PRACTICAL APPLICATION OF DORMANCY INDUCTION TECHNIQUES TO GREENHOUSE-GROWN CONIFERS IN SWEDEN

Gunnel Rosvall-Ahnebrink[1]

Abstract.--Experiments to determine the effects of different hardening treatments in the nursery on 1-year-old Scots pine *(Pinus sylvestris* L.) and Norway spruce *(Picea abies* [L.] Karst.) seedlings are described. Seedling performance after early autumn planting and early lifting for overwinter cold storage were better if long night treatments were used. Long night treatments are used in several Swedish nurseries.

Résumé.--Description d'expériences visant à déterminer les effets de différents traitements d'endurcissement en pépinière sur les semis de pin sylvestre *(Pinus sylvestris* L.) et d'épinette de Norvège *(Picea abies* (L.) Karst.) âgés d'un an. Après plantage au début de l'automne et arrachage précoce en vue de leur entreposage à froid pour l'hiver, ces semis présentaient une meilleure performance s'ils étaient soumis à des traitements nyctipériodiques. De tels traitements sont en usage dans les pépinières suédoises.

INTRODUCTION

Planting in the autumn often fails (e.g., Hulten and Jansson 1974). One probable reason for this is that planting stock is not physiologically adapted to the relatively harsh conditions at the planting site. Also, seedlings growing outdoors in the nursery sometimes suffer from autumn frost damage, and this leads to reduced seedling quality. To avoid damage to stock overwintering in cold storage, seedlings must be fully dormant when lifted (Hocking and Nyland 1971, Venn 1980). However, sometimes as early as mid-October in northern Sweden, snow or frozen ground make lifting difficult or impossible.

To adapt planting stock to the conditions it will be exposed to in autumn it is desirable that the development of cold hardiness be regulated in the nursery during summer and autumn. Photoperiod, light intensity, and temperature are probably the most important external factors that regulate the development of cold hardiness. However, their influence varies at different stages of the development process (Weiser 1970).

For Norway spruce *(Picea abies [L.]* Karst.) and Scots pine *(Pinus sylvestris* L.), the most common species in Sweden, it has been demonstrated that short days, or more correctly, long nights (LN), are the most important factor inducing dormancy (e.g., Dormling et al. 1968, Heide 1974, Aronsson 1975, Christersson 1978). Recommendations for the practical application of LN-treatment in nurseries have been made by Sandvik (1975, 1980) for Norway spruce and by Rosvall-Ahnebrink (1977, 1980) for Norway spruce and Scots pine.

The results presented in this paper are derived from a number of nursery experiments with one-year-old containerized Norway spruce, Scots pine and lodgepole pine *(Pinus contorta* Dougl.) seedlings. One aim of the experiments was to determine suitable growing schedules for nursery stock during the final period in the nursery. Emphasis was placed

[1]Forest Officer, Department of Silviculture, Swedish University of Agricultural Sciences, Umeå, Sweden

on investigating how the development of cold hardiness can be regulated by LN treatments in the greenhouse, and these treatments have been compared with the growing schedules normally used. Some results of these experiments have been published (Rosvall-Ahnebrink 1977, 1980), but more detailed reports are in preparation.

MATERIALS AND METHODS

Seedlings

Scots pine and Norway spruce seeds from mid-Sweden (about 60° N) were sown in paperpot containers in the spring of 1977 and 1978 (Table 1) at the Nassja nursery (60° N).

Low humified peat, containing 1 kg dolomite lime per m^3, was used as the growing medium and the seeds were covered with a thin layer of styrofoam pellets.

The seedlings were kept in a production-size plastic-covered greenhouse for three months or more, depending on the hardening treatments applied. The greenhouse was heated to prevent temperatures from dropping to less than 15°C, and was ventilated when the temperature exceeded 25°C. During hot days, maximum temperatures were sometimes 40°C.

Fertilization was started two to three weeks after sowing. Each week, 2-4 g N per m^2 were applied in the form of a complete liquid fertilizer with N:K:P in the proportions of 100:65:13 (Ingestad 1967). Pine seedlings for the autumn planting trial were fertilized until late July when LN treatment began, or else they were moved outdoors. All other seedlings were fertilized until mid-August.

Hardening treatments

Three different hardening treatments were used in various sequences from mid-July (1978) or late July (1977), when seedlings were still in active growth. The conditions were (1) LN-treatment in greenhouse, (2) natural night length in greenhouse, and (3) natural night length outside (seedlings moved outdoors).

During the LN-treatment seedlings were daily covered with black curtains from 4 p.m. to 8 a.m. (16-hr night). Natural night length, defined as time between sunset and sunrise, is approximately 6 hr at 60°N in mid-July.

The different hardening treatments are presented in the lower portions of Figures 1-3 (pine, planted in autumn 1977), Figures 4-6 (spruce, planted in autumn 1978), Figure 7 (pine, cold stored during winter 1978-1979) and Figure 8 (spruce, cold stored during winter 1978-1979).

During the hardening period in 1977, daily maximum temperatures in the greenhouse varied between 20°C and 40°C, and daily minimum temperatures in the greenhouse varied between 10°C and 20°C. Seedlings growing outside were not exposed to temperatures below 0°C before they were outplanted.

In 1978, daily maximum temperatures in the greenhouse varied between 25°C and 45°C. Daily minimum temperatures were about 20°C to mid-September, and thereafter about 15°C.

Table 1. Data for Scots pine and Norway spruce seedlings used in autumn planting and overwinter cold storage experiments.

Experiment	Seed origin	Container	Sowing	Hardening treatments started
Pine, autumn planting in 1977	Seed orchard at Sör Amsberg (61°N), grafts from 61°N	Paperpot FH 408, 850 containers per m^2	4 May, 1977	25 July, 1977
Pine, cold storage during winter 1978-1979	Seed orchard at Hedesunda (60°N), grafts from 60°N	Paperpot FH 508 585 containers per m^2	14 April, 1978	17 July, 1978
Spruce, autumn planting in 1978 and cold storage during winter 1978-1979	Seed orchard at Sollerön (61°N), mother trees from 59°N	Paperpot FH 408, 980 containers per m^2	18 April, 1978	17 July, 1978

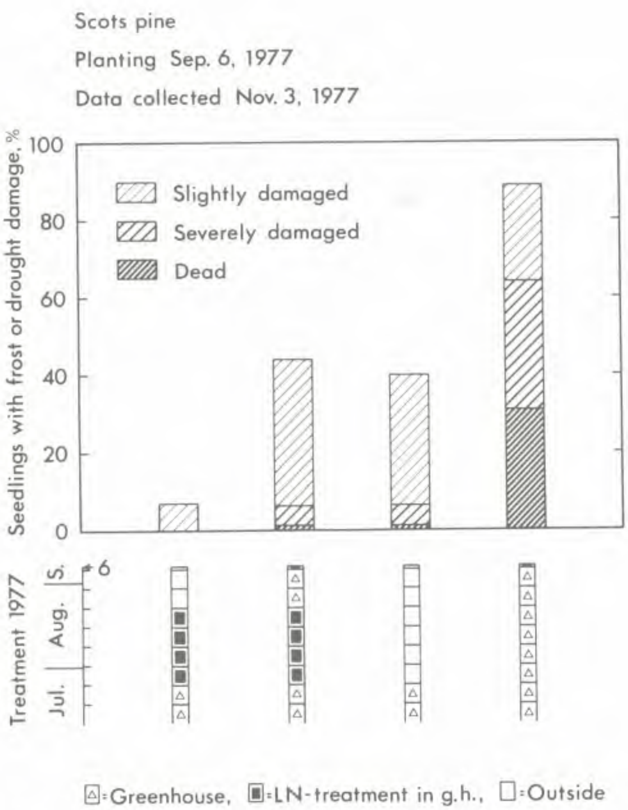

Figure 1. Scots pine (61°N) seedlings with frost or drought damage 2 months after autumn planting, at a site near Bredmossen (60°N). During the final 6 weeks in the nursery (60°N), the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

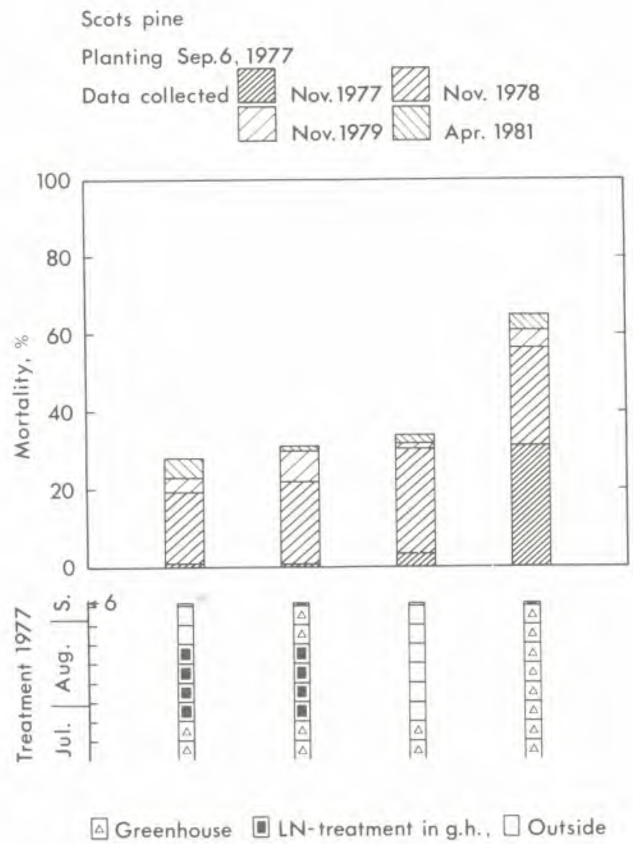

Figure 2. Accumulated mortality of Scots pine (61°N) seedlings after autumn planting, at a site near Bredmossen (60°N). During the final 6 weeks in the nursery (60°N), the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

Outdoor daily maximum temperatures were about 15°C lower than in the greenhouse, and daily minimum temperatures were about 10°C lower than in the greenhouse. Seedlings growing outdoors were exposed to temperatures below 0°C on 20, 21 and 25 September.

Autumn planting

Field trials were established to evaluate the effects of the treatments on seedling performance after early autumn planting.

On 6 September 1977, six weeks after hardening treatments started, the pine seedlings were planted on a harsh site (Bredmossen, 60°N) that had been difficult to regenerate. Twenty-five seedlings of each treatment were randomly assigned to rows within each of six blocks. Height, condition class (0-5; 0 = not damaged, 1-2 = slightly damaged, 3-4 = severely damaged, 5 = dead) and cause of damage were recorded in early November 1977, November 1978, November 1979 and April 1981.

On 30 August 1978, six weeks after hardening treatments began, the spruce seedlings were planted at a site (Stjärnsund, 60°N) less harsh than that where the pine seedlings were planted. The planting design was similar to that used on the pine seedlings, except that only 20 seedlings were planted in each row. Seedling performance was recorded as described above in late October 1978, October 1979 and April 1981.

Cold storage

A cold storage experiment was begun in 1978 to evaluate the effects of the treat-

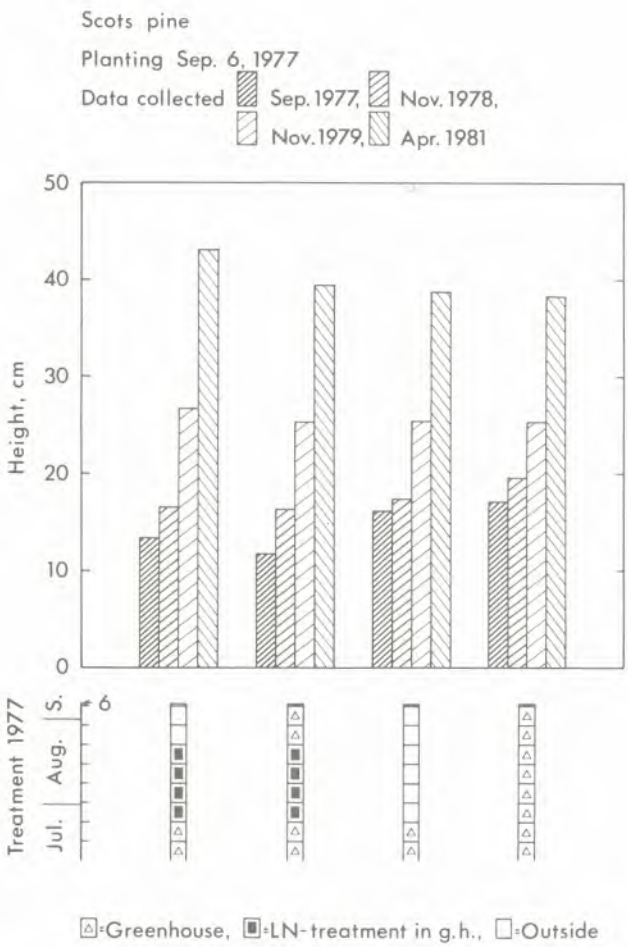

Figure 3. Height of Scots pine (61°N) seedlings after autumn planting, at a site near Bredmossen (60°N). During the final 6 weeks in the nursery (60°N), the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

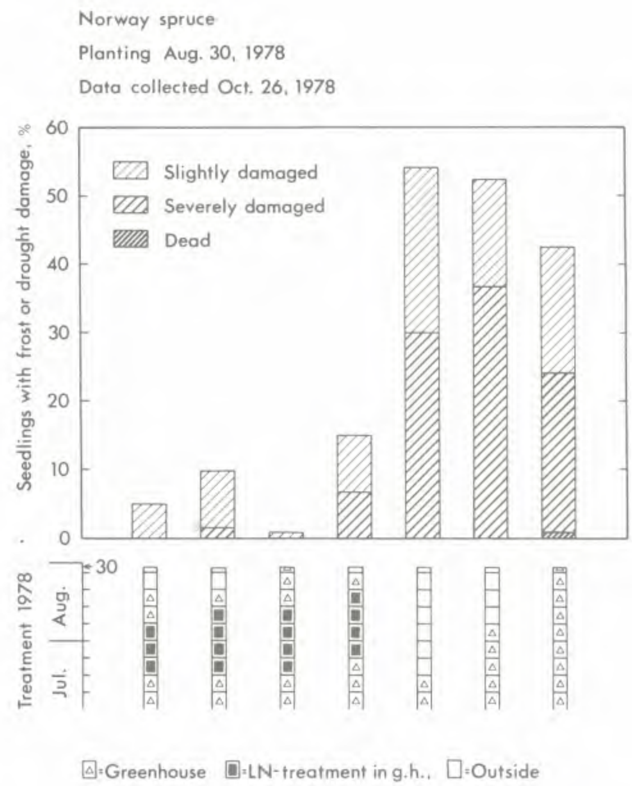

Figure 4. Norway spruce (59°N) seedlings with frost or drought damage 2 months after autumn planting, at a site near Stjärnsund (60°N). During the final 6 weeks in the nursery (60°N), the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

ments on overwinter storage. Pine and spruce seedlings were lifted earlier than normal, on 13 and 27 September, eight or ten weeks after hardening treatments began. Three replicates, each of 11-15 seedlings per treatment and date, were placed in waxed cardboard boxes and stored at -5 °C until 11 May 1979. After a week of thawing the seedlings were planted on nursery land and their condition records were assessed on 23 May 1979, in the same way as in the autumn planting trials.

RESULTS

Autumn planting

The hardening treatment at the nursery during the last six weeks before early autumn planting was of great importance for plantation performance (Fig. 1-6).

On both sites, frost and drought were the most important causes of damage within two months of planting. Seedlings in hardening treatments which prevented severe damage by frost or drought during this period also had the lowest mortality two or three growing seasons after planting.

The pine seedlings (Fig. 1-3) were probably exposed to frost almost immediately after planting, and this resulted in dramatic differences among the treatments. The most favorable was the LN-treatment followed by outdoor conditions. For pine seedlings grown exclusively under natural night lengths, hardiness was significantly improved by an outdoor period of 6 weeks.

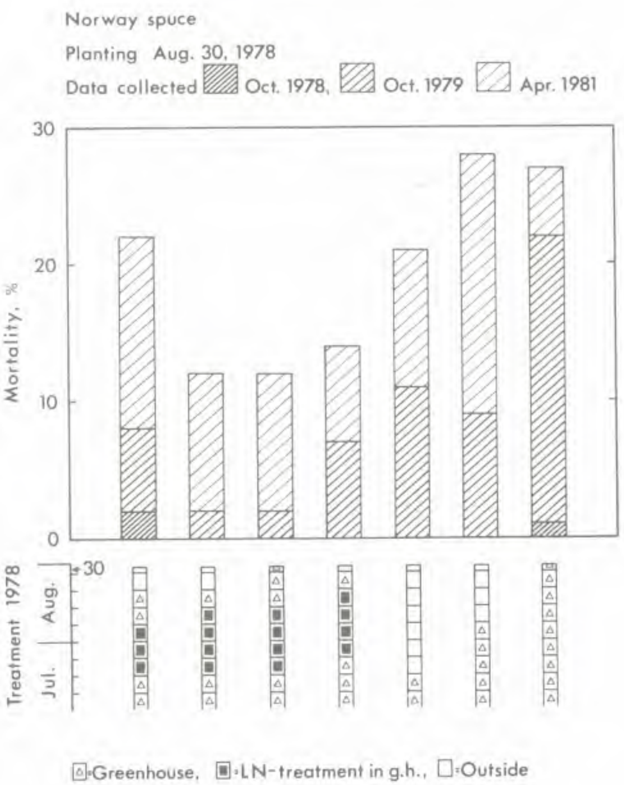

Figure 5. Accumulated mortality of Norway spruce (59°N) seedlings after autumn planting, at a site near Stjärnsund (60°N). During the final 6 weeks in the nursery (60°N), the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

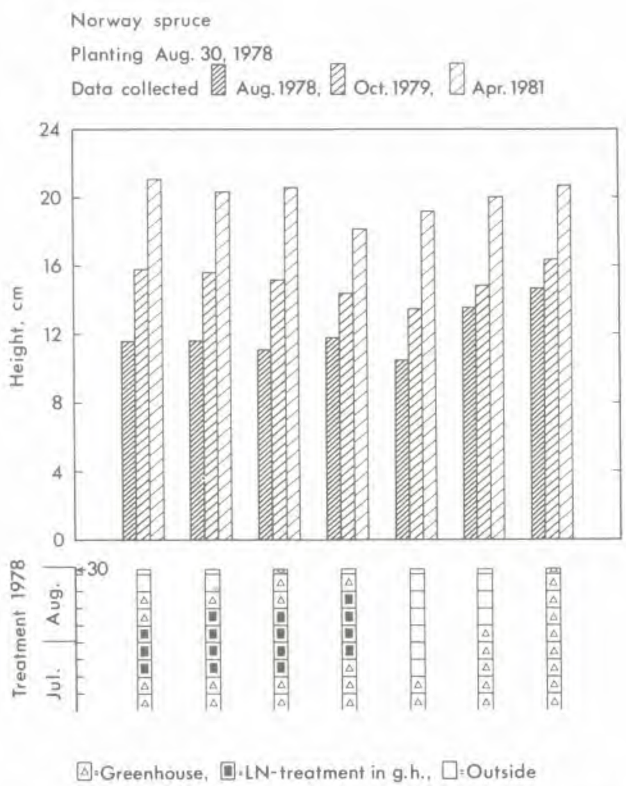

Figure 6. Height of Norway spruce (59°N) seedlings after autumn planting, at a site near Stjärnsund (60°N). During the final 6 weeks in the nursery (60°N) the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

The spruce seedlings (Fig. 4-6) were probably exposed to frost for two weeks after planting. Seedling performance was considerably improved by LN treatment, and the date when LN treatment began was important. Unlike the results with pine, hardiness of spruce was not improved by an outdoor period for seedlings grown in only natural night length conditions.

Cold storage

Lifting pine seedlings on 13 September (Fig. 7), 8 weeks after the hardening treatments began, was fatal irrespective of previous treatment. When lifted 2 weeks later (Fig. 7), seedlings grown outdoors had been exposed to frost, and their tolerance of storage was improved. Pine seedlings exposed to LN treatment followed by outdoor conditions showed the best performance. The storage tolerance of pine seedlings grown under natural night length conditions was better if they were grown outdoors from mid-July instead of from early August. Storage was fatal if the seedlings were moved directly from the greenhouse to cold storage, irrespective of previous night length treatment. Pine seedlings exposed to LN treatment began to grow again if they were kept in the greenhouse after the LN-treatment (data not shown).

In the case of spruce it was not possible to store seedlings from 13 September (Fig. 8), eight weeks after hardening treatments began, although LN-treatment followed by outdoor conditions improved storage tolerance to a limited extent.

When the seedlings were lifted two weeks later (Fig. 8) storage tolerance in these treatments was further improved. Although

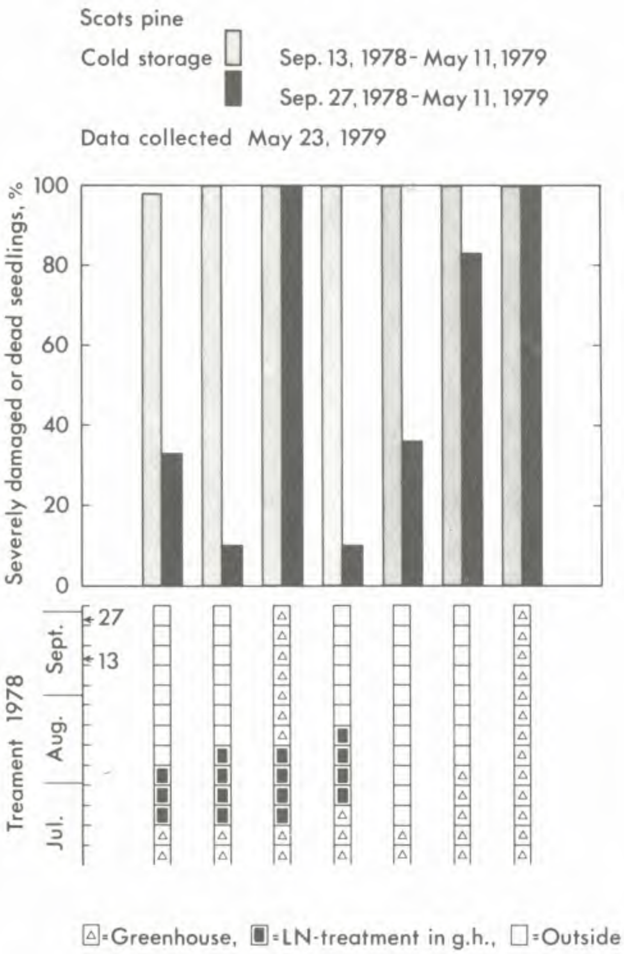

Figure 7. Severely damaged or dead Scots pine (60°N) seedlings after cold storage at -5°C over winter and planting on nursery land (60°N). During the final 8 or 10 weeks in the nursery (60°N) before storage, the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

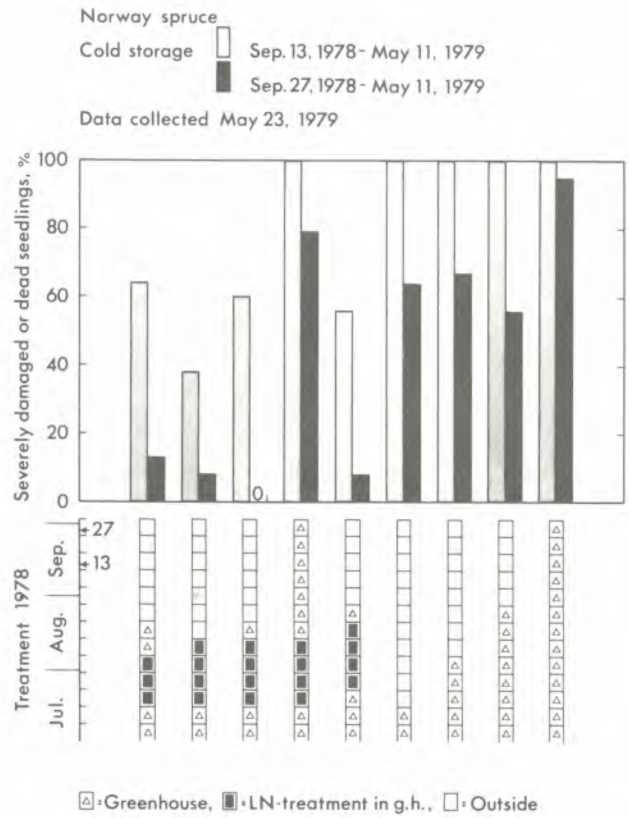

Figure 8. Severely damaged or dead Norway spruce (59°N) seedlings after cold storage at -5°C over winter and planting on nursery land (60°N). During the final 8 or 10 weeks in the nursery (60°N) before storage, the 1-year-old seedlings were given different hardening treatments, under natural night length or long night (LN) conditions.

leaving spruce seedlings in greenhouse conditions after LN-treatment did not cause bud break (data not shown), it was nevertheless detrimental to the hardening process. If spruce seedlings were grown under natural night length conditions from mid-July, outdoor conditions during at least four weeks before storing favored hardiness development. However, moving seedlings to outdoor conditions in mid-July was no better than moving them out in mid-August.

CONCLUSIONS

The environmental conditions to which seedlings are exposed in the nursery, from mid- or late July, are very important to seedling performance after early autumn planting and early lifting for overwinter cold storage.

Hardiness development can be initiated earlier than normal by starting LN-treatment in the greenhouse in mid-July. A period of about four weeks with long nights is sufficient. Pine seedlings should be moved outdoors directly after that period, to allow hardiness development to continue. Spruce seedlings can be kept in the greenhouse for an additional week to favor lignification and bud maturation (data not presented). About six weeks after the hardening process is initiated, seedlings are tolerant to light frosts.

If seedlings are to be kept over winter in cold storage, hardiness development must continue during at least four more weeks. Temperatures below 0°C during this period will probably improve hardiness.

Under natural night length conditions, the development of cold hardiness in pine is favored by outdoor conditions, and outdoor conditions from an earlier date are better than those from a later date. For spruce as well, the development of cold hardiness is favored by outdoor conditions, but the date on which the seedlings are moved outdoors is not as important as for pine.

Practical application of LN treatment

Today, LN treatment to regulate the development of cold hardiness during the final portion of the growing season is used in several Swedish nurseries. The Sör Amsberg nursery, owned by Stora Kopparberg-Bergvik, began using the method on a small scale as early as 1974. At that time they covered the seedlings in the greenhouse manually. Today they use the LN treatment on a large scale, and their black-out systems, which are now automatic, are placed inside the greenhouses.

In recent years several other nurseries have started using the method on a smaller scale. In these nurseries the black-out systems are placed outside, and in two of them seedlings can be covered automatically.

Early summer

Nursery experiments have been conducted to investigate whether LN treatment can be used for purposes other than that of regulating the development of cold hardiness during the final portion of the growing season (Rosvall-Ahnebrink, in prep.).

After sowing in a heated greenhouse early in the year, seedlings are very susceptible to damage if they are planted out in June or July without pretreatment. To improve the hardiness of this crop, experiments have been conducted with LN treatment. Norway spruce and Scots pine seedlings have been exposed to long nights in the greenhouse, starting in May or June, for a period of three to seven weeks. In some cases the period with LN treatment has been followed by one to two weeks in darkness at about 5°C.

Results of tests for frost and drought hardiness demonstrate that hardiness during summer can be considerably increased by using some of the above treatments. However, further experiments are required before recommendations can be made to the nurseries.

Pine seedlings sown in a heated greenhouse early in the year, to be planted in the autumn or following spring, often differ greatly in height and shoot morphology, even if they are grown outdoors from June.

Experiments with Scots pine have been conducted to produce seedlings that appear to be two years old, with secondary needles and lateral buds, although they are produced in one season. If early-sown pine seedlings are given the LN treatment during a short period in spring or early summer, and then are grown in natural night length conditions, they will look like two-year-old seedlings in the autumn. The experiments have demonstrated that two weeks of LN treatment are sufficient to produce this effect.

Field trials have been established to determine whether these pine seedlings will perform better than those produced in the usual manner. In the meantime, the method is being used on a large scale in one Swedish nursery (Sor Amsberg), and several other nurseries show a keen interest in it.

LITERATURE CITED

Aronsson, A.
1975. Influence of photo- and thermoperiod on initial stages of frost hardening and dehardening of phytotron-grown seedlings of Scots pine *(Pinus silvestris* L.) and Norway spruce *(Picea abies* [L.] Karst.). Stud. For. Suec. 128:1-20.

Christersson, L.
1978. The influence of photoperiod and temperature on the development of frost hardiness on seedlings of *Pinus silvestris* and *Picea abies.* Physiol. Plant. 44:288-294.

Dormling, I., Gustafsson, A. and von Wettstein, D.
1968. The experimental control of the life cycle in *Picea abies* (L.) Karst. Silv. Genet. 17:44-63.

Heide, O.
1974. Growth and dormancy in Norway spruce ecotypes *(Picea abies)*. I. Interaction of photoperiod and temperature. Physiol. Plant. 30:1-12.

Hocking, D. and Nyland, R.
1971. Cold storage of coniferous seedlings. A review. App. For. Res. Inst., State Univ. Coll. For., Syracuse, New York, Res. Rep. No. 6. 70 p

Hulten, H. and Jansson, K-A.
1974. Biologisk uppföljning av rotade plantor vid praktisk skogsodling planteringsär 1972. [Biological follow up of rooted plants at practical artificical regeneration. Planting year 1972.] R. Coll. For., Dep. Refor. Stockholm, Sweden, Res. Notes 56. 42 p.

Ingestad, T.
1967. Methods for uniform optimum fertilization of forest tree plants. 14th IUFRO Congress, Section 22. p. 265-269.

Rosvall-Ahnebrink, G.
1977. Artificiell invintring av skogsplantor i plastväxthus. [Artificial hardening of spruce and pine seedlings in plastic greenhouses.] Exp. genek. R. Coll. For., Dep. For. Genet., Res. Notes 27. p. 153-161.

Rosvall-Ahnebrink, G.
1980. Kan vi varaktigt förändra en plantas invintringsförlopp? [Is it possible to permanently change the hardening process for Norway spruce and Scots pine seedlings?] Sveriges Skogsvardsforbunds Tidskrift. Specialnummer Skogsgenetik och skogstradsforadling 1980. (1-2):170 178.

Sandvik, M.
1975. Kontroll av innvintringstempoet hos granplanter i praktiske produksjonsanlegg. Arsskr. norske skogpl.sk. 1974:49-56.

Sandvik, M.
1980. Environmental control of winter stress tolerance and growth potential in seedlings of *Picea abies* (L.) Karst. N. Z. J. For. Sci. 10:97-104.

Venn, K.
1980. Winter vigour in *Picea abies* (L.) Karst. VII. Development of injury to seedlings during overwinter cold storage. A literature review. [Vinterstyrke hos gran. VII. Utvikling av skader pa planter under kjolelagring over vintern. En litteraturoversikt.] Rep. Norwegian For. Res. Inst. 35:483-530.

Weiser, C.J.
1970. Cold resistance and injury in woody plants. Science 169:1269-1278.