SILVA FENNICA

Laura Pikkarainen[1], Jaana Luoranen[2], Antti Kilpeläinen[1], Teppo Oijala[3] and Heli Peltola[1]

Comparison of planting success in one-year-old spring, summer and autumn plantings of Norway spruce and Scots pine under boreal conditions

Highlights

- In Norway spruce, 84% of all plantings were successful, whereas in Scots pine, the corresponding number was 52%.
- The major reason for poor planting results was poor work quality.
- An extended planting season is possible for Norway spruce in southern and central Finland.
- In Scots pine, there are still large uncertainties in the success of summer and autumn plantings.

Abstract

In Nordic countries, tree planting of seedlings is mainly performed during spring and early summer. Interest has increased in extending the planting window throughout the unfrozen growing season. This study compared the success of one-year-old spring, summer and autumn plantings in practical forestry in Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.) in southern and central Finland. Planting success was based on the number of viable seedlings per hectare relative to a species-specific target density. The influence of different factors to poor planting results were determined, including quality of site preparation and planting, and sources of natural damage. Overall, in Norway spruce, 85, 69 and 84% and in Scots pine 53, 55 and 40% of spring, summer and autumn plantings succeeded. In Norway spruce, the planting results were consistent between the southern and central regions, whereas in Scots pine, the success was slightly lower in the south. The poor work quality and a low density of appropriate planting spots, contributed to poor planting results, regardless of planting season, region or tree species. Considering different damages, especially mammal damage contributed to the failure of Scots pine spring plantings, whereas in summer plantings, corresponding single failure reason could not be identified. Based on our findings, extending the planting season of Norway spruce could be recommended in both regions. For Scots pine, there is still significant uncertainty about the success of summer and autumn plantings, partially due to the limited number of plantings available for analyses.

1 Introduction

Regardless of tree species, seedlings in Nordic countries are mainly planted from spring to early summer. This short planting season causes significant work pressure for seedling producers, planting organizers, and manual and machine planters (Nilsson et al. 2010; Luoranen et al. 2018). Interest has increased to extend the planting season from early spring through late autumn, throughout the period with unfrozen soil. Based on previous studies, the planting season can be extended in Norway spruce (*Picea abies* (L.) Karst.) to late autumn (Luoranen et al. 2005, 2006, 2015; Wallertz et al. 2016). Field performance of Norway spruce seedlings has also been adequate for mechanized plantings done from spring until the end of September (Luoranen et al. 2011). Extending the planting season into the summer months can even improve the growth of planted Norway spruce (Helenius et al. 2005; Luoranen et al. 2006) seedlings because of the favorable temperature conditions for the growth and rooting of the seedlings. However, the risk for stress events, such as drought periods, is higher in the summer months than in spring, when the water content of the soil is naturally higher (Grossnickle et al. 2000, 2005; Grossnickle and Folk 2003; Helenius et al. 2005; Luoranen et al. 2006).

In Scots pine (*Pinus sylvestris* L.), summer- and autumn-planted seedlings have been found to perform relatively well under favorable weather conditions (Luoranen and Rikala 2013; Luoranen 2018) contrary to when stressful conditions were encountered (e.g., drought) (Huuri 1974; Valtanen 1986; Luoranen et al. 2018). On the other hand, on less fertile and drier sites where the average risk of drought damage is greater, even short drought periods may impair regeneration results in Scots pine plantings (Huuri 1973; Luoranen et al. 2018). In some cases, the poor performance of the autumn plantings could be explained by poor rooting of the Scots pine before winter due to the late planting date, i.e., after mid-September (Metsämuuronen et al. 1978; Luoranen and Rikala 2013; Luoranen 2018).

In Finland, Norway spruce and Scots pine seedlings are overwintered either in a freezer or outdoors under ambient conditions. These dormant seedlings are recommended to be planted between early spring and mid-June, whereas actively-growing seedlings are recommended to be planted from mid-June to August (Luoranen et al. 2005, 2006, 2007). Short-day-treated seedlings are recommended to be planted later, from August onward (Luoranen and Rikala 2015). However, to ensure the proper field performance of seedlings after planting, they must be in good condition at the time of planting (Helenius et al. 2002; Grossnickle 2005). Actively-growing seedlings are more susceptible to drought and mechanical injury and early autumn frost damage, than seedlings planted while dormant (Deans et al. 1990; Grossnickle et al. 2000; Grossnickle and Folk 2003). On the other hand, drought risks in summer plantings may be reduced through the careful handling, storage, deep planting and watering of the seedlings (Helenius et al. 2002, 2005; Luoranen and Viiri 2016). Therefore, during the transportation and storage of seedlings, their exposure to severe stress factors, such as rapidly changing temperatures, drought and mechanical stress, should be avoided (Helenius et al. 2002).

With appropriate site preparation and planting, the growing conditions and early performance of seedlings can be improved. Site preparation, such as mounding, improves the growth potential of the seedlings by increasing soil temperature and nutrient and moisture availability (Johansson 1994; Hansson et al. 2018). The competition for nutrients with the surrounding vegetation is also lower on mounds (Nilsson and Örlander 1999). Appropriate site preparation can also reduce the damage caused by insects, such as pine weevil (*Hylobius abietis*) (Örlander and Nilsson 1999), and by abiotic factors, such as frost, drought or flooding (Örlander et al. 1990). Moose, vole and drought cause together currently the most biotic and abiotic damage in young seedling stands in Finland, based on the National Forest Inventory (NFI12) (Nevalainen et al. 2018).

Based on above studies of the early performance of planted Norway spruce and Scots pine seedlings on different planting dates, it is not yet possible to recommend, without any reservation, the use extended planting windows for Norway spruce and Scots pine seedlings in practical scale plantings in different regions of Finland. This is because previous trials extending the planting season are in carefully-established experiments, and applicable only in restricted geographical areas. Additionally, the seedling material (Grossnickle and Folk 2003), the handling, shipping and field storage of the seedlings (Helenius et al. 2002) as well as the site preparation and planting quality (Luoranen et al. 2018; Wallertz et al. 2018), affect together with a number of abiotic and biotic risks (Wallertz et al. 2016) on the regeneration results in practical forestry. Their effects on the regeneration results may also vary largely depending on planting date, tree species and geographical region. Therefore, it is important to study in more details the early performance of Norway spruce and Scots pine seedlings stands established in practical forestry at different planting dates and regions, and based on large enough datasets in order to recommend the use of extended planting windows without any reservation.

In the above context, the aim of this survey study was to compare the developmental results of one-year-old spring, summer and autumn plantings of Norway spruce and Scots pine in practical forestry in southern and central Finland. The evaluation of regeneration success was done based on the number of observed viable seedlings per hectare for 1270 planting areas. Additionally, the effect of different factors on poor planting results were examined, including quality of site preparation and planting, and sources of natural damage.

2 Material and methods

2.1 Data collection

The data used in this study was based on forest regeneration results in Norway spruce and Scots pine seedling stands in the operating area of the Metsä Group company in Finland. The regeneration areas (1270 areas in total) were planted between spring and autumn in 2016 (Table 1). The inventory was carried out by local forest operations managers and trainees between the spring and autumn of 2017. In this work, plantings up to the end of week 25 (26th June) were classed as spring plantings, plantings performed during weeks 26–34 (27th June to 28th August) were classed as summer plantings and plantings from week 35 (29th August) onward were classed as autumn plantings.

Field inventories were performed using systematic, circular 50-m^2 sample plots. The number of sample plots depended on the size of the regeneration area, and they were scattered systematically across the longest cross-section of the area. A minimum of four sample plots were used in

Table 1. Number of planting sites in different planting seasons, by tree species and geographical region. Areas were classified into two groups based on accumulated temperature sums: central Finland 1000–1200 d.d. and southern Finland >1200 d.d. (Äijälä et al. 2014).

Region/	Norway spruce		Scots pine	
Planting season	Central	Southern	Central	Southern
Spring	243	475	134	198
Summer	62	24	12	10
Autumn	39	43	13	17

regeneration areas of ≤1 ha. If the area was >1 ha, one additional sample plot was taken for each 0.5 ha. No more than 10 sample plots were used regardless of the size of the area. For each sample plot (radius = 3.99 m), the number of viable (healthy) seedlings and good quality planting spots were assessed visually and counted, respectively. Seedlings with minor damage, such as the lack of new shoot growth or a low number of damaged needles caused by frost or drought, were classed as viable. Only prepared planting spots (e.g. with mounding or patch scarification) were considered as appropriate planting spots. In addition, the quality of work for planting and site preparation were evaluated using two grading classes, good and poor. Their quality was evaluated as good if the seedlings were planted deep enough, the soil was compressed carefully around the seedling base, and there was enough mineral soil around the seedling at the planting spot. The quality of work was poor if it did not fullfill those criteria.

The mean values for temperature and precipitation in 2016 were calculated separately for each planting seasons (spring, summer, autumn) for central (six districts) and southern (seven districts) Finland (Table 2), based on data obtained from the Finnish Meteorological Institute, using the program described by Venäläinen et al. (2005). For this purpose, each operational district of the Metsä Group was classified according to the accumulated temperature sum (i.e., degree days [d.d.] for daily mean values, T ≥5 °C) into either a region in central Finland with 1000–1200 degree day (d.d.) or in southern Finland with >1200 d.d. (Äijälä et al. 2014). The mean temperature in spring, summer and autumn in 2016 did not differ much from the corresponding long-term averages (period of 1981–2010, Finnish Meteorological Institute). The mean precipitation was higher in spring and summer in 2016 compared to the corresponding long-term averages. This was opposite in autumn (Table 2).

2.2 Evaluation of planting results

Plantings were evaluated based on the number of observed viable seedlings per hectare, with the regenerated site used as a basic unit in analysis. Observed planting results were graded against a target density, using four classes – weak, moderate, good and excellent (Table 3). The target number of viable seedlings per hectare varied, however, to some degree within the different grading classes according to tree species and the geographical location of the site (Äijälä et al. 2014). The target densities for the southern sites were lower than those given in the Finnish forest management recommendations for practical forestry (see Äijälä et al. 2014).

Table 2. Average weather data for two geographical sub-regions (central [N = 6], southern [N = 7]) in Finland. Pmean – mean precipitation sum (mm), with the average of 1981–2010 in brackets; Tmean – mean temperature (°C), with the average of 1981–2010 in brackets; Tmin – mean minimum temperature (°C); Tmax – mean maximum temperature (°C). April, May and June were included in the spring plantings, July and August in the summer plantings, and September and October in the autumn plantings.

Region	Planting time	Pmean	Tmean	Tmin	Tmax
Central Finland	Spring	51 (36)	10 (8)	–2	22
	Summer	111 (68)	16 (15)	5	25
	Autumn	28 (52)	7 (6)	–2	16
Southern Finland	Spring	49 (34)	11 (9)	–1	23
	Summer	80 (67)	16 (16)	6	25
	Autumn	32 (58)	7 (8)	–2	18

Table 3. Range of viable seedling density per hectare for the corresponding grade based on target density.

Tree species	Target, seedlings/ha	Grade, seedlings/ha			
		Excellent	Good	Moderate	Weak
Scots pine	2500	≥ 2375	2374–2125	2124–1300	1299 ≥
Scots pine	2200	≥ 2090	2089–1870	1869–1300	1299 ≥
Scots pine	2000	≥ 1900	1899–1700	1699–1300	1299 ≥
Norway spruce	2000	≥ 1900	1899–1700	1699–1200	1199 ≥
Norway spruce	1800	≥ 1710	1709–1530	1529–1200	1199 ≥
Norway spruce	1600	≥ 1520	1519–1360	1359–1200	1199 ≥

Planting success was graded as excellent (4) for a planting site if the average density of viable seedlings per hectare was 95% of the target density; good (3) if the density was between 85 and 95% of the target density; moderate (2) if the average density was lower than 85% of the target density, but if at least 1300 viable seedling/ha for Scots pine and 1200 viable seedling/ha for Norway spruce were observed; and weak (1) if the density was less than for the moderate grade (2) (Table 3).

In the evaluation of the probability of a successful planting, the planting result was considered to be successful if the grade was excellent (4) or good (3). If the grade was moderate (2) or weak (1), the planting result was considered to be poor. The probability of a successful planting was modeled using a logistic regression model in IBM SPSS Statistic 24, using a forced entry method. The independent variables were selected subjectively based on preliminary data-analysis. In the final model, tree species, planting time, region and the interaction between tree species and planting time were used as independent variables. Both the accumulated temperature sums from the planting date up to the end of the year, and the temperature sums from April until the inventory of the site in 2017, were also used as covariates in the preliminary model, but were dropped from the final model because their use did not reduce the residual variance. The significance level used for evaluating the parameter estimates of the model was $p < 0.05$. The proportion of explained variance (R^2) was calculated to provide an estimation of accuracy of the model prediction.

The accuracy of the classification of successful versus poor plantings was analyzed using the poor planting as the reference category. The overall accuracy was the ratio of the number of correctly classified observations relative to the total number of observations. Based on the final model, the success of the planting results between the categories of independent variables was also analyzed. This was done in terms of odds ratios, which showed how many times the compared category had a greater/lesser effect, compared to the reference category. The reference categories for the odds ratios of the main effects were Norway spruce (vs. Scots pine), spring (vs. autumn and summer), southern region (vs. central region) and, for the interaction, Norway spruce in spring.

Additionally, we analyzed how the different factors contributed to the failure of a planting result (in terms of % of failure cases), overall and in the different planting seasons, based on the entire empirical dataset collected for southern and central Finland. The main reasons for poor planting results were categorized into two main groups: 1) poor quality of regeneration work (planting error, poor site preparation, poor seedling material), and 2) natural damage, including mammal (deer, moose, voles and hares) and birds, fungus, frost, drought, other damage (reduced planting quality due to excessive vegetation, overwatering of the soil, rocky terrain or other terrain-related difficulties), and unknown reason (i.e. invalid or unclear reasons for poor plantings), respectively.
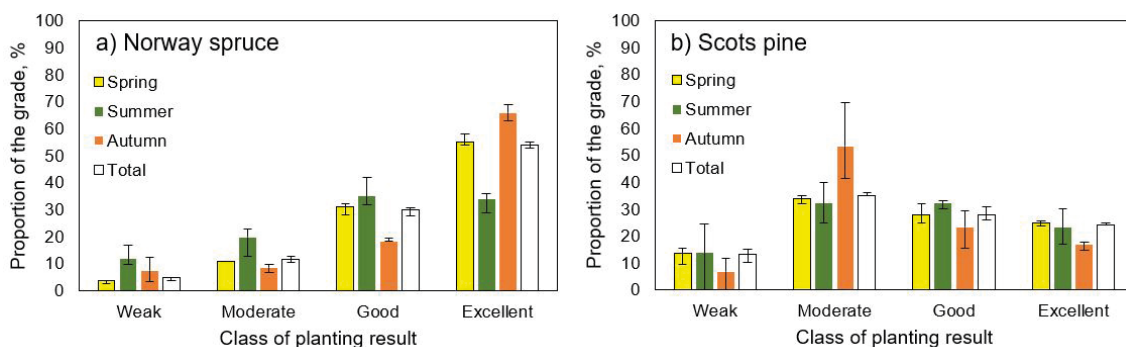
Fig. 1. Proportion of all Norway spruce (a) and Scots pine (b) plantings in different planting-result classes (weak, moderate, good, excellent), given overall (total) and separately for different planting seasons (spring, summer, autumn). Error bars show the range of proportions between southern and central Finland.

3   Results

3.1 Planting results

For Norway spruce and Scots pine, 84 and 52% of all plantings were successful. By season, Norway spruce, planting results were successful in 85, 69 and 84% of spring, summer and autumn plantings, respectively. For Scots pine, the corresponding numbers were 53, 55 and 40%, respectively (Fig. 1). Overall, the average number of viable seedlings/ha (and standard deviation) was 1707 ± 253, 1581 ± 327, 1694 ± 281 in Norway spruce and 1686 ± 415, 1705 ± 426, 1731 ± 399 in Scots pine in spring, summer and autumn plantings, respectively.
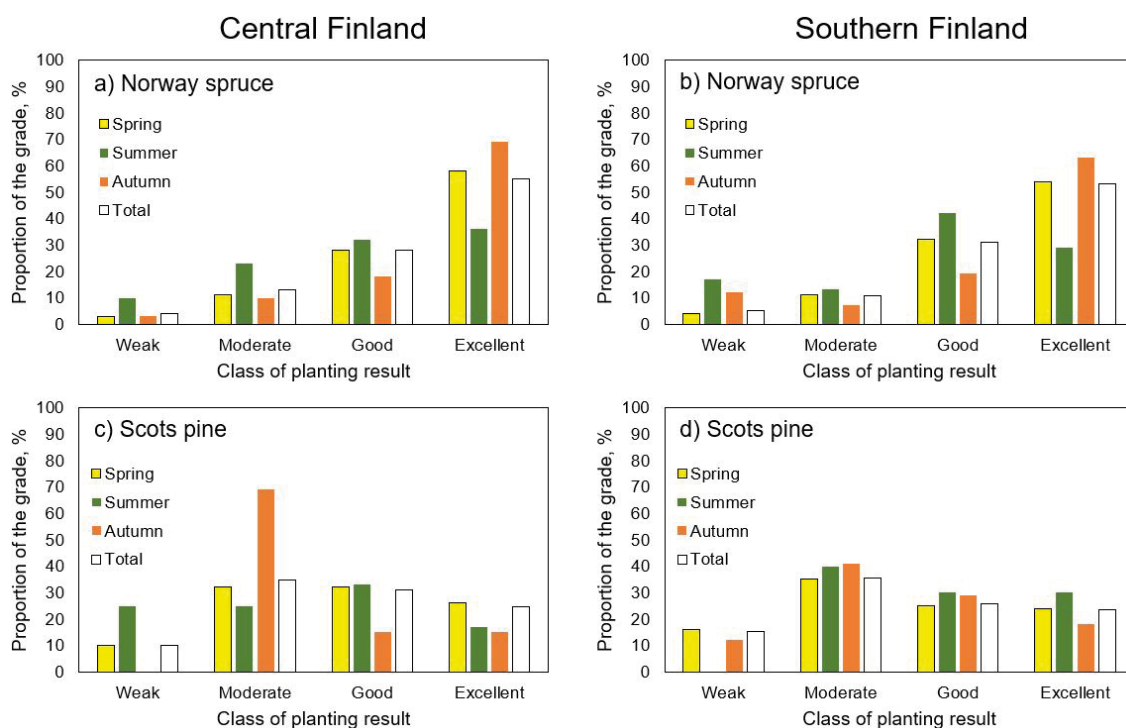

Fig. 2. Proportion of Norway spruce (a, b) and Scots pine (c, d) sites in different planting-result classes (weak, moderate, good, excellent), given overall (total) and separately for different planting seasons (spring, summer, autumn) in central (a, c) and southern (b, d) Finland.

Table 4. Binary logistic regression model for the probability of a successful planting result. The modeling data consist of 1270 planting sites in southern and central Finland. Exponentiated estimate denotes the odds ratio.

Variable	Estimate	Std. Err	p-value	Odds ratio	95% C.I. for Exp(B) Lower	Upper
Intercept	1.713	0.115	0.000			
Tree species (ref. Norway spruce)						
Scots pine	−1.668	0.153	0.000	0.189	0.140	0.255
Planting time (ref. spring)						
Autumn	−0.117	0.321	0.716	0.890	0.474	1.669
Summer	−1.044	0.262	0.000	0.352	0.211	0.588
Region (ref. south)						
Central	0.159	0.143	0.268	1.172	0.885	1.552
Interaction (ref. spring Norway spruce)						
Summer Scots pine	1.096	0.512	0.032	2.992	0.249	1.795
Autumn Scots pine	−0.403	0.504	0.424	0.669	1.096	8.163

The reference category is: Poor

For Norway spruce, the plantings succeeded equally well in southern and central Finland (83 and 85%, respectively). For Scots pine, the result was slightly poorer in southern (50%) than in central Finland (56%). Spring plantings of Norway spruce were 86% successful across both the southern and central regions sites. In Scots pine, 49 and 58% of the spring plantings were successful in southern and central Finland, respectively. In summer plantings of Norway spruce, the plantings were successful in 71% of the southern and 68% of the central sites. The corresponding percentages for the Scots pine summer plantings were 60% in southern and 50% in central Finland. Autumn plantings of Norway spruce were successful in 82% and 87% in southern and central sites. The corresponding percentages for Scots pine autumn plantings were 47% and 30% in southern and central Finland (Fig. 2).

The logistic regression model (Table 4) was accurate nearly 75% of the time (Table 5). The model explained about 16% of the variance (R^2), and correctly predicted 99% of the sites with successful planting results, but only 6% of the sites with poor planting results. In terms of the odds ratio, the successful planting result was 81% lower for Scots pine ($p < 0.001$) (Table 4). Similarly, the odds ratio of successful planting results in summer and autumn plantings were, in general, 65 and 11% lower than those in spring plantings ($p < 0.001$, $p = 0.716$). The odds ratios of the successful planting results were also 17% higher in central Finland than in southern Finland ($p = 0.268$) (however, most of plantings were in spring). The planting success of Scots pine was significantly ($p < 0.05$) lower than that for Norway spruce. The success of summer plantings of both tree species was also significantly ($p < 0.05$) lower than spring plantings. However, since the success of Scots pine plantings in summer was 3 times higher than that of Norway spruce in spring, there was also a significant interaction between these variables (Table 4, Fig. 2).

Table 5. Accuracy of classification of the planting results.

Observed	Predicted Poor	Successful	Percent Correct
Poor	18	312	5.5%
Successful	12	928	98.7%
Overall percentage	2.4%	97.6%	74.5%

Table 6. The numbers and proportions (%) of poor planting results, due to poor work quality and natural causes of damage, in different planting seasons for Norway spruce and Scots pine. The "mammals and birds" category includes moose, deer, bird, vole and hare damage. Other reason category includes reduced planting quality due to excessive vegetation, overwatering of the soil, rocky terrain or other terrain-related difficulties and the unknown reason category includes invalid or unclear reasons for poor plantings, respectively.

Reason for poor planting result	Norway spruce				Scots pine			
	Spring	Summer	Autumn	Total	Spring	Summer	Autumn	Total
Planting mistake	15 (14%)	3 (11%)	2 (14%)	20 (13%)	14 (9%)	0 (0%)	1 (6%)	15 (8%)
Poor soil scarification	29 (27%)	6 (22%)	1 (7%)	36 (24%)	14 (9%)	3 (30%)	5 (28%)	22 (12%)
Poor seedling material	1 (1%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Insects	5 (5%)	5 (19%)	0 (0%)	10 (7%)	6 (4%)	1 (10%)	2 (11%)	9 (5%)
Mammals and birds	8 (7%)	1 (4%)	2 (14%)	11 (7%)	63 (40%)	1 (10%)	2 (11%)	66 (36%)
Fungi	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)	0 (0%)	2 (1%)
Frost	2 (2%)	0 (0%)	5 (36%)	7 (5%)	2 (1%)	1 (9%)	3 (17%)	6 (3%)
Drought	2 (2%)	0 (0%)	2 (14%)	4 (3%)	3 (2%)	0 (0%)	0 (0%)	3 (2%)
Other reason	15 (14%)	4 (15%)	0 (0%)	19 (13%)	15 (10%)	1 (10%)	2 (11%)	18 (10%)
Unknown reason	31 (29%)	8 (30%)	2 (14%)	41 (28%)	38 (24%)	3 (30%)	3 (17%)	44 (24%)

3.2 Reasons for poor planting results

Overall, the main factor for poor planting densities was poor work quality; that is, low density of appropriately prepared planting spots and planting mistakes (Table 6). However, the percentage of sites with poor planting densities for other and unknown reasons was high. For Norway spruce, biotic factors were not as prevalent for poor planting results as was poor work quality; the small amounts of biotic-caused damage observed was mainly by insects in spring and summer and by mammals (especially voles) mostly in spring. In the few number of autumn plantings of Norway spruce, poor planting results were caused by frost and drought. In spring plantings of Scots pine, mammal damage and poor work quality clearly contributed to the poor planting results. Damage from other biotic factors was not as noteworthy. Many Scots pine plantations failed for other and unknown reasons.

4 Discussion

Planting results were overall better for Norway spruce than in Scots pine (84 and 52% of the sites were graded good or excellent, respectively). Similar results were found by Saksa and Kankaanhuhta (2007) in 3-year-old plantings of Norway spruce and Scots pine in southern Finland (61% and 55% of the sites were successful, respectively). They also found higher failure risk of planting for Scots pine. Similarly, Kinnunen (1977) found a higher cumulative mortality at 5-year-old planting sites for Scots pine (19%) than for Norway spruce (6%). In our study, planting Norway spruce in spring and autumn was clearly more successful (84–85%) than in summer (69%). For Scots pine, the planting results in spring and summer were slightly better (53–55%) than in autumn plantings (40%). The planting success of Norway spruce was constant across southern and central Finland, whereas Scots pine succeeded slightly better in central Finland.

In general, the planting results for Norway spruce summer plantings were quite successful. The success of summer planted Norway spruce seedlings has also been found in previous experimental studies (Helenius et al. 2002; Luoranen et al. 2005; Luoranen and Rikala 2015). Summer plantings of Scots pine, however, were generally less successful than in Norway spruce in this

study. Counter to our results, Valtanen et al. (1986) reported that the growth and survival of summer-planted Scots pine were poorer than for autumn-planted seedlings. According to Huuri (1974), the summer-planted Scots pine seedlings grew quite well, but the survival varied greatly among the planting sites. Poor summer planting results of Scots pine have been explained by the drought period (Valtanen et al. 1986) and by soil properties (Huuri 1973). In our study, clearly lower mean summer precipitation in the southern Finland during the planting year might also have reduced success of summer Scots pine plantings compared to central Finland.

Autumn plantings of Norway spruce were found to be successful in this study, regardless of region. Luoranen et al. (2018) found that autumn plantings of Norway spruce may be successful if the planting work and site preparation are done properly. For Scots pine, the success of autumn plantings was the poorest, regardless of region. The results of several previous studies on the autumn planting of Scots pine were variable. In the study of Luoranen and Rikala (2013), planting date did not affect the survival of Scots pine seedlings. However, growth was weaker in the following growing seasons for autumn-planted seedlings compared to those from spring plantings. According to Luoranen (2018), autumn plantings of Scots pine were quite successful when the winter weather conditions were not harsh, the seedlings were appropriately planted, and there was no field storage before planting. This situation was reversed for conditions involving shallow snow depths and cold temperatures in the winter, and prolonged field storage (Luoranen et al. 2018). Based on this information, the safest season to plant Scots pine in southern and central Finland is still spring. Further observations are needed, however, to obtain more accurate recommendations.

In this study, regardless of planting season, geographical region or tree species, poor planting results were mainly due to poor work quality and other (or unknown) reasons. In many cases, rocky terrain made site preparation difficult, resulting in too low a density of prepared planting spots per hectare. In previous studies, the planting result was also greatly affected by the site preparation and the properties of the soil (Kankaanhuhta et al. 2009; Luoranen et al. 2018). Overall, the planting results could be improved by focusing on sufficient number of prepared planting spots.

Damage by insects (exclusively pine weevil) was the largest cause for poor planting success among biotic factors for Norway spruce in the spring and summer plantings. There were no observations of pine weevil damage in autumn plantings of Norway spruce, probably because of the short period between the planting and data collection. Autumn-planted Norway spruce suffered relatively more often from frost and drought damage than the spring- and summer-planted seedlings. Luoranen et al. (2018) also noted that summer- and autumn-planted Norway spruce seedlings might be more vulnerable to spring frost damage the following spring. Nevertheless, the proportion of frost damage in Norway spruce was not remarkably high in this study.

In Scots pine, mammal damage decreased the success of spring plantings on a large proportion of sites, regardless of region. In the future, the risk of drought-induced damage may increase in spring and early summer, compared to the present, due to shallower snow depth and earlier snow melt under a warming climate (Ruosteenoja et al. 2018). The risk of pine weevil damage may also increase under warmer growing conditions in young plantations without proper site preparation and planting work quality (Nordlander et al. 2017; Wallertz et al. 2018). These factors should be considered while planning the timing for planting operations, regardless of tree species.

To conclude, the large number of plantings sites (1270 planting sites of the Metsä Group) in our study represented the overall regeneration success for Scots pine and Norway spruce plantings over different planting seasons in central and southern Finland. This is despite the use of summer trainees to inventory the plantings, which may have affected in some degree in the interpretation of viable seedlings or reasons for failure. Based on our findings, extending the planting season from spring to autumn can be considered safe for Norway spruce. However, in plantings of Scots pine, the failure risk was clearly higher than for Norway spruce, regardless of planting season. Based

on our findings, extending the planting season from spring to autumn is not yet recommended for Scots pine, partially also due to the limited number of summer and autumn plantings in our analyses. It may be wise to continue to plant Scots pine in the spring or early summer. The possible occurrence of drought should be considered, regardless of tree species and geographical region.

We recognize that our findings were based only on one-year inventory data which, together with low number of different failure cases, did not allow us to provide more general planting guidance under boreal conditions throughout Nordic countries. Creation of such a guide would require repeated inventories over multiple years in different boreal regions. This approach would allow detailed analysis of the impacts of annual and intra-annual variations in climatic and damaging factors on the planting success as affected by seasons and regions.

Acknowledgements

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