COLD STORAGE OF CONTAINERIZED PLANTING STOCK AND SUBSEQUENT PERFORMANCE AFTER OUTPLANTING

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Abstract.--Two-year growth performance of containerized Scots pine *(Pinus sylvestris* L.) seedlings overwintered outdoors was compared with that of cold stored (-5 C) seedlings. When planted early in the spring before the onset of shoot growth, seedlings overwintered outdoors were of superior quality and performed better than cold stored stock, particularly in the second growing season. The results also indicate that cold stored seedlings do not perform well when planted late in the growing season.

Résumé.--Après deux ans de croissance, on a comparé des plants en mottes emballées de pin écossais *(Pinus sylvestris* L.) qui avaient passé l'hiver à l'extérieur et d'autres qui avaient été stockés au froid (-5°C). Plantés tôt le printemps avant le début de la croissance des pousses, les plants qui avaient passé l'hiver à l'extérieur étaient de qualité supérieure à ceux qui avaient été stockés au froid, particulièrement au cours de la deuxième saison de croissance. Les résultats montrent aussi que les plants stockés au froid se développent mal lorsqu'ils sont plantés vers la fin de la saison de croissance.

INTRODUCTION

Good plantation establishment is the key to economical reforestation. About 200 million containerized seedlings are planted annually in Sweden at a total cost of about $55 million. This cost includes seedling production, transportation, site preparation, and planting. Poor plantation establishment therefore results in large financial losses.

In Sweden the best time for planting is that period in spring from the time the frost is out of the ground until the trees start their shoot elongation. This normally ranges from early April to early June, depending on latitude. The short spring planting period, with its rapid increases in soil and air temperatures, creates problems in the handling of containerized planting stock, particularly in relation to the initiation of shoot growth prior to planting. However, cold storage during winter and early spring prevents seedling shoot and root growth before planting, thereby allowing delivery of seedlings to the planting site with their growth processes in phase with the environment of the site. This enables the planting season to be extended, while the seedlings can be packed ready for shipping as soon as there is demand from the field. For these reasons, cold storage has frequently been used for handling seedlings in Sweden during the past 5 years.

Containerized seedlings that are to be cold stored over winter are put into storage when the shoot is fully dormant (normally October for mid-Sweden [60 N]). The seedlings must be dry when put into storage to prevent fungal growth, but there is normally no pre-conditioning of the seedlings before or after packing. Seedlings are packed into waxed cardboard boxes and placed directly

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into storage, where the boxes are stacked in such a way that air can circulate around them.

In Sweden the usual type of storage facility has a direct refrigeration system with a temperature range of -3 to -5 °C. With this system and at temperatures below 0 °C it is difficult to maintain relative humidities over 80%. Consequently, it is essential that the boxes be airtight to prevent the seedlings from drying out during long-term storage.

Sub-zero storage temperatures are used mainly to keep the trees dormant, with their respiration rate as low as possible to prevent fungal development. Many studies in Scandinavia, the United States and Canada have demonstrated problems with high respiration rates and fungus growth associated with long-term storage of coniferous seedlings at above-freezing storage temperatures (Sandvik 1964, Hocking and Nyland 1971, Young 1976, Uhlig 1977).

Seedlings are normally shipped during May or June and are stored at the planting site in the boxes used for cold storage. The boxes are delivered to the planting site, and holes are punched in them to permit some light to reach the seedlings. In this way, photosynthesis can take place, and dry weight losses due to respiration can be prevented. The use of partly closed boxes during storage at the planting site also prevents drying of the growing medium (normally sphagnum peat) and helps to avoid extreme day and night temperatures until the growing medium is thawed and the seedlings can be planted. The period from shipping to planting is usually 1-2 weeks. If the seedlings are not planted within this period the boxes must be opened fully and the growing medium kept moist.

Recently, there have been indications that some cold stored seedlings handled in the above manner exhibit high mortality and poor growth. In view of the large-scale adoption of sub-0 °C refrigerated storage of forest tree seedlings in Sweden, it is essential that we determine whether there is a need to change or improve current techniques for long-term (6-8 month) storage. Initial investigations will evaluate the effects of timing and duration of cold storage upon the survival and growth of outplanted seedlings.

This paper presents some preliminary results from a comparison of the growth performance after outplanting of Scots pine *(Pinus syZvestris* L.) seedlings overwintered (a) under normal long-term cold storage at -5 °C, and (b) in an outdoor storage area under snow from early December to the end of March.

EXPERIMENTAL METHOD

Scots pine containerized stock from a mid-Swedish provenance (60 °N) at 200 m altitude was used in this study. The seedlings were grown in FH 408 paperpots (70 cm^3), the most commonly used container in Sweden, filled with peat chips. The seeds were sown in early April and the seedlings were grown in the greenhouse until early June. The containers were then moved outdoors and kept there until mid-October when part of the crop was put into cold storage at -5 °C. The remainder were left over winter in the nursery, where they were covered with snow from early December until the end of March. Temperatures in the growing medium were close to 0 °C during the winter and never fell below -2 °C.

The following spring seedlings were planted successively during the growing season. All the seedlings overwintered outdoors were planted in early May before shoot growth occurred. Cold stored seedlings were also planted at the same time. However, some cold stored stock was also planted in early June and July to study the possibility of using it for extending the planting season. All seedlings were graded by height to keep variation between treatments within ±1 cm; they were planted in a randomized block design at the nursery.

RESULTS AND DISCUSSION

The following results are from the first two growing seasons after planting and are shown as averages of 25 or 50 seedlings per treatment. Because there was no mortality, the results are based on living seedlings.

Height increments for cold stored and outdoor overwintered stock in the first year after planting are presented in Figure 1. The fact that no differences in shoot height growth were observed suggests that there was no difference between the two storage methods. However, it may also reflect nursery conditions during storage or good growing conditions at the planting site during this first year. The shoot growth of cold stored stock began about one week later than that of stock overwintered outdoors, and this indicates that cold stored stock was more dormant at time of planting.

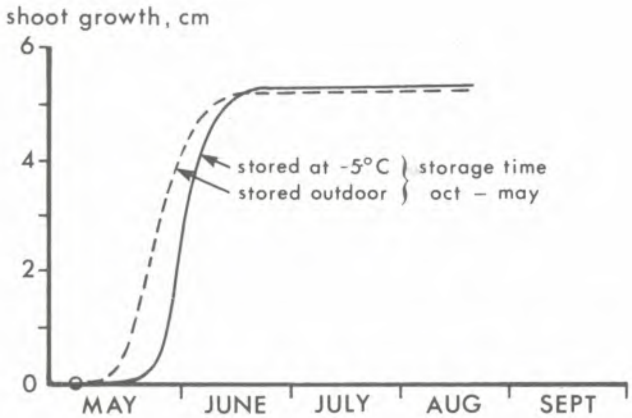

Figure 1. Height increment during the first year after planting (n = 50).

At the beginning of each month throughout the growing season, seedlings were analyzed for the starch content of their needles. Starch content was determined by a method originally outlined by Hansen and Wier (1975). Soluble carbohydrates were extracted by percolation with 80% ethanol, starch being extracted by percolation with 35% perchloric acid. The starch content of the percolates was determined using anthrone dissolved in sulphuric acid, followed by spectrophotometric detection. The standard solution for the determinations was glucose, which was converted into amylose equivalents before the starch content of the samples was estimated. Primary needles were sampled until all secondary needles were over 1 cm. Large differences in starch content occurred between the two storage treatments at the beginning of May (Table 1). Seedlings that had been stored outdoors over winter had a starch content of 22% of needle dry weight in comparison with 5% for stock that had been stored at -5 °C. The data show only starch contents, the main storage product in woody plants, and do not take into account other carbohydrate reserves which may have been present.

Table 1. Starch content in primary needles during the growing season (n = 100).

Storage	May	June	July	Aug.
	Starch as % of needle dry weight			
Outdoors	22	22	14	9
-5°C	5	21	14	9

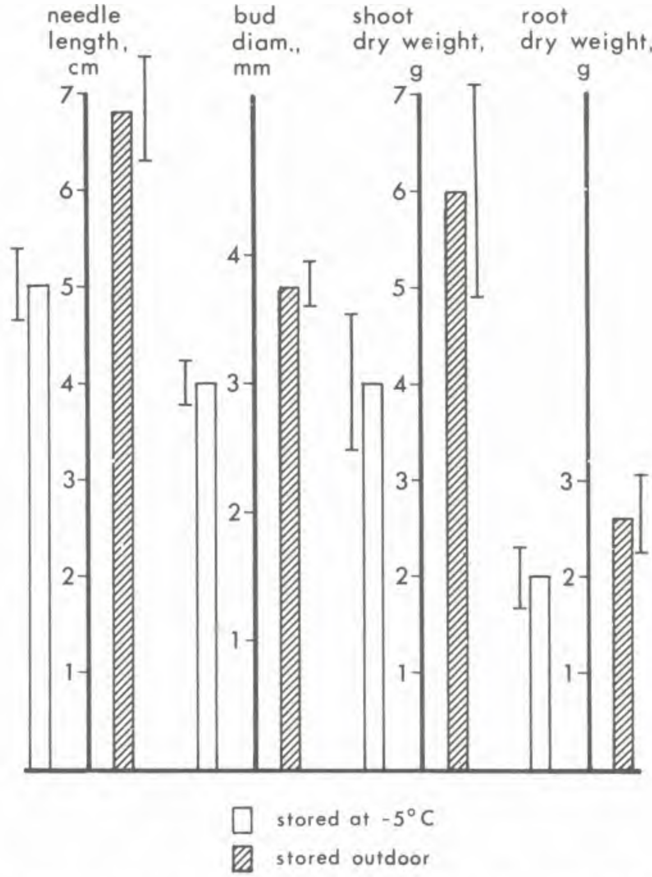

Figure 2. Seedling development at the end of the first growing season (n = 25).

It appears that cold stored stock may miss the period in early spring when carbohydrates are able to accumulate. Low carbohydrate reserves during a period of intensive shoot growth could imply a stress situation that, except for first year height growth, could produce a seedling which enters the fall season with few needle primordia on an under-developed bud. The results indicate that such stress also has an adverse effect upon root growth and needle length (Fig. 2).

Seedlings that had been overwintered outdoors were, except in height growth, significantly superior at the end of the first growing season to those stored at -5 °C in terms of secondary needle length, bud diameter and shoot dry weight. This suggests a physiological difference between treatments that would be likely to affect the next year's growth. That this was so became apparent when the seedlings were analyzed after the second growing season (Fig. 3).

Substantial and significant differences in shoot growth and dry weights between treatments occurred during the second growing season, with better growth from seedlings overwintered outdoors. These differences are likely to remain for several years because of better establishment of seedlings stored outdoors.

These results do not suggest that long-term storage of seedlings at temperatures below 0°C is inadvisable, but they do indicate that there are reasons for improving long-

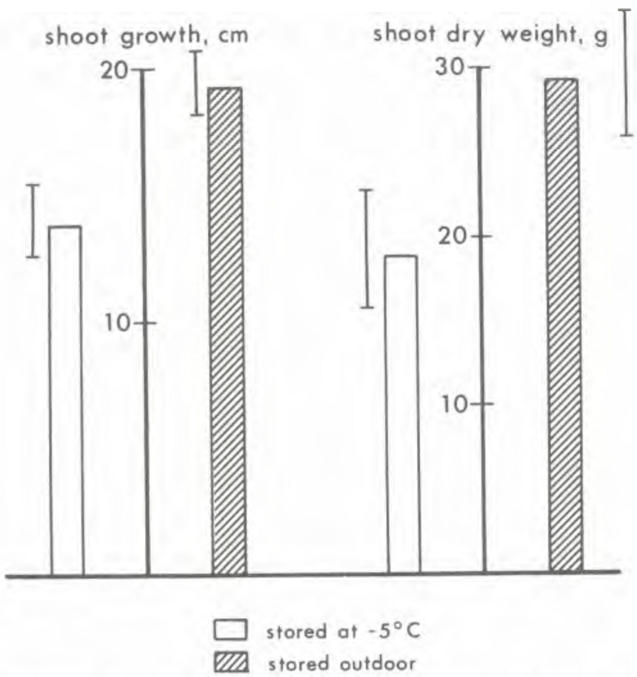

Figure 3. Shoot growth (n = 50) and dry weight (n = 25) at the end of the second growing season.

term storage procedures as they are currently applied in Sweden. The importance of good establishment for avoiding mortality and poor growth in plantations cannot be overemphasized. With all the stresses at the planting site, such as moisture deficits, insects and competition it is essential that we produce forest seedlings that have good potential for establishing themselves and growing quickly after outplanting.

Work to investigate root growth capacity in relation to plantation establishment after cold storage is of great importance (Stone and Jenkinson 1971, Jenkinson and Nelson 1978, Burdett 1979, Stone and Norberg 1979, Jenkinson 1980, Sutton 1980). Some of these authors have worked out practical nursery regimes for obtaining a high root growth capacity after planting. These take into account planting location, species, seed source, nursery climate, lifting date, storage temperatures and planting date. The recommendations are based upon the seasonal pattern of root growth that has to be considered in long-term cold storage practice. Since root growth after planting is the key to good establishment, it is essential that practical nursery regimes which take account of local conditions and species requirements be introduced.

Time of planting during the growing season is also important for the establishment of long-term cold stored seedlings. As noted in the previous section, cold stored seedlings were also outplanted in early June and July so that the feasibility of using such stock to achieve a longer planting season could be examined.

Shoot growth and dry weight measurements during the first growing season after successive plantings of cold stored seedlings indicated no significant differences in shoot growth between the three plantings (Fig. 4). However, although shoot dry weights were the same for the May and June plantings they showed a significant decline for the July planting. Root dry weights declined progressively from May to July, an indication that very little root growth occurs in late-planted Scots pine stock which has undergone long-term cold storage.

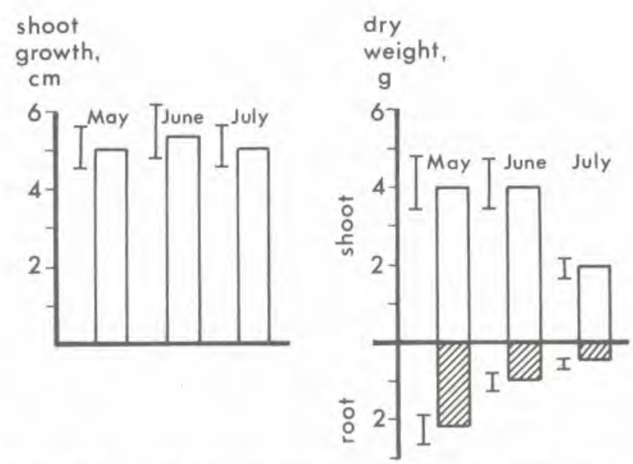

Figure 4. Shoot growth (n = 50) and dry weight (n = 25) at the end of the first year after planting for cold stored seedlings planted successively during the growing season.

As noted earlier, shoot growth of cold stored Scots pine seedlings began quickly after they were planted. Once shoot growth starts, the rate of root growth is reduced. The main period for seedling root growth in spring is therefore the time between the attainment of a soil temperature favorable to root growth and the time when shoot growth begins. For Ponderosa pine *(Pinus ponderosa*

Laws.) the soil temperature (at 8 cm depth) when significant root growth can begin is about 10°C (Jenkinson 1980). If Scots pine reacts in a similar manner, a relatively early planting of cold stored stock would be essential to ensure that some root growth has taken place before shoot growth begins.

The progression of shoot growth for cold stored seedlings planted at different times during the growing season is illustrated in Figure 5. Only the May planting had a two-week period after planting before shoot growth started: the June and July plantings required just one week. This suggests a longer period available for root growth in the May planting, a hypothesis borne out by the considerably higher root system dry weights of seedlings from this early planting (Fig. 4).

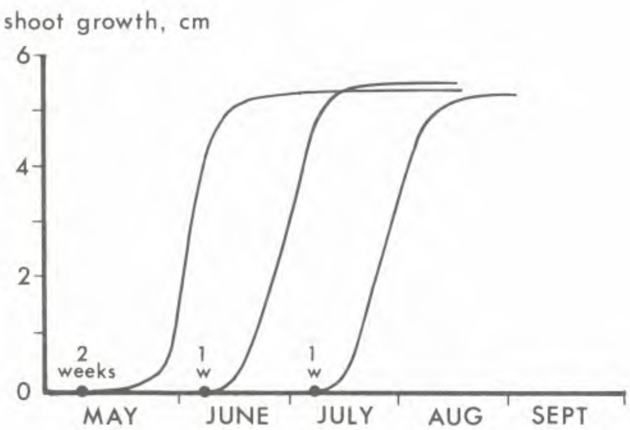

Figure 5. Height growth progression during the first growing season of cold stored seedlings planted successively during the growing season (n = 50).

The poor root growth and low shoot dry weights associated with late-planted cold stored seedlings during their first year after outplanting also showed up in poor shoot growth during the second growing season (Fig. 6).

These results indicate that when we extend the planting season in Sweden by using cold stored seedlings we can expect reduced performance. It can be concluded that cold stored Scots pine seedlings should not be planted later than the middle of June. However, this is based upon current cold storage techniques.

Despite these results, long-term cold storage still appears to hold promise for the future. In particular, cold storage facilitates the handling and shipping of large

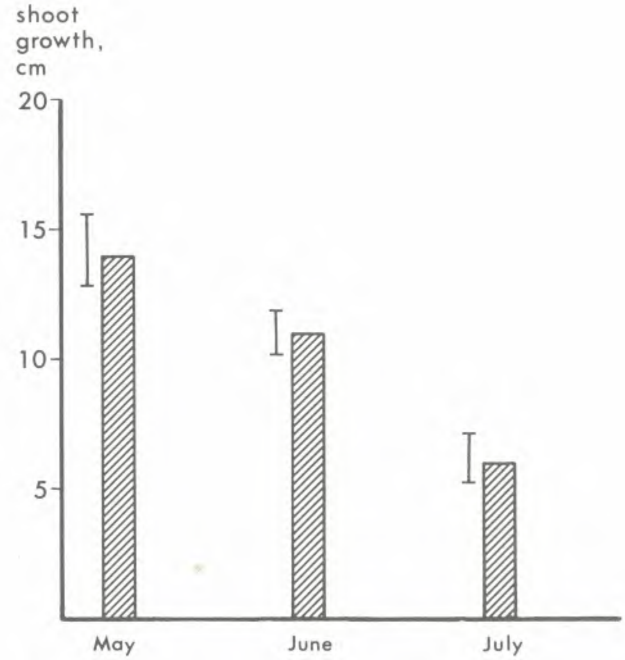

Figure 6. Shoot growth at the end of the second year after planting for cold stored seedlings planted successively during the growing season (n = 50).

quantities of nursery stock. By considering root growth patterns and the possibility of pre-conditioning seedlings, and by careful choice of planting date, I am convinced that we can have high-quality cold stored seedlings that will give us the good establishment we need for economical reforestation.

CONCLUSIONS

When Scots pine is planted in early spring, before the onset of shoot growth, seedlings overwintered outdoors become established and grow better than does cold stored stock. This is evident from evaluations of shoot and root dry weights, secondary needle lengths and bud diameters at the end of the first growing season in the two stock types, where seedlings overwintered outdoors performed better than cold stored stock.

The results imply a stress situation resulting from low carbohydrate reserves, in the form of starch, during the period of intensive shoot growth in cold stored seedlings. This does not take into consideration other forms of carbohydrate reserve which might be present; other carbohydrates were undoubtedly present, but not in the starch form.

The better shoot growth and dry weight accumulation, during the first growing season, of outplanted seedlings overwintered outdoors was also reflected in superior second-year growth performance.

Cold-stored Scots pine planted late in the growing season does not perform well. Seedlings planted in May and June had better shoot and root dry weights at the end of the first growing season than did seedlings planted in July. This is attributed to the reduced amount of root growth in late-planted seedlings. The effects of late planting were also reflected in the poorer second-season shoot growth of seedlings planted in July.

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