# The impact of planting time on growth and browsing damage to Scots pine seedlings

- Field study at a forest site in Attsjö, southern Sweden

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Karolina Forsén
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## Abstract

Regeneration with Scots pine often fail to reach set goals in Swedish forestry. As regeneration often is performed through planting of seedlings, it is of importance to understand how different factors in planting practices affect the outcome. A study was conducted, building on a previous study, using an existing study site in Attsjö, southern Sweden. Scots pine seedlings were planted for the original study, at different weeks in autumn of 2020 and the spring of 2021. At an on-site follow-up conducted in March 2025 for this study, all seedlings were measured regarding height and diameter. Existing damage were also noted and severity rated. The analysis of the data collected showed that the seedlings from all autumn planting times (year 2020) were similar regarding mean growth, damage levels and survival. The seedlings planted in spring 2021 had grown taller and wider, were overall less damaged and had lower mortality than the seedlings planted in autumn. The main factor thought to have caused the differences in results between the autumn planted seedlings and spring planted seedlings were browsing by deer animals, as earlier results showed that many of the autumn planted seedlings were browsed already in their first winter on site. The results indicate that spring planting is to prefer when planting Scots pine on forest sites with considerable browsing pressure.

Keywords: Pinus sylvestris, regeneration, time of planting

## Popular science summary

Scots pine is a tree species native to Sweden and common in the forest landscape. Planting of seedlings is the most common way to regenerate forest sites. Many of the Scots pine seedlings planted in Sweden die within the first years after planting. This study builds on previous research on a site in Attsjö, in southern Sweden. It follows how Scots pine seedlings planted in different time of year (autumn and spring) have developed in terms of growth and damage levels. The seedlings were measured in field and the collected data was analysed. The outcome shows that groups of seedlings that early on largely became browsed still are behind in growth and are more damaged, four growing seasons after they were planted. The results indicate that spring planting is to be preferred when planting Scots pine seedlings on forest sites in areas with high browsing pressure.

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# 1. Introduction

## 1.1. Scots pine in Swedish forestry

The native species Scots pine (*Pinus sylvestris*) is a common tree species in Swedish forests - pine forest is the most common forest type (40%) on productive forest land as to the country at large (Swedish University of Agricultural Sciences, 2024). In Kronoberg county, 13% of young forests (1-4 meters high) are pine dominated – the most common forest type in the young forests of Kronoberg is instead spruce forests (58%), according to the Swedish Forest Agency (n.d.-a).

The efforts to regenerate pine forests are often not as successful as planned – high mortality in Scots pine seedlings (often caused by browsing by deer) are often making it difficult for forest owners to establish Scots pine dominated forests (Ara et al., 2022).

Many forest sites in Sweden that previously was covered with mostly Scots pine have been regenerated with Norway spruce instead. However, as Felton et al. (2019) have shown, a development towards larger areas of continuously spruce dominated forests can lead to consequences, such as changes in biodiversity and increased risk of damage to the spruce. A more spruce dominated forest landscape may, in extension, lead to more browsing damage on the remaining stands that are more vulnerable to browsing (Felton et al., 2019).

## 1.2. Forest regeneration in Sweden

The most common way to regenerate forests in Sweden is by plating seedlings, which has been done at about 87% of the logged area since year 2018 (Swedish Forest Agency. n.d.-b).

## 1.3. Seedling establishment

### 1.3.1. Planting time

A long season for planting seedlings in forestry can be wanted for several reasons, for example because of shortage of labour (Luoranen et al., 2018).

A study on Norway spruce seedlings, with site experiments in south-eastern Norway and southern Sweden, showed that seedlings planted in August had a significantly higher increase in biomass than seedlings planted in November, or in May the following year (Wallertz et al., 2016).

Scots pine seedlings planted in autumn or spring were less likely to survive than those planted during the summer in a study, in central Finland, by Luoranen and Rikala (2012).

Both container Scots pine seedlings and bare root Scots pine seedlings planted in autumn were significantly taller than those planted the following spring (except compared to the group spring planted container seedling treated with Stockosorb) when measured after the first growing season, in a study by Repáč et al. (2021) in northwestern Slovakia.

### 1.3.2. Initial root growth

The root growth in autumn of newly planted pine seedlings have been shown by Luoranen (2018) to correspond to when root growth starts the following growing season – the roots of the seedlings planted in August started to grow earlier the next year than the roots of seedlings planted in late autumn.

The stress (*planting stress*), that a newly planted seedling undergoes before it has developed roots that grow into the soil on the site can affect how it performs later when it is established (Grossnickle, 2005). Planting stress can be lowered by planting seedlings with good technique (Grossnickle, 2005) and seedlings with root systems of high quality are more likely to establish successfully (Grossnickle & Ivetić, 2022).

### 1.3.3. Winter conditions and deacclimation

There has been a general trend toward fewer days of snow cover in Sweden since mid-1980's (SMHI, 2022). With climate change and thus a warmer climate, the length of the period with snow is estimated to decrease, though an expected increase in precipitation can lead to a deep snow cover at times (SMHI, 2022).

Scots pine seedlings are sensitive to fluctuating temperatures during snowless winters – the seedlings deacclimate during warmer periods and are then at risk of frost damage if the temperature drops again (Luoranen et al., 2024).

## 1.4. Biotic causes to damage on seedlings

Johansson et al. (2014) found, in a study in Sweden, that Scots pine seedlings were less damaged than Norway spruce seedlings the first three years after planting – however, the Scots pine seedlings continued to be sensitive to damage when the damage to Norway spruce had plateaued. Browsing by deer, Pine twisting rust (Melampsora pinitorqua), damage by pine weevils and voles were a few causes for pine seedlings to die, yet for many of the dead seedlings it was not possible to identify cause (Johansson et al, 2016).

### 1.4.1. Browsing damage

Browsing of shoots and stems of young trees by deer can lead to decreased growth, lowered vitality and even death for the trees (Swedish Forest Agency, 2025). The results from the last three ÄBIN (inventory of moose browsing on forest trees in Sweden) shows that the damage level of pine trees is severe in the county of Kronoberg, southern Sweden, with 54% of the pines being undamaged by browsing (Swedish Forest Agency, n.d.-a). The goal for Sweden is for 85% of the pine trees, in the height span measured in the inventory, to be undamaged by grazing (Swedish environmental protection agency, 2018).

Access to food for deer and the sizes of the populations of deer species (moose especially) are important factors to the degree of browsing damage (Pfeffer et al., 2022). Forest composition and climate (Pfeffer et al., 2022) as well as large scale landscape patterns can also affect the degree of damage caused by deer (Cassing et al., 2006).

A study by Månsson et al. (2007) showed that a group of trees of the broadleaved tree species rowan (*Sorbus aucuparia*), aspen (*Populus tremula*) and willow (*Salix ssp*.) had a much higher probability (14 times) of being browsed by moose than a group of Scots pine and downy birch (*Betula pubescens*). The authors discussed, however, that as the most preferred tree species in the study also were the least ample, the degree of preferability is hard to generalise as it might be connected to the tree species composition. Norway spruce was browsed to a very low degree in the study (Månsson et al. 2007).

Pine is an important source of food for moose and constitutes a large part of the diet, especially during the winter months (Spitzer, 2019). The other deer species roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) also feed on pine, though it makes up considerably smaller parts of their diets (Spitzer, 2019).

In a study by Bergqvist et al. (2012) browsing (mainly by roe deer) was studied on a winter following planting of Scots pine seedlings in combination with either ash (*Fraxinus excelsior*) or silver birch (*Betula pendula*). The results by Bergqvist et al. (2012) showed no difference in the browsing of the Scots pine seedlings depending on what tree species they were mixed with. Felton et al. (2022) found proportionally more damage to pine trees in landscapes with less of the broadleaved tree species that are most preferred by deer.

Moose tend to browse proportionately more on previously browsed tree individuals than on previously undamaged trees, as shown in a study on Scots pine, by Bergqvist et al. (2003). Mathisen et al. (2017) found, in a study in Norway, that moose browsed more on previously browsed tree individuals of both conifer and deciduous tree species, indicating that it may be a general behaviour.

Bergqvist et al. (2018) found in a study (with study sites spread throughout Sweden) that young forests were proportionally more used by browsers for winter forage, while mature forest stands and non-forest land also were important sources of forage, since a larger part of the landscape consist of these land types. For Scots pine specifically, the forage cover was significantly higher in young forests than in mature forests and non-forest land (Bergqvist et al., 2018).

### 1.4.2. Pine weevil damage

Pine weevil (*Hylobius abietis*) is an insect causing large economic loss due to its feeding on bark of the stems of conifer seedlings – and is one of the pest insect species causing most damage in European forestry (Fedderwitz et al., 2018).

When the damage caused by pine weevils are extensive enough it is mortal to the seedling and Domevscik et al. (2024) write that environmental stressors - such as drought – can increase the mortality of (Norway spruce) seedlings.

The use of insecticides to prevent Pine weevil damage has been banned in Sweden from October 2023 (Lind, 2023). Instead, physical barriers (mechanical treatments) can be applied to the seedlings and silviculture measures (such as soil scarification) can lower the risk of damage (Nordlander et al., 2009).

## 1.5. Seedling treatments

In 2023, 44% of Scots pine seedlings used in Sweden was treated with some kind of mechanical treatment (Swedish Forest Agency, 2024).

These kinds of treatments are used to lower the frequency of damage caused by for example pine weevil and browsing deer animals. There are different brands with different product formulations.

### 1.5.1. Hylonox

Hylonox is a mechanical treatment used to reduce gnaw by Pine weevil on seedlings, containing the mineral quartz (Organox, n.d.-a). Eriksson et al. (2018) found containerized Norway spruce seedlings treated with Hylonox to be significantly less damaged after two years than untreated seedlings.

39% of the seedlings treated with Hylonox had sufficient coverage in a follow-up on bare root seedlings, in a thesis study by Broman and Johansson (2019). The authors discussed that it might have been a consequence of the Hylonox falling off after drying out in field, or of lacking technique when the product was first applied.

Domevscik et al. (2024) found that 35% of Hylonox treated Norway spruce seedlings planted a specific year had no cover left from the treatment two seasons later and the Hylonox treated seedlings in total did not have significantly higher survival rates than the untreated seedlings.

### 1.5.2. Trico

Trico is a deer repellent, with an emulsion of fatty acids from sheep as the active substance, that is sprayed on the tops of seedlings and saplings (Organox, n.d.-b).

Seedlings treated with Trico have been found to be significantly less damaged than untreaded seedlings in thesis studies by Tallgren and Andersson (2020) and Olsson (2020)

## 1.6. Short day treatment

Short day treatment is a way for nurseries to imitate long nights using dark curtains to cover seedlings during specific hours of the day (Wallin et al., 2021). In southern and central Sweden short day treatment is, according to Wallin et al. (2021), mostly performed with Norway spruce seedlings during the second half of July, making the seedlings enter dormancy and thus be prepared for the cold of winter.

Scots pine seedlings can be short day treated early in the season (May or early June) which makes them grow secondary needles in a few weeks (Luoranen & Rikala, 2012). This is done in an aim to get seedlings that are more tolerant to stress, and therefore more suited for late season planting (Luoranen & Rikala, 2012).

## 1.7. A need for more knowledge

Since regeneration of Scots pine forests in Sweden often is unsuccessful, (Ara et al., 2022), more knowledge is needed to develop more successful practices for regenerating Scots pine. Seeing that planting of seedlings is by far the most common practice for regeneration of forests in Sweden (Swedish Forest Agency. n.d.-b), more knowledge about what makes planting likely to succeed has an evident applicability in practice. Not much research on the topic have been done and therefor it is very relevant to study it more.

## 1.8. Delimitations

The focus of the data analysis will be on the effects of planting time and on how early browsing of seedlings affect later growth and damage levels. The different plant types and treatments will not be a focus area in the analysis.

The different plant types and treatments are, however, briefly covered in general terms in the literature study to give a more complete introduction to the field study started in year 2020.

## 1.9. Purpose

The purpose of this thesis is to study how the seedlings in Attsjö have developed regarding growth and damage, the two seasons after they were previously followed up. This, to expand the knowledge about if (and how) planting time affects the growth and damage levels of planted Scots pine seedlings.

## 1.10. Research question

- Are there any differences in height, diameter, browsing damage and survival of the seedlings depending on the time of year they were planted?

# 2. Materials and methods

## 2.1. Field study

### 2.1.1. Design and results of the original study on the site

A field study was also carried out in March of 2025. The study site was an already existing study site in Attsjö, Kronoberg county. That study was set up in year 2020 to gather more knowledge about autumn planting of Scots pine seedlings and how different seedling types and treatments affect the performance, which is described in an unpublished report by Wallertz and Hjelm (n.d.). The seedlings were of a few different types (either one- or two-needled) and some had undergone different treatments (short day treatment, the mechanical treatments Hylonox and Trico). Seedlings were initially planted at three different times: week 36, week 38 and week 41 of 2020 – and an additional planting was later decided upon and was carried out in week 15 of 2021. In this study, the differences regarding seedling types and treatments are disregarded – what is studied is planting time.

The seedlings are planted into rows and sections. Sections one, two and three were planted in year 2020 and consisted of 75 rows in total (25 in each section). The seedlings were planted in a pattern making every third row planted the same week. Each row consisted of 12 seedlings. There were in total 900 seedlings planted on the site in year 2020.

In the spring 2021 a fourth section was planted with 25 rows with 6 seedlings in each. Since this section was not originally planned when the experiment was set up, there were not enough space to follow the same planting pattern, and this section differ therefor from the rest of the experiment in design. There were in total 150 seedlings planted on the site in the spring of 2021.

The site had a site index of 20 for Scots pine (Wallertz and Hjelm, n.d.). Annual mean precipitation in the ten-year period 2015-2024 was measured to 693 millimeters at a wheather station in Växjö (SMHI, n.d.). The seedlings were planted in soil that had been prepared through disc trenching. Coloured plastic sticks were used to differentiate each individual seedling. Larger wooden sticks with written numbers were used to show the different rows of the experiment.

The results by Wallertz and Hjelm (n.d.) showed that seedlings planted late in the season (week 41) had significantly less biomass than the seedlings planted in week 36 and week 38, when they were measured one growing season after planting.

The seedlings planted in 2020 had considerable levels of browsing damage at the time of a follow-up in May of 2021: about 70% of the one-needled seedlings had damage from browsing and about 50% of the two-needled seedlings (Wallertz and Hjelm, n.d.).

### 2.1.2. Study conditions in year 2025

At the time of this field study (in year 2025) some of the plastic and wooden sticks were overgrown, some broken and some of the numbers of the wooden sticks were not possible to read. The old marking sticks were, at large though, useful as tools to navigate on site.

In the follow-up in March 2025 each seedling was measured regarding diameter and height. The diameters were measured using a caliper at the base of the seedlings, as close to the ground as practically possible (figure 1).
Heights were measured with a folding rule from the ground up to the top shoots of the seedlings (in the cases where top shoots were missing the hights were measured up to the highest living needles). The results were noted digitally to an Microsoft Excel spreadsheet. Browsing damage was visually examined and type of browsing damage was noted as well as degree of damage. The types of damage examined was browsing damage on the latest top shoot (figure 2), browsing damage on side shoots (figure 3) and damage on stem (figure 4) and each type of damage was designated a number between zero to five (table 1). Damage on stem was damage that clearly indicated that they were caused by a deer animal. Smaller stem damage where there was uncertainty whether they were caused by deer or something else (for example insects) were not noted.

*Figure 1: The stem diameter of the seedlings was measured as close to the ground as possible*

*Table 1: Classification codes for the different types of damage*

| Classification code | Type of damage |
|---|---|
| **0** | No damage |
| **1** | Top shoot damage |
| **2** | Side shoot damage |
| **3** | Top shoot damage + side shoot damage |
| **4** | Stem damage |
| **5** | Shoot damage + stem damage |

To what degree the seedlings was damage was rated as 0: not damaged, 1: negligibly damaged, 2: somewhat damaged, 3: heavily damaged, 4: damaged to a life-threatening degree, 5: dead, 6: dead since earlier/seedling not found (table 2). Dead since earlier refers to if the seedling was noted as dead at earlier follow-ups.

*Table 2: Rating of damage level*

| Rating | Damage level |
|---|---|
| **0** | Not damaged |
| **1** | Negligibly damaged |
| **2** | Somewhat damaged |
| **3** | Heavily damaged |
| **4** | Damaged to a life-threatening degree |
| **5** | Dead |
| **6** | Dead since earlier/seedling not found |

*Figure 2: Browsing damage on top shoots. Photo: Karolina Forsén, March 2025*

*Figure 3: Browsing damage on side shoots. Photo: Karolina Forsén, March 2025*


*Figure 4: Damage on stem. Photo: Karolina Forsén, March 2025*

## 2.2. Analysis of data

The collected data was summarised in Microsoft Excel and analysed in both Microsoft Excel and the program RStudio.

Mean heights and mean diameters were calculated first for each row. The means was then calculated for each section of each planting time using the mean values of the rows. At last, the mean values of each planting time in total were calculated using the calculated means of each section. These steps were taken to minimize the impact of differences in growing conditions at different parts of the site.

ANOVA-tests and Tukey's HSD tests was performed on the mean height and mean diameter for each planting time, using the program RStudio. To visualize the results boxplots were made using RStudio.

The number of seedlings for each planting time with each type of damage was calculated using Microsoft Excel and Microsoft Word. How many seedlings that had each damage level for each planting time was calculated as well. Diagrams were made in Microsoft Word to visualize the results.

# 3. Results

The times when the seedlings were planted is henceforth called: autumn 1 (week 36 of 2020), autumn 2 (week 38 of 2020), autumn 3 (week 41 of 2020) and spring (week 15 of 2021).

## 3.1. Seedlings heights

### 3.1.1. Mean heights

The seedlings planted in spring are significantly higher than those planted at each of the autumn-planting times (table 3). There are no significant differences between the heights of the seedlings planted at the planting times autumn 1, autumn 2 and autumn 3 (table 3).

*Table 3: Result of Tukey's HSD test for mean heights for each planting time. 1, 2 and 3 are short for autumn 1, autumn 2 and autumn 3. Bolded text shows p-values that implies significant differences in height.*

| Compared planting times | Difference (cm) | Adjusted p-value |
|---|---|---|
| **2-1** | 8.83640 | 0.2576169 |
| **3-1** | 0.03840 | 0.9999998 |
| **spring-1** | 38.97998 | **0.0000000** |
| **3-2** | -21.301891 | 0.2612366 |
| **spring-2** | 30.14358 | **0.0000001** |
| **spring-3** | 38.94158 | **0.0000000** |

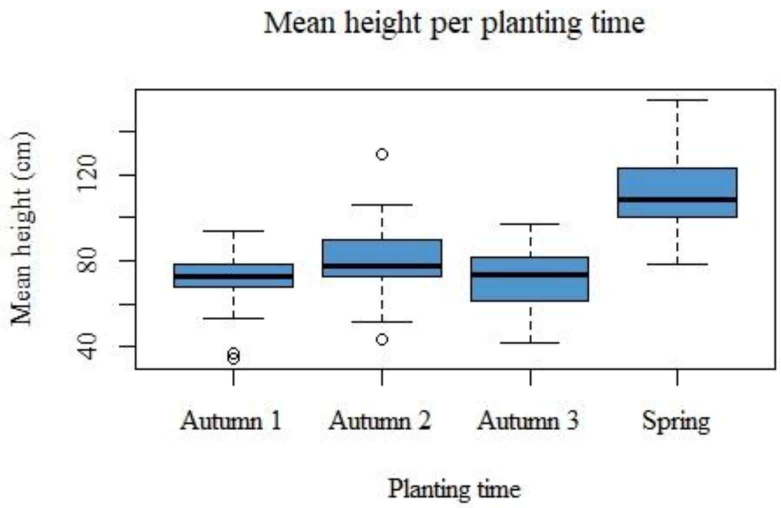


*Figure 5. Box plot, showing the distrubution of the mean heights of the seedlings in the rows for each planting time . The box show the middle 50 % of the values and the black line in the box show the median of all values. The whiskers show the range of the data. The individual circles below/above the whiskers show outliers, values that are significantly different than the other values.*

### 3.1.2. Height development

The mean heights of the seedlings planted at planting time 1, 2 and 3 was very similar at the follow-ups in autumn 2021 and autumn 2022 (Wallertz & Hjelm, n.d.) (figure 6). At the follow-up in spring 2025, the mean heights of the seedlings from autumn 1 and autumn 3 was almost the same and the seedlings from autumn 2 was a little ahead in height. The mean height of the seedlings planted at planting time 4 was already at the time they were measured, autumn 2021, ahead of the other seedlings and the difference between the mean heights was then larger at the follow-up in 2022 and even larger at the follow-up in spring 2025 (figure 6).

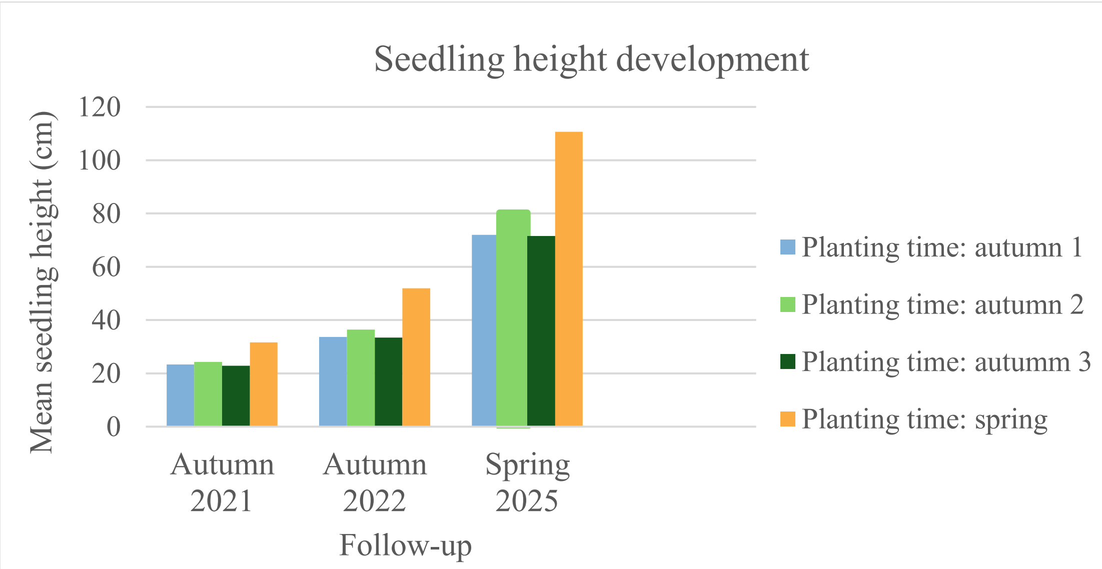


*Figure 6. The mean heights of the seedlings for each planting time at the time of the follow-ups in autumn 2021, autumn 2022 and spring 2025*

## 3.2. Seedling diameters

The mean diameters of the seedlings planted at planting time 4 are significantly different than those planted at planting time autumn 1 and autumn 3, however not than those planted at planting time autumn 2 (table 4). No significant differences were found between the diameters of the seedlings planted at the planting times autumn 1, autumn 2 and autumn 3 (table 4).

*Table 4: Result of Tukey's HSD test for mean diameters for each planting time. 1, 2 and 3 are short for autumn 1, autumn 2 and autumn 3. Bolded text shows p-values that implies significant differences in diameter.*

| Compared planting times | Difference (mm) | Adjusted p-value |
|---|---|---|
| **2-1** | 2.076800 | 0.4996927 |
| **3-1** | -0.236000 | 0.9985427 |
| **spring-1** | 5.117483 | **0.0049522** |
| **3-2** | -2.312800 | 0.4039677 |
| **spring-2** | 3.040683 | 0.1824604 |

| | | |
|---|---|---|
| **spring-3** | 5.353483 | **0.0029735** |

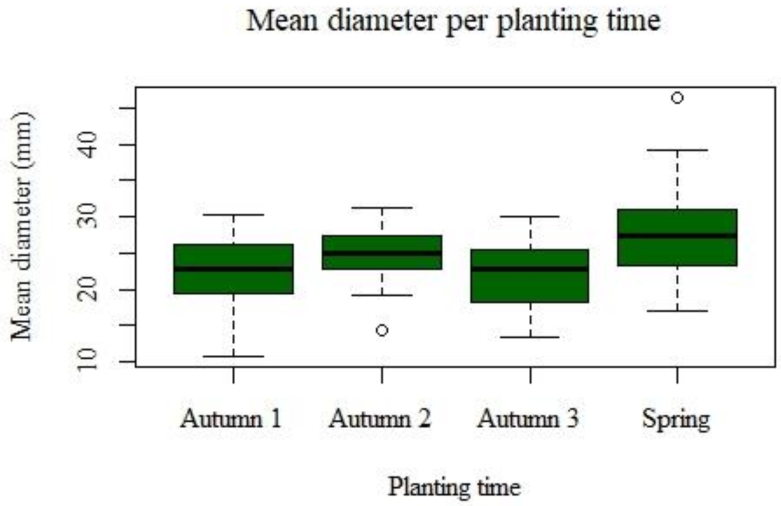


*Figure 7. Box plot, showing the distrubution of the mean diameters of the seedlings in the rows for each planting time. The box show the middle 50 % of the values and the black line in the box show the median. The whiskers show the range of the data. The individual circles below/above the whiskers show outliers, values that are significantly different than the other values.*

## 3.3. Damage levels

### 3.3.1. Autumn planted seedlings

The damage levels were very similar for the planting times autumn 1, autumn 2 and autumn 3 (figure 8). Only 1-2% of these seedlings were undamaged by browsing (figure 10). 4-7% of these seedlings had negligible damage, 13-17% were somewhat damaged and 30-32% were heavily damaged (figure 8). 5-7% of the seedlings planted at the autumn planting times were damaged to a life-threatening degree, 1-3% were found dead and 36-38% of these seedlings were dead since earlier and/or could not be found at all on site (figure 8).

### 3.3.2. Spring planted seedlings

The damage levels for the springs planted seedlings clearly differs from that of the other planting times (figure 8). 14% of these were undamaged by browsing, 16% had negligible damage, 24% of them were somewhat damaged and 22% heavily damaged (figure 8). 4% of the seedlings planted in spring was damaged to a life-threatening degree, 1% were found dead and 21% of these seedlings were dead since earlier and/or not found (figure 8).

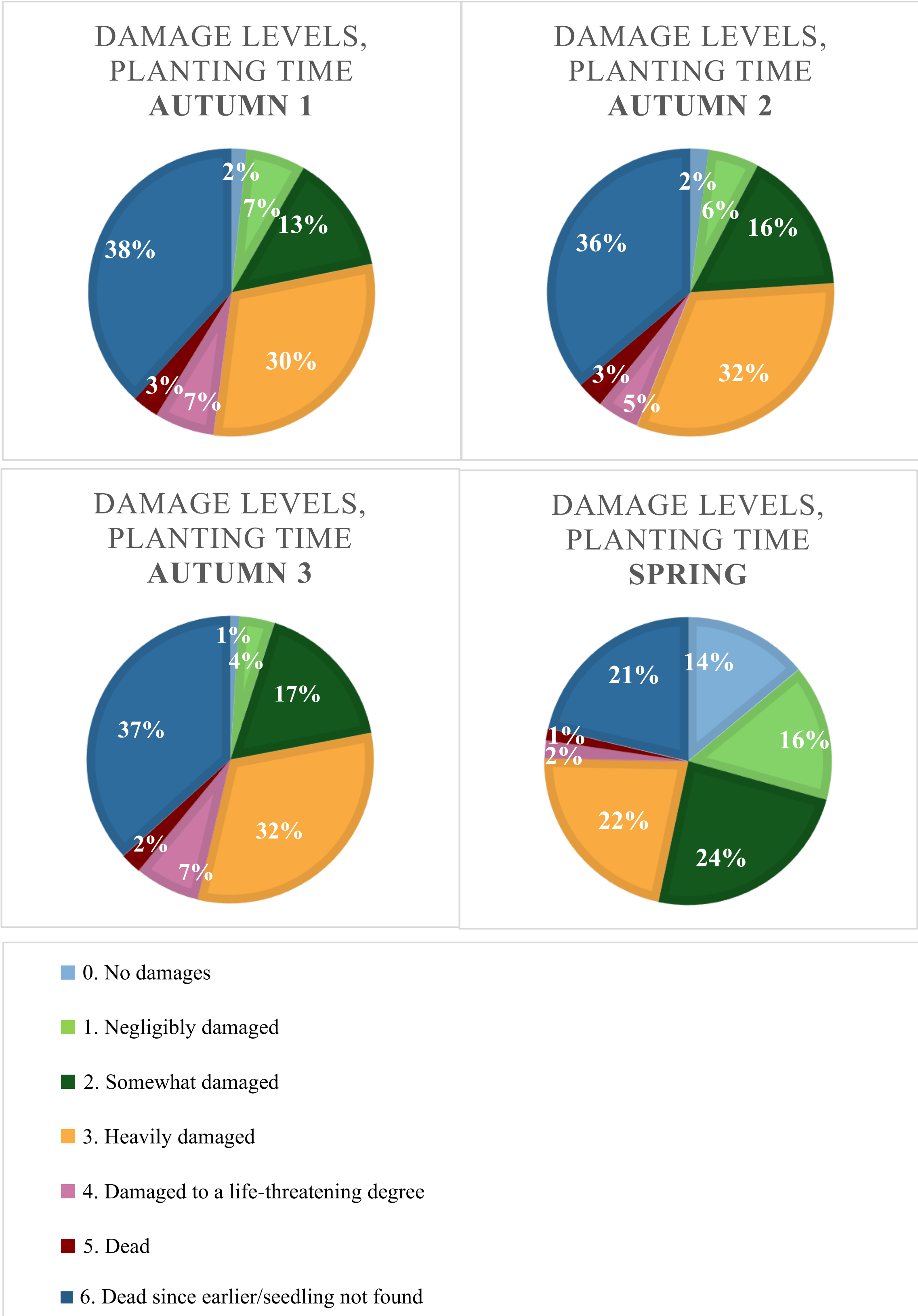


*Figure 8. Damage levels, for each planting time, at the time of follow-up in the spring of 2025.*

## 3.4. Seedling mortality

The mortality of the seedlings from autumn 1, autumn 2 and autumn 3 was quite similar at all follow-ups (figure 9). A clear difference in mortality is seen between those and the seedlings planted in spring, that have died to a much lower extent (figure 9).

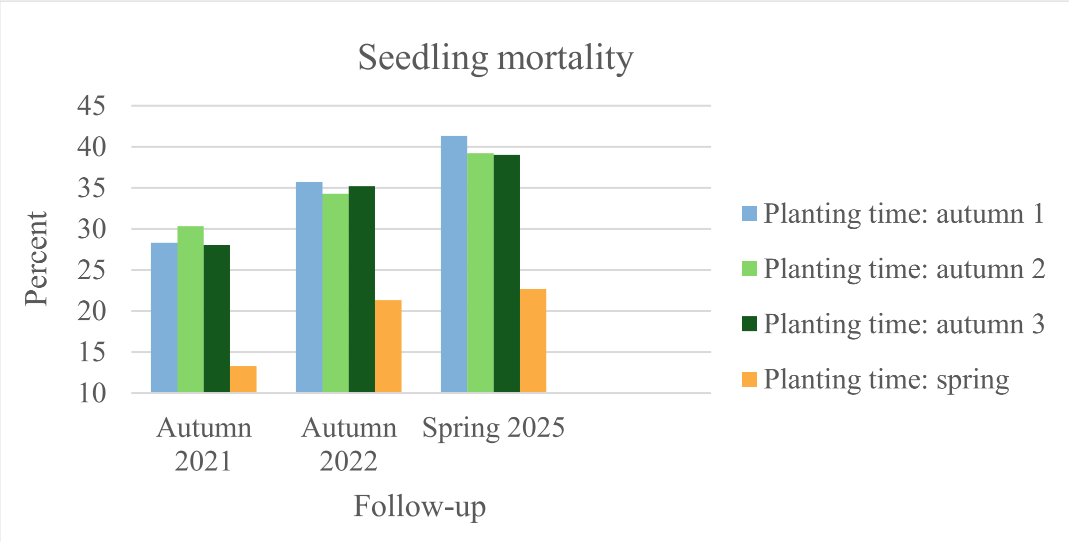


*Figure 9. Seedling mortality at the times of the follow-ups in autumn 2021, autumn 2022 and spring 2025.*

## 3.5. Type of damage

The most common type of damage was side shoot damage, followed by top shoot damage + side shoot damage (figure 10). 3,8% of the seedlings had shoot damage and stem damage, 1,5% had stem damage (without having shoot damage) and 0,5% had top shoot damage (without other damage) (figure 10). 5,7% of the seedlings had no damage (figure 10).

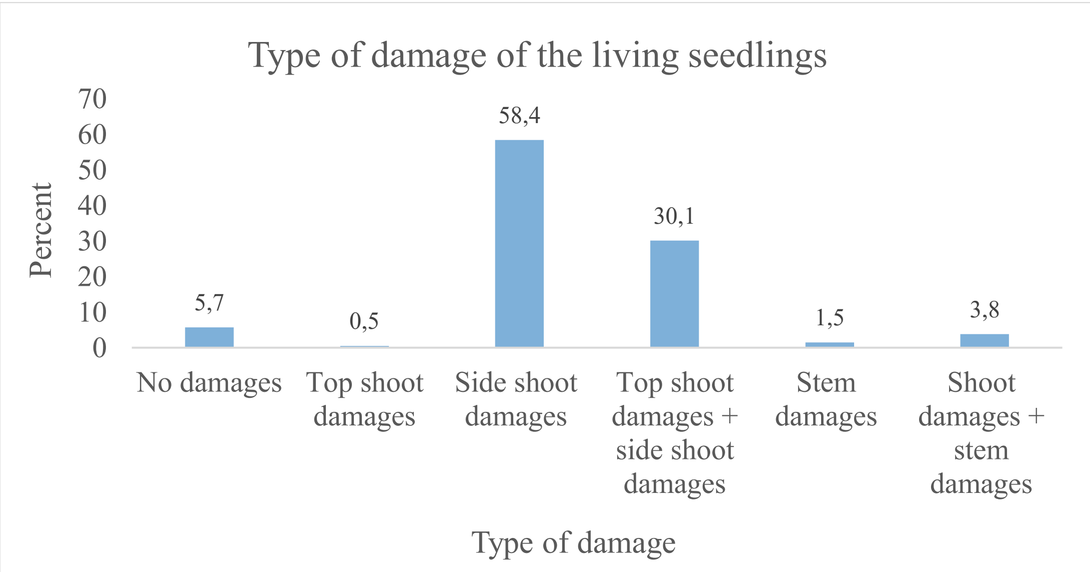


*Figure 10. Distribution of different type of seedling damage at the time of the follow-up in spring 2025.*

# 4. Discussion

The spring planted seedlings had, already after the first growing season, grown higher than those planted in autumn and that lead had grown at the time of the follow-up in 2022 and the follow-up in spring 2025. Whether it was solely because of the early damage to the autumn planted seedlings the first winter, or if it is also was a consequence of the plants not being able to establish quickly after being planted later in the season (or something else) is hard to decide. Grossnickle (2005) found that planting stress can affect the performance of seedlings later in their life span, maybe that is something that could have contributed to the results of this study. At the time of the first follow-up where mortality was measured (in autumn 2021) in the original study by Wallertz and Hjelm (n.d.), many of the seedlings planted in autumn had already died and not close to as many spring planted seedlings had died. The lower mortality of the spring planted seedlings is reasonably, to a large degree, a consequence of the planting time.

ÄBIN (Swedish Forest Agency, n.d.-a) have shown that 54% of pines are undamaged in the county of Kronoberg. The result of this study shows that only 1-2% of the seedlings planted in autumn and 14% of the seedlings planted in spring lacked any signs of browsing damage. Why the site in Attsjö have been subject to so much browsing could have different causes. Something that could have contributed to these results is that relatively few broadleaved trees had established on the site through natural regeneration and the landscape is pine dominated. Felton et al. (2022) found that pine trees were proportionally more damaged in landscapes with less density of the broadleaf trees that are most browsed.

Rebrowsing is one possible reason why the autumn planted seedlings still were more damaged and had higher mortality than the spring planted seedlings at the time of the follow-up in year 2025. Moose tend to rebrowse previously browsed trees, as shown by Bergqvist et al. (2003) and Mathisen et al. (2017) and browsing of the autumn planted seedlings the first winter might have been followed by more browsing of these seedlings (in comparison to the spring planted seedlings) later on.

Of course, there are some potential sources of error and flaws to the study design. The way of spreading out the autumn planted seedlings into different rows in each section on the site should have led to reduced impact on the results caused by differences in growing conditions throughout the site (in comparison to if all seedlings were divided after planting time and planted in totally separate areas of the site). This does not apply to the spring planted seedlings though, as they were decided upon later and all planted in one single section of the site. This aspect of the study design can have affected the results to some degree.

Not many studies have been found regarding how planting time impact the development of Scots pine seedlings (or even other tree species) and as the studies found are done in different geographical areas or the planting have been done in different parts of the growing season, it is hard to know how comparable they are - yet are still valuable to consider. A study on Norway spruce by Wallertz et al. (2016) showed that the seedlings planted in August grew quicker than the seedlings planted in November, or May the following year. Scots pine seedlings in this study was clearly affected by the high browsing pressure while Norway spruce seedlings are in general not very browsed by deer animals. This could be at least part of why the results of the study by Wallertz et al. (2016) and the results of this thesis study differ.

Luoranen and Rikala (2012) found more growth in summer (July) planted seedlings than seedlings planted in autumn or spring. Luoranen and Rikala (2012) also found a higher survival of spring planted seedlings then seedlings planted in August and September when measured after three growing seasons. These results are in line with the results of this study. Browsing damage is not mentioned in the study by Luoranen and Rikala (2012), however it is mentioned that higher mortality of plants planted after mid-August might be due to higher vulnerability to winter damage because of them being disturbed in their hardening process.

Repáč et al. (2021) found that seedlings planted in autumn performed similarly or better regarding growth and survival, than the spring planted seedlings. Those results contradict the results of this study. Though it is mentioned that the seedlings were treated with a chemical browsing repellent, browsing is not otherwise mentioned. Repáč et al. (2021) concludes with an inquiry of more research and studies where seedlings are followed for a longer period of time after planting.

The results from this study indicate that spring planting of Scots pine is to prefer over planting later in the season. Seeing that this study is a case study it is not appropriate to draw any far-reaching conclusions. More similar studies would be valuable to see if the results would be recurring for Scots pine planting on other forest land sites. It would be interesting to make a very similar study to this, to research the impact of planting time, though with the seedlings planted in a fenced area to see what the results would be if browsing from deer animals would not be an influencing factor. It would also be of value to conduct studies with numerous different planting times (spring, summer and autumn), making it possible to make more within-site comparisons. The treatment Trico was used on some of the seedlings in this experiment. It would be good to see more research on how Trico, as well as other mechanical treatments used to reduce browsing damage, perform both when used alone and when combined with another treatment such as a pine weevil treatment. Seeing that 44% (in Sweden) of Scots pine seedlings were treated with mechanical treatment in the year 2023 (Swedish Forest Agency, 2024), it is a topic relevant to study further.

# 5. Conclusion

Browsing have greatly affected the seedlings on the site. Almost none of the autumn planted seedlings had no visible browsing damage at the follow-up in 2025. Though most of the spring planted seedlings also were damaged (86%), there is a clear difference, and the mean height of those seedlings are significantly higher than the autumn planted seedlings. The results from this study indicate that spring planting is to be preferred over autumn planting when planting Scots pine seedlings at forest land sites in areas with high browsing pressure.

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