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Seedling, planting site and weather factors affecting the success of autumn plantings in Norway spruce and Scots pine seedlings

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ABSTRACT

Due to the lack of labor and the mechanization of planting work, seedlings should be planted during the entire period of unfrozen soil, from early spring to late autumn. In experimental studies, it is difficult to investigate all the risk factors related to different planting windows. In Finland, the winter of 2015–2016 was harsh for seedlings. First temperatures were above zero, then they suddenly dropped to < -30 °C without any protective snow cover. These conditions offered a good opportunity to study the success of autumn plantings and clarify which factors best predict the field performance of autumn planted conifer seedlings. In the survey, 22 regeneration sites planted with Scots pine (*Pinus sylvestris* L.) and 71 with Norway spruce (*Picea abies* (L.) Karst.) seedlings were inventoried in the summer of 2016. Scots pine seedlings were more sensitive, and the regeneration result was good only in a few sites. With Norway spruce, the results were better although both good and poor results were found. For Norway spruce, we modeled the probability of severe damage and leader growth damage separately for summer (July and August), September and October plantings. The most important factors affecting the probability of damage was the quality of the planting and the planting spot as well as the soil type. If a planting hole was open or a seedling was planted in a planting spot other than a mineral-covered mound, the risk of damage was high. In fine and course textured soils, as well as medium coarse soils with a high risk of frost heaving, the probability of damage was also high. Low precipitation after planting and during the following spring also increased the probability of leader growth damage. Planting in the summer and early September exposed seedlings to leader growth damage, especially when the seedlings were planted in sites with a high risk of frost damage in autumn and spring. The results indicate that the planting of Scots pine seedlings in the autumn should be avoided. Norway spruce seedlings can be planted even in October when the work quality is good and suitable sites are selected for plantings.

1. Introduction

In the Nordic countries, most seedlings are planted within one month's time in May and early June. In Finland, for example, there is a shortage of planters due to the aging of forest owners and reduced labor. The mechanization of planting work is one solution being considered to solve the problem (Harstela, 2004). However, the use of planting machines is still low, and in Finland only 1.5% of plantings are done by machine (Peltola and Kankaanhuhta, 2017). A prerequisite for increasing the use of machines in planting is that it is cost-efficient. For this, the work period of a machine should be as long as possible during the period when the soil is unfrozen. The lack of labor in manual planting also increases the need to extend the planting window from the spring to other planting windows, such as September and October. The collection of logging residues also increases the need for other planting windows than spring: from winter cuttings the logging residues need to be dried out before collection, and a regeneration site is ready for planting not until the late summer or autumn.

The autumn planting of conifer seedlings has been examined in experimental studies both with bare roots (e.g. Heikinheimo, 1941; Mork, 1951) and container seedlings (e.g. Kinnunen, 1989; Valtanen et al., 1986). Autumn planting has been shown to be successful in experimental studies even in October and November with current seedling types used in the Nordic countries. Planting is successful as long as the seedlings were well-watered, carefully planted without any stress factors during and after planting, and when the weather conditions are favorable in the following spring and autumn (Luoranen and Rikala, 2013). However, seedlings planted in late autumn have reduced ability

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to recover from damage, such as pine weevil (*Hylobius abietis*) feeding, (Wallertz et al., 2016). The reduced ability to recover from such attacks is thought to be a cause for the poor rooting of seedlings just after planting (Wallertz et al., 2016). The root growth of Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.) seedlings slows down towards the autumn, and in late autumn the roots do not grow at all (Wallertz et al., 2016). In the following spring after planting, poorly rooted and unrooted seedlings also start their root growth slower than earlier planted and better rooted seedlings (Luoranen, 2018). Due to these factors, seedlings planted in the late autumn probably have an increased risk of dying also after other damage than pine weevil feeding.

The mid-winter frost hardiness of seedlings varies with prevailing temperatures (Repo et al., 2001 and references therein). The frost hardiness may decrease by tens of degrees during mild weather in mid-winter (Repo et al., 2001; Strimbeck et al., 1995). The changes may happen in just a few hours (Repo et al., 2001). Re-hardening may also occur but at a much slower rate (Strimbeck et al., 1995). Furthermore, the soil temperature may fall and the soil may freeze deeply during snowless times. Lindström and Troeng (1995) showed that soil temperatures in mounds dropped below −15 °C when the air temperature was −26 °C for a few days during snowless times. At the same time, the temperature under the snow cover was just below 0 °C.

In the winter of 2015–2016, large areas in southern and central Finland experienced temperatures over 0 °C for the several weeks, and then the temperature suddenly dropped to below −30 °C (The Finnish Meteorological Institute, 2017). At the same time there was no protecting snow cover on the seedlings. In the future, these kind of climatic conditions are predicted to become more common in the Nordic countries (Jylhä et al., 2009). These harsh winter conditions increase the risk of winter damage and may reduce the field performance of newly planted seedlings. All these affect the silvicultural practice and guidelines for future regeneration operations. The winter 2015–2016 and winter damage observed after that offered a great opportunity to clarify the success of autumn plantings after a harsh winter and try to determine out the most important factors affecting survival and winter damage of conifer container seedlings.

The aim of the study was to investigate the success of summer and autumn plantings both with Norway spruce and Scots pine seedlings after a harsh winter. We fitted prediction models to the inventory data from practical scale plantings aiming to clarify which seedling, regeneration site and weather factors most affected the risk of sustaining damage.

2. Material and methods

2.1. Study sites and sampling design

The survey was done together with four companies which had planted conifer seedlings in the autumn of 2015. A total of 92 regeneration sites were selected. The surveyed sites were located in different parts of Southern and Central Finland (Fig. 1). For further analysis, the areas were divided into smaller geographical areas (Fig. 1). Sites were planted from the middle of July to the end of October 2015. The planting dates were categorized into three planting windows: summer (July and August), September and October.

The survey was done during the summer of 2016, in most cases in June and early July. Six people carried out the field work. In most cases each person had their own geographical area, but in some cases two people worked in the same area but for different companies. For each site, the method of soil scarification and knowledge about slash removal or stump lifting were collected from the databases of the companies. For the seedling material planted on each site, information about short day (SD) treatment in the nursery before delivery to the planting sites (yes/no/unknown), and the package method (open container or other open box/closed cardboard box) was also logged (Table 1).

A systematic plot sampling was used in the survey. The sampling was based on the area of the regeneration site, which varied between 0.6 ha and 21.2 ha. The distance between systematically sampled circular plots (50 m^2, radius 3.99 m) was shorter on the smaller regeneration sites than on larger sites. On average, eight circular sample plots were sampled per site. In each sample plot, the site type (using the classification by Cajander, 1949), soil type, stoniness, soil moisture and sample plot position were visually determined (Table 1). Soil type was assessed visually based on the size and number of soil particles. There were five categories: coarse mineral soil, medium coarse mineral soil, medium coarse mineral soil with high risk of frost heave (till soil containing ≥30% fine fractions), fine mineral soil and peat. For each seedling within a sample plot, the cause (winter damage, spring frost, browsing by mammals, insect feeding, planting error, other known, unknown) and degree of damage (healthy, slightly damaged, dying, dead), as well as the condition of leader growth in a seedling (one healthy leader growth, multiple leaders, no new leader growth) were recorded. Multiple reasons for damage were recorded for some seedlings, thus the sum of percentages is over 100% in Results. For further calculations, multiple leaders and no new leader growth were combined to describe the damaged leader growth or terminal bud (called later leader growth damage). When the cause of damage was difficult to determine (in the cases of drought, or damage caused by a hard winter or winter desiccation), the causes were all determined as winter damage. The criterion for a good regeneration result was that the proportion of dying and dead seedlings within a site was ≤5%.

For each seedling, the quality of soil scarification (good; seedling planted in prepared soil, but not planned one (e.g. mounded sites in which a seedling had been planted in a patch); harvesting residues, slash or stones inside a mound; other reasons which reduced the quality) and planting work (good; unfilled planting hole; other reason for poor planting) were evaluated. The height of the planting spot was also assessed visually from the unprepared soil surface to the top of a mound rounding to the nearest 5 cm.

2.2. Weather data

For each site, weather data [daily mean, min and max, temperature sum (threshold value + 5 °C), precipitation] for the planting windows as well as for January 2016 and for each month from July to October 2015 and from April to June 2016 were collected from the data of Finnish Meteorological Institute using the program described by Venäläinen et al. (2005).

In the planting year 2015, temperatures during planting were the lower the later the seedlings were planted. In October, the northernmost areas were also the coldest. In January 2016, the minimum temperature in the southernmost areas was −27.5 °C and in the northernmost it reached −35.8 °C, being on average −31.7 °C. The length of the period that the temperatures were below −15 °C was on average 15 days in January. The total precipitation in the early part of January (during the coldest period) was on average 15 mm, varying from 7 (in the south) to 29 mm (in the east). According to the maps for snow cover (The Finnish Meteorological Institute, 2017), the snow cover was 1–10 cm on 5 January, and 10–25 cm on 25 January in the overall study area. In the southernmost areas, the snow melted between late March and early April. In the rest of the areas the snow melted in early April and the snow cover was < 1 cm on 15 April.

Average temperatures varied between 2.9 and 4.7 °C in April 2016. The minimum temperatures were between −9.6 (in Central-Finland) and −3.2 °C (Southeast Finland). In April, the precipitation was on average 51 mm in the study area being the greatest (76 mm) in Southeast Finland and the lowest (23 mm) in North Karelia. The temperature sum accumulated in April varied from 8 days (d.d.) in the southern part of Central Finland to 26 d.d. in North Karelia.

In May 2016, the precipitation sum varied between 13 and 40 mm, and in June between 40 and 98 mm. In May, the mean temperature was