$) at the given age in young stands of spruce with a birch admixture of 20 – 40%.

In the researched stands damage caused by biotic factors (insects and browsing) was detected (Fig.1). From insects – only larvae damage of small spruce fly (*P.abietina*) was found only in 8-year-old pure stand of spruce (40/4) on the southern and southeastern side in the upper part of tree crowns. In this stand by small spruce fly damaged tree damage intensity was 2.2%, and damaged trees looked like burnt. In other studies damage was detected only on the southern side (Holonec, Cherechesiu, & Tăut, 2004; Miezīte, Dubrovskis, & Ruba, 2017). 8-year-old pure spruce stand (40/4) on the north side is surrounded by seasoning mixed birch stand in *Oxalidosa*, from the northeast – mature mixed spruce stand in *Hylocomiosa*, from the east – mature birch mixed stand in *Myrtilloso-polytrichosa*; respectively, from the southeast – seasoning birch stand and on the south side – mature birch stand, both in *Oxalidosa*.

West winds are prevailing in Latvia, consequently young spruce stand 40/4 is placed on the side of shelter, what according to Holonec, Cherechesiu & Tăut(2004), contributes to spread of *P.abietina* damage (Miezīte, Dubrovskis, & Ruba, 2017).

Damage caused by browsing was detected in all investigated spruce young stands (Fig. 1). The smallest browsing damage was detected in the mixed spruce

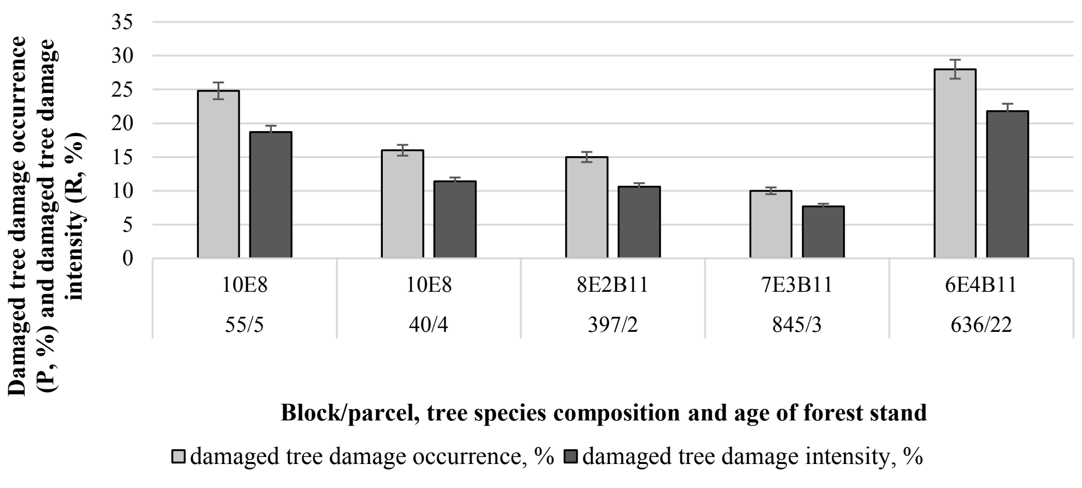

Figure 1. Occurrence of browsing damage (P,%) and damaged tree damage intensity (R,%) in pure and mixed *P.abies* stands.

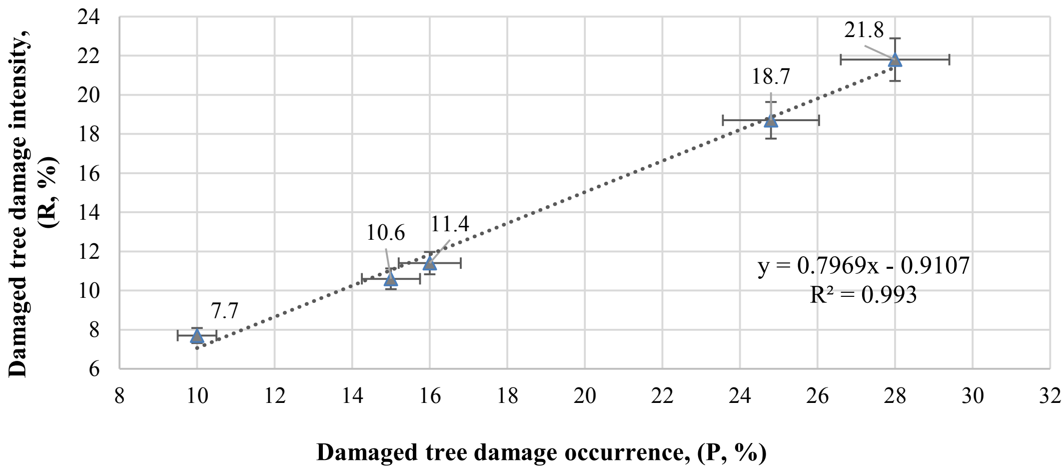

Figure 2. Relationship between the damaged tree damage occurrence and damaged tree damage intensity in the investigated *P.abies* young stands.

stand 845/3 (birch admixture 30%) unlike other pure and mixed spruce stands. Mixed stand 845/3 from the north is surrounded by agricultural land that is not sown with winter crops, and therefore does not attract browsing, while from the east – middle-aged mixed birch stand in *Myrtillosa turf. mel.*, from the south – declining mixed black alder stand in *Oxalidosa turf mel.*, from the southeast -declining mixed spruce stand in *Myrtillosa mel.*, from the northwest – declining mixed aspen stand in *Oxalidosa*.

In turn, more significant damage was detected in forest stands with a smaller area: in 8-year-old pure spruce stand (55/5) and 11-year-old mixed spruce stand with birch admixture (636/22). In this mixed stand (admixture 40%) the highest occurrence of damaged trees is 28.0% and damaged tree damage intensity – 21.8%. This is due to the location of parcel in the forest massif, because there is an agricultural arable land on the southern part of the stand. In contrast, there are no significant differences between forest stands 40/4 and 397/2 (damage occurrence 16.0% and 15.0%, damage intensity 11.4% and 10.6%). From this it can be concluded that occurrence of browsing damage depends on the size of forest area,the adjoining territory and its location in the forest massif, which coincides with the results of other scientists' researches (Bušs, 1981; Chen, 1999), although it is unambiguous to evaluate the significance of the side effect in forest ecosystem is very complicated (Harper *et al.*, 2005; Pētersons *et al.*, 2009).

There is a significant difference between occurrence of browsing damage in investigated young stands ($p=0.001$) and also between damaged tree damage intensity ($p=0.003$).

After applying regression analysis (Fig. 2) it can be concluded that the determination coefficient $R^2=0.993$ and the correlation coefficient $|r|=0.996$ indicate a close linear correlation between the damaged tree damage occurrence and damaged tree damage intensity in the researched spruce stands ($p=0.00025$). The linear regression equation is $y=0.7969x-0.9107$, respectively, the coefficient of confidence is $0.67<0.91$ ($\alpha=0.05$). Since the zero value does not belong to the confidence interval, we can reject the zero hypothesis and assume that there are significant differences ($\alpha=0.05$) between the intensity of browsing damage in the studied young spruce stands.

In pure (55/5) and mixed (397/2; 845/3) spruce stands it is necessary to do thinning. It contributes to the development of forest stands, because cutting off unpromising and damaged trees, healthy trees can take up larger soil area and get more nutrients. The thinning should be performed timely; otherwise, it may affect the growth of tree, despite the fact that spruce is a shade tolerant species.

Conclusions

1. Damage caused by insects and browsing was detected both in pure and mixed stands of *Picea abies* (L.) H. Karst.
2. Damage caused by larvae of small spruce fly *(Pristiphora abietina* Christ) occurs in *Picea abies* (L.) H.Karst. stands in the south and south-east side.
3. Nature of browsing damage depends significantly on the area of pure and mixed *Picea abies* (L.) H. Karst. stand, location in the forest massif and adjoining territory ($p<0.05$).

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