# The field performance of bare-root stock compared with container stock of western hemlock and western red cedar under Irish conditions

Conor O'Reilly[1], Charles Harper[2] and Michael Keane[3]

## Abstract

The first-year survival and height growth of container-grown seedlings were compared with those achieved by bare-root stock of western red cedar (*Thuja plicata* D. Don) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) planted in field trials in Ireland. In the first experiment using western hemlock planted in 1995/96 on a reforestation site, there was no consistent effect of stock type or date of planting (October, December, January and March) on field performance. Seedlings planted on part of the site that was mounded survived better and suffered less weevil damage than those planted on the part that was not mounded. In the second experiment carried out in 1997/98, seedlings of both species were stored in co-extruded polythene bags at ambient temperatures for up to four weeks after lifting in November, December, January and March, and then planted on a reforestation site. Containerised seedlings of both species survived well in the field regardless of date of planting or duration of storage. However, bare-root western red cedar stock had a lower survival than containerised seedlings. Survival was reduced further by extended storage for plants lifted on some dates. Western hemlock bare-root stock survived well except for seedlings stored after lifting in February. Seedlings planted in March had the lowest survival (bare-root western red cedar only) and height increment (both species). Despite the superior tolerance of container stock to handling stresses, better performance can be expected for such seedlings planted before the end of February. Well-conditioned, carefully handled bare-root western hemlock should perform well if planted from November to February.

## Introduction

The proportion of planting of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) in Ireland has been recognised in the government's forest strategy, *Growing for the Future* (Anon. 1996), as undesirably high. In order to increase species diversity there are higher grants available for planting 'diverse' conifers other than Sitka spruce or lodgepole pine (*Pinus contorta* (Dougl.)). Therefore, western red cedar (*Thuja plicata* D. Don) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are among the species that are likely to become more widely planted in Ireland. Both can have a significantly higher end-use value than Sitka spruce, and may be viable alternatives to spruce on some sites. Both species can also be used in mixtures. However, achieving good establishment success has been a major problem with both species.

Currently, most planting in Ireland is done using bare-root stock. Bare-root seedlings[4], however, may be more prone to adverse handling stresses than container-grown stock

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1 Department of Crop Science, Horticulture and Forestry, Faculty of Agriculture, University College Dublin, Belfield, Dublin 4. (conor.oreilly@ucd.ie).

2 Eurofortech (European Network for Forest and Wood Industries), 39 Mountjoy Square, Dublin 1. (charles@eurofortech.com).

3 Coillte, Newtownmountkennedy, Co. Wicklow. (keane_m@coillte.ie).

4 The term seedling is used in the broadest generic sense to include all phases of growth of planting stock in the nursery, including transplanted seedlings.

(Hobbs 1984, Tinus and Owston 1984), and western red cedar and western hemlock are considered relatively sensitive to poor handling. The use of containerised stock may also facilitate an extension of the planting season (Tinus and Owston 1984, Brissette *et al.* 1991). Another advantage is that the length of the production cycle is shorter for containerised seedlings (about 1 year) than for bare-root stock (2-4 years), thus making it easier to match supply with expected demand. However, containerised planting stock is more expensive to produce in Ireland, is limited in supply and is usually smaller than bare-root stock.

The main objective of this study was to compare the first-year field survival and growth of container-grown and bare-root stock of western red cedar and western hemlock planted in Ireland. The effect of planting date and plant storage duration (under ambient conditions) on field survival and growth was examined also.

## Materials and methods

Bare-root and containerised seedlings were obtained from commercial nurseries and planted in a series of experiments established in 1995/96 and 1997/98. All of the western hemlock seedlings used in 1995/96 were derived from seeds that originated in the same seed zone in coastal Washington, USA (seed zone 030 (797); 0-150 m elevation). The containerised western red cedar seedlings used in 1996/97 were of Qualicum, Vancouver Island, BC, Canada seed origin (93(711) C1 Lot 2; 0-150 m). The western hemlock and western red cedar bare-root stock supplied from the Forestry Commission, Wykeham Nursery in 1997/98, were derived from seed that originated from Vancouver Island (probably from the only one recommended by the Forestry Commission (711) C1; 0-150 m)), but the exact origin is not known.

### *1995/96 experiment (Clogheen)*

Bare-root and containerised western hemlock (western red cedar was not available that year) seedlings of four different stock types were used (Table 1). The seedlings were planted on four different dates: the 27 October and 12 December, 1995, and the 6 January and 26 March, 1996 at a site at Clogheen Forest (52° 16' N, 8° 00 W; 119 m elevation). A full factorial combination of the four stock types and four planting dates was used. The trial was established on a north-facing, sheltered reforestation site that previously had carried a crop of Scots pine (*Pinus sylvestris* L.). The soil was a peaty podsol of old red sandstone origin. The dominant vegetation consisted of *Calluna vulgaris, Ulex europaeus* and *Rhododendron ponticum*. No weed control measures were undertaken. The bare-root seedlings were carefully lifted a few days before planting, packed in co-extruded polythene bags and dispatched for planting. Similarly, the containerised stock was placed in waxed cardboard boxes and dispatched for planting. The site consisted of two separate areas, which were adjacent to each other (about 2-4 m apart at the closest point). One area was mounded while the other area was not. Each area had an identical design, containing a fully randomised block experiment with a full factorial combination of all treatments in each of three blocks. The plots were established as rows containing 30 seedlings. Because of the coarse nature of the soil (including stones and boulders), mound quality was poor. Seedlings were planted on top of the mounds. Plant spacing was 2 m within and between rows.

**Table 1**. *Western hemlock stock types used in 1995/96 at Clogheen, Co Tipperary. Values in parentheses are standard errors of the mean.*

| *Production system* | *Stock description and age* | *Nursery of origin* | *Mean height cm* |
|---|---|---|---|
| *Bareroot* | 2+2 transplant (4 years) | Cappagh Nursery Aughrim, Co Wicklow. | 37.6 (1.10) |
| *Bareroot* | Transplanted miniplug[5], MP+1 (2 years) | Coillte Rathluirc, Co Cork. | 25.8 (0.39) |
| *Container* | 'Quick Pot' plug (2 years) 200 $cm^3$ container | D. Buckley, Carrigtwohill, Co Cork. | 29.3 (0.50) |
| *Container* | Finnpot[6] No. 628 (1 year) 148 $cm^3$ container | M. Smith Tralee, Co Kerry. | 17.3 (0.28) |

*1997/98 experiment (Aughrim)*

In addition to evaluating the effect of stock type, the effect of temporary storage under ambient conditions prior to planting on the subsequent survival and first-year height increment of seedlings was investigated. One bare-root and one Finnpot containerised stock type each of western red cedar and western hemlock were used (Table 2). The Finnpot seedlings were dispatched in the container trays to the Coillte Tree Improvement Centre, Kilmacurra, Co Wicklow in November 1997 and held outside under ambient conditions until placed in bags for long-term storage.

**Table 2**. *Western red cedar and western hemlock stock types used in 1997/98, at the Aughrim, Co Wicklow experiment site. Values in parentheses are standard errors of the mean (n=60 and 84 for western hemlock and western red cedar, respectively).*

| *Species* | *Production system* | *Stock description and age* | *Nursery of origin* | *Initial diameter[7] mm* | *Initial height[7] cm* |
|---|---|---|---|---|---|
| *Western red cedar* | Transplant | 1u1 (2 years) | Forestry Commission, Wykeham Nursery, Yorkshire. | 4.80 (0.286) | 49.0 (2.55) |
| *Western red cedar* | Container | Finnpot No. 628 (1 year) 148 $cm^3$ container volume | M. Smith, Tralee, Co Kerry. | 2.79 (0.167) | 27.7 (1.44) |
| *Western hemlock* | Transplant | 1u1 (2 years) | Forestry Commission, Wykeham Nursery, Yorkshire. | 2.67 (0.116) | 28.2 (0.73) |
| *Western hemlock* | Container | Finnpot No. 628 (1 year) 148 $cm^3$ container volume | M. Smith, Tralee, Co Kerry. | 1.57 (0.054) | 22.3 (0.48) |

5 Originated as miniplug container (16 $cm^3$) seedlings (4-6 weeks old) that were transplanted in a bare-root nursery for remainder of cycle.

6 Finnpots are made from a mixture of paper and peat with the entire pot being planted.

7 Initial height and diameter values are based upon measurements made in the field immediately after planting.

Three hundred and fifty bare-root seedlings of each species were lifted on each occasion on 25 November 1997 and on 13 January, 20 February and 31 March 1998, dispatched in polythene co-extruded bags and arrived the next day at Kilmacurra. The stock was stored overnight at 2 to 4 °C. Seedlings of both stock types of each species were then subjected to 0 (no storage), 2 or 4 weeks storage under ambient conditions. The air (minimum and maximum) temperatures at Dublin Airport (data not available for Kilmacurra) during the period after lifting until the last date of planting for each lift date ranged from -3.4 to 13.3 °C, -4.8 to 12.2 °C, -0.7 to 14.5 °C, and -4.0 to 15.3 °C for the November, January, February and March lift dates, respectively. The bare-root plants were removed from the original co-extruded bags, bulked and mixed, and then divided into three bundles (containing at least 116 seedlings each). Each bundle was placed in a new co-extruded bag and assigned at random to one of the three storage-duration treatments. Similarly, 350 containerised seedlings were sampled at random from the container trays and placed in co-extruded bags on the same date as the bare-root stock was treated. The sealed co-extruded bags were placed in the shade at Kilmacurra.

After storage, the seedlings were dispatched to a reforestation site at Aughrim, Co Wicklow (52° 16' N, 8° 00' W; 119 m elevation) and planted within two days. The date of planting varied with the storage-duration treatment for each lift date. The trial was established on a moderately exposed reforestation site that previously had a crop of Scots pine. The soil was a free-draining podsol. Glyphosate (3 l $ha^{-1}$ a.i.) was applied prior to planting to control competing vegetation. The experiment was a randomised block, factorial design with seven blocks. Each block contained a single replication of each of the 48 treatment combinations (two species x two stock types x four lift dates x three storage durations). Each replicate was a row containing 10 seedlings. The site was 'spot' mounded (i.e. without additional drainage) at 2 m intervals. The seedlings were planted on the top of the mounds.

## Measurements, observations and data analyses

Survival, initial height (measured shortly after planting) and height at the end of the first growing season were recorded for plants in each experiment. Height increment as a percent of initial height was determined from these data (this parameter is a good indicator of relative height increment of seedlings when initial height differs). Weevil damage levels were recorded for the 1995/96 trial at Clogheen, but little or no damage was noted on seedlings growing at Aughrim.

The data were analysed using a randomised block factorial design using replicate means at each site to test for the effects of stock type, planting date and the interaction of stock type with planting date. Storage duration and its interaction with stock type and planting date were used as additional factors for the 1997/98 data. Performance of the stock on the two areas at Clogheen could not be statistically compared because the design did not permit this (i.e. the soil preparation treatment was not randomised within the site). The data for percentage survival and percentage of seedlings that suffered from weevil damage were transformed to arc-sine square root proportion before analyses.

## Results

### *1995/96 experiment (Clogheen)*

Although the effect of soil preparation could not be compared statistically (confounded with separate areas of site), survival was better for seedlings planted on the mounded area (92%, averaged across all treatments) than on the uncultivated area (84%). However, percent height increment in the first year after planting (increment as percentage of initial height) was similar for seedlings growing on the mounded area (137%) and on the uncultivated area (141%).

Stock type (two bare-root and two containerised stock types), lift date and their interactions significantly influenced survival at each area of the site (Table 3). In general, survival was high (>80%) for all stock types, except for some seedlings planted in March (Figure 1). The MP+1 (containerised minplugs transplanted in a bare-root nursery) transplants (70%) growing on the uncultivated area, and the Finnpot containerised seedlings planted in March on both the uncultivated and mounded areas had poor survival (43 and 54%, respectively).

**Table 3**. *The effect of stock type and lift date and their interaction on the survival and growth of western hemlock seedlings planted on uncultivated area and mounded areas at Clogheen in 1995/96. Values in bold font are significant at the p≤ 0.05 level.*

| *Treatment* | *Survival* | | *Percent height increment* | | *Weevil damage* | |
|---|---|---|---|---|---|---|
| | *Uncultivated* | *Mounded* | *Uncultivated* | *Mounded* | *Uncultivated* | *Mounded* |
| | *p≤* | | | | | |
| *Stock (S)* | **0.0007** | **0.0001** | **0.0005** | 0.1979 | **0.0037** | **0.0023** |
| *Lift date (L)* | **0.0015** | **0.0054** | **0.0001** | **0.0001** | **0.0031** | 0.3891 |
| *S x L* | **0.0021** | **0.0024** | **0.0001** | **0.0005** | 0.3653 | 0.2018 |

Stock type, lift date and their interactions significantly affected percent height increment for seedlings growing on the uncultivated area, whereas stock type effects alone were significant for those growing on the mounded area (Table 3). In general, percent height increment of the containerised stock was similar to that of the bare-root stock (Figure 2). The difference between planting dates in height increment was greatest for seedlings planted on the uncultivated area. Except for the March lift date, there was little or no difference in height increment between stock types for seedlings lifted on other dates. Percent height increment was particularly low for seedlings planted in March. The Finnpot seedlings planted that month had the lowest increment (88%); survival was also low for these seedlings. However, percent height increment after planting was high for seedlings of this stock type lifted on other dates, especially for seedlings planted on the uncultivated area.

Weevil damage to seedlings was more frequent on seedlings growing on the uncultivated area (46%) than on the mounded area (20%), although differences between the two areas could not be validated statistically. Stock type and planting date significantly influenced the amount of weevil damage within each area, but their interactions were not significant (Table 3). On average, weevil damage was less severe for seedlings lifted and planted in March (Figure 3). There was no consistent effect of stock type on the frequency of weevil damage.

*1997/98 experiment (Aughrim)*

Lift date, and the interaction of stock type with lift date influenced survival of both species, while stock type alone also affected survival of western red cedar (Table 4). In general, the survival of containerised stock was high (86-100%), regardless of species, planting date, or duration of storage in co-extruded bags under ambient conditions prior to planting

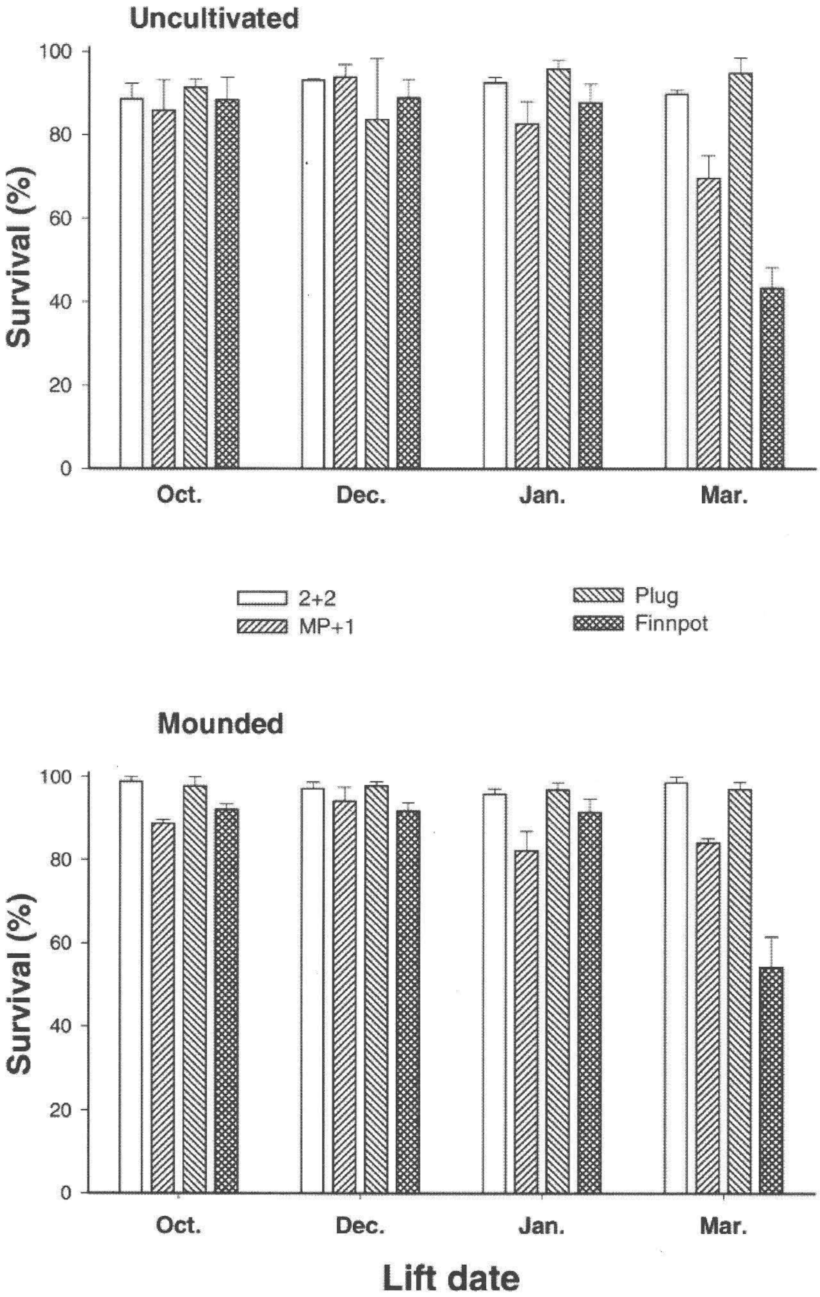


**Figure 1**. *Survival of western hemlock seedlings at the end of the first growing season at Clogheen. Vertical lines are standard errors.*

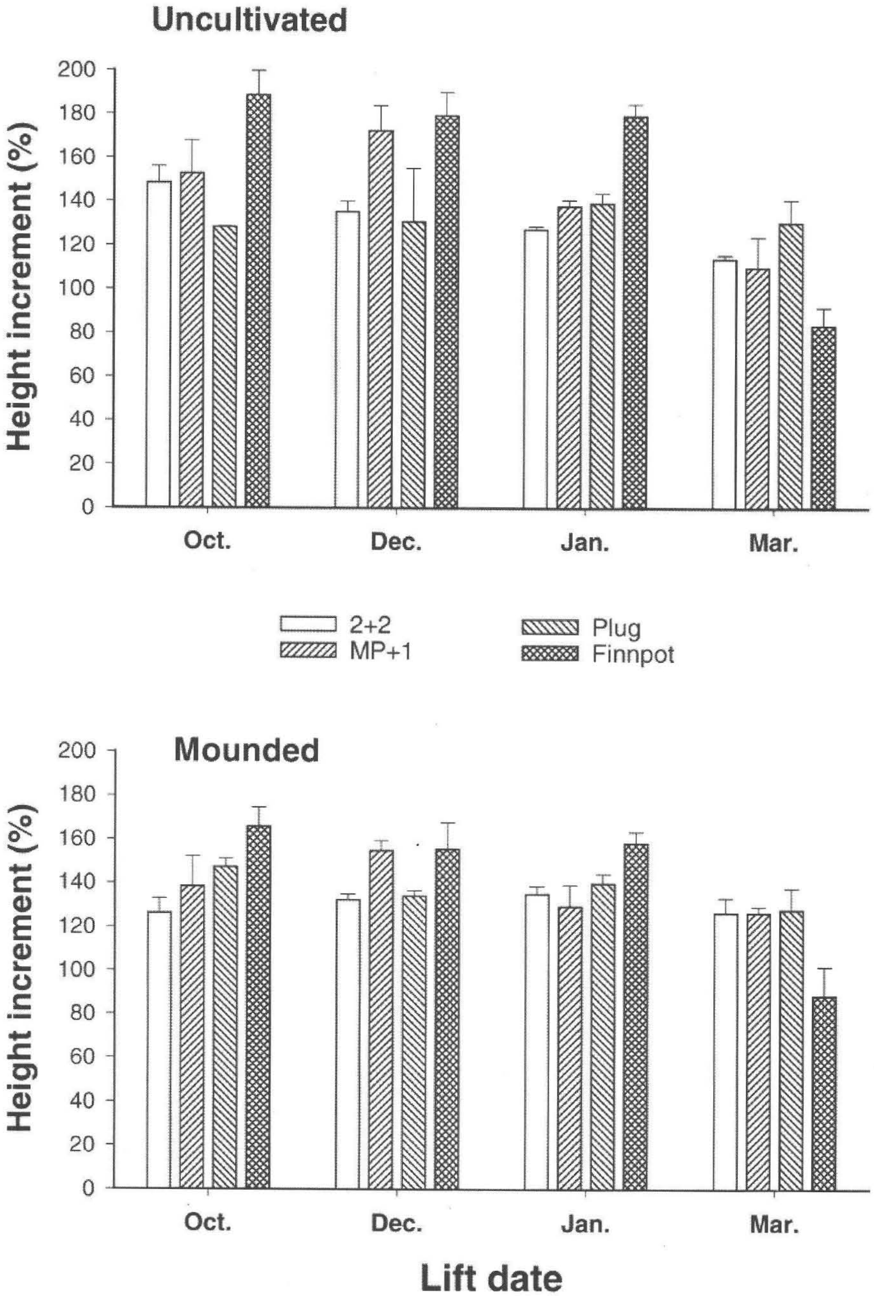


**Figure 2**. *Height increment of western hemlock seedlings at the end of the first growing season at Clogheen. Vertical lines are standard errors.*

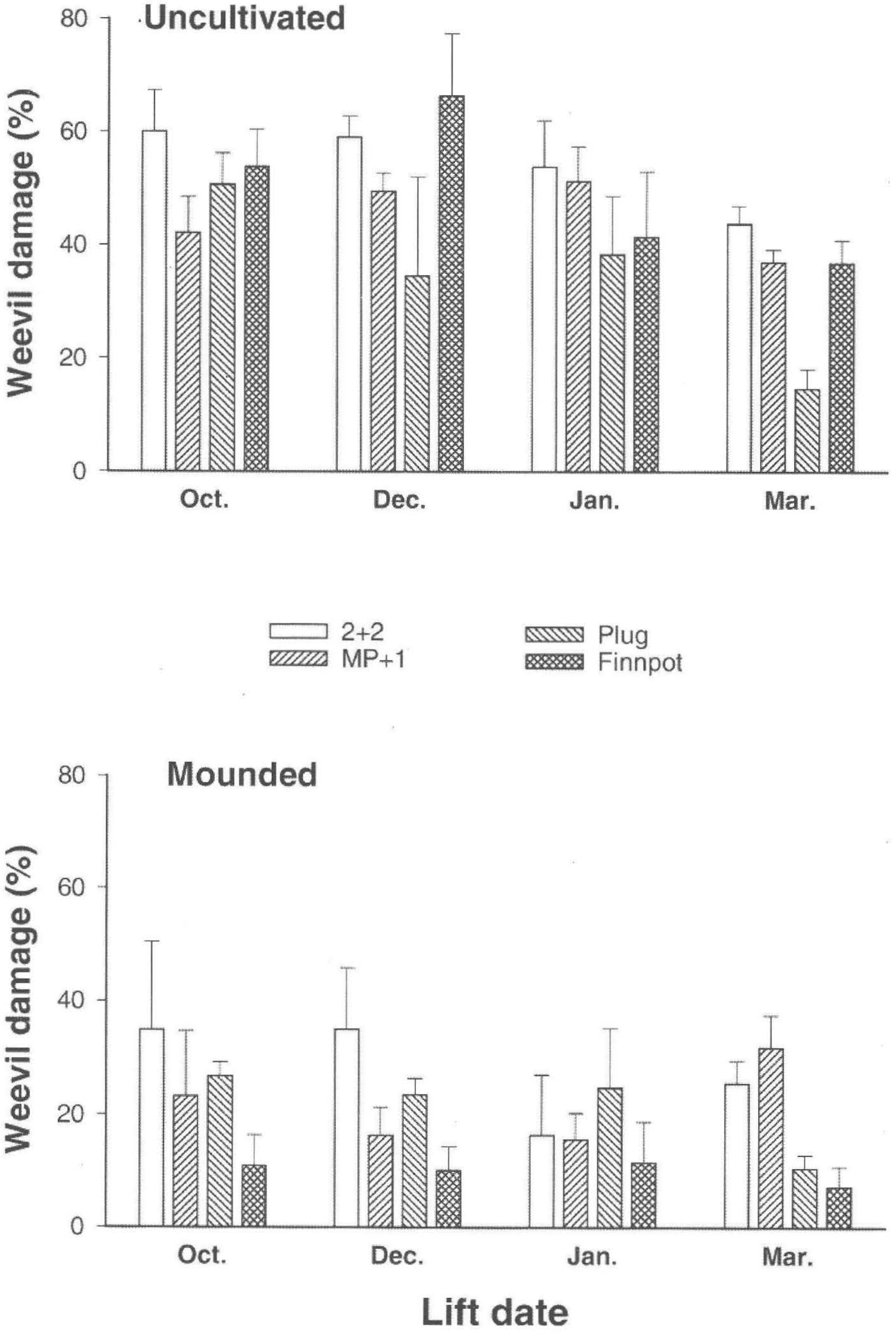


**Figure 3**. *Proportion of western hemlock seedlings damaged by large pine weevil at the end of the first growing season at Clogheen. Vertical lines are standard errors.*

(Figure 4). Treatment effects were larger for the transplants, especially in western red cedar. Survival of western red cedar was low for the transplants planted soon after lifting (0 days storage) in November (56%) and March (53%), but was good for those lifted in January (86%) and February (98%). Storage for up to four weeks had little effect on survival for seedlings lifted in November or February, but reduced it for those lifted in January or March. Storage for four weeks reduced survival from 86% to 60% for western red cedar seedlings lifted in January and from 54% to 22% for those lifted in March. In contrast, lift date had a small effect on survival in western hemlock. Storage reduced survival from 91% to 61% (two weeks) and 70% (4 weeks) for seedlings lifted in February, but storage had little effect for seedlings lifted on other dates.

Percent height increment was influenced by stock type and lift date for both species, but many treatment interactions were also significant for western hemlock (Table 4). On average, percent height increment after planting of seedlings lifted in March was lower than for those lifted on other dates in both species (Figure 5). For freshly planted (0 days storage) western red cedar, bare-root (41%) and containerised (71%) seedlings lifted in November grew well compared with those lifted in March (0% and 23%, respectively). However, survival of bare root western red cedar seedlings was poor, except for stock lifted in February (Figure 4). Ambient storage duration had no effect on percent height increment in western red cedar, except for stock lifted in March (Figure 5). The shoots of plants stored after lifting in March died back after planting, reducing increment from 0% to -25% (25% shorter than at the time of planting). In general, containerised western hemlock grew better than the bare-root stock. Storage had no consistent effect on height increment in western hemlock, although it appeared to increase increment for containerised stock lifted in November.

**Table 4**. *The effect of planting stock type, lift date, and storage duration on the survival and height increment of western red cedar and western hemlock seedlings planted at Aughrim in 1997/98. Values in bold font are significant at the $p \leq 0.05$ level.*

| *Treatment* | *Survival* | | *Percent height increment* | |
|---|---|---|---|---|
| | *Western red cedar* | *Western hemlock* | *Western red cedar* | *Western hemlock* |
| | | *$p \leq$* | | |
| *Stock (S)* | **0.0001** | 0.3016 | **0.0001** | **0.0001** |
| *Lift date (L)* | **0.0001** | **0.0001** | **0.0003** | **0.0001** |
| *Storage (ST)* | 0.1093 | 0.2563 | 0.8029 | 0.8143 |
| *S x L* | **0.0001** | **0.0135** | 0.5778 | **0.0009** |
| *S x ST* | **0.0302** | 0.4215 | 0.5274 | 0.5125 |
| *L x ST* | 0.9942 | 0.2318 | 0.9867 | **0.0194** |
| *S x L x ST* | **0.0015** | 0.0651 | 0.7590 | **0.0236** |

## Discussion

The results of this study showed that survival and early height growth could be improved by using containerised stock of western red cedar and western hemlock compared with using bare-root stock. In particular, mortality after planting is likely to be lower for containerised stock than for bare-root stock, especially following adverse handling. Bare-root western red cedar seedlings were more sensitive to duration of ambient storage than

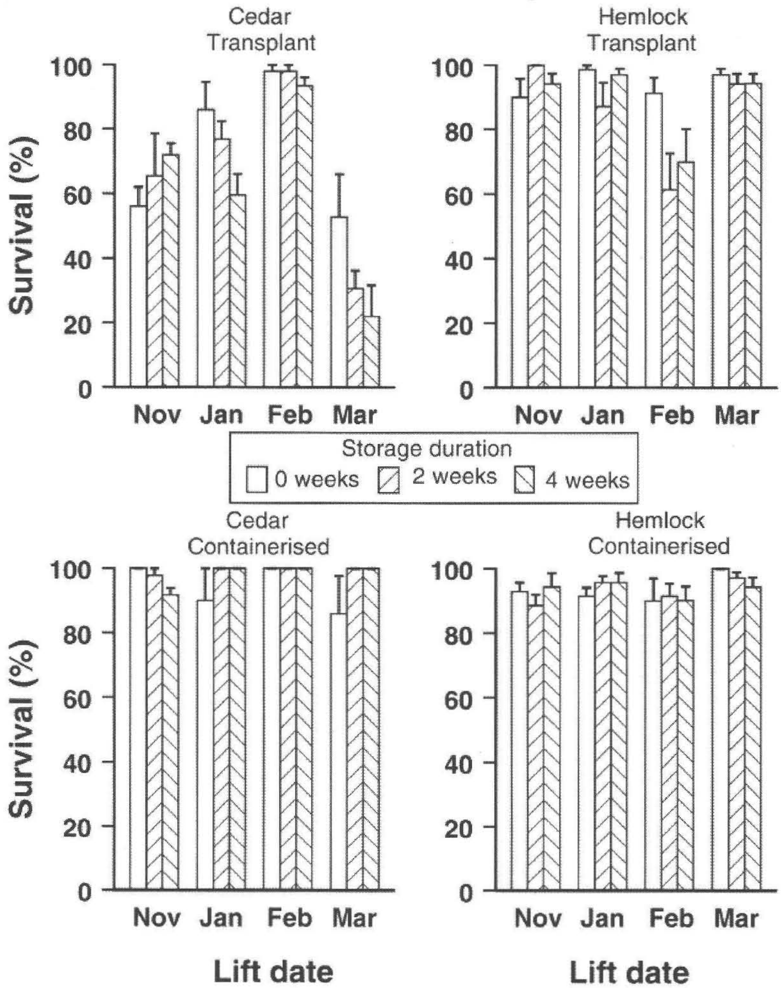


**Figure 4**. *Survival at the end of the first growing season of bare-root and containerised western red cedar and western hemlock seedlings stored for up to four weeks under ambient condition prior to planting at Aughrim. Vertical lines are standard errors.*

bare-root western hemlock seedlings. Nevertheless, bare-root western hemlock should perform well in the field provided the stock is carefully handled and planted between November and March.

In general, height growth (western hemlock only) was better at the Clogheen site than at the Aughrim site. Differences in soil and weather conditions after planting and/or other site factors and differences in the characteristics of the stock used may have contributed to the variation in seedling height growth between sites, but the exact reason(s) is (are) unknown.

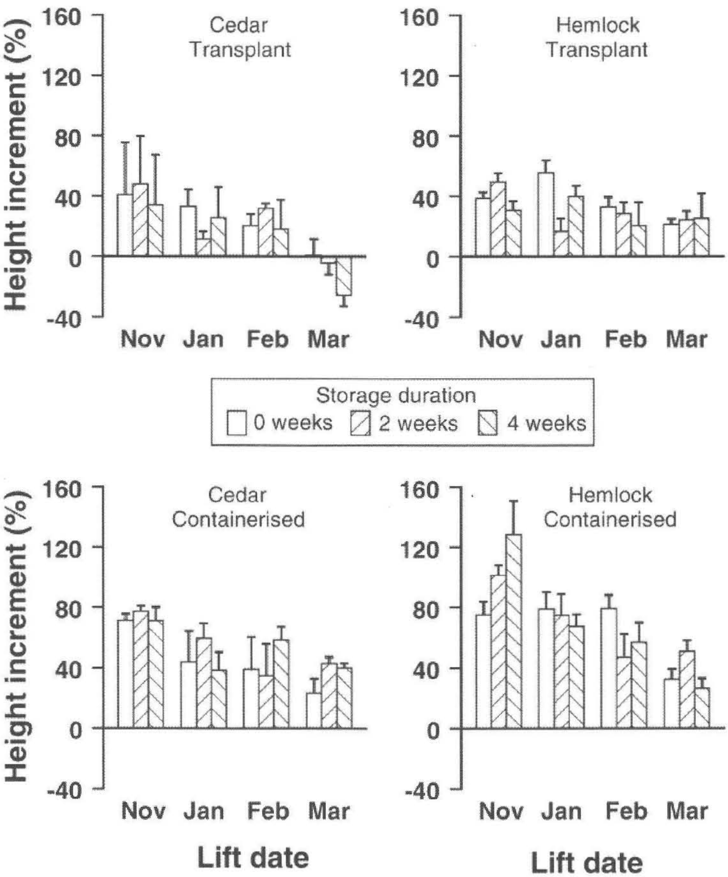


**Figure 5**. *Height increment at the end of the first growing season as a percent of initial height of bare-root and containerised western red cedar and western hemlock seedlings stored for up to four weeks under ambient condition prior to planting at Aughrim. Vertical lines are standard errors.*

For seedlings planted at Clogheen in 1995/96 (western hemlock only), survival was slightly better on the mounded than on the uncultivated area, but percent height increment was similar for seedlings growing on both areas. Since mounded ground is usually warmer, drier, and has less vegetation, thus favouring root growth (Nelson and Ray 1990), it is not surprising that the seedlings were observed to have survived better on mounds.

Seedlings growing on the mounded area also suffered less weevil damage than those grown on the uncultivated area. This effect has been found for other species (Orlander and Nilsson 1999). Although smaller on average at planting than the bare-root stock (Table 1), both stock types suffered similar levels of weevil damage.

There was no consistent effect of stock type or planting date on survival or growth of seedlings in the 1995/96 experiment at Clogheen, perhaps because all stock was handled carefully prior to planting. However, results from the 1997/98 experiment indicate that while western hemlock bare-root seedlings survived well, better height growth could be expected from container stock.

The main finding of the second experiment, carried out at Aughrim in 1997/98, was that containerised seedlings of western red cedar and western hemlock survived well in the field regardless of date of planting or duration of storage. Survival of bare-root stock was lower than that of containerised stock of western red cedar and was reduced further by storage treatment for seedlings lifted on some dates. Western hemlock bare-root stock survived well, except for those stored after lifting in February. In addition, seedlings lifted in March (and planted into April) had poor survival (bare-root western red cedar only) and/or height increment, similar to the results for western hemlock in the first experiment. In Ireland, much planting is carried out in March and April, but the results from this study indicate that field performance might not be consistent for seedlings planted during this period, as found previously in Ireland for bare root seedling of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) (O'Reilly *et al.* 1999a&b), hybrid larch (*Larix* x *eurolepsis* Henry) (O'Reilly *et al.* 2001) and some broadleaved species (O'Reilly *et al.* 1999c).

Results from many other studies have shown that containerised stock outperform bare-root stock, especially on demanding sites (Arnott 1976, Amidon *et al.* 1982, Hobbs *et al.* 1982, Hahn and Smith 1983), although this may not always be the case (Mason and Biggin 1988, Helgerson *et al.* 1989). The effect may be species-specific. For example, in one study conducted in British Columbia, bare-root stock of Douglas fir performed best, but containerised stock outperformed bare-root stock in western hemlock (Arnott 1975).

Although the duration of storage prior to planting either reduced or had little effect on field performance in most cases in this study, it appeared to improve height increment for containerised western hemlock lifted in November in the Aughrim experiment. It is not clear if this is an anomalous or real effect. Perhaps the roots of the seedlings lifted in November became active (in the plug) while in storage prior to planting, thus allowing them to become established quickly following planting. However, a longer period of storage might have caused deterioration. Since the date of planting also varied with duration of storage, environmental conditions that favour establishment success after planting may have been more favourable for those stored for the longest period after lifting in November. Nevertheless, the results show that storage prior to planting generally reduced field performance, especially for bare-root stock.

Because of differences in initial height, percent height increment was used as a measure of plant growth in this study. While the relative growth of tall plants may be less than that of shorter plants, absolute height growth is often greater. Tall seedlings frequently outperform shorter seedlings in the long term on many sites, as shown for bare-root Sitka spruce seedlings in Britain (South and Mason 1993). Absolute height increment of the taller bare-root stock was compared with that of the shorter containerised seedlings in this study also, and this would slightly reduce differences between stock types (data not shown). Nevertheless, the survival and height growth responses of the containerised stock were more consistent, regardless of treatment.

The advantage of using containerised rather than bare-root stock of western red cedar and western hemlock may be much greater in operational forestry than is suggested from the results presented here. Under operational forestry conditions, seedlings are subjected to a variety of handling stresses, including the possibility of suffering from desiccation damage (McKay 1997, McKay *et al.* 1994). Container seedlings are likely to withstand desiccation stress better than bare-root seedlings (*ibid.*), thus probably magnifying the differences between stock types. Nevertheless, some caution should be exercised in extrapolating these results to operational forestry.

Results from the first year's (western hemlock only) experiment revealed that is important to use good quality seedlings, regardless of stock type. Good field performance cannot be expected from using poor quality containerised stock. Furthermore, containerised seedlings are not immune to adverse handling; they are particularly prone to damage if handled when the shoots are succulent (Brissette *et al.* 1991). There is a general perception that the growth of container stock is not influenced greatly by planting date, but the results of this study showed that planting date influenced height growth of container stock (proportionally) more than that of bare-root stock. Therefore, container stock should not be used to extend the planting season if first-year height increment is considered important, but they can be used successfully if high survival alone is considered sufficient. Container stock may need more early post-planting care (e.g. weed control), although this may not be a major factor since they may grow more quickly.

It is unlikely that provenance differences could have greatly influenced the results reported in this study since most of the stock originated from similar part of the species range (most from the same seed zones). The cultural practices used in the nurseries and differences in stock size (as discussed above) may have confounded differences due to production system used. Finally, only one year's data are available for western red cedar.

## Conclusions and recommendations

1. Containerised seedlings of western hemlock and western red cedar are likely to suffer less from handling stresses and therefore are likely to outperform bare-root stock in the field. The advantage of using containerised stock is greater for western red cedar than for western hemlock. Despite the superior tolerance of handling stresses, better performance can be expected from container stock planted before the end of February.
2. Well conditioned and carefully handled bare-root western hemlock may perform well if planted from November to February, and because they are generally larger than container stock, may need less weed control.
3. Mounding may improve the growth performance of western hemlock (western red cedar not tested) and may reduce the incidence of weevil damage. Surprisingly, although the transplants were taller than the container seedlings at Clogheen, weevil damage was similar in both stock types.

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