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PINUS SYLVESTRIS L. REGENERATION FROM SEED TREES IN *VACCINIOSA* AND *MYRTILLOSA*

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Scots pine (*Pinus sylvestris* L.) is an economically important tree species in temperate forests, including Latvia. Purposeful selection work has resulted in the provision of faster-growing planting material for forest planting. Natural restoration initially requires less investment, it has several disadvantages. When using this method, it must be considered that the forest stands will have an uneven species composition, the age and height of the trees will differ. The study was carried out in young naturally regenerated stands in *Vacciniosa* and *Myrtillosa* forest site type and compared with planted stands The aim of the study was to evaluate the natural regeneration and last 5 year tree height increment of Scots pine regenerated from the seed trees in the *Vacciniosa* and *Myrtillosa*, compared to planted stands, as well as to assess the impact of tree health on pine height increment. In total 10 young stands were surveyed, 66 sample plots were established and 704 trees were measured. The area of the temporary sample plot was 25 m^2 with a radius of 2.82 m. Comparing the annual height increases of Scots pine, both in naturally regenerated and planted young stands in *Vacciniosa* and *Myrtillosa*, it was found that there are statistically significant differences between forest types, stand origin type, as well as in existing stands in the last 5 years by years ($p < 0.05$). The most significant damage to young pine stands is caused by needle cast, ungulates, and large pine weevil.

Keywords: pine, regeneration, abiotic and biotic factor damage

INTRODUCTION

Scots pine is the second most common coniferous species in the world (Pinus sylvestris, 2020), common in Eurasia at altitudes up to 2,600 m above the sea level (Matyas et al., 2003). Pine is an economically important tree species in many European countries, where it is abundant, especially in the countries around the Baltic Sea (Ruotsalainen, Persson, 2013), including 28% of the total forest area in Latvia. In countries such as Finland, Poland, and Sweden, it is the dominant species in more than 50% of the forest (Krakau et al., 2013).

Growing conditions significantly determine the appearance of Scots pine - slender, long trunk and wide crown for trees grown in mineral soils (Fisher, 2002), including Vacciniosa and Myrtillosa forest site type. Vacciniosa is a moderately podzolic and moist sand soil, often with a rust horizon, while Myrtillosa is a weakly podzolic and moderately moist sand soil. In both forest types, groundwater is deep (Zālītis, 2006).

The predominant species in the *Vacciniosa* forest site type ground cover is *Vaccinium vitis-idaea* L., lichens, *Dicranum polysetum* Sw., Respectively in *Myrtillosa* - *Vaccinium myrtillus* L., *Pteridium aquilinum* (L.) Kuhn, *Pleurozium schreberi* (Brid.) Mitt., *Hylocomium splendens* (Hedw.) B., S. Et G., *Dicranum polysetum* Sw. (Mangalis, 2004). In *Vacciniosa* pine forms site index III stands, respectively, in *Myrtillosa* pine grows very well, forming economically important site index II stands (Zālītis, Jansons, 2013).

Purposeful selection work has resulted in the provision of faster-growing planting material for reforestation, however, it is economically advantageous in the most fertile forest types. In less fertile soils, natural regeneration from adjacent stands or abandoned seed trees is more common. Natural regeneration, compared to sowing and planting, produces more young trees under the same conditions, but the number of regenerated trees will also decrease the most over the next 11 years. Using genetic material collected from one stand for sowing and growing seedlings and restoring the stand in three ways - naturally, sowing and planting - trees planted at a height of 2.5 - 3.0 times or by 4.9 and 5.6 years exceed the sown and naturally regenerated trees, respectively (Akczell, 1993).

Liepa (1996) mentions in his work that the height increment in planted Scots pine forest stands are initially higher than in Scots pine stands that have regenerated naturally. This difference can be explained not only by higher quality seeds or plants, but also by improved growth conditions during soil preparation. However, when choosing the type of regeneration, other factors need to be considered, such as finances and the health status of the felled and adjacent forest stand. Because the increment of height as an important indicator of young stands correlates with the health condition of the forest stand. For most pine species, the height increase occurs within two years, initially allowing the bud itself to form, but then ensuring its growth in length (Salminen, 2009). Thus, it can be said that the increase in altitude is influenced not only by the climatic conditions of a given year, but also by the events of the previous year, such as precipitation and temperature (Salminen, Jalkanen, 2005). The average diameter of trees in planted Scots pine stands is higher than in naturally regenerated stands at identical heights (Huuskonen, Miina, 2006), however more resistant to damage caused by the large pine weevil (Hylobius abietis L.). The most important damage done by needle cast is from brown needle cast (*Lophodermiuim seditiousum* Minter, Staley & Millar)). It causes a decrease in growth (Drenkhan, 2011). In case of re-infection, tree death is possible (Baumanis et al., 2014). Pine-aspen rust (*Melampsora pinitorqua*) is caused by a pathogenic fungus, co-hosted by shoots of common aspen (*Populus tremula* L.), which infects young shoots and trunks of pine.

Infection occurs in May and June by wind. As a result of the disease, the infected shoots curve in the shape of the letter "S". As a result of the infection, the growth of the tree decreases, the future timber assortments are damaged (Fjellborg, 2009). The deer's food base consists mainly of woody plants, but they also use herbs and grasses as food. It has been studied that deer prefer deciduous trees in summer and conifers in winter. Deer damage trees by feeding on their shoots, buds, bark, as well as rubbing their bark when cleaning the antlers (Gill, 1992).

The lower growth rates, within one stand, can be explained by the location of the sample plot in the stand, the edge effect, as one of the influencing factors reducing the height increase, where it was observed that trees growing in the middle of the felling are 11-37% higher as trees growing closer to the edges. The hilly terrain also influences the height increment (Burtons, 2002; Miezīte et al., 2015).

The increase in height of young trees is one of the most important indicators for determining the quality and productivity of the future forest stand. It is determined by both the growing season and the growth intensity (Jansons et al., 2011).

The aim of the study was to evaluate the natural regeneration and last 5 year tree height increment of Scots pine regenerated from the seed trees in the *Vacciniosa* and *Myrtillosa*, compared to planted stands, as well as to assess the impact of tree health on pine height increment.

RESEARCH METHODS

Sample plots were established in 10 stands - the naturally regenerated (private forests) from the seed trees (20 pieces per ha) and in the planted stands (state forests) in the *Vacciniosa* (Mr) and *Myrtillosa* (Ln) forest site type. In total 66 plots (hereinafter PL) were established and 704 trees were measured and surveyed. Each PL area is 25 m^2 with a radius of 2.82 m. The diameter of each tree in the PL measured at the root collar using an electronic calliper (accuracy 0.1 cm). The X and Y coordinates are recorded in the centre of each circular PL using a *Trimble Geo 7x*.

Increases in tree heights is also influenced by climatic conditions, so it is worth looking at how the studied forest stand is located in the total forest massif as the influence of air temperature, wind and frosts in spring and autumn are indirectly related to the location of the forest stand. In the forest, the trees themselves create a pleasant microclimate - those trees located on the edges of the forest massif (especially on the western side are affected by the prevailing winds in Latvia) are more or less exposed to various external influences, see Table 1, which shows the location of each stand within the forest massif.

Table 1. Forest stand location in forest massif

Coordinated of first PL in forest stand (X; Y)	Site type, species composition, age, regeneration type	Stand area, ha / Count of PL	Forest stand location in forest massif			
			Z	A	D	R
542695; 286062	Mr, $10P_8$, d	2.97 / 7	x	–	x	–
542946; 286080	Mr, $10P_8$, d	2.12 / 7	x	–	x	–
543032; 286092	Mr, $10P_8$, d	1.18 / 6	x	x	x	–
542257; 286823	Mr, $10P_8$, d	9.65 / 15	x	x	x	–
542163; 284795	Mr, $10P_8$, s	4.57 / 11	x	–	x	–
542583; 285001	Mr, $10P_8$, s	0.26 / 4	x	x	x	–
539829; 283131	Ln, $10P_8$, s	0.97 / 4	x	x	–	x
539926; 283143	Ln, $10P_8$, s	0.45 / 4	–	x	x	x
540074; 288966	Ln, $10P_8$, d	0.43 / 4	x	x	–	x
540150; 288863	Ln, $10P_8$, d	0.56 / 4	–	x	–	x

Legend: Mr – *Vacciniosa*; Ln – *Myrtillosa*; Z – North; A – East; D – South; R – West; s – Planted stands; d – naturally regenerated stands.

In PL the height increases of the last five years of Scots pine were determined with the help of a measuring rod (measuring tape attached to a two-meter-long batten) with an accuracy of 0.5 cm. The tree height measured for all trees in the PL. Visually determined vitality of each tree in the PL. The evaluation scale of abiotic, biotic and anthropogenic factors damage was used for the existing assessment of the vitality of Scots pine in PL (Miezīte et al., 2013), Table 2.

Table 2. Assessment of the damage of the abiotic, biotic and anthropogenic factors and crown vitality of Scots pine

Assessment of damage and crown of Scots pine	Degree of damage (b_i)
Scots pine without visible diseases and growth disorders. Tree crown without visible damage, symmetrical, distinctly green needles.	0
Economically insignificant damage or imperfections of Scots pine (some broken or bitten branches, minor damage to the trunk, banks on the branches or trunk, etc.). Partially weakened tree crown, the number of healthy needles decreased by 1/3, but the length of new shoots – by 1/4.	1
Economically significant damage to Scots pine (one or more minor damage to the trunk that occupies less than ½ of the circumference of the tree trunk) or imperfections (damage caused by an asymmetrical crown, double top). Very weakened pine with a rare crown, the proportion of green needles decreased by 2/3, but the length of shoots – by one 1/3.	2
Significant damage to Scots pine (damage to central shoot or signs of forging, tree without top (broken, withered, bitten), pine trunk not upright, trunk damage occupying more than ½ of trunk circumference, trunk damage and insect damage under bark and on wood). Drying pine, yellowing needles, the number of new shoots reaches only 1/3 of the total number of tree shoots; there are no possible shoots of the current year.	3
In the current year withered Scots pine (needles yellow or brown).	4
Withered pine (without needles)	5

Sourse: Miezīte et al. (2013)

The average height increase in young stands calculated according to formula (1):

$$Z_{Hvid.} = \frac{H}{a}, \qquad (1)$$

where Z_{Hvid} – average height increase of Scots pine stand, m;
H – average stand height, m;
a – stand age, years (Liepa, 1996).

In turn, the average current height increase is calculated using formula (2):

$$Z_{vid.tek.p} = \frac{H_{np}}{n_p}, \qquad (2)$$

where $Z_{vid.tek.p}$ – current average height increase, m;
H_{np} – average height increase in the last 5 years, m;
n_p – growth period, years (n_p=5) (Liepa, 1996).

The incidence of tree damage calculated according to formula (3) (Miezīte et al., 2013):

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

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) used to determine the intensity of tree damage:

$$R = \frac{\sum n_i \cdot b_i \cdot 100}{N \cdot k}, \qquad (4)$$

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.

Descriptive statistics used to evaluate the dendrometric parameters of Scots pine, while two-factor analysis of variance was used to evaluate the height increases (Arhipova, Bāliņa, 2003). Data were calculated and analysed in Microsoft Excel.

Hypothesis - there are significant differences both in the origin of forest stands and in the last 5 years of annual height increases in young stands in *Vacciniosa* and *Myrtillosa*, while there are no significant differences in height between healthy and damaged trees.

RESEARCH RESULTS AND DISCUSSION

Summary of dendrometric parameters of young pine stands

Different tree ages were found in naturally regenerated young stands. In turn, the growth process of trees in the planted young stands has been influenced by abiotic and biotic factors.

In the naturally regenerated $10P_8$ young stands in *Vacciniosa*, the stand thickness is 4490 ± 772 trees per ha, their average height is 1.08 ± 0.04 m, but the average diameter of trees at the root collar is 2.0 ± 0.12 cm. In the planted 10P8 young stands in *Vacciniosa*, the stand thickness is 3670 ± 939 trees per ha, their average height is 1.16 ± 0.04 m, but the average diameter of trees at the root collar is 2.5 ± 0.14 cm (Table 3.11). In naturally regenerated 10P8 young stands in *Myrtillosa*, the stand thickness is 4200 ± 738 trees per ha, their average height is 1.93 ± 0.09 m, but the average diameter of trees at the root collar is 4.2 ± 0.28 cm. In the planted 10P8 young stands tin *Myrtillosa*, the stand thickness is 3000 ± 72 trees per ha, their average height is 2.07 ± 0.09 m, but the average diameter of trees at the root collar is 4.8 ± 0.24 cm (Table 3).

Table 3. Summary of dendrometric parameters of Scots pine in naturally regenerated and planted young stands in *Vacciniosa* and *Myrtillosa*

Young stand composition and forest site type	Origin of stand	Stand thickness, trees per ha ± SE	Average tree height, m ± SE	Average tree diameter, cm ± SE
$10P_8$ Mr	Naturally	4490 ± 772	1.08 ± 0.04	2.0 ± 0.12
$10P_8$ Mr	Planted	3670 ± 939	1.16 ± 0.04	2.5 ± 0.14
$10P_8$ Ln	Naturally	4200 ± 738	1.93 ± 0.09	4.2 ± 0.28
$10P_8$ Ln	Planted	3000 ± 72	2.07 ± 0.09	4.8 ± 0.24

Dendrometric indicators in planted forest stands are higher than in naturally regenerated forest stands - tree height in average by 6.8% and tree diameter 21.7% on average, but the density of young stands is lower - by 7.9%. The density of planted young stands is higher, therefore the competition of trees for nutrients increases, therefore some trees have smaller indicator increments (Saksa, Miina, 2007). The density of young stands is higher in naturally regenerated stands.

Comparison of height increases of Scots pine in naturally restored and planted forest stands in Vacciniosa and Myrtillosa

Only the plots in 8-year-old Scots pine stands were used to assess the annual increase in height over the last five years. In naturally regenerated young stands in *Vacciniosa*, there are significant differences between the annual increases in the height of Scots pine in the last 5 years ($p=0.041<\alpha=0.05$). On the other hand, there are no significant differences between healthy and damaged trees in naturally regenerated young stands in *Vacciniosa* ($p=0.332>\alpha=0.05$). In naturally regenerated young stands in *Vacciniosa*, the annual average height increase of the measured trees in the range varies from 0.14 to 0.40 m. When evaluating the planted young stands in *Vacciniosa*, there are significant differences between the annual height increases of the last 5 years ($p=0.012<\alpha=0.05$). In the planted young stands in *Vacciniosa*, the annual average height increase of the measured trees varies in the range of 0.16-0.49 m. There are no significant differences between the annual average height increase of healthy and damaged pines ($p=0.240>\alpha=0.05$).

Annual pine growths differ significantly (p $0.004<\alpha=0.05$) in naturally regenerated and planted young stands in *Myrtillosa*, while there are no significant differences between healthy and damaged trees ($p=0.053>\alpha=0.05$). In turn, evaluating the annual height increases of the last 5 years in the planted pine stands in *Myrtillosa*, statistically significant differences were found ($p=0.042<\alpha=0.05$), as well as there are significant differences ($p=0.045<\alpha=0.05$) between healthy and damaged trees. In the naturally regenerated young stands in *Myrtillosa*, the annual average height increase of the trees measured varies in the range of 0.17-0.52 m, correspondingly, in the planted stands - 0.1-0.62 m.

In naturally regenerated young stands in *Vacciniosa*, the average periodic increase in height over the last five years is 0.22 m; planted - 0.23 m; 0.33 m and 0.36 m, respectively in *Myrtillosa*. In all cases, the average height increase of Scots pine is significantly smaller ($p = 0.003 < \alpha = 0.05$) than the average periodic height increase of the last 5 years (Fig. 1).

Comparing the annual height increases in *Vacciniosa* and *Myrtillosa* in the last 5 years, the annual height increases in the naturally regenerated young stands differ significantly from year to year ($p=0.001<\alpha=0.05$), but there are no significant height differences between healthy and damaged trees ($p=0.052>\alpha=0.05$). This means that the hypothesis is confirmed.

In comparison, the annual height increases of planted pine trees in *Vacciniosa* and *Myrtillosa* differ significantly by years ($p=0.002<\alpha=0.05$), as well as there are significant differences ($p=0.033<\alpha=0.05$) between annual height increases between healthy and damaged trees.

There is a tendency that height increases gradually increase (Fig. 1), however, in 2018. (hot, dry - precipitation 472.7 mm (annual norm 692.3 mm)) is a sharp decline, which again gradually in 2019. (warm, long vegetation season, precipitation 629.2 mm (annual norm 692.3 mm)) stabilizes. For most pine species, the increase in height occurs within two years, initially allowing the bud itself to form, but then ensuring its growth in length (Salminen, 2009). Thus, it can be said that the height increase is influenced not only by the climatic conditions of a given year, but also by abiotic factors of the previous year, such as precipitation and temperature (Salminen, Jalkanen, 2005).

Comparing the height increases of Scots pine in naturally regenerated young stands and planted young stands in *Vacciniosa*, it was found that the annual height increase in planted stands is 8.9% higher than in naturally regenerated young stands, but in young stands in *Myrtillosa* - 4.0%.

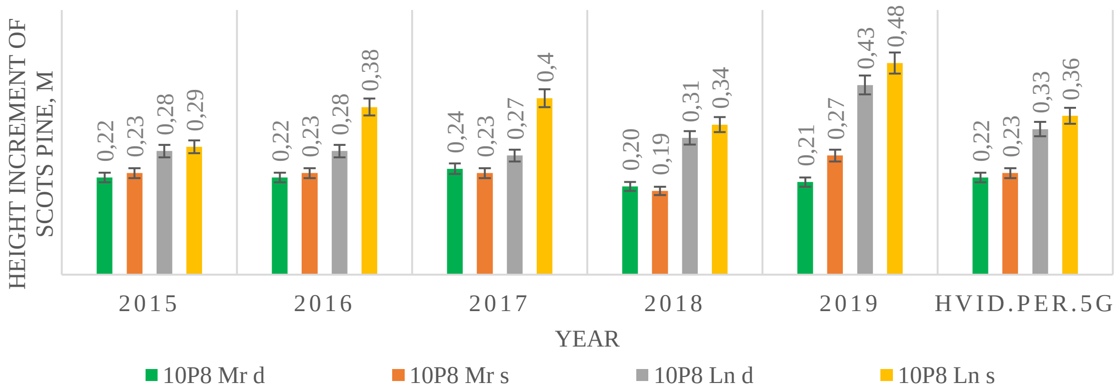

Figure 1. Height increment (±SE) of Scots pine in the last five years in naturally regenerated and planted young stands

In both forest types, the most damaged trees were found with low intensity damage, regardless of the origin, despite the high incidence of damage (Fig. 2). The intensity of the damage does not significantly depend on the incidence (p=0.126>α=0.05). Damage caused by needle cast (36%) was found more significant in naturally regenerated young stands in *Vacciniosa*, because these stands are thicker. Therefore, it promotes the spread of needle cast (Jansons, 2008), but the observed damage is not statistically significant, while in the plantations - large pine weevil (13%), ungulates (25%) and *Melampsora pinitorqua* Rostr. (6%) induced damage. Large pine weevil (27%) causes the most significant damage to naturally regenerated young stands; while in the plantations - large pine weevil (21%) and ungulates (42%). The intensity of tree damage in naturally regenerated young stands in *Vacciniosa* is 22%, while in *Myrtillosa* - 12%, in planted areas - 25% and 31%, respectively. In young stands of Scots pine of different origins, the health status of the trees in *Vacciniosa* and *Myrtillosa* does not significantly affect the formation of the future forest stand. Because by clearing forest stands from trees whose growth process is disturbed due to various factors (bitten top, damaged central shoot bud, etc.), the number of remaining trees in all studied young stands will ensure productive development of future forest stands (Cabinet Regulation 935 "Regulations on Tree Felling").

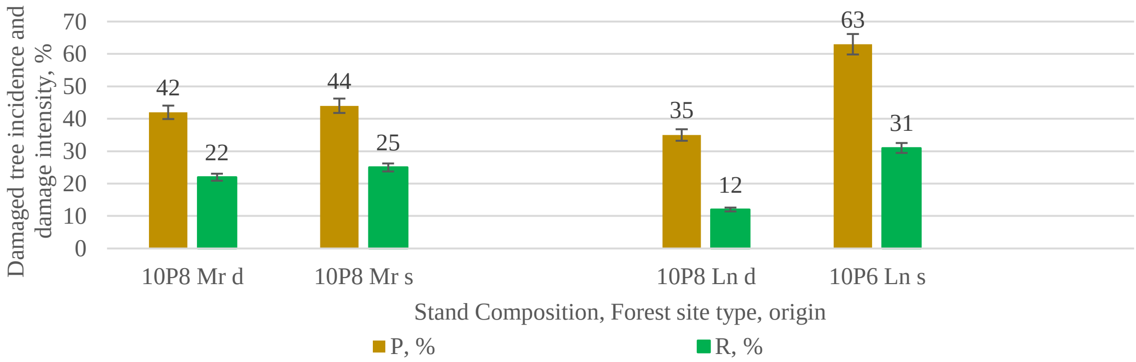

Figure 2. Damaged tree incidence (P, %) and damage intensity (R, %)

As soil in *Myrtillosa* is more fertile, the diversity of ground cover and undergrowth species is higher and richer, respectively, which in turn attracts more various living organisms, including pine abiotic factors - insects and cloven-hoofed animals. These stands are away from busy forest roads, as it is along forest stands in *Vacciniosa*. Therefore, human activities did not interfere with ungulates. The extent of their damage in forest stands depends mainly on the population density of deer and elk and the available food base in the area (Knibb, 2018), therefore it can be concluded that the density of ungulates in the measured forest stands is not too high and there is sufficient food available for animals. Ungulate damage was found in all young stands, but with low tree damage intensity, except for young stands in *Myrtillosa*, which are located relatively far from the infrastructure. Similar damage values have been found in other studies (Done, 2021).

CONCLUSIONS

1. Dendrometric values in young Scots pine stands in *Vacciniosa* and *Myrtillosa* are higher in planted than in naturally regenerated stands - the tree height by 6.8% but tree diameter by 21.7% on average, while the density is lower - by 7.9%.

2. In naturally regenerated young stands in *Vacciniosa*, the average periodic increase in height over the last five years is 0.22 m; in planted stands - 0.23 m; 0.33 m and 0.36 m, respectively in *Myrtillosa*. In all cases, the average height increase of Scots pine is significantly lower than the average periodic height increase of the last 5 years.

3. Comparing the height increases of Scots pine in naturally regenerated and planted young stands in *Vacciniosa*, the annual height increase in planted stands is 9% higher than in naturally regenerated, while in young stands in

Myrtillosa - by 4%. There are significant differences between the last 5 years of annual height increases in young stands in *Vacciniosa* and *Myrtillosa*, both by forest stand origin and by years, while there are no significant differences between healthy and damaged trees.

4. The intensity of damage to damaged trees in naturally regenerated young stands in *Vacciniosa* is 22% and in *Myrtillosa* 12%, respectively in planted stands - 25% and 31%. In the naturally regenerated young stands, the most significant damage in *Vacciniosa* is caused by needle cast, in the naturally regenerated young stands in *Myrtillosa* - by large pine weevil, while in the planted - ungulates and insects. Damages of ungulates is more significant in planted forest stands in *Myrtillosa*, which are located deeper in the forest massif.

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