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NORWAY SPRUCE *PICEA ABIES* (L.) H. KARST. GROWTH AND DAMAGES IN AGRICULTURAL LANDS

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The planted forest areas in Latvia are growing every year, 6.5 thousand ha were planted in 2021. Norway spruce (*Picea abies* (L.) H. Karst.) is one of the tree species used to afforest agricultural lands. The aim of the study is to investigate the Norway spruce growth and damage in agricultural lands. Six sites were selected in three forest types – *Oxalidosa*, *Myrtillosa turf.mel.* and *Myrtilloso-polytrichosa*. The data required for the study were obtained by creating five circular plots in a rectangular area with a radius of 5.64 m and an area of 100 m^2. Norway spruce trees were listed in each sample plot, height, diameter, damage and degree of damage were measured for all trees, as well as the growth of the last three years. The study found that forested agricultural lands with Norway spruce are heavily damaged by ungulates (red deer, roe deer), biting their leader or lateral branch, therefore the annual average height increases are variable, but the proportion of damage in different types of forest does not differ significantly. The growth of Norway spruce is different in different types of forest, the best growth results are observed in the *Myrtilloso-polytrichosa*, where the trees have a larger average height and diameter.

Keywords: *Picea abies*, height increment, damage, average fertility forest types, agricultural land

INTRODUCTION

Latvia is one of the most forested countries in the European Union, where forests cover 37.7% of the EU land area (www.europarl.europa.eu). According to the Latvian national forest monitoring data of 2017-2021, forests in Latvia occupy 50.14% of the entire territory of the country, while arable land accounts for 17.81%, overgrown agricultural land and shrubland - 2.98%. The world areas covered by forests are continuing to decrease every year - if in 1990 forests covered 31.6%, then in 2020 they accounted for 30.8%. In order to improve the situation, the afforestation of land that cannot be used for agriculture is carried out, thus increasing the richness of the forest, preserving biological diversity, diversifying the landscape and reducing environmental pollution. The established planted forest areas in Latvia continue to grow. In 2021, 6.5 thousand ha of forests were planted and Norway spruce (*Picea abies* (L.) H. Karst.) has the largest share in the planted areas - 45% (Valsts meža dienests, 2022).

Norway spruce is one of the tree species used to afforest agricultural lands. Afforestation of agricultural lands is an effective way of sequestering CO_2, but there is a significant risk of damage to even-toed ungulates (red deer, roe deer) - after afforestation, even-toed ungulates do not change the habits of the feeding area. The lack of forestry measures contributes to the formation of low-quality stands on afforested agricultural lands. It is important to tend young forest stands, especially in areas which overgrow quickly, so as not to create competition with herbaceous plants.

Norway spruce is the third most common tree species in Latvia (Dreimanis, 2016; Lībiete et al., 2019). According to the Latvian national forest monitoring data (2017-2021), spruce as the dominant tree species in the entire territory of Latvia occupies 628.69 thousand ha (± 15.06 thousand ha) or 19.41% of the forest area. Spruce is the fastest growing coniferous species in Latvia (Jansone, 2020).

From the point of view of coniferous species, spruce has the greatest growing risks, since in most cases the threats are economically significant or even very strong. Spruce is a tree species which is most sensitive to air pollution and smoke from gases. It is further aggravated by dry summers and bare frosts in winter (Mangalis, 2004). Spruce grows better under warmer conditions and where there is sufficient humidity (Zālītis & Lībiete, 2005). According to the projected climate change, the growth of Norway spruce will decline significantly, especially in areas outside its natural range (Altman et al., 2017). In Europe, large areas of Norway spruce stands are most often affected by drought and heat, so the

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frequency of drought periods may increase due to the changing climate (Jansone, 2020). Climatic conditions in Norway spruce forests are considered to be the dominant factor determining the tree growth. Increased summer temperatures and changes in precipitation are also associated with drought stress, which can cause mortality in Norway spruce (Bāders et al., 2020). With the changes in climate, the vegetation period becomes longer, which can contribute to higher productivity of forest stands, but this can be affected by prolonged periods of drought or frost (Jansone, 2020). Also, climate changes can cause the formation of August shoots, thus contributing to more regular frost damage (Zeltiņš, 2017). Spruce stands can be threatened by biotic factors, such as pests, diseases and even-toed ungulates, thus having a negative impact on increase in growth and successful development of the stand.

Spruce is very productive on the sites of fertile forest types. The effect of forest type on growth potential is small – 5% (Zālītis & Lībiete, 2005). However, care should be taken when growing this species in *Myrtillosa mel.* and in *Myrtillosa turf.mel*. site types in large areas, since the active root horizon does not deepen to a large extent in drained soils, and the root system of spruce is already shallow, therefore such stands are threatened by wind. Under the influence of the drainage system, the growth in the growing stock of spruce increases 3-4 times, but the growth in diameter and height was detected in the second decade after the drainage. As a result of drainage, the number of small roots of spruce roots increases (Lībiete et al., 2019).

In order to create a vital and productive forest stand, when afforesting unused agricultural land, it is necessary to take into account soil properties, soil hydrological regime, microclimate, installation technologies, quality of the planting material, agro-technical care and further management (Daugaviete & Lazdāns, 2014).

The most suitable soil type for spruce is slightly to strongly acidic, podzol sandy loam, sandy clay: sod podzol soils; sod podzol gley, cultivated soils; sod gleyed, as well as brown forest soils (Daugaviete, 2000; Mangalis, 2004).

In afforested agricultural lands, the site index of spruce stands is higher than that in natural forest stands. It reaches I, even I^a site index. The average annual growth increase of spruce stands reaches 10-12 m^3 ha^{-1} (Daugaviete et al., 2015). Spruce can be used in flat, well-drained areas, as well as in admixture on slopes and hilltops.

Afforestation of abandoned agricultural lands is an effective measure to mitigate climate change (Lutter et al., 2021). Norway spruce trees growing on forest lands are considerably ($p < 0.05$) more sensitive to climatic factors compared to those growing on agricultural lands (Cukor et al., 2020).

The aim of the study was to investigate the growth and damages to Norway spruce on agricultural lands. To achieve the aim, the following research tasks have been set: 1. to determine the dendrometric indicators of Norway spruce on agricultural lands, depending on the forest type; 2. to assess the damages in young stands of Norway spruce on agricultural lands; 3. to analyze and compare the growth of spruce depending on the forest type.

RESEARCH METHODS

The research sites belong to the Jelgava department of Zemgale regional forest district. Four research sites are located in Iecava parish of Bauska municipality and the other two in Ukri parish of Dobele municipality (Figure 1). These sites used to be agricultural lands, but currently they are afforested with three-year-old spruce (planted in 2020), forming pure stands of Norway spruce.

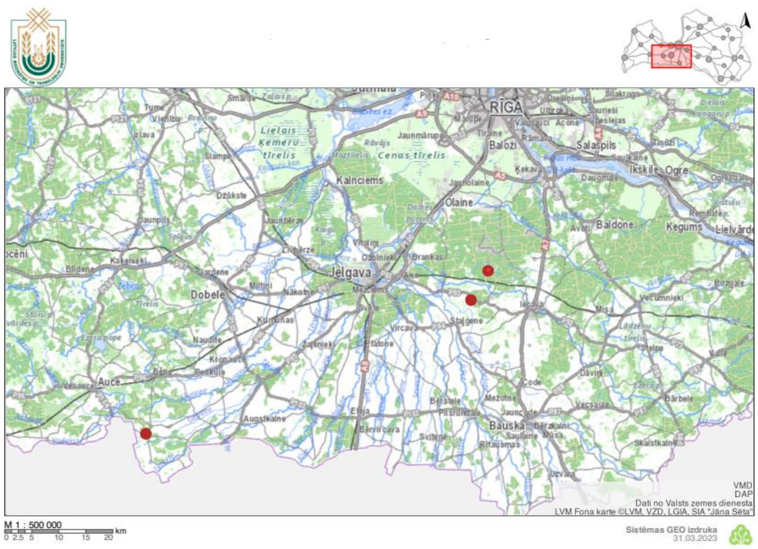

Figure 1. Research sites in Latvia

Six sites were selected in three forest types – *Oxalidosa*, *Myrtilloso-polytrichosa* and *Myrtillosa turf.mel*. which had not been tended (two stands per forest type). The forest type is defined by soil properties using soil analysis. In *Oxalidosa* there is medium fertile and humid mineralsoil, in *Myrtilloso-polytrichosa* there is medium fertile and wet mineralsoil and in *Myrtillosa turf.mel.* there is medium fertile and drained peat soil.

Bare root plants with an improved root system were used as planting material in all six research sites. In *Oxalidosa* and *Myrtillosa turf. mel.*, the category of planting material was defined as "the place of extraction known", but in

Myrtilloso-polytrichosa – ”improved”. In *Myrtilloso-polytrichosa*, the soil was prepared in furrows, but in *Oxalidosa* and *Myrtillosa turf. mel.* it was prepared in mounds. The soil preparation differs but it does not influence the parameters of trees.

In each research site, the required data were collected by the method of sample plots. Five circular sample plots with a radius of 5.64 m and an area of 100 m^2 were established in a rectangular area. A total of 30 sample plots were surveyed. Norway spruce trees were counted and their parameters recorded in each sample plot - their height, diameter, damage and degree of the damage were measured, as well as the growth increment over the last three years. The diameter of the tree at the root collar was measured with a caliper. It was assessed whether the tree was damaged, and if so, the degree of damage was determined according to the methodology developed by O. Miezite (Miezite et al., 2013). The degree of damage was assessed according to a six-point scale (Table 1).

Table 1. Assessment of damage of abiotic, biotic and anthropogenic factors in degrees

Number	Assessment of damage	Degree of damage
1	tree without signs of weakening and growth disorders	0
2	economically insignificant damages or defects (some branches broken or bitten off, small damages to the trunk, galls on branches and trunks, etc.)	1
3	economically significant damages (one or several minor damages to the trunk not exceeding half of its circumference, etc.) or defects (one-sided crown of a tree; double top, one or more minor damages to the trunk not exceeding half of the circumference of the trunk, etc.)	2
4	very severe damages (damage to the central leading shoot of the tree, signs of its premature death; dead, broken or bitten off top; the tree trunk is bent and unable to regain its vertical position; the tree has one or more trunk damages, the scars of which exceed half of the trunk circumference; on the tree trunk along its entire length, resin streaks or passages under the bark and in the upper layers of the wood are visible)	3
5	the tree has become dead (standing tree) this year (needles and leaves yellow or brown)	4
6	Dead	5

Data on annual height growth of Norway spruce were compared and analyzed using univariate analysis of variance. Likewise, the analysis of variance was performed for the average height, average diameter, as well for the incidence and intensity of damages to Norway spruce, finding out whether there is a significant difference in these indicators between forest types.

RESEARCH RESULTS AND DISCUSSION

A total of 285 Norway spruce trees were measured in the established 30 sample plots. For each research site, the total number of trees in the sample plots, the average number of trees per sample plot and the actual number of trees per hectare were calculated. Currently, Latvian legislation requires that the minimum number of spruces in a young stand must be 1,500 trees per hectare in order for a forest stand to be recognized as regenerated (Meža atjaunošanas,...). The number of trees in the research sites does not meet this requirement, which means that the stands do not meet the requirements to be considered planted. The number of trees in the research sites does not meet this requirement, in *Oxalidosa* there are 780 trees per hectare, in *Myrtillosa turf. mel*.- 800 trees per hectare and in *Myrtilloso-polytrichosa* - 1270 trees per hectare.

The height of Norway spruce. The largest average height was in *Myrtilloso-polytrichosa* – 0.50 ± 0.04 m, where Norway spruce was much larger than in *Oxalidosa* and *Myrtillosa turf. mel.* forest types The minimum tree height was 0.41 m, and the maximum measured was 0.57 m. The smallest spruces were found under *Myrtillosa turf. mel* (0.33 ± 0.05 m) forest type conditions, which could be explained by the fact that there is excessive moisture in this location, which inhibits full growth of young trees. The average height of Norway spruce trees was also calculated only for healthy trees which were not damaged (Figure 2).

By performing the analysis of variance according to Fisher's criterion, it was determined with a 95% confidence level that there was no significant difference between the average height of trees in different forest types ($p = 0.116 > 0.05$). The total impact index of the variance analysis, which characterizes the average height of Norway spruce trees in the forest types, was 100%, correspondingly, the proportion of the background impact was 85.3%. This means that other factors have greater impact on the average height of Norway spruce trees, the proportion of the impact of forest type accounts for only 14.7%. The annual growth in height, which is up to the height of about two meters, relatively slowly reaches a growth rate of 10-20 cm, however, after that there is a rapid increase in average height, average diameter and growing stock, which can reach up to 20 m3 ha-1per year (Zālītis, 2006; Lībiete et al., 2019). Spruce trees in young stands often suffer from spring frosts, as a result of which the side shoots are affected by frost and, consequently, growth decreases (Zālītis & Lībiete, 2005; Lībiete et al., 2019). Frosts damage mainly the shoots of young trees 1-1.5 m above the soil surface. The greatest growth in the height and diameter of spruce occurs at the age of 15-20 years, the increase in the growing stock at the age of 30 years, while the current growth increase depends on the site index of the stand (Lībiete et al., 2019).

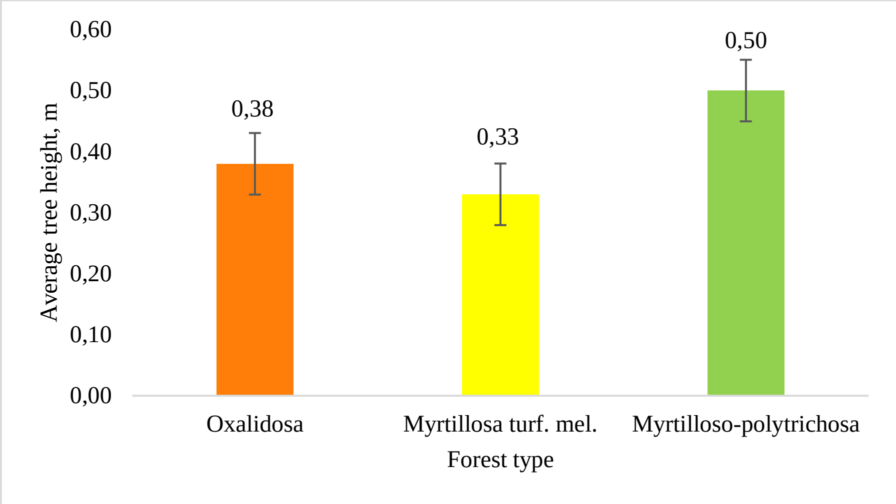

Figure 2. The average height of Norway spruce trees by different forest types.

Norway spruce diameter. The diameter of Norway spruce at the root collar was measured in all the research sites. Figure 3 shows the average diameter by forest type. The largest average diameter was in *Myrtilloso-polytrichosa* - 0.81 ± 0.08 cm, where the average height was also the largest. The minimum tree diameter was 0.67 cm, and the maximum measured was 0.90 cm. The smallest average diameter was in *Oxalidosa forest type* - 0.49 ± 0.08 cm. The growth in diameter is affected by various fluctuations in external environmental factors, such as lighting intensity, soil moisture and air temperature. The air temperature strongly affects the diameter increment at the beginning of the vegetation period, while soil moisture is significant in July and August, when the soil is drier. The growth in height of young spruces is adversely affected by excessive humidity in July and August. Another study concluded that the growth in height is reduced by constant winds (Lībiete et al., 2019).

By performing the analysis of variance according to Fisher's criterion, it was determined with a 95% confidence level that there was a significant difference between the average diameter of trees in different forest types (p = 4.61 × 10-10 < 0.05). The total impact index of the variance analysis which characterizes the average diameter of Norway spruce trees in the forest types is 100%, correspondingly, the share of the background impact is 20.3%. This means that it is the forest type that has a greater impact on the average diameter of Norway spruce trees - 79.7%.

In *Myrtilloso-polytrichosa* forest type Norway spruce shows the highest results of dendrometric indicators, although it has lower site index (II-III) compared to *Oxalidosa* (I^a-I). This could be explained by the fact that in *Myrtilloso-polytrichosa* the category "improved" planting material is higher, namely for the category "improved" the material has been obtained from the parents of the forest tree seed plantation family, clone or a mixture of clones, and it was selected according to the phenotype at the level of individuals. On the other hand, in *Oxalidosa* and *Myrtillosa turf. mel.* forest types, it is the category "the place of extraction known", which has been obtained in a definite extraction area from individual trees or in a forest stand.

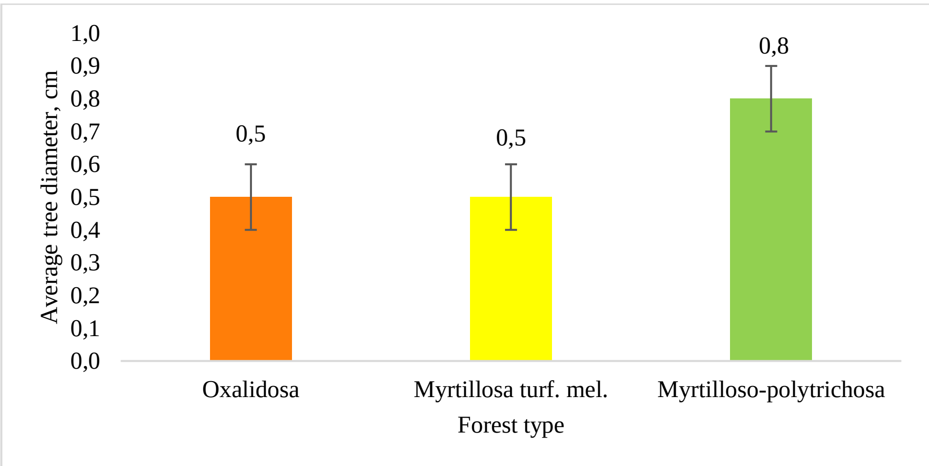

Figure 3. The average diameter of Norway spruce trees by different forest types.

In the study conducted in the Czech Republic, which compared the diameter and height indicators of Norway spruce in forest lands and afforested agricultural lands, it was found that these parameters are considerably higher in forest lands than in afforested agricultural lands (Cukor et al., 2019).

Damages to Norway spruce. Even-toed ungulates (red deer and roe deer) cause the greatest damage to Norway spruce on afforested agricultural lands. A study conducted in the Czech Republic found that even-toed ungulates caused

85.8% of damage in afforested agricultural lands and 53.8% in forest lands (Cukor et al., 2019). Most of the trees were damaged in the third degree, with the tops bitten off, i.e. 107 trees out of 285 trees. Two trees were completely dead. Only 86 Norway spruce trees in the sample plots were found without damages. Figure 4 shows a diagram with the occurence of tree damage depending on the type of forest.

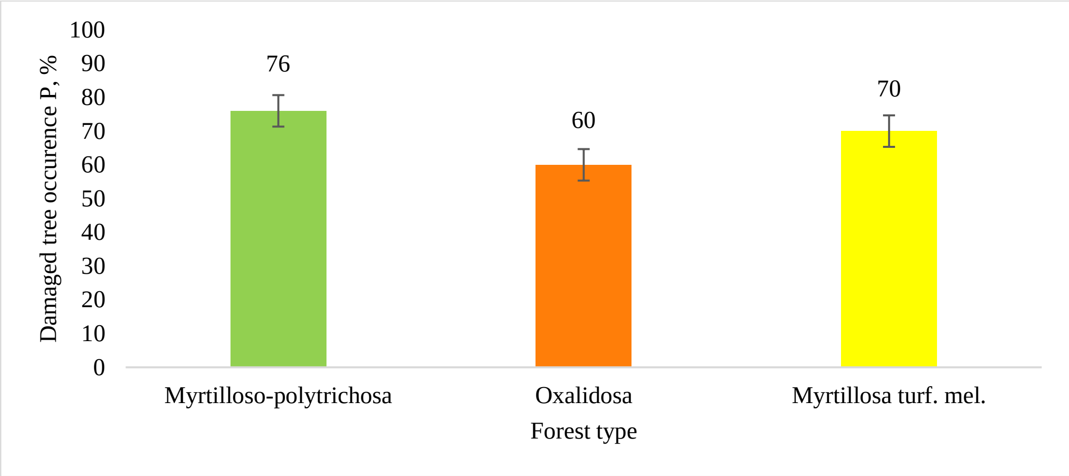

Figure 4. The occurance of tree damage depending on the type of forest

The highest occurance of damage was observed under *Myrtilloso-polytrichosa* (75.59 %) forest type conditions where all five degrees of damage were found, while under *Oxalidosa* and *Myrtillosa turf. mel.* forest type conditions - three degrees. The highest damage intensity of Norway spruce is in *Myrtillosa turf. mel.*- 57.92%. The lowest intensity is observed in *Myrtilloso-polytrichosa*, which has the highest occurence of damage, but its intensity is not as significant as it is in *Oxalidosa* and *Myrtilloso - turf. mel.*

Although in *Oxalidosa* forest type *Cervacol Extra* was used to protect Norway spruce against even-toed ungulates, the obtained results show that there was no difference in the occurence and intensity of tree damage compared to the other stands.

By conducting Pearson's correlation with a 95% confidence level, it was found that there was a moderately close, positive, statistically significant correlation between the occurence of damage to Norway spruce trees and the intensity of damage in forest types ($r = 0.8$; $p < 0.0001$) (Figure 5).

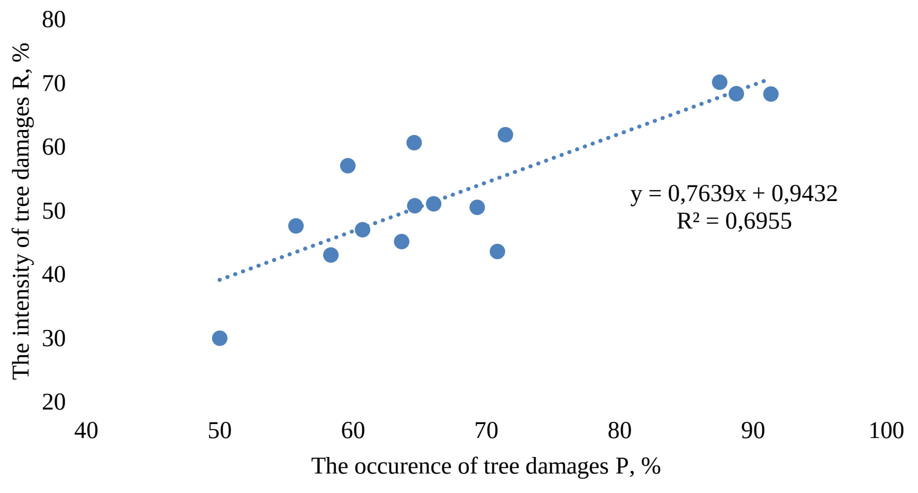

Figure 5. The correlation between the occurence of damage to Norway spruce trees and the intensity of damage in forest types.

By performing the analysis of variance according to Fisher's criterion, it was determined with a 95% confidence level that the incidence of damage to Norway spruce trees between the studied forest types does not differ significantly ($p = 0.06 > 0.05$), the same holds true concerning the intensity of tree damage ($p = 0.19 > 0.05$).

Height growth of Norway spruce. In the research sites, the height growth of Norway spruce were measured in each sample plot. They were determined between the whorls of the tree trunk. The average height growth was calculated for healthy trees in which the growth was observed. In 2020, the greatest average height growth of Norway spruce was observed in *Myrtilloso-polytrichosa* (10.86 ± 3.96 cm), in 2021 – in *Myrtilloso - turf. mel.* 13.56 ± 7.19 cm), and in 2022

– in *Oxalidosa* (13.88 ± 6.81 cm). There is a significant difference between the average height growth in 2020 and forest types, as well as between the average tree height growth in forest types in the years 2021 and 2022.

CONCLUSIONS

The largest average tree height of Norway spruce is in *Myrtilloso-polytrichosa* (0.50 ± 0.04 m) forest type, which is the same for damaged and healthy trees, while in *Oxalidosa* forest type the average tree height for healthy trees is 0.07 m lower than for damaged trees in the sample plots. The average tree height does not differ significantly between forest types ($p > 0.05$). The largest average tree diameter is in *Myrtilloso-polytrichosa* - 0.81 ± 0.08 cm, while the smallest average tree diameter is in *Oxalidosa* - 0.49 ± 0.08 cm. There is a significant difference ($p < 0.05$) between the average tree diameter and forest types. *Myrtilloso-polytrichosa* shows the highest results of dendrometric parameters ($H_{ave} = 0.50 \pm 0.04$ m; $D_{ave} = 0.81 \pm 0.08$ cm), although it has lower site index (II-III) than *Oxalidosa* (I^a-I), which could be explained by the fact that in *Myrtilloso-polytrichosa* there is a higher planting material category "improved", while in *Oxalidosa* and *Myrtilloso - turf. mel.* it is "the place of extraction know".

The highest occurence of damage to Norway spruce is in *Myrtilloso-polytrichosa* (75.59%), where 67.7% of the 127 measured trees in the sample plots were damaged, and all five degrees of damage were observed there. One of the most important reasons is overpopulation of deer family animals – red deer and roe deer.

In *Oxalidosa* and *Myrtilloso-polytrichosa* the average height growth in Norway spruce over the last three years have been increasing every year, whereas in *Myrtilloso - turf. mel.* the average tree height growth decreased in 2022, which could be explained by the fact that it has the highest intensity of tree damage (57.92%). In *Oxalidosa* there are no significant differences between the average height growth of the last three years ($p > 0.05$), while in *Myrtilloso - turf. mel.* and in *Myrtilloso-polytrichosa* these differences exist ($p < 0.05$).

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