SILVA FENNICA

Silva Fennica vol. 49 no. 1 article id 1300
Category: research article
www.silvafennica.fi
ISSN-L 0037-5330 | ISSN 2242-4075 (Online)
The Finnish Society of Forest Science
The Finnish Forest Research Institute

Jaana Luoranen[1] and Risto Rikala[2]

Post-planting effects of early-season short-day treatment and summer planting on Norway spruce seedlings

Luoranen J., Rikala R. (2015). Post-planting effects of early-season short-day treatment and summer planting on Norway spruce seedlings. Silva Fennica vol. 49 no. 1 article id 1300. 9 p.

Highlights

- Summer planting and short-day treatment advanced the bud burst and increased the height of Norway spruce seedlings after planting, compared to autumn and spring planted or untreated seedlings.

Abstract

Effects of short-day (SD) treatment on bud burst, growth and survival of Norway spruce (*Picea abies* [L.] Karst.) container seedlings after summer planting were studied in an experiment established in Suonenjoki, Central Finland. One-year-old seedlings were SD-treated for three weeks starting on 18 June, 24 June and 8 July 2004 and then planted on 22 July, 5 August, 6 September 2004 and, as a normal spring planting, on 10 May, 2005. Untreated control seedlings were also planted on these dates. Second flush on the planting year and bud burst the following spring was monitored in planted seedlings, whereas seedling height and survival were determined at the end of growing seasons 2004–2006. We observed a non-significant risk of a second flush if seedlings were SD-treated on 18 June. Also, SD-treated seedlings planted in July or August showed advanced bud burst and increased height the following growing season without significant effects on survival, compared to autumn and spring planted seedlings. Planting in July or early August was associated with a significant increase in the incidence of multiple leaders in later years. Based on our results, to begin a three-week SD treatment in late June or early July and then plant seedlings in late July or early August could be a good practice.

Keywords bud burst; height growth; *Picea abies*; short-day treatment; summer planting; survival
Addresses [1] Natural Resources Institute Finland (Luke), Natural resources and bioproduction, Juntintie 154, FI-77600 Suonenjoki, Finland; [2] The Finnish Forest Research Institute, Suonenjoki Unit, Suonenjoki, Finland
E-mail jaana.luoranen@luke.fi
Received 9 May 2014 **Revised** 22 October 2014 **Accepted** 21 January 2015
Available at http://dx.doi.org/10.14214/sf.1300

1 Introduction

The artificial shortening of photoperiod by short-day (SD) treatment is a common technique applied in forest nurseries to stop height growth and improve frost hardiness of seedlings prior to planting in late August or September or prior to freezer storage (Dormling et al. 1968; Heide 1974; Colombo et al. 2001). Although the current planting season includes July and early August, Luoranen et al. (2006) found that summer-planted seedlings were more sensitive to early autumn frosts if they had not received a SD treatment before planting. Furthermore, SD treatment improves drought tolerance (Luoranen et al. 2007; Tan 2007) which is especially important for seedlings planted in the summer.

Previous studies have shown that early-season SD treatment (i.e., started in late June or early July) can be applied to Norway spruce (*Picea abies* (L.) Karst.) seedlings without increasing the subsequent risk of a second flush in the nursery provided that the treatment period lasts at least three weeks (Kohmann and Johnsen 2007; Kohmann and Sonsteby 2007; Luoranen et al. 2009; Fløistad and Granhus 2013). In a small scale experiment, Konttinen and Rikala (2006) found that the risk of a second flush was lower if current-year seedlings were outplanted after SD treatment rather than being kept in the nursery. Other than this implication, little is known of the post-planting effects of early-season SD treatments on Norway spruce seedlings, especially in the context of summer planting.

It is well known that SD treatment started in July or August advanced bud burst in conifer seedlings the following spring (e.g., Heide 1974; Odlum and Colombo 1988; Bigras and D'Aoust 1993; Hawkins et al. 1996; Fløistad and Granhus 2010). In earlier studies, bud burst was monitored either in the nursery (Fløistad and Kohmann 2004; Konttinen et al. 2007), growth chambers (Fløistad and Granhus 2010) or immediately after spring planting the year following SD treatment (Odlum and Colombo 1988; Luoranen et al. 1994; Hawkins et al. 1996; Konttinen et al. 2003). Rantanen and Luoranen (1998) showed that summer planting may also advance bud burst the following season. Although summer planting is becoming more common, the interaction between summer planting and early-season SD treatment has not been explored yet. Early bud burst can expose seedlings to spring frosts and thereby cause multiple-leaders to form and reduce growth in summer-planted Norway spruce (Luoranen et al. 2006).

The aim of this study was to clarify the effects of early-season SD treatment and its interaction with summer planting on bud burst, growth and survival for the first few years after planting. This study continues our earlier work in which we investigated the effects of early-season SD treatment on frost hardening and the risk of a second flush for Norway spruce seedlings in the nursery (Luoranen et al. 2009).

2 Materials and methods

2.1 Seedling material

One of the Norway spruce (*Picea abies* (L.) Karst.) container seedling batches (Exp. 2004 J/04) presented in Luoranen et al. (2009) was also used here. The seedlings were grown at the Finnish Forest Research Institute in Suonenjoki (62°39′N, 27°03′E, altitude 142 m a.s.l.). Seeds were sown on 5 June 2003 in Plantek PL81F plastic trays (81 cells per tray, 546 cells m^{-2}, cell volume 85 cm^3: BCC, Iso-Vimma, Finland) filled with limed (2.0 kg m^{-3}) and base-fertilized (0.8 kg m^{-3} of 16N:8P:16K soluble fertilizer with micronutrients) light sphagnum peat. All seeds were obtained from a seed orchard supplying central Finland. Seedlings were raised according to standard nursery

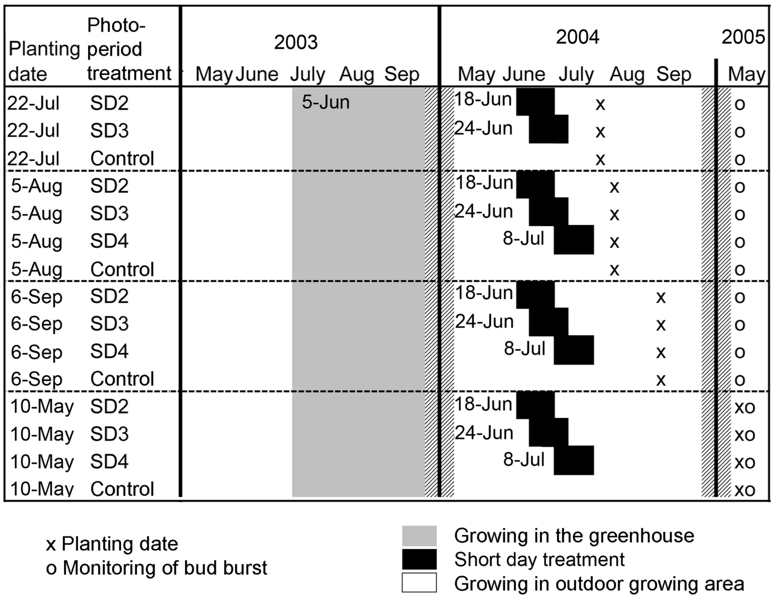

Fig. 1. Treatments, growing and planting schedule for Norway spruce container seedlings grown and planted in Suonenjoki in 2003–2005.

practice in Finland. They were irrigated 2–4 times per week depending on evapotranspiration and fertilized with 0.1% Taimi-Superex solution (19-4-20 for N-P-K + micronutrients; Kekkilä Co., Tuusula, Finland) on average once a week. Seedlings were grown in a greenhouse until the end of September, when they were transferred to an outdoor growing area until the start of SD treatments in 2004. Three-week SD treatments (14-hour nights and 10-hour days) were started on 18 June (SD2; same abbreviations as in Luoranen et al. 2009), 24 June (SD3) and 8 July (SD4) 2004 (Fig. 1). On 18 June, the natural day-length in Suonenjoki was 20h03min, and on 28 July (when SD4 ended) it was 17h43min. The culture protocol for seedlings was described more precisely in Luoranen et al. (2009).

2.2 Planting experiment

An experiment was established at a former nursery field of fine sand in Suonenjoki. Seedlings were planted in rows to a depth of 2–3 cm (measured from the soil surface to the upper surface of peat plugs) with 0.5 m between seedlings in each row and 1 m between rows. Forty seedlings in each photoperiod treatment (S) and planting date (P) were planted in four blocks (10 seedlings per block) using a split-plot design (planting date as the main plot and photoperiod treatment as a subplot). Planting took place on 22 July, 5 August, 6 September 2004, and 10 May 2005. Seedlings that received SD treatment beginning 8 July (SD4) were not planted on 22 July (see Fig. 1).

Seedling height (±0.5 cm) was measured at planting (only for seedlings planted on 10 May 2005) and at the end of growing seasons 2004–2006. Seedling vigour was determined each autumn and classified as surviving when they were healthy looking or when damage was slight. If a seedling had two or more leaders, or leader growth was disturbed in some way, it was scored as having multiple leaders. Second flush was monitored when seedling height was measured in autumn 2004. Bud burst in spring 2005 of planted seedlings were monitored three times a week in five randomly selected seedlings for each treatment and block. Buds were scored as flushing when individual needle tips were visible. Bud burst was determined to occur when 50% of the seedlings had flushing terminal buds.

Table 1. Weather data for the Suonenjoki Research Unit (Finnish Forest Research Institute) in 2004–2006 and long-term average (1974–2006). T indicates temperature.

	2004	2005	2006	1974–2006
		Mean temperature (2 m), °C		
May	8.9	8.7	9.9	9.0
June	10.6	14.0	15.5	14.2
July	14.8	18.2	17.4	16.6
August	16.2	15.3	17.5	14.3
September	12.4	10.5	11.3	9.3
		Monthly precipitation, mm		
May	58	97	43	40
June	102	80	35	68
July	58	138	35	82
August	147	55	38	80
September	59	34	66	57
		The latest day when T < 0 °C at 10 cm in spring		
Temperature	–2.4	–0.1	–0.8	
Date	8 June	2 June	30 May	
		The latest day when T < –3 °C at 10 cm in spring		
Temperature	–7.0	–3.5	–7.0	
Date	14 May	2 May	18 May	

2.3 Weather

The Suonenjoki Research Unit provided weather data during the experimental period (Table 1). The early summer of 2004 was colder than the annual average but the late summer and autumn were warmer. Monthly temperatures in 2005 were near the long-term average, except for a warmer July. Total precipitation was higher than the long-term average in 2004 and 2005. Summer 2006 was warmer and precipitation was much lower than in an average year. Spring night frosts 10 cm above ground level were common in each year of the study. The coldest nights were in the beginning of May in 2005 and in the middle of May in 2004 and 2006. Typically, the last night frosts occurred in early June.

2.4 Statistical analysis

Differences in height, timing of bud burst, probabilities for second flush, unburst buds, and multiple leaders among planting dates and photoperiod treatments were analyzed in IBM SPSS Statistics version 20. A linear mixed model (MIXED) was used to analyze bud burst and a repeated linear mixed model was applied to the height data. Probabilities for second flush, unburst buds and multiple leaders were analyzed with generalized linear mixed models (GENLINMIXED). In all analyses, planting date (P) and photoperiod treatment (S) were considered fixed effects and block, planting date within the block (main plot) and photoperiod treatment within planting date and block (subplot) as random effects. A normal distribution was used in the MIXED model. We employed a binomial distribution with logit-link function in the GENLINMIXED models. The Satterthwaite method was used to compute the degrees of freedom for each significance test. Multiple comparisons were made with the Bonferroni correction. Differences with a p-value < 0.05 were considered to be significant.

3 Results

3.1 Second flush and bud burst

Second flush only occurred in SD2 seedlings, but the probability of second flush did not differ significantly from that for other photoperiod treatments (Table 2). The bud burst was significantly earlier for seedlings planted in the summer, compared to seedlings planted the following spring (Table 2). No differences in the onset of bud burst were found among photoperiod treatments for seedlings planted in July or August, but buds of SD-treated seedlings burst earlier than those of control seedlings planted in September (8–10 days earlier) or May (6 days earlier). The proportion of seedlings with unburst buds varied from 3–15%, with no statistically significant differences among planting dates or photoperiod treatments (Table 2).

3.2 Survival and multiple leaders

Only four of 720 seedlings died during the three-year study period and no further analysis of mortality could be performed. Significantly more seedlings with multiple leaders were found among those planted in July (24%) or August (30%) than those planted in September (10%) or May (6%) three years after planting (Table 2). Photoperiod treatment did not affect the proportion of seedlings with multiple leaders.

Table 2. Percentage of seedlings showing a second flush after short day (SD) treatment in same summer; the date when 50% of seedlings were flushing the spring after the SD treatments; the percentage of seedlings with unburst buds in the spring after the SD treatments; and the percentage of seedlings with multiple leaders at the end of third growing season. Seedlings were SD-treated on three different occasions in 2004 and then planted on three dates in summer 2004 and on a single occasion in spring 2005. Control seedlings were grown under natural photoperiod conditions. P-values given by a generalized linear mixed model or linear mixed model analysis are presented after each variable. Different letters indicate a statistically significant difference ($p<0.05$) among photoperiod treatments for dates when 50% of seedlings were flushing within the planting dates. A superscript [1] indicates statistically significant difference to spring planting within the photoperiod treatment.

Planting date	Photoperiod treatment	Second flush	Bud burst	Unburst buds	Multiple leaders
22-Jul	SD2	3	22-May a[1]	10	33
	SD3	0	18-May b[1]	10	23
	Control	0	22-May a[1]	15	18
5-Aug	SD2	5	22-May a[1]	5	30
	SD3	0	22-May a[1]	0	33
	SD4	0	21-May a[1]	15	21
	Control	0	23-May a[1]	10	40
6-Sep	SD2	3	23-May a	15	10
	SD3	0	26-May a	5	15
	SD4	0	24-May a	5	15
	Control	0	2-Jun b	5	3
10-May	SD2		19-May a	10	8
	SD3		25-May a	5	3
	SD4		24-May a	10	8
	Control		1-Jun b	15	5
p-values	Planting date (P)	0.986	<0.001	0.860	<0.001
	Photoperiod treatment (S)	0.808	<0.001	0.997	0.565
	P × S	1.000	0.004	0.906	0.304

3.3 Seedling height

At the end of the planting season, control seedlings were a similar size across all planting dates and taller than seedlings in all SD treatments (Fig. 2). Seedlings in the latest SD treatment (SD4) were also taller than seedlings treated earlier (i.e., SD2 and SD3). In subsequent years, the earlier the seedlings were planted the more their height increased, regardless of photoperiod treatment, but SD-treated seedlings gained more height than control seedlings without clear differences among the start date of SD treatments (Table 3). Three years after planting, no statistically significant differences in height among photoperiod treatments within a planting date were found but September- and May-planted seedlings were 6–13 cm shorter than those planted in July or August (Fig. 2).

Table 3. Repeated (measuring year, Y) mixed model analysis of variance for planting date (P) and photoperiod treatment (S) on height of Norway spruce seedlings.

	F	p
Date (P)	80	<0.001
Treatment (S)	16	<0.001
Year (Y)	4644	<0.001
P × S	2	0.140
P × Y	259	<0.001
S × Y	15	<0.001
P × S × Y	2	0.001

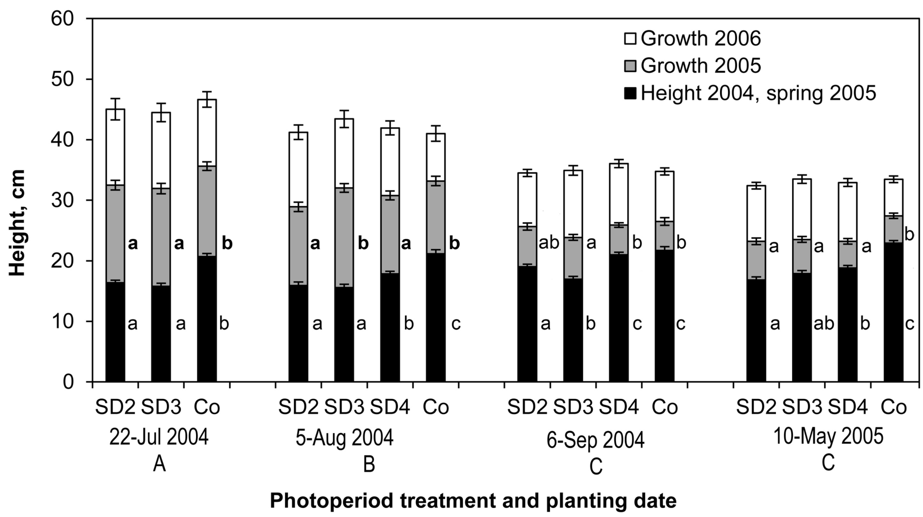

Fig. 2. Height of seedlings at the end of growing seasons 2004 (height at planting for seedlings planted in the spring 2005), 2005 and 2006. Seeds were sown on 5 June 2003 and seedlings were short day-(SD) treated on three different occasions in 2004 and then planted on three dates in summer 2004 and on a single occasion in spring 2005 (N=10 seedlings in 4 blocks). Untreated control (Co) seedlings were grown under natural photoperiod conditions. Vertical bars indicate the standard errors (SE) of mean height at the end of each season and different letters below the plating dates show statistically significant differences ($p<0.05$) among planting dates and letters next to bars show differences among treatments within a planting date and a measurement year.

4 Discussion

Results indicate that summer planting and SD treatment by itself affected the field performance of Norway spruce seedlings more than the start date of SD treatment. Planting in July and early-August advanced the bud burst the following spring regardless of photoperiod treatment. Short day treatment advanced the onset of bud burst for seedlings planted in September and May. Thus, our results agree with earlier studies where SD treatment has been observed to advance bud burst in spring-planted seedlings or seedlings kept in a nursery (e.g., Rosvall-Åhnebrink 1980; Odlum and Colombo 1988; Hawkins et al. 1996; Fløistad and Granhus 2010).

Earlier bud burst in summer-planted seedlings may be due to more established roots that in turn enhance water and nutrient uptake the following spring. Another reason could be earlier bud formation due to physiological stress suffered by seedlings planted in summer. Buds were then formed in warmer conditions in a similar way to SD-treated seedlings. Sutinen and Luoranen (unpublished) found that the bud scale layers in SD-treated seedlings were thinner compared to untreated seedlings and hence even slight elongation of the primordial shoot in spring pushes the bud scales apart and the bud appears to burst. Similarly, planting stress might impair the formation of bud scales in seedlings planted in July and early-August. Control seedlings planted in late autumn or the following spring probably formed buds later and did not exhibit any of the effects with respect to bud scales or the onset of bud burst.

Incompletely or malformed bud scales might also account for some summer-planted seedlings with unburst buds and multiple leaders in later years. A thinner bud scale would make the primordial shoot more susceptible to winter and spring frost. Night frosts occurred in the middle of May when buds were beginning to burst. Thus, the reason for increased multiple leaders for summer-planted seedlings can be explained by an increased risk for frost damage due to advanced bud burst, compared to autumn and spring planted seedlings. Previously, SD treatment has been shown to increase the number of buds that fail to burst and the incidence of abnormal flushing (McClaren et al. 1994; Luoranen et al. 1994, 2006). In the present study, we did not find any differences in the appearance of unburst buds and multiple leaders among photoperiod treatments.

Both summer planting and SD treatment also increased height, as shown by earlier studies with summer planting (Mork 1952; Luoranen et al. 2006) or SD treatment (Heide 1974; Hawkins et al. 1996; Odlum and Colombo 1988; Rostad et al. 2006). Previously, Luoranen et al. (2006) explained the enhanced growth of summer-planted seedlings in terms of rapid rooting and earlier onset of root growth the following spring (Luoranen et al. 2006). Based on the present study, improved growth of summer-planted seedlings could also be due to earlier bud burst and a consequently longer growing season. In addition to earlier bud burst, Luoranen et al. (1994) found that height growth of SD-treated seedlings continued for longer the following season which may also explain the greater growth of SD-treated seedlings.

We found a second flush only in seedlings receiving the SD treatment started on June 18 (SD2). Luoranen et al. (2009) also considered SD treatments started on June 18 and July 24 but rather than being outplanted after treatment, seedlings remained in nursery conditions. In that study, the proportion of SD2 seedlings with a second flush was similar to that observed for outplanted seedlings in the present study. However, while Luoranen et al. (2009) observed a second flush in SD3 seedlings maintained in the nursery, outplanted seedlings did not show this effect here. A treatment period of three weeks is recommended for SD treatments started earlier in the season (Kohmann and Johnsen 2007; Fløistad and Granhus 2010, 2013). This agrees with our earlier conclusions (Luoranen et al. 2009) with respect to minimizing the risk of a second flush in second-year spruce seedlings of local origin.

5 Conclusions

Summer planting and SD treatment advanced terminal bud burst the following spring by up to 10 days and increased the height without any effect on survival after planting, compared to autumn and spring planting and untreated control seedlings of Norway spruce. However, summer planting increased the incidence of multiple leaders which is likely due to the increased risk for frost damages as a result of earlier bud burst. Seedlings intended for planting after mid-July can be SD-treated for three weeks in late June without significantly increasing the risk of a second flush.

Acknowledgements

Seedlings used in the experiment at the Suonenjoki Research Unit were grown, maintained, planted and measured by Kyösti Konttinen, Ritva Pitkänen, Auli Lehtinen, Eeva Vehviläinen and Osmo Korhonen. We are grateful for their technical assistance in establishing experiments and collecting data. We thank Dr. Juha Lappi for statistical advice, Mr. Pekka Voipio for figure preparation, Dr. Johanna Riikonen for valuable comments on the manuscript and Dr. Michael Hardman for checking the English. The study was supported by the Finnish Forest Research Institute through projects 3296, 3450 and 3554.

References

Bigras F.J., D'Aoust A.L. (1993). Influence of photoperiod on shoot and root frost tolerance and bud phenology of white spruce seedlings (*Picea glauca*). Canadian Journal of Forest Research 23: 219–228. http://dx.doi.org/10.1139/x93-029.

Colombo S.J. (1997). Frost hardening spruce container stock for overwintering in Ontario. New Forests 13: 449–467.

Colombo S.J., Menzies M.I., O'Reilly C. (2001). Influence of nursery culture practices on cold hardiness of coniferous forest tree seedlings. In: Bigras F.J., Colombo S.J. (eds.). Conifer cold hardiness. Kluwer Academic Publishers. p. 223–252.

Dormling I., Gustafsson Å., von Wettstein D. (1968). The experimental control of the cycle in *Picea abies* (L.) Karst. Silvae Genetica 17: 44–64.

Fløistad I.S., Kohmann K. (2004). Influence of nutrient supply on spring frost hardiness and time of bud break in Norway spruce (*Picea abies* (L.) Karst.) seedlings. New Forests 27: 1–11. http://link.springer.com/article/10.1023/A%3A1025085403026.

Fløistad I.S., Granhus A. (2010). Bud break and spring frost hardiness in *Picea abies* seedlings in response to photoperiod and temperature treatments. Canadian Journal of Forest Research 40(5): 968–976. http://dx.doi.org/10.1139/X10-050.

Fløistad I.S., Granhus A. (2013). Timing and duration of short-day treatment influence morphology and second bud flush in *Picea abies* seedlings. Silva Fennica 47(3) article 1009. http://dx.doi.org/10.14214/sf.1009.

Hawkins C.D.B., Eastham A.M., Story T.L., Eng R.Y.N., Draper D.A. (1996). The effect of nursery blackout application on Sitka spruce seedlings. Canadian Journal of Forest Research 26: 2201–2213. http://dx.doi.org/10.1139/x26-249.

Heide O.M. (1974). Growth and dormancy in Norway spruce ecotypes. II. After-effects of photoperiod and temperature on growth and development in subsequent years. Physiologia Plantarum 31: 131–139. http://dx.doi.org/10.1111/j.1399-3054.1974.tb03117.x.

Kohmann K., Johnsen Ø. (2007). Effects of early long-night treatment on diameter and height growth, second flush and frost tolerance in two-year-old *Picea abies* container seedlings. Scandinavian Journal of Forest Research 22: 375–383. http://dx.doi.org/10.1080/02827580701520486.

Kohmann K., Sønsteby F. (2007). Sommerplanting med tidlig langnattbehandlete planter. [Summer planting with early long night treated seedlings]. Forskning fra Skog og landskap – 2/07 14 p. [In Norwegian with English summary].

Konttinen K., Rikala R. (2006). Kuusentaimia kesäistutuksiin – kylvö kevättalvella ja istutus heinäkuussa? [Norway spruce seedlings for summer plantings – sowing in winter and planting in July?] Taimiuutiset 4/2006: 5–8. [In Finnish].

Konttinen K., Rikala R., Luoranen J. (2003). Timing and duration of short-day treatment of *Picea abies* seedlings. Baltic Forestry 9(2): 2–9.

Konttinen K., Luoranen J., Rikala R. (2007). Growth and frost hardening of *Picea abies* seedlings after various night length treatments. Baltic Forestry 13(2): 140–148.

Luoranen J., Puttonen P., Rikala R. (1994). Lyhytpäiväkäsittely kuusen paakkutaimien kasvatuksessa. [The use of short day treatment in growing of Norway spruce container seedlings]. Folia Forestalia – Metsätieteen aikakauskirja 1994/1: 51–67. [In Finnish].

Luoranen J., Rikala R., Konttinen K., Smolander H. (2006). Summer planting of *Picea abies* container-grown seedlings: effects of planting date on survival, height growth and root egress. Forest Ecology and Management 237(1–3): 534–544. http://dx.doi.org/10.1016/j.foreco.2006.09.073.

Luoranen J., Helenius P., Huttunen L., Rikala R. (2007). Short-day treatment enhances root egress of summer planted *Picea abies* seedlings under dry conditions. Scandinavian Journal of Forest Research 22(5): 384–389. http://dx.doi.org/10.1080/02827580701551382.

Luoranen J., Konttinen K., Rikala R. (2009). Frost hardening and risk of a second flush in Norway spruce seedlings after an early-season short day treatment. Silva Fennica 43(2) article 209. http://dx.doi.org/10.14214/sf.209.

McClaren E.L., Krasowski M.J., Hawkins C.D.B. (1994). Summer plant culling criteria of interior spruce: keeping the bad and throwing the good? In: Landis T.D., Dumrose R.-K. (tech. coords.). National Proceedings, Forest and Conservation Nursery Associations. USDA Forest Service, General Technical Report RM-257: 118–129.

Mork E. (1952). Planting experiments with Norway spruce (*Picea abies*) at different times during the growing season. Reports of the Norwegian Forest Research Institute XI(38–40): 32–77. [In Norwegian with English summary].

Odlum K.D., Colombo S.J. (1988). Short day exposure to induce budset prolongs shoot growth in the following year. USDA Forest Service, General Technical Report RM-167: 57–59.

Rantanen A., Luoranen J. (1998). Lyhytpäiväkäsiteltyjen kuusen paakkutaimien syysistutus. [Autumn planting of short day treated Norway spruce container seedlings]. In: Poteri M. (ed.). Taimitarhatutkimuksen vuosikirja 1998. Metsäntutkimuslaitoksen tiedonantoja 696: 71–80. [In Finnish].

Rostad H., Granhus A., Fløistad I.S., Morgenlie S. (2006). Early summer frost hardiness in *Picea abies* seedlings in response to photoperiod treatment. Canadian Journal of Forest Research 36(11): 2966–2973. http://dx.doi.org/10.1139/x06-167.

Rosvall-Åhnebrink G. (1980). Kan vi varaktigt förändra en plants invintringsförlopp? [Is it possible to permanently change the hardening process for Norway spruce and Scots pine seedlings?]. Sveriges Skogsvårdsförbunds Tidskrift. Special nummer, Skogsgenetik och skogsträdsförädling, häfte 1–2. p. 170–178. [In Swedish with English summary].

Tan W. (2007). Impacts of nursery cultural treatments on stress tolerance in 1 + 0 container white spruce (*Picea glauca* [Moench] Voss) seedlings for summer planting. New Forests 33: 93–107. http://dx.doi.org/10.1007/s11056-006-9016-5.

Total of 24 references