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Overwinter Physiology and Implications for Handling and Time of Planting of Scots and Corsican Pine Bare-Rooted Seedlings

INFORMATION NOTE

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ABSTRACT

Scots pine resembles Sitka spruce in its general root physiology but it is harder to establish because it has a lower root growth potential, a shorter period of root inactivity and poorer root frost hardiness. Corsican pine is particularly difficult to establish because it has very poor root growth potential, a limited period of root inactivity and poor root frost hardiness; sensitivity to drought at the seedling stage may be a further difficulty. Nevertheless, survival rates of >90% are possible. Recommendations on the best practice for lifting and storage are given.

INTRODUCTION

1. Scots pine (*Pinus sylvestris* L.) is the second most important species in commercial forestry in Britain, covering approximately 13% of the forest area (Anon., 1996). It is particularly common in Scotland where its use north of the Forth–Clyde valley has been encouraged recently by grant aid for Native Pinewoods under the Woodland Grant Scheme. Corsican pine (*Pinus nigra* var. *maritima* (Ait.) Melville), though covering only 2% of Britain's forest area (Anon., 1996), is locally important in eastern England and has been the dominant species around Thetford since the 1960s (Dannatt, 1996).

2. Scots pine has optimum growth over a wider range of temperature and rainfall conditions than Corsican pine (warm to slightly cool and moist to dry for Scots pine v. warm and dry for Corsican pine), but optimum growth of Scots pine occurs in less exposed situations and a narrower range of soil nutrient regime (poor to medium for Scots pine v. poor to very rich for Corsican pine); optimum growth of both species occurs in similar soil moisture conditions (moist to moderately dry) (Pyatt and Suarez, 1997). Scots pine has greater shoot frost hardiness and is easier to establish than Corsican pine but the latter has better growth rate and form (Crowther *et al*., 1991; Coppock, 1986) with an average yield of 13 m^3/ha/an compared with 9 m^3/ha/an for Scots pine (Anon., 1996).

3. This Note summarises information gathered on 2-year-old bare-rooted seedlings raised at Wykeham Nursery during 1990–1994. The physiological condition of the seedlings was monitored over each winter. The outplanting performance of stock planted directly without storage and in spring after storage is also presented. Information from two other studies is used to form conclusions and recommendations: a study of morphological and physiological differences among Scots pine seed origins (Perks and McKay, 1997) and a study of the condition of bare-rooted Corsican pine raised at Delamere Nursery during storage at Santon Downham, East Anglia and its first year performance (McKay *et al*., 1998).

METHODS

4. Seedlings were raised as 1u1 stock at Wykeham Nursery (0° 32´ W, 54° 16´ N, 215 m altitude) following the precision sowing, undercutting and wrenching regime outlined by Mason (1994). Seed identities and seedling morphology at the end of the nursery phase are given in Table 1 on page 2.

5. In winters 1991/92 and 1992/93, 2-year-old seedlings were lifted from the nursery on eleven and seven occasions respectively between early October and April, a subsample sent to the Forestry Commission, Northern Research Station for testing and the remainder planted out. In winters 1990/91 and 1991/92, seedlings were lifted at intervals throughout November to mid-March and stored at +2°C for planting in late March or early April. In 1993/94, Corsican pine was stored on five occasions between November and early March at either +2 or -2°C until late March. Subsamples were tested before and after storage in all cold storage experiments.

Table 1 Seed identities and seedling size at planting

Year	Species	Identity	Provenance	Origin	Height (cm)	Root Collar Diameter (mm)
1990/91	Scots pine	87 (NT45)	Alice Holt	East & Central England	31.1	5.9
1991/92	Scots pine Corsican pine	86 (NT 70) 87 (4032) L8	Dorset Thetford	Scotland Unknown in Corsica	26.5 10.9	4.9 4.2[1]
1992/93	Scots pine Corsican pine	86 (NT 70) 87 (4032) L8	Dorset Thetford	Scotland Unknown in Corsica	25.8 15.5	4.2 3.9
1993/94	Corsican pine	87 (4032) L8	Thetford	Unknown in Corsica	16.8	3.7[1]

Note[1]: Seedlings had poor root systems because of shallow undercutting

6. The forest sites were all cultivated, second-rotation sites within 5 km of the nursery. The site used in 1990/91 was at North Moor, a level site clear felled in 1988/89, where an ironpan had developed over a stony, sandy loam (Lower Calcareous Grit). The outplanting sites used in 1991–94 were at High Langdale End, where ironpan soils had developed over a sandy loam (Kellaways). Seedlings were planted by research staff within 24 hours of lifting in the experiments studying fresh planting and within 4 days of removal from storage in the cold storage experiments. Heights and root collar diameter were measured at planting and after the first and second growing seasons. Survival was assessed after years 1 and 2.

7. Each winter, three characteristics of the seedlings' root systems were determined on freshly lifted plants at each lifting date: membrane function of the fine roots; frost resistance of the fine roots; and root growth potential of the entire root system. Membrane function and root growth potential were also measured after storage. Membrane function was assessed by the rate of root electrolyte leakage, REL (McKay, 1992). In freshly lifted, undamaged plants, it is a measure of cell activity with actively growing material having higher leakage rates than non-dividing material which has hardened off. Damage to cell membranes by frost increases the leakage rate so this can be used to quantify the level of frost damage. Frost resistance was determined by cooling fine root sections to one of a series of minimum temperatures for 3 hours and calculating the temperature causing 50% electrolyte leakage ($TREL_{50}$). The selected level of 50% REL represents significant damage to the seedling although it does not necessarily translate to 50% mortality, for example McKay *et al.* (1996) found that 100% mortality of small, cell-grown Scots pine was associated with RELs of 35–40% in November and 65–70% in February. Root growth potential (RGP) was determined by placing plants in a favourable environment and counting the number of new roots >1 cm long produced in 14 days as described by Tabbush (1988).

RESULTS

Scots pine

8. Root electrolyte leakage of freshly lifted stock in October was about 17% but then fell during the next 6–8 weeks to reach 10–12%; this level was maintained until late January after which values increased slightly to 15% by the end of March (Figure 1a). The RELs of seedlings stored at +2°C on dates from the end of October to mid-March until early April were not significantly greater after storage than before storage.

9. Root growth potential of freshly lifted stock in 1991/92 fluctuated around 5–10 during October to mid-December but then increased to >15 during January and February before decreasing sharply during March (Figure 1b). This is the typical RGP pattern for evergreen conifers (Ritchie and Dunlap, 1980). In 1992/93 however RGP was <10 throughout the winter. In 1991/92, the only year when a direct comparison can be made of RGP at lifting and after storage beginning on the same date, cold storage significantly reduced RGP so that the RGP of stock stored until April was poorer than at lifting.

10. In 1991/92, root frost hardiness increased steadily from early October, when the $TREL_{50}$ was -2°C, to early January, when the $TREL_{50}$ was -7 to -8°C (Figure 1c). Roots dehardened during February and March and by late March the $TREL_{50}$ was -4°C. In 1990/91, a similar trend was apparent but the minimum hardiness figure was higher (-6 to -7°C).

11. Survival of stock planted in early October was poor (50–60%) but increased as lifting was delayed (Figure 2a). In 1991/92 survivals of >80% were achieved with most dates from early November to the last lifting date in late March and survivals of >90% were achieved from January to late March. In 1992/93 survival was poorer than in 1991/92 with >80% survival associated with a shorter planting period of mid-December to the last lifting date in mid-March and >90% associated with lifting and planting from mid-February to mid-March. Lifting and planting dates did significantly affect height (Figure 2b) and diameter (Figure 2c) growth but the patterns in the two years were contradictory – early and late dates gave poorer growth than dates during the period November–February in 1991/92 but better growth in 1992/93.

12. The survival of stock stored at +2°C in 1990/91 was best when plants were lifted to storage in mid-December to early February; stock lifted earlier or later for storage had 75–85% survival (Figure 2a). In the following winter, survival was generally better and there was >85% survival for all storage dates from early October to the end of February and >90% survival for mid-January to mid-March storage dates. In general height and diameter growth were not significantly influenced by the date of cold storage.

Corsican pine

13. REL values in October were 21–23% but fell during November to reach 12–13% during December (Figure 3a). REL values increased again in February and March 1992 but the rise was earlier (January) the following year.

14. RGP at lifting was low with a maximum of 8 in both years and values for early October and late March were especially poor (Figure 3b). RGP was significantly reduced by storage at +2°C and RGP after storage was generally <5.

15. In 1991–92, root frost hardiness increased from -3°C in mid-October to a maximum of -7°C in January and then plants dehardened to reach a level of -3 to -4°C in the second half of March (Figure 3c).

16. Second year survival of stock planted directly in early October was poor (~ 50%) but it increased as lifting was delayed (Figure 4a). In 1991/92, lifting dates from mid-November to mid-March were generally associated with >90% survival. The only exception was for plants lifted on December 10 during a very cold spell (see Table 3). The survival of stock planted directly the following year was much poorer and survivals of >80% were achieved only in plants lifted in February and March. Height growth was significantly affected by lifting dates in 1991/92 (plants lifted in early October had poorer height growth than all other lifting dates) but not 1992/93 whereas diameter growth was affected in 1992/93 (plants lifted in late November and mid-March had the best growth) but not 1991/92.

17. Survival of plants which had been cold stored at +2°C in late October 1991, the earliest date used, was very poor, *c.* 30% after two growing seasons. However, storage beginning in mid-November until mid-March for planting in early April generally gave survivals of >90%. The exception was plants stored on December 10. Height and diameter growth showed similar seasonal patterns – poor growth of stock stored in late October and maximum increments with February storage. In 1993/94, the plants used in the comparison of storage at +2 and -2°C were small and would not have been considered usable and so general survival was low. However, it is clear that sub-zero storage has resulted in much poorer survival than storage at +2°C (Table 2).

DISCUSSION

18. The **patterns** of REL, RGP and root frost hardiness of the two pine species were similar to most evergreen conifers. However the REL began to increase in spring some weeks earlier than other species. In Scots pine the increase occurred after mid-February, about 4 weeks earlier than other conifers, while for Corsican pine it occurred after early February in 1991/92 and late December in 1992/93. Consequently there was a limited period when REL was consistently low and stress resistance at a maximum. For Scots pine this was mid-November to mid-February but for Corsican

Table 2 Survival (%) after two growing seasons of Corsican pine lifted at different times during 1993/94 for storage at +2 or -2°C until planting on 22 March

Storage temperature	Storage date					Fresh lift
	Nov 9	Dec 7	Jan 4	Feb 1	Mar 1	Mar 22
+2	13	36	31	42	62	
						67
-2	0	0	9	8	8	

pine the period of maximum stress resistance varied from mid-November to mid-February in one winter to only mid-November to December the following year.

19. Compared with Scots pine, Corsican pine generally had higher RELs before and after storage, lower RGPs and poorer resistance of the root system to frost. The higher REL before storage indicates a higher rate of root cell activity in Corsican pine than in Scots pine suggesting that the fine roots of the former will be more easily damaged by a range of stresses. The REL values for the two pines are intermediate between Sitka spruce which has a low REL over winter and Douglas fir which has a high REL. RGP of freshly lifted Scots pine was variable from year to year but was always greater than Corsican pine which had a particularly low RGP. This confirms other comparative studies (E.R. Wilson, personal communication) and indicates that Corsican pine will be slow to regenerate roots after transplanting even if soil temperature and moisture are favourable. Corsican pine is thought to have adapted to the spring droughts of its natural habitat by developing a long tap root with few laterals close to the surface (Aldrich-Blake, 1930).

20. These three factors – root membrane integrity, root growth potential, and root frost hardiness – may explain why Corsican pine is more difficult to establish than Scots pine but others factors may also be involved. Studies on Corsican pine establishment in France have shown that drought before and after transplanting can reduce root regrowth through its effect on the seedlings water potential (Girard *et al*., 1997). Transplanted seedlings remained water-stressed for 218 days even if the soil was maintained at field capacity after planting and 253 days if irrigation was delayed for 14 days after planting (Kaushal and Aussenac, 1989). In both studies there was no root regrowth if the xylem water potential was below about -1.5 MPa.

21. The frost hardiness of Scots pine fine roots agrees well with the values obtained in 1993/94 for four native Scots pine origins and selected commercial, A(70), seedlings (Perks and McKay, 1997) which hardened to a maximum of -7 to -8°C in early January before dehardening to -2.5°C in late March. Root frost hardiness of both species is comparatively poor. Only Douglas fir of conifers tested at the Northern Research Station is damaged by more moderate temperatures while Sitka spruce and larch can tolerate almost 10°C lower temperatures in mid-winter.

22. In spite of these potential difficulties, these experiments showed that good survival can be achieved with carefully handled bare-rooted undercut and wrenched stock planted on cultivated sites provided neither planting nor cold storage take place too early or too late in the season. However, there were considerable differences from year to year; survival and growth was much poorer in 1992/93 than in 1991/92 even though the seed origins were identical and stock was of similar above ground morphology in the two winters. There are several possible reasons for these differences – in 1992/93 there may have been poorer root development in the plants used (this is suggested by the poorer RGP in 1992/93) or less favourable climatic conditions.

23. The effect of climate at the time of planting on survival is indicated by the significantly poorer survival of both Scots and Corsican pine lifted on 10 December 1991 during a very cold period compared with earlier and later dates when temperatures were much higher (Table 3). Temperatures must have been low enough to damage Corsican pine before storage since both directly planted and cold-stored stock

showed a similar reduction in survival. On the other hand, only directly planted Scots pine was adversely affected suggesting that temperatures before storage were not too severe for Scots pine but that it was damaged by being planted back into a cold soil. We suggest that this is due to winter desiccation which occurs when water lost through transpiration cannot be fully replaced by water uptake from a cold soil; poor soil–root contact shortly after planting will exacerbate the problem. Neither of our physiological indicators identified damage to plants lifted on December 10. It is most likely that roots were damaged by cold during the interval between lifting and either storage or planting when they were not protected by the buffering of the soil. This damage would have occurred *subsequent* to a subsample being removed for testing.

CONCLUSIONS & PRACTICAL RECOMMENDATIONS

- Both species but especially Corsican pine have a comparatively short period of minimum REL and maximum stress resistance so there is only limited flexibility in the optimum timing of lifting, handling and planting. Greater care must be taken to reduce the risk of stresses outside this period.

- The root systems of both species, but especially Corsican pine, are comparatively sensitive to frost. After lifting, plants stored in bags should be given overhead protection.

- Corsican pine has a very low RGP and is sensitive to post planting drought. It should always be planted on cultivated, weed-free sites.

- Seedlings can be damaged during lifting from and by replanting into very cold soils. Planting should cease when soil temperatures are below 1.0°C at 10 cm depth.

- Corsican pine should be stored at +2° and not at sub-zero temperatures. Although we do not have direct evidence, we suggest that Scots pine should also be stored at +2°C.

- Survival rates of > 90% were achieved both after direct planting and cold storage. In autumn, Scots pine should not be lifted until the REL has fallen below 12% and Corsican pine should not be lifted until the REL has fallen below 15–18%. In spring, direct planting and storage at +2°C for outplanting in April can continue until the RELs have risen to around 15% for Scots pine and 20% for Corsican pine.

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Table 3 Mean weekly soil temperatures (°C) at 10 cm depth in 1991/92 under the nursery seedlings

October				November				December				
6	13	20	27	3	10	17	24	1	8	15	22	29
11.4	6.0	7.6	7.4	5.1	2.7	3.4	6.0	4.4	0.8	3.0	4.5	6.0

January				February				March			
2	12	19	26	2	9	16	23	1	8	15	22
4.9	2.6	1.6	0.2	3.1	3.4	1.6	4.7	4.0	4.5	6.0	5.0

Figure 1

Scots pine: a. root electrolyte leakage (%), b. root growth potential (number of new roots >1 cm in length), and c. temperature (0°C) causing 50% electrolyte leakage from fine roots at lifting (solid symbols) and after cold storage at +2°C from different lifting dates (open symbols) in 1990/91 (– · – ·), 1991/92 (——), and 1992/93 (– – –).

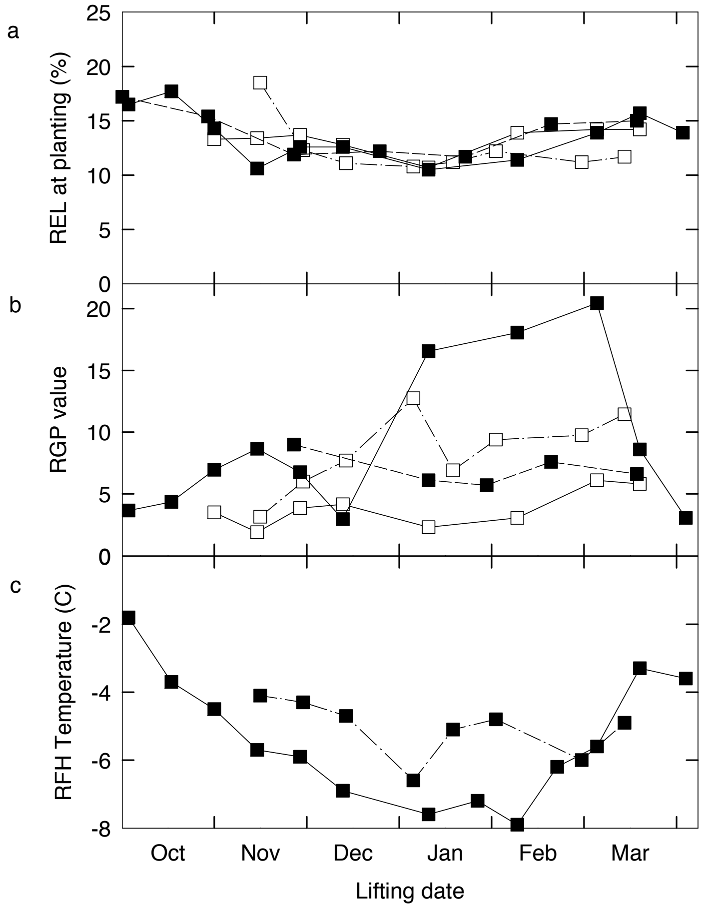
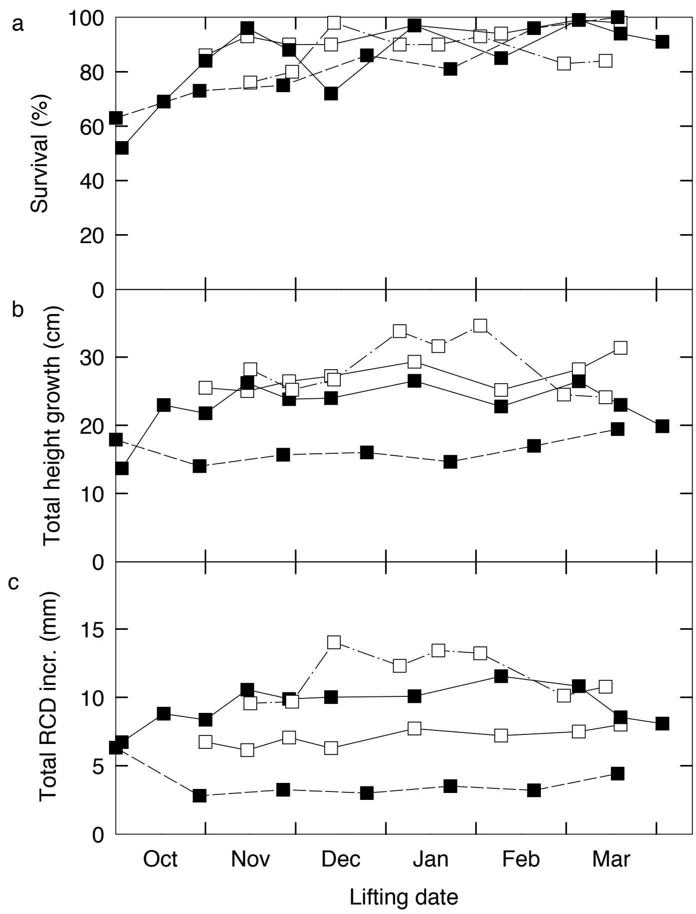


Figure 2

Scots pine: a. second year survival (%), b. height increment (cm), and c. diameter growth (mm) in two years of stock planted directly (solid symbols) or after cold storage at +2°C from different lifting dates until early April (open symbols) in 1990/91 (– · – ·), 1991/92 (——), and 1992/93 (– – –).



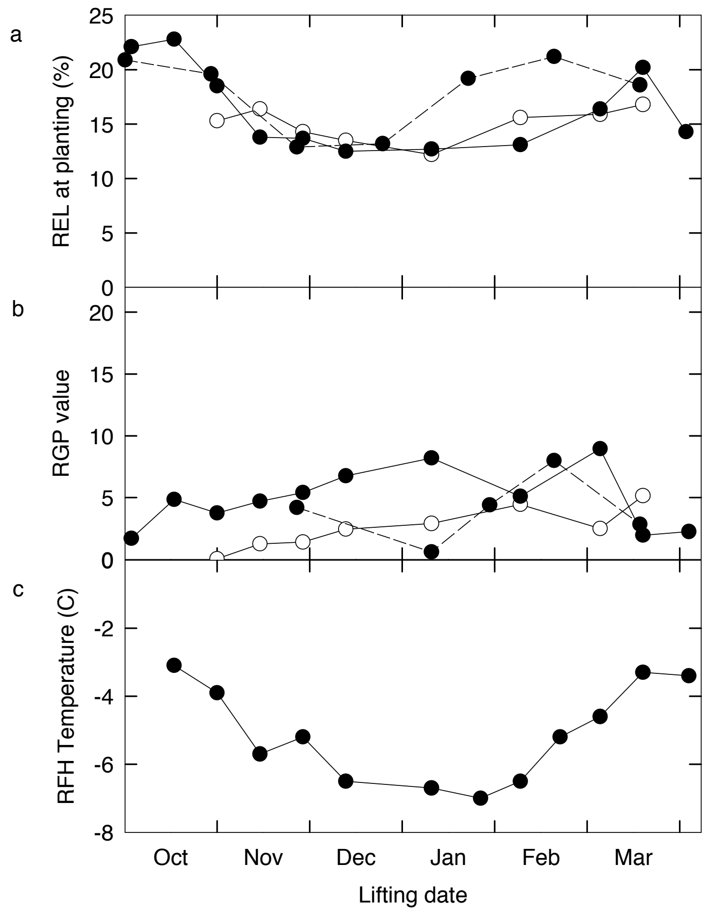


Figure 3

Corsican pine: a. root electrolyte leakage (%), b. root growth potential (number of new roots >1 cm in length), and c. temperature (0°C) causing 50% electrolyte leakage from fine roots at lifting (solid symbols) and after cold storage at +2°C from different lifting dates (open symbols) in 1991/92 (——), and 1992/93 (– – –).

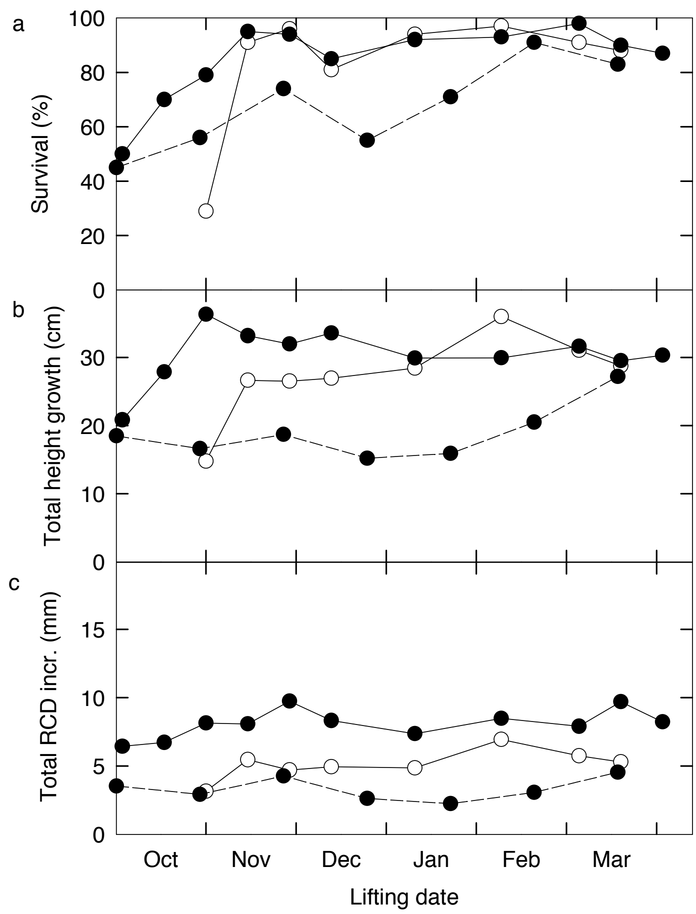


Figure 4

Corsican pine: a. second year survival (%), b. height increment (cm), and c. diameter growth (mm) in two years of stock planted directly (solid symbols) or after cold storage at +2°C from different lifting dates until early April (open symbols) in 1991/92 (——), and 1992/93 (– – –).

REFERENCES

ALDRICH-BLAKE, R.N. (1930).
The plasticity of the root system of Corsican pine in early life.
Clarendon Press, Oxford. (63 pp.)

ANON. (1996).
The forestry industry year-book.
The Forestry Industry Council of Great Britain.

COPPOCK, R.C. (1986).
A comparison of five different types of Corsican pine planting stock at Delamere Forest.
Quarterly Journal of Forestry **80**, 165–171.

CROWTHER, R.E., LOW, A.J. and TABBUSH, P.M. (1991).
Establishment and tending. In, *Forestry practice.*
Forestry Commission Handbook 6.
HMSO, London

DANNATT, N. (1996).
Thetford Forest: its history and development.
In, *Thetford Forest Park: the ecology of a pine forest.*
Forestry Commission Technical Paper 13.
Forestry Commission, Edinburgh.

GIRARD, S., CLEMENT, A., COCHARD, H., BOULET-GERCOURT, B. and GUEHL, J.M. (1997).
Effects of desiccation on post-planting stress in bare-root Corsican pine seedlings.
Tree Physiology **17**, 429–435.

KAUSHAL, P. and AUSSENAC, G. (1989).
Transplanting stock in Corsican pine and cedar of Atlas seedlings: internal water deficit, growth and root regeneration.
Forest Ecology and Management **27**, 29–40.

MASON, W.L. (1994).
Production of undercut stock. In, *Forest nursery practice*, eds J.R. Aldhous and W.L. Mason, 112–121.
Forestry Commission Bulletin 111.
HMSO, London.

McKAY, H.M. (1992).
Electrolyte leakage from fine roots of conifer seedlings: a rapid index of plant vitality following cold storage.
Canadian Journal of Forest Research **22**, 1371–1377.

McKAY, H.M., THORN, C. and KEMPTON, E. (1998).
Frost and insecticide damage to Corsican pine seedlings between lifting and planting.
Quarterly Journal of Forestry **92**, 55–62.

McKAY, H.M., PERKS, M.P. and ENNOS, R. (1996).
Physiological and morphological differences in Scots pine populations in particular tolerance to low root temperatures.
Final report to the Scottish Forestry Trust.

PYATT, D.G. and SÚAREZ, J.C. (1997).
An ecological site classification for forestry in Great Britain.
Forestry Commission Technical Paper 20.
Forestry Commission, Edinburgh

PERKS, M.P. and McKAY, H.M. (1997).
Morphological and physiological differences in Scots pine seedlings of six seed origins.
Forestry **70**, 223–232.

RITCHIE, G.A. and DUNLAP, J.R. (1980).
Root growth potential: its development and expression in forest tree seedlings.
New Zealand Journal of Forest Science **10**, 218–248.

TABBUSH, P.M. (1988).
Silvicultural practices for upland restocking.
Forestry Commission Bulletin 76.
HMSO, London.

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