10th INTERNATIONAL SCIENTIFIC CONFERENCE RURAL DEVELOPMENT 2021
CHALLENGES FOR SUSTAINABLE BIOECONOMY AND CLIMATE CHANGE
21-23 September, 2021, Vytautas Magnus University Agriculture Academy, Lithuania

VYTAUTAS MAGNUS UNIVERSITY AGRICULTURE ACADEMY

Proceedings of the 10th International Scientific Conference Rural Development 2021

Edited by assoc. prof. dr. Judita Černiauskienė

ISSN 1822-3230 (Print)
ISSN 2345-0916 (Online)

Article DOI: http://doi.org/10.15544/RD.2021.031

PINUS SYLVESTRIS L. NATURAL REGENERATION AFTER GRADUAL CONTINUOUS FELLING IN *VACCINIOSA*, *MYRTILLOSA* AND *HYLOCOMIOSA*

Edgars DUBROVSKIS, Forestry Faculty, Latvia University of Life Sciences and Technologies, 2 Liela street, Jelgava, LV-3003, Latvia, edgars.dubrovskis@llu.lv *(corresponding author)*
Olga MIEZĪTE, Forestry Faculty, Latvia University of Life Sciences and Technologies, 2 Liela street, Jelgava, LV-3003, Latvia, olga.miezite@llu.lv
Līga LIEPA, Forestry Faculty, Latvia University of Life Sciences and Technologies, 2 Liela street, Jelgava, LV-3003, Latvia, liga.liepa@llu.lv
Solveiga LUGUZA, Forestry Faculty, Latvia University of Life Sciences and Technologies, 2 Liela street, Jelgava, LV-3003, Latvia,solveiga.luguza@llu.lv

Natural regeneration takes place with those tree species that have long adapted to the given conditions. The study analyzed six Scots pine stands in *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest types. Sample plots (500 m^2) were established five years after the gradual continuous felling. The aim of the study is to assess the natural regeneration after the gradual continuous felling in 2014 in the *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest types. The number of Scots pine regrowth trees differs significantly between forest stands ($p < 0.05$), while the average height of trees does not differ significantly between forest types ($p > 0.05$). The sanitary condition of Scots pine trees does not affect their natural regeneration. The most significant damage is caused by the great pine weevil (*Hylobius abietis*) and the ungulates (*Artiodactyla*).

Keyword: *Scots pine, regrowth, ungulates, Hylobius abietis L.*

INTRODUCTION

Natural restoration initially requires less investment, it has several disadvantages. When using this method, it must be taken into account that the forest stands will have an uneven composition of species, the age and height of the trees will differ. The quality of the new stand will depend directly on the seed and adjacent trees left by the previous stand (González-Martínez, Bravo, 2001). Pine is regenerating with seeds better in dry forest types such as *Cladinoso-callunosa*, *Vacciniosa*, *Myrtillosa* and *Hylocomiosa*, although birch admixture is often observed (Daugaviete et al., 2005). After gradual felling, stand openings create a variety of light regime conditions both at the openings themselves and at their edges, depending on the angle of the sun and the height of the surrounding trees (Canham et al., 1990). As the opening increases, the amount of light in its center increases as a function of 10 of the diameter of the opening and the height of the surrounding stand trees (Lieffers et al., 1999). Failure to carry out reforestation measures for a long time can lead to severe overgrowth with ground covering plants in the area, which can create unfavorable conditions for the natural regeneration of the target tree species. In such areas, species change often takes a place, which provides for the entry of pioneer species or soft deciduous trees, creating undesirable competition for target species, such as pine or spruce (Vilkriste, Daugaviete, 2005). A thick layer of humus (above 4 cm) and rapid felling area overgrowth with ground covering plants, hinder seed germination (Riepšas, Urbaitis, 1996)

The final felling can be categorized into two main categories - clear felling and gradual felling. Clear-felling is widely used in Latvian forests, but it should be noted that the use of clear-felling disrupts the biological rhythm, which affects the specific area for several years. In contrast, gradual continuous felling is a significantly more environmentally friendly method that should be used more actively (Miezīte et. al., 2016). Gradual felling in Latvia is used in areas where clear felling is prohibited in accordance with regulatory enactments. The use of gradual felling is a compromise solution to the economic, ecological and social contradictions of forest management (Zdors, Donis, 2011).

Random felling has a minimal effect on Scots pine forest vegetation in poor growing conditions. *Deschampsia flexuosa* spreads in the ground cover of oligotrophic pine stands, as well as different projective cover of ground cover floors is formed, as is the case in natural pine forests, increased cover of herbaceous layer and smaller cover of moss layer. It results from a complex effect of various factors (Bambe, Donis, 2008). Successful stand regeneration is based on the survival of young trees. Both, insects and other organisms, that feed on plants pose a significant threat to their survival. The biggest and most significant threat to young coniferous forests, which are formed in clear felling areas, is the Large pine weevil (*Hylobius abietis* L.). The great pine weevil is considered to be one of the most economically important pine pest in Europe, especially in regions where coniferous forests are managed by the main felling method - clear felling (Leather et al., 1999; Nordlander, et al. 2009). The main ungulate species that damage Norway spruce stands are the roe deer (*Capreolus capreolus* L.), the red deer (*Cervus elaphus* L.) and the elk (*Alces alces* L.) Damage caused by these animals can significantly reduce the growth of forest stand trees, as well as create a higher risk of trees becoming infected with various diseases (Metslaid, et al. 2013). The influence of ungulates can significantly affect the structure and species composition of the forest stand (Borkowski, Ukalski, 2011).

The *Vacciniosa* forest type has poor soil - mainly sand - in such soil the groundwater is deep, so it does not affect the aeration of the soil. As the soil is poor, pines do not grow too long in such conditions. The *Myrtillosa* forest type has well-aerated mineral soils, podzolic soils formed from sandy loam and loamy sandstone, while *Hylocomiosa* forest type has podzolic soil formed from sand, loamy sand, loamy even clay loam. The *Myrtillosa* forest type soil is moderately rich, and the *Hylocomiosa* forest type soil is fertile (Liepa, 2018). Gradual fellings need to be applied and explored more than is currently the case, as they may be used more in the future than they are today. Therefore, the aim of the study is to evaluate natural regeneration after gradual continuous felling in 2014 in *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest type.

RESEARCH METHODS

The study analyzed the natural regeneration in *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest types. Two 500 m^2 large sample plots with a radius of 12.62 m were surveyed and measured in each forest type. In each sample plot all tree DBH were measured with a forest caliper “Caliper MA800”, and total 30 tree height in each stand. The characteristics of the studied forest stands are shown in Table 1.

Table 1. Characteristics of forest stands

Forest type/ forest block/ compartment	Coordinates, x: y	Forest stand compsition, age	Forest stand area, ha	Number of sample plots (500 m^2) in stand	Number of natural regeneration counting sample plots (25 m^2)
Mr/66/3	527512; 392776	$10P_{116}$	1.3	2	14
Mr/66/10	527616; 392556	$10P_{111}$	2.1	2	14
Ln/203/26	526008; 381525	$10P_{110}$ ats E_{96}	1.7	2	14
Ln/66/19	527489; 391907	$10P_{114}$	1.8	2	14
Dm/5/11	527607; 397179	10P ats E_{111}	2.2	2	14
Dm/97/21	527370; 391255	$10P_{115}$	2.0	2	14
		Total	10.9	12	84

Legend: Mr – Vacciniosa; Ln – Myrtillosa; Dm – Hylocomiosa; P – Scots pine; E – Norway spruce; ats – tree species stock up to 2% of total growing stock.

Temporary plots with an area of 25 m^2 and a radius of 2.82 m were set up five years after the gradual felling for tree count estimation, tree height measurement with Hultafors 3 m measuring tape and tree vitality assessment (Table 2). All trees with a height of 10 cm and higher are counted in the sample plots.

Table 2. Assessment of biotic factor damage of regrowth trees

Damage assessment	Degree of damage
Regrowth tree without signs of weakening and growth disorders	0
economically insignificant damage or faults (some branches of the regrowth tree are broken, insignificant damage to the trunk bark)	1
economically significant damage (one or more small damage to the trunk of a regrowth tree that does not exceed half of the circumference of the trunk, etc.)	2
severe damage (damage to the central shoot of a regrowth tree, signs of its premature drying; withered, broken tip; tree trunk bent and unable to occupy a vertical position; resins trough all trunk)	3
regrowth tree withered in the current year (needles yellow or brown)	4
Regrowth tree withered (dry and without needles)	5

Formula 1 was used to determine the number of trees per hectare:

$$N = \frac{N_p \cdot 10000}{L}, \tag{1}$$

where N – number of trees per hectare according to the data of the sample plots (trees per ha);
N_p – number of trees in the sample plots (trees);
L – the total area of the inventory plots (m^2)

The volume of tree was calculated according to formula 2 (Liepa, 1996; 2018):

$$V = \psi * L^{\alpha} * D^{\beta \lg L + \varphi},\quad (2)$$

where L – stem height, m;
D – diameter with bark at 1.3 m from root collar, cm;
ψ, α, β, φ – empirically determined coefficients (for pine ψ – $1.6541 \cdot 10^{-4}$; α – 0.56582; β – 0.25924; φ –1.59689.)

The incidence of tree damage was calculated according to Formula 3:

$$P = \frac{n \cdot 100}{N},\quad (3)$$

where P – incidence of tree damage, %;
n – number of damaged trees, trees per ha;
N – total number of surveyed trees, trees per ha.

Formula 4 was used to determine the intensity of tree damage:

$$R = \frac{\sum_{i=1}^{6} n_i b_i \cdot 100}{N \cdot k},\quad (4)$$

where R - damage intensity, %;
n_i – number of damaged trees, trees per ha;
b_i – damage degree;
N – total number of surveyed trees, trees per ha;
k - highest damage degree, points. (Miezīte et al., 2013; Ruba et al., 2013; Ruba et al., 2014).

Analysis of variance was used to characterize the number of adult stand trees and regrowth trees between stands and plots (Arhipova, Bāliņa, 2003).

RESULTS AND DISCUSSION

Dendrometric indicators of adult stands in *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type

The largest number of trees per hectare was found in forest stands Mr/66/3 - 460 trees per ha and Mr/66/10 - 420 trees per ha (Table 3). The smallest number of trees was in the forest stand Ln/66/19 - 340 trees per ha, while Ln/203/26 - 400 trees per ha. In forest stand Dm/5/11 is 360 trees per ha, while Dm/97/21 - 400 trees per ha, by diversifying the felling intensity, can provide sufficient natural regeneration and growth of regrowth (Erefur, 2010). The number of trees in forest stands after gradual continuous felling does not differ significantly in in *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest type ($p > 0.05$).

Table 3. Dendrometric parameters of adult pine stands in *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest type

Dendrometric indicator	Stand					
	Mr/66/3	Mr/66/10	Ln/203/26	Ln/66/19	Dm/5/11	Dm/97/21
$D_{vid., cm}$	32.3±0.91	30.7±0.21	39.2±0.97	37.3±1.25	32.7±0.96	35.6±0.93
$H_{vid., m}$	21.3±0.47	20.8±0.48	23.0±0.52	22.6±0.55	21.4±0.0.34	22.2±0.68
V, m^3	0.9579± 0.070	0.9292± 0.084	1.6171± 0.1176	1.2491± 0.1159	0.0901± 0.0725	1.2093± 0.086
Number of trees per ha	460	420	400	340	360	400

Legend: Mr – *Vacciniosa*; Ln – *Myrtillosa*; Dm – *Hylocomiosa*; $D_{vid.}$ – average tree diameter; $H_{vid.}$ – average tree height; V – average tree volume.

Evaluation of Scots pine natural regeneration five years after gradual continuous felling in *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type

The number of saplings per hectare is large in some stands. In the forest stand Mr/66/3 were left 460 trees per ha, respectively the number of saplings in this forest stand is 6900 trees per ha (Fig. 1). In the forest stand Ln/66/19 the number of trees per hectare is 340, but saplings- 6000 pieces per ha. The lowest number of saplings (1040 pieces per ha) is in the forest stand Dm/5/11 where the number of trees is 360 trees per ha. In this forest stand, the natural regeneration is hindered by the rich ground cover, because it prevents the seed from reaching the soil. There are 420 trees per ha in the forest stand Mr/66/19, while the number of saplings in the stand is 1720 pieces per hectare. The small number of regrowth trees is similar to stand Dm/5/11 - the natural regeneration is hindered by the rich ground cover. The number of saplings differs significantly between forest stands and forest types ($p < 0.05$).

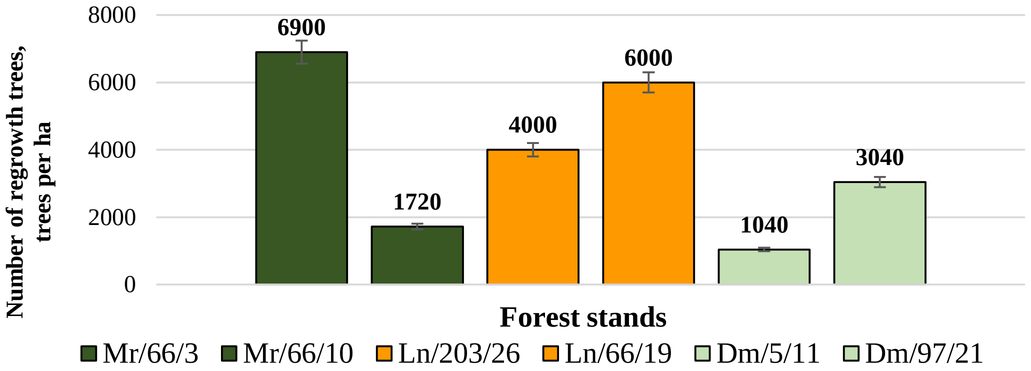

Figure 1. The number of Scots pine regrowth trees after gradual continuous felling in *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type

In the forest stand Mr/66/3 and Mr/66/10, the average height of the regrowth trees is 0.4±0.06 m and 0.2±0.04 m. The incidence of Scots pine sapling damage in the forest stand Mr / 66/3 was 27% of the total measured trees (Fig. 2), while insignificant damage incidence in stand Mr/66/10 – 2% was observed. In the forest stand Mr/66/3, the most significant damage is caused by Large pine weevil (*Hylobius abietis*) (17 %), 7% is ungulate caused damage but from diseases (*Melampsora pinitorqua*) only 3%. The sum of intensity of tree damage in the *Vacciniosa* forest type is 14% - 13 % in forest stand Mr/66/3 and 1 % in Mr/66/10 (Fig. 3).

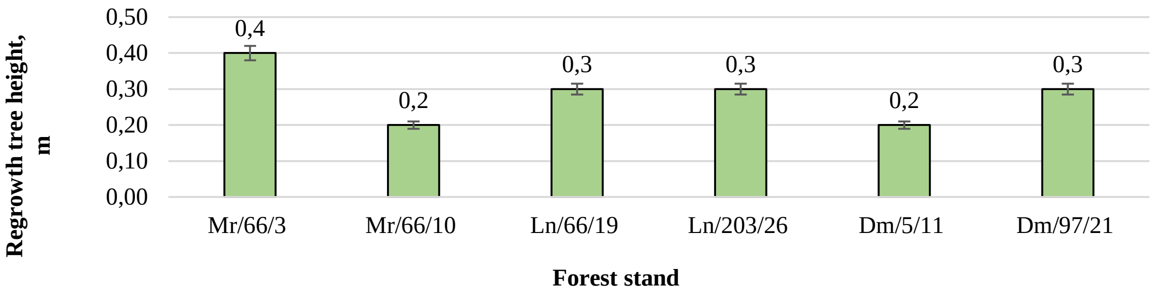

Figure 2. Scots pine regrowth average height (m) in *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type

In the forest stand Ln/66/19 and Ln/203/26 the average height of the regrowth trees reached 0.3±0.07 m and 0.3±0.04 m, as the light regime under the crown cover is the main factor strengthening natural regeneration, stimulating survival and growth (Gray, Spies, 1996; Lieffers, et al. 1999).

The incidence of damaged trees in the forest stand Ln/66/19 was 11%, and all of them are caused by the Large pine weevil (*Hylobius abietis)*. In the forest stand Ln/203/26 damage incidence is 13%, mainly caused by large pine weevil (9%) and ungulates (4%). The damage intensity in *Myrtillosa* forest type is 11% – in Ln/66/19 and Ln/203/26 intensity is 5% and 6%, respectively.

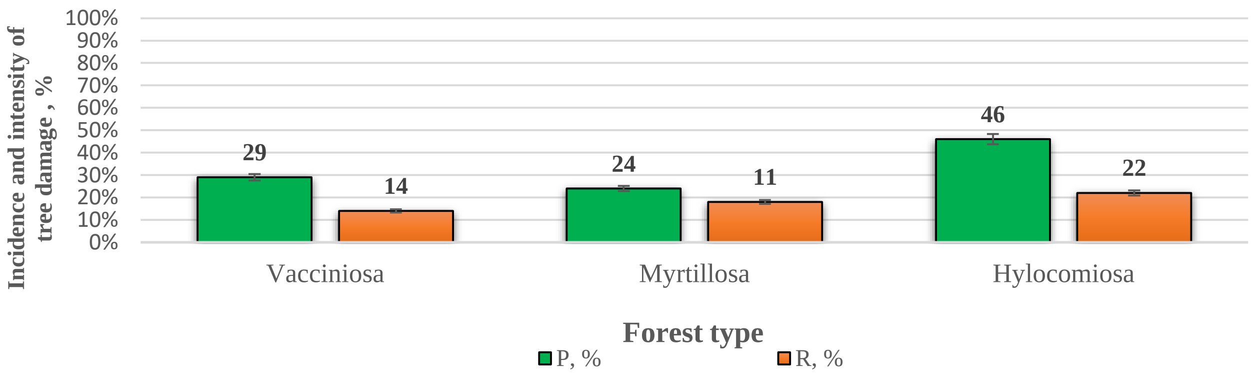

Figure 3. Incidence and intensity of Scots pine sapling damage in *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type

In the forest stand Dm/5/11 and Dm/97/21, the average height of regrowth trees is 0.2±0.08 m and 0.3±0.07 m. The incidence of tree damage in the forest stand Dm/5/11 is 24%, including damage by ungulates (14%) and large pine weevil (10%). The incidence of tree damage in the forest stand Dm/97/21 is 13%, and it is caused by ungulates. In *Hylocomiosa* forest type intensity of tree damage is 22% – in forest stands Dm/5/11 is 9 % but in stand Dm/97/21 is 13%. Damage to the Scots pine regrowth is most significant in *Hylocomiosa* forest type as there is richer ground cover that promotes the attraction of ungulates.

The natural regeneration after the after gradual continuous felling in 2014 in *Vacciniosa*, *Myrtillosa* and *Hylocomiosa* forest type has been partially successful – a minimal number of samplings per ha has been reached, but the specified tree height has not been reached, which prevents felling of the next plot. In order to be able to perform felling of the next plot, the height of the saplings must reach the height specified in the regulatory enactments, i.e. 1.0 m (Regulations of the Cabinet of Ministers No.308).

CONCLUSIONS

1. The thickness of forest stands after gradual continuous felling does not differ significantly between *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type (p>0.05).
2. The number of Scots pine regrowth trees differs significantly between forest stands (p<0.05), while the height of the regrowth trees does not differ significantly between forest stands (average stand height is 0.2-0.4 m).
3. The sanitary condition of Scots pine regrowth trees does not affect the natural regeneration, as the intensity of tree damage is 11 - 22% and the most significant damage is done by large pine weevil (*Hylobius abietis*), pine-aspen rust (*Melampsora pinitorqua*) and ungulates (*Artiodactyla*).
4. The number of adult trees remaining in forest stands (340-460 trees per ha) does not affect the growth and number of regrowth trees in *Vacciniosa, Myrtillosa* and *Hylocomiosa* forest type.
5. Regeneration of Scots pine is hindered by thick ground cover in the *Vacciniosa* and *Hylocomiosa* forest type.

REFERENCES

1. Arhipova I., Bāliņa S. 2003. Statistika Ekonomikā. *Risinājumi ar Spss Un Microsoft Excel. (*Statistics in Economics. *Solutions With Spss and Microsoft Excel)* Rīga: Datorzinību centrs. 352 p. (In Latvian)
2. Bambe B., Donis J. 2008. The Impact of Shelterwood Cuttings on Forest Vegetation**.** *Mežzinātne,* Vol. 17 (50). Available: http://www.silava.lv/userfiles/file/Mezzinatne%2017 (50)2008/5_Bambe_mezzinatne_17_opt.pdf
3. Borkowski J., Ukalski K. 2012. Bark Stripping by Red Deer in a Post – Disturbance Area: The Importance of Security Cover. *Forest Ecology and Management*, Vol. 263, pp. 17 – 23. https://doi.org/10.1016/j.foreco.2011.09.029
4. Canham C. D., Denslow J. S., Platt W. J., Runkle J. R., Spies T. A., White P. S. 1990. Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests. *Canadian Journal of Forest Research,* Vol. 20, pp. 620–631. https://doi.org/10.1139/x90-084
5. Daugaviete M., Lazdāns V., Ošlejs J. 2005. *Reforestation methods*. From: A guide for Latvian private forest owners. Compiled by J. Ošlejs. Rīga: LVMI "Silava", pp. 95–104. (In Latvian)
6. Erefur C. 2010. *Regeneration in continuous cover forestry systems*. Doctoral thesis. Swedish University of Agricultural Sciences, Umeå, 53 pp.
7. González-Martínez S. C., Bravo F. 2001. Density and population structure of the natural regeneration of Scots pine (*Pinus sylvestris* L.) in the high ebro basin (Northern Spain). *Annals of Forest Science*, Vol. 58 (3), p. 277-288. https://doi.org/10.1051/forest:2001126
8. Gray A. N., Spies T. A. 1996. Gap size, within-gap position and canopy structure effects on conifer seedling establishment. *Journal of Ecology*, Vol. 84, pp. 635–645. https://doi.org/10.2307/2261327
9. Leather S. R., Day K. R., Salisbury A. N. 1999. The biology and ecology of the large pine weevil, hylobius abietis **(***Coleoptera: Curculionidae):* A problem of dispersal? *Bulletin of Entomological Research*, Vol. 89(1), pp. 3–16. https://doi.org/10.1017/s0007485399000024.
10. Lieffers V. J., Messier C., Stadt K. J., Gendron F., Comeau P. G. 1999. Predicting and managing light in the understory of boreal forests. *Canadian Journal of Forest Research*, Vol. 29, pp. 796–811. https://doi.org/10.1139/x98-165
11. Liepa I. 1996. *Pieauguma mācība*. (The lesson of increment) Jelgava: LLU, 123 p. (In Latvian)
12. Liepa I. 2018. *Meža taksācija.* (Forest inventory.) Jelgava: Avots, 238 p. (In Latvian)
13. Metslaid M., Köster K., Jõgiste K., Randveer T., Voolma K., Moser W. L. 2013. The effect of simulated bark stripping by moose on scots pine height growth: An experimental treatment. *Baltic Forestry,* Vol. 19 (1), pp. 61 – 66.
14. Miezite O., Okmanis M., Indriksons A., Ruba J., Polmanis K., Freimane L. 2013. Assessment of sanitary conditions in stands of norway spruce (*Picea abies* karst.) Damaged by spruce bud scale (*Physokermes piceae schrnk*.). *iForest*, Vol. 6, pp. 73-78. https://doi.org/10.3832/ifor0703-006
15. Miezīte O. 2016. The regrowth conservation after selection cutting of forest stands growing in hylocomiosa site type**.** Agriculture and Forestry, Vol. 62. https://doi.org/10.17707/AgricultForest.62.4.15
16. Nordlander G., Nordenhem H., Hellqvist C. 2009. A flexible sand coating (conniflex) for the protection of conifer seedlings against damage by the pine weevil hylobius abietis. *Agricultural and Forest Entomology*, Vol. 11(1), pp. 91–100. https://doi.org/10.1111/j.1461-9563.2008.00413.x
17. Regulations of the Cabinet of Ministers No.308. Regulations for forest reforestation, afforestation and plantations**.** (Meža atjaunošanas, meža ieaudzēšanas un plantāciju meža noteikumi). Seen 24.08.2021 URL: https://likumi.lv/ta/id/247349-meza-atjaunosanas-meza-ieaudzesanas-un-plantaciju-meza-noteikumi (In Latvian)
18. Riepšas E., Urbaitis G. 1996. Impact of some ecological factors on natural regeneration of recreational *Scots pine* stands. *Baltic Forestry*, Vol. 2, pp. 9-15.

19. Ruba J., Miezite O., Luguza S., Baltmanis R. 2013. Abiotic risks of managing young forest stands of norway spruce (*Picea abies* (L.) Karst.). Annula 19th International *Scientific Conference Proceedings "Research for Rural Development*", Vol. *2*, pp. 27-33.
20. Ruba J., Miezīte O. 2014. Impact of risk factor management on the sanitary condition of norway spruce (*Picea abies* [L.] Karst.) pure stands in Latvia**.** *Journal of Forest Science*, Vol. 60(5), pp. 181–189. https://doi.org/10.17221/4/2014-JFS
21. Vilkriste L., Daugaviete M. 2005. Reforestation - an economically viable measure**.** From: A guide for Latvian private forest owners. Compiled by J. Ošlejs. Rīga: LVMI "Silava", pp. 121–126. (In Latvian)
22. Zdors L., Donis J. 2011. Light regime in uniform and group shelterwood cuttings. *Mežzinātne*, Vol. 24(57), pp. 41–57.