BIOTIC AND ANTHROPOGENIC RISK FACTORS IN NORWAY SPRUCE MIXED STANDS MANAGEMENT

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Abstract
Latvia is one of the forest-richest countries in Europe. Very often in young forest stands of spruce admixture of coniferous or deciduous trees are taking place. During the growth trees suffer from influence of different risk factors. Damages in mixed stands depend on chosen mode and intensity of economic activities. Forest management cannot be imagined without creating the infrastructure (roads, ditches, etc.). However, the development of infrastructure may cause an effect of fragmentation and lead to changes in the forest structure. The aim of the research is to analyze influence of forest spatial features on the sanitary state of mixed stands of spruce. In 2011 and 2012 mixed stands of spruce younger than 40 years were investigated in all regions of Latvia. Nineteen stands were measured and surveyed and 80 sample plots were arranged. With the help of Geographical Information System (GIS) data base of the State Forest Service of Latvia the forms of forest plots (regular or irregular), as well as location of neighboring infrastructural objects and location of mixed stands in forests were stated. In unnaturally created regular form plots damages of risk factors usually tend to be larger than in those, which have been created naturally. With the credibility of 95%, linear connection between occurrence of damages caused by browsing and intensity is relevant ($r=0.937 > r_{0.05}=0.575$), as well as occurrence and intensity of damages caused by *Lophophacidium hyperboreum* Lagerb. ($r=0.999 > r_{0.05}=0.575$).
Key words: regular plot form, forest array, spruce, mixed stands, risk factor.

Introduction

Latvia is considered to be one of the richest forest-growing countries in Europe, as forests occupy more than half of the state territory (State Forest Service, 2012a). According to forest monitoring data, total forest area in Latvia is 3497.08 thousand hectares, including 262.58 thousand hectares occupied by young forest stands of spruce (Statistical inventory of Latvian forest resources, 2010). Forest, as any other natural plant community, is usually determined by diversity of species. Forested areas of conifers, where initially only one tree species grows, often mix with other tree species and mixed spruce – deciduous stands develop (Gobakken and Næsset, 2002). The owners of the forest have to take into account that management of such stands will be different from treatment of pure conifer stands. Forest management should be done in a way that doesn't allow worsening of the sanitary state of forest, recognizing influence of risk factors in time.

However, it is not possible to escape from the influence of different risk factors in management of young forest stands. Each year trees are endangered by biotic factors like: insects, diseases, browsing, abiotic – frost, soil moisture, windfalls, snow throws, which influence the forest and stands lose their growth potential or even die (State Forest Service, 2012b). The most common reasons for damages in Latvian forests in 2012 were connected to human activities – 34.2%, insects – 23.0%, browsing – 21.2%, diseases caused by fungi – 11.7% and damages caused by abiotic factors – 7.6% (Statistical inventory of Latvian forest resources, 2012).

According to statistical data, human actions have the largest influence on the environment. Anthropogenic damages or those created by human in mixed stands depends on intensity of economic activities and management regime. Damages can be slightly broken branches of trees or small scratches of trunks, or intermediate cutting that has not been done in time. It happens that trying to increase profitability of the stand, too many trees are cut in a stand, which can leave a negative effect on the future productivity of stand. Manmade objects of infrastructure like roads, rides, drainage ditches, which are integral parts of the forest management, may influence neighboring stands in both ways - positively and negatively. That leads to the change of spatial specifics of the forest, as well as biotic interaction and dynamics of population (Marcantonio et al., 2013). Besides, infrastructural objects created by human cause fragmentation effect (Deldago et al., 2007). By changing the forest structure, also a spatial distribution of trees in mixed stands is changed. Natural (irregular) forest stand forms are replaced by artificial (regular) stand forms. However, using forest ecosystem for different goals, all possible measures should be taken not to worsen the sanitary state of the forests and not to spoil forest structure. To achieve this goal, forests have to be managed according to principles of sustainable forestry.

By surveying the sanitary state in mixed stands, it is possible to avoid the influence of different risk factors and by choosing appropriate management technique, to increase productivity of mixed stands. The aim of the research is to analyze the impact of biotic and anthropogenic risk factors in Norway spruce mixed stands management. To achieve this aim, following tasks are set:

1. to analyze the impact of biotic risk factors on the sanitary state in mixed stands of spruce;

2. to analyze impact of anthropogenic risk factors on sanitary state of spruce.

Materials and Methods

The empirical data were measured in 19 mixed stands of spruce which were not older than 40 years. Collection of data was done two years - 2011 and 2012. In total 80 sample plots were set up. In Norway spruce mixed stands with admixture of birch, pine, oak, ash and gray alder following biotic damage was detected: spruce aphid *Elatobium abietinum* (Walker), spruce bud scale *Physokermes Piceae* Shrnk., little spruce sawfly *Pristiphora abietina* Crist., eastern spruce gall aphis *Sacchiphantes abietis* L., spruce bud moth *Zeiraphera ratzeburgiana* Sax., snow blight *Lophophacidium hyperboreus* Lagerb., spruce needle rust *Chrysomyxa abietis* (Wallr.) Ung., root rot *Heterobasidion annosum* (Fr.) Bref., browsing and abiotic damage like: snow crushes, snow breaks, frost and anthropogenic damages. Characterization of Norway spruce mixed young forests is given in Table 1.

The number of sample plots depends on area of forest plots. Rectangular plots that are located on the

Table 1

Characterization of Norway spruce mixed young forest stands

Research objects	Geographic coordinates (Lat; Lon)	Species composition	Forest site type	$D_{av.}$, cm	$H_{av.}$, m	Number of trees per hectare	Spatial shape
In 2011, 10 mixed young forest stands surveyed							
Jelgava 21/14	56.7318507; 23.7515365	$8E2B_6$	*Mercurialiosa mel.*	1.9	2.5	4100	not regular
Šķēde 9/2	57.2481950; 26.0649684	$8E1B1O_8$	*Oxalidosa*	1.9	2.6	2530	not regular
Šķēde 9/17(1)	4.4863337; 70.43398740	$7E3B_{17}+P_{17}$	*Oxalidosa*	9.1	10.4	1850	regular
Šķēde 19/20	57.2433051; 22.6840973	$8E2O_{23}$	*Hylocomiosa*	12.2	13.1	7800	regular
Šķēde 8/35(3)	57.2616275; 22.7677850	$7E3B_{17}+P_{17}$	*Oxalidosa*	14.7	15.7	3850	regular
Jelgava 187/9	56.7031988; 23.5668003	$9E1B_8$	*Myrtillosa turf. mel.*	3.0	3.0	2330	not regular
Jelgava 50/9	56.8329285; 23.6987532	$6E2Oz1B1P_9$	*Myrtillosa mel.*	3.6	3.4	1460	regular
Viesīte 1/4	56.4212798; 25.2995895	$7E2B1A_8$	*Oxalidosa*	2.7	3.6	5600	not regular
Līvbērze 176/3	56.4212798; 25.2995895	$8E2B_{10}$	*Myrtillosa turf. mel.*	1.8	2.7	5700	regular
Līvbērze 176/6	56.8221322; 23.6815388	$7E3B_9$	*Myrtillosa turf. mel.*	2.5	3.1	3700	regular
In 2012, 9 mixed young forest stands surveyed							
Rēzekne 77/11	56.4325759; 27.3941559	$9E_{14}1P_{14}$	*Hylocomiosa*	4.4	4.1	1050	regular
Rēzekne 74/13	56.4369605; 27.3899869	$8E_82P_8$	*Hylocomiosa*	2.5	2.8	5400	regular
Jelgava 115/9	56.5570359; 23.7085786	$8E_{36}1Ba_{21}1B_{21}$	*Oxalidosa*	12.2	13.9	2370	regular
Šķēde 70/16	57.2274421; 22.8481182	$9E1Oz_6$	*Oxalidosa*	4.6	5.2	5400	regular
Šķēde 8/20	57.2616796; 22.7575702	$9E1B_{11}$	*Oxalidosa*	7.0	6.5	2660	not regular
Šķēde 56/10	57.2382117; 22.8323237	$8E2P_{13}$	*Myrtillosa mel.*	3.1	3.8	3940	regular
Šķēde 57/19	57.2345296; 22.8392492	$6E3P_{27}1B_{21}$	*Hylocomiosa*	9.6	11.0	2620	regular
Jelgava 34/11	56.7224405; 23.7632981	$6E4P_{10}$	*Myrtillosa*	3.9	17.1	7700	regular
Šķēde 65/1	57.2328401; 22.8333715	$9E_{13}1P_{13}$	*Mercurialiosa mel.*	5.1	6.5	3470	regular

* $D_{av.}$ – average tree diameter, $H_{av.}$ – average tree height, number - the stand composition and age, E – *Picea abies* (L.) Karst., B – *Betula pendula* (Roth), A - *Populus tremula* L., P – *Pinus sylvestris* L., Oz - *Quercus robur* L., O - *Fraxinus excelsior* L., Bl - *Salix caprea* L., Ln - *Myrtillosa*, Mr - *Vacciniosa*, Dm – *Hylocomiosa*, Dms - *Myrtilloso-sphagnosa,* Vr - *Oxalidosa,* Vrs - *Myrtilloso- polytrichosa*, As - *Myrtillosa mel.,* Ks - *Myrtillosa turf. mel.,* Ap - *Mercurialiosa mel.*

Table 2

Damage degrees of biotic factors

Damage evaluation	Damage degree
Trees without indications of weakening or growth disturbances	0
Economically insignificant damages or faults (few broken branches, small stem damages)	1
Economically significant damages (trees with one or more small stem damages that do not exceed half of the stem diameter, etc.)	2
Highly damaged (damages of the central shoot of tree, it´s premature die-back; withered, broken top; stem of a tree is bent and cannot take a vertical position; tree with one or more stem damages where scars exceed half of stem diameter; visible resin galls on the whole length of tree stem)	3
Trees died in the current year (needles and leaves are yellow and brown)	4
Dead trees	5

diagonal or along transects, go through only a major density stands and cover the whole area of the forest. All plots were randomly selected, and most of them - were circular. The main indicator for choosing the type of sample plots was the average tree height of the stand. With the average tree height up to 12 m a 50 m^2 sample plots were created with a circle radius of 3.99 m, but in stands with average tree height H ≥ 12.0 m a sample plot of 200 m^2 with a 7.98 m radius were created (Rūba, 2012).

With the electric sliding calliper or simple calliper in sample plot diameter of each tree stem was measured at breast height with accuracy 1 mm, in this work were used. Average tree height was measured for 20-30 trees using measuring instrument VERTEX with accuracy 1 cm. The coordinates of each young growth were determined with a GPS device LKS-92 by transforming geographic coordinates (Rūba, 2012b).

Damages of biotic factors were divided into six damage degrees (Table 2).

To determine the number of trees per hectare, was used the following formula (1):

$$N = \frac{N_p \cdot 10000}{L}, \quad (1)$$

where N - number of trees per hectare after sample plot inventory data, pieces ha^{-1}, N_p - number of trees in the sample plot, pieces and L – area of sample plot, m^2.

Damage occurence proportion was calculated by using formula (2):

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

where P - damage occurrence proportion, %, n - number of damaged trees, pieces ha^{-1} and N - total number of measured trees, pieces ha^{-1}.

Damage intensity was calculated by using formula (3):

$$R = \frac{\sum n_i b_i \cdot 100}{N \cdot k}, \quad (3)$$

where R - damage intensity, %, n_i – number of damaged trees, pieces ha^{-1}, b_i - degree of damage, N - total number of measured trees, pieces ha^{-1} and k - highest degree of damages (points) (Miezīte et al., 2013; Ruba et al., 2013).

To find out how young stands of Norway spruce are influenced by stands next to them, the location of stand in forest array was determined. Forest plot forms were found using the State Forest Service geographic information system (GIS) maps ArcGIS 9.1, 9.2 and 9.3 (Forest State service, 2007). Irregular forest plots were naturally formed, but regular were transformed by a human into triangular or rectangular forest plots. Correlation and regression analyses were used for finding out the relevance between the occurrence and intensity of damages. All mixed stands in this research were artificially restored. To perform data processing, stand heights were divided into 2 groups: 2.5 - 4.0 m and 4.1 m above. Spruce snow blight *Lophophacidium hyperboreus* Lagerb. damage was determined by characteristicl features - brown spots on infected needles, disease develops with colouring needles red-brown, later - tan grey and fall off. Eastern spruce gall aphis *Sacchiphantes abietis* L. was determined by oakgalls (up to 18 cm) on the Norway spruce shoots (ANNILA et al., 2006). Used methodology have already been tested and used in previous publications (Ruba et al., 2013a).

Results and Discussion

The impact of biotic factors on sanitary state of mixed stands of spruce

The most serious damages, due to which clear stands as well as mixed stands suffer from, are those caused by browsing. Insignificant damage is browsing caused by tearing off the bark, in such a way weakening trees, and causing slow down of growth

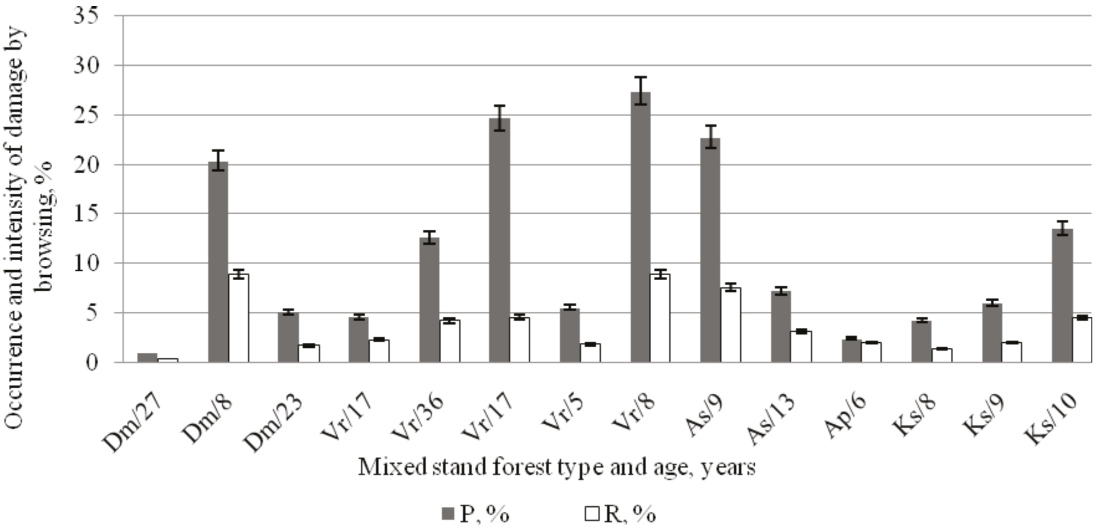

Figure 1. Occurrence and intensity of damages by browsing depending on the forest type and stand age (P – occurrence of damage; R – intensity of damage).

of them. As a result, also a tree increase declines, but more significant damages are caused by moose and red deer in sparse stands, breaking off main shoots of the tree, and as a result of it Norway spruce languish or even perish (Tauriņš, 1982). From 19 mixed stands of Norway spruce chosen randomly, damages of browsing were stated in 14 of them, but there were no such damages in others. Assessing the impact of risk factor of browsing, it was found out that less damage was in the mixed stands which in forest array were placed between two mature stands (Руба, 2012). Low indicators of damage intensity (0.3% – 2.0%) might be explained by the situation in forest array of mixed stands between gravel roads. Browsing repels the sand and dust landed on needles and leaves, hindering the ingestion of nutrients. As to the mostly damaged mixed stands, it has to be stressed, that there are several of them – Rēzekne 74/13, Viesīte 1/4, Jelgava 50/9 and Līvbērze 176/3. The incidence of damages in those stands varies between 4.5 – 9.0% (Fig. 1). Those indicators testify that damages caused are serious and browsing may be considered to be one of the most threatening biotic factors, which influence the sanitary state in researched objects negatively. One of the most damaged mixed stands is located in Rēzekne 74/13, which is 8 years old in *Hylocomiosa* forest type (occurrence of damage – 20.4%, intensity of damage – 9.0%).

The main species in stand is Norway spruce *Picea abies* (L.) Karst. in admixture with Scots pine *Pinus sylvestris* L. (20%). This forest stand is surrounded by middle-aged stands of Scots pine, road and amelioration ditch on the west side. High occurrence indicators of damages caused by browsing were in 8 years old mixed stand in Viesīte 1/4 (occurrence – 27.4%, intensity – 8.9%). The main species is Norway spruce (70%) with the admixture of birch *Betula Pendula* (Roth) and aspen *Populus tremula* L. in *Oxalidosa* forest type. The other damages caused by bud scale *Physokermes Piceae* Shrnk. and leaf beetle *Chrysomelidae* were detected in this stand which is surrounded by a ride, road, *Alnus incana* (L.) Moench maturity and Norway spruce young stands. High occurrence indicators (occurrence – 22.7%, intensity – 7.6%) were in mixed stand Jelgava 50/9. The main species is Norway spruce (60%) in admixture with oak *Fraxinus excelsior* L., birch, Scots pine, which are located on drained soil in *Myrtillosa mel.* In describing damaged mixed stands, it has to be stressed that most damages can be stated particularly in artificially made plots of regular form. Two of previously mentioned stands are stands of high density, where the number of trees in a hectare varies between 5400 and 5600 and they belong to the height group (2.6 – 4.0 m). During the research it was found out that there is a significant correlation between occurrence and intensity of browsing, while $r=0.937 > r_{0.01}=0.575$. In searching for correlation between occurrence and intensity of browsing by forest types and regions, the results of analysis of variance showed that there is no significant difference between forest types, while $p=0.187 > \alpha=0.05$, as well as there is no significant difference between regions of Zemgale, Kurzeme and Latgale, $p=0.079 > \alpha=0.05$.

The snow blight *Lophophacidium hyperboreum* Lagerb. is the second biotic risk factor which occurs in up to 40 years old forests in Latvia. Of course, it is mostly peculiar in the forests in Finland, though such damages were found in Latvia after a very snowy winter in 2010 and 2011. The needles, located under the snow, were affected by the disease, sallow, became grey and fell off at the end. Climatic factors, when a large amount of snow falls in winter and trees are under the snow for a long time (Annila et al., 2006) could be mentioned as those that foster the prevalence of snow blight. The disease was found in mixed stands aged from 6 to 27 years in regions of Kurzeme and Latgale. The intensity of damages caused by snow blight is less than intensity of damages caused by browsing. Severely damaged needles (occurrence – 81.0%, intensity – 14.3%) were in 14 years old mixed stand Rēzekne 77/11 in *Hylocomiosa* and 13 years old mixed stand Šķēde 56/10 with Norway spruce as main species (80%) and (90%) in admixture with Scots pine in *Myrtillosa mel.* The damages caused by snow blight are larger in young forest stands, which are situated between seasoning stands in *Myrtillosa mel.*, and this research results coincide with the previous research results (Ruba et al., 2013). Meanwhile, insignificant damages were in 8 and 12 years old mixed stands with Norway spruce as leading species (80%) in admixture with Scots pine, which has artificially created forest plots and located in *Hylocomiosa* and *Mercurialiosa mel.* Lower indicators of occurrence and intensity of damages might be explained by location of mixed stands of Norway spruce between agricultural land, road and amelioration ditch in the forest array, where there were no trees around the stand and the disease spread slower. During the research it was proved that there is significant difference between occurrence and intensity of damages caused by snow blight $r=0.999 > r_{0.01}=0.575$. No significant difference was found between occurrence and intensity of damages by snow blight and forest types, $p = 0.274 > \alpha=0.05$, as well as no significant difference between the regions of Latgale and Kurzeme, $p=0.391 > \alpha=0.05$.

As a third factor, which was found out in surveyed mixed stands of Norway spruce, is eastern spruce gall aphis *Sacchiphantes abietis* L. This is the pest, which sucks juices from the needles and damages shoots of the spruce, making yellow oakgalls (Annila et al., 2006). The damages of this pest are insignificant in mixed stands because occurrence of damages does not exceed 3.5% and intensity – 3.0%. Assessing the indicators of damages done by other insects (see Materials and Methods) it can be affirmed that entomological factors do not affect the sanitary condition in surveyed mixed stands.

The impact of anthropogenic risk factors on the sanitary state of spruce

Besides biotic factors the sanitary state in the forests is mostly influenced by anthropogenic actions of a human in the process of carrying out different actions of forest management in young stands, such as changing natural – irregular form plots to regular form plots, changing the specifics of the forest. Striving for the merits of the forest, the human disarranges natural balance of processes and changes the dynamics of spatial structure of mixed stands. Through the influence of anthropogenic factors, the changes in the forest specifics might not result immediately, or might be insignificant, but they will show up after a longer time. That is why it is important to think about maintaining scenery of the forest before planning any actions (Baskent, 1999). During this research it was found out that damage by browsing increased in the stands, which are higher than 2 meters. Forest owners often did not provide repellents; as a result, the damage intensity increased thus worsening the health state in mixed stands of the Norway spruce. More damage was caused by browsing found in the regular form plot forests by the number of trees 5400 – 5600 and height group of 2.6 – 4.0 m, where as dominant tree species (60 – 80%) is Norway spruce in admixture with oak (20%), birch (20-30%) and Norway spruce (80 – 90%) in admixture with Scots pine (20%) in forest types of *Oxalidosa, Hylocomiosa* and *Myrtillosa turf. mel.* which are located between infrastructural objects, young forest stands of Norway spruce and middle-aged stands of Scots pine. Less damages were detected in regular and irregular form plots by tree number, which is the closest to the optimal 2330 – 3700 and the height group 2.6 – 4.0 m and over 4.1 m with the Norway spruce as the dominant tree species (60 – 90%) in admixture with birch (10 – 30%) and Scots pine (30%). Assessing damages caused by snow blight in mixed stands, it was stated that the most significant were those in forests of regular form plots by the number of the trees 1050-3940 and height groups 2.6-4.0 m and above 4.1 m with the Norway spruce as predominant tree species (80-90%) in admixture with Scots pine (10 – 20%), which were surrounded by Scots pine and birch young forest stands, amelioration ditches and maturity stands of Scots pine. At the same time, insignificant damages were in regular form plots by the tree number of 3470-5400 on hectare at the height group 2.5 – 4.0 m and above 4.1 m with Norway spruce as predominant tree species (80 – 90%) with admixture of Scots pine (10 – 20%) which are surrounded by middle-aged Scots pine stands, agricultural land, amelioration objects and young forest stand of Norway spruce. However, improvements of the state of mixed stands may be achieved by the help of thinning, regulating the pace of tree growth in the preferred direction to get wood of high quality in future. Making of contents of stands helps to create the preferred content and thickness of future tree species. From the mixed stands surveyed, 4% was with the height group of 2.6 – 4.0 m and 5% with height above 4.1 m, where the total number of

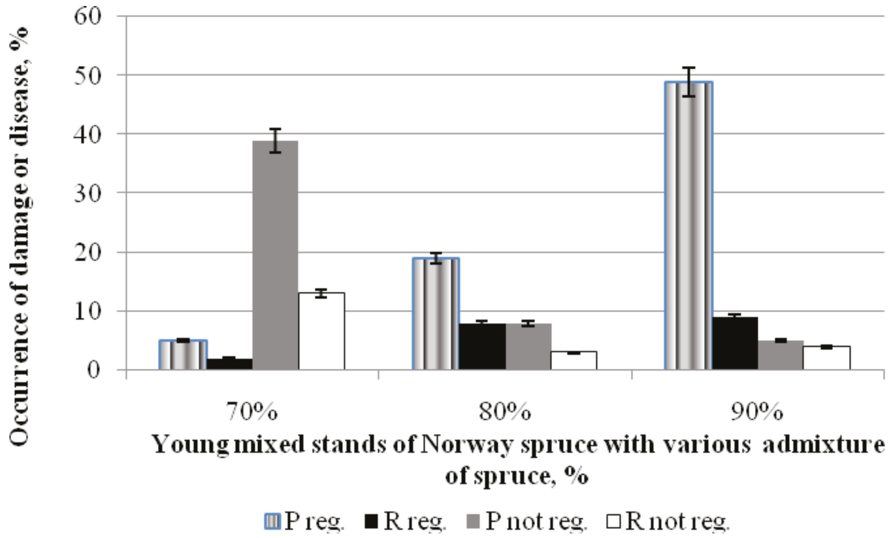

Figure 2. Biotic and anthropogenic risk factor occurrence and intensity in young mixed stands of Norway spruce with various admixture of spruce.

trees on hectare varies between 1050 and 7800 on hectare, which means that half of them need thinning. Thinning is usually carried out, when the average height of trees is bigger than 2 m (Regulations of Latvian Cabinet of Ministers No. 935, 2013) and the trees of particular species, which interfere the growth of dominant species are cut down. If damages caused by browsing are detected in the stands, thinning starts later, when trees reach 3-4 meters in height. Thinning can help improve the health status of forest stands, the rate of tree growth, reduce the competition between other trees, thus, improving the availability of nutrients, water and sun resources (Larsons, 1969). The optimal tree number after thinning is 1400 to 2000 on hectare in mixed stands of Norway spruce and deciduous trees (Grīnvalds et al., 2008). Conclusions about the optimal number of trees in stands cannot be done yet, while in only two stands the number of trees varies between 1460 and 1850, in turn, others need thinning. However, questions about the optimal tree species in the admixture species, which would give the largest amount of wood, is still being considered by the scientists (Krastiņš, 1981). Productivity in mixed Norway spruce and birch stands is higher than in pure stands (Frivold, 1982). The results of research coincide with the theory, stating that mixed stands of spruce have several advantages in comparison to clear stands. Judged by the research done previously and now about the sanitary state in clear stands and mixed stands, it would be advisable to grow mixed stands of spruce, because the intensity of biotic damages stated in clear stands is much higher than that in mixed stands. For example, the intensity of browsing reaches 0.8 – 20.2%, accordingly in mixed stands 0.3 – 0.9%, also intensity of damages caused by snow blight differs in clear stands (0.2% – 18.8%), while in mixed stands it is lower 0.2 – 14.3% (Ruba et al., 2013b). Such disease like root rot *Heterobasidion annosum* (Fr.) Bref., was found in clear stands on height group above 4 m with intensity of 0.3 – 17.2%, but in this research it was detected only in one stand, and it was not influenced by the sanitary state in mixed forests in Latvia.

There is no significant difference between biotic and anthropogenic risk factors occurrence and intensity in young mixed stands of Norway spruce with various admixture of spruce (70, 80, 90%) depending on the forest plot form (regular and irregular), $p=0.413 > \alpha=0.05$ (Fig.2).

During the research it was found out that difference between occurrence of damage and height groups (see Materials and Methods) is no significant ($p=0.086 > \alpha=0.05$). Similarly, there is no significant difference between damage intensity ($p=0.361 > \alpha=0.05$). It follows that forest managers should maintain the natural shape of the compartment (irregular), as much as possible. To provide the conservation of the spatial structure of the forest and not to cause worsening of sanitary state in mixed stands, it is not necessary to stop forest management actions (Bells and Nikodemus, 2000), but it is necessary to assess the methods of forest management.

Conclusions

1. Two main risk factors that most negatively affect the sanitary conditions in forests in Latvia are browsing and *Lophophacidium hyperboreu* Lagerb.
2. There is no significant difference between biotic and anthropogenic risk factors occurrence and

intensity in young mixed stands of Norway spruce with various admixture of spruce (70, 80, 90%) depending on the forest plot form (regular and irregular), $p=0.413 > \alpha=0.05$.

3. Sanitary condition in forests is often worsened by forest owners, because they do not protect mixed young forest stands which are higher than 2 m from browsing. As a result, it leads to higher browsing damage intensity.

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