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An Update on Nursery Propagation and Establishment Best Practice for Larch in Britain

INFORMATION NOTE

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SUMMARY

This Information Note summarises the results of a series of experiments, including a synthesis of data from previous Forest Research publications, to provide information regarding recent advances in propagation of hybrid larch using cutting production systems.

Recent research has shown that cutting stock plant management, cutting rooting environment and the correct manipulation of subsequent nursery practices can increase the yield of marketable nursery stock. These improvements in vegetative propagation are described. A series of experiments studied physiological attributes (using plant quality tests) and early forest performance of cuttings and transplants of Japanese, European and hybrid larch. Physiological attributes included root growth potential, root membrane function, shoot and root frost hardiness, and resistance to cold-storage. The optimum time for handling, cold storage and planting is described. In the nursery, undercutting and wrenching improved subsequent survival. In the field, planting position and weed control influenced growth and survival. The use of cuttings did not lead to changes in height or diameter growth when compared with transplants of the same genetic origin. Rooting pattern showed some dependence upon propagation technique and the implications for stability are discussed.

INTRODUCTION

Two species of larch are grown commercially in the UK: European larch (*Larix decidua* Mill.) and Japanese larch (*Larix kaempferi* (Lamb.) Carrière). The first generation (F1) cross between the two species is hybrid larch (*Larix* x *marschlinsii* Coaz). This displays hybrid vigour and combines the good form and resistance to canker (*Lachenellula willkommii*) of European larch (EL) with the more rapid growth of Japanese larch (JL) (Edwards, 1956; Pâques, 1989; Morgan, 1992). An improvement of 15–20% in final crop volume is predicted from a breeding programme of selected superior hybrid larch (HL) progeny, when compared with unimproved JL, with concurrent improvements in height, diameter and form (Lee, 2003).

HL has high economic potential as a timber tree in temperate and sub-alpine Europe. However, this potential has yet to be fully realised in the UK due to two main difficulties: the poor efficiency of planting stock production and establishment problems. Most seedlings grown as 'hybrid larch' in forest nurseries are produced from open-pollinated seed that may contain as little as 14% true hybrid progeny (Ennos and Qian, 1994). An alternative approach is to produce known hybrid seed by controlled pollination and then use vegetative propagation to multiply the small number of seedlings produced (Mason, 1989). However, inconsistent rooting success is a particular problem.

In Britain, larch has traditionally been considered difficult to establish (Laing, 1938). Although the tree is adaptable to a wide range of site types (MacDonald *et al.*, 1957), plant failure rates during the early establishment phase are often twice those of Sitka spruce on the same sites (Morrissey and O'Reilly, 2002). Losses of up to 50% have previously been reported for larch in the UK (McKay and Howes, 1994). Therefore, larch establishment costs are often high. Recent experience tends to confirm this view: in 1998, a major survey of JL and HL planted on upland restocking sites recorded average losses of 26% by the end of the first growing season (unpublished data). This concurs with previous restocking surveys, from 1989 to 1997, which recorded larch failures of 17–36%.

The objectives of this Information Note are:

- to provide an update on best practice propagation methods for HL and consider the longer-term implications for tree stability of HL cuttings;
- to provide a synthesis of best practice advice on improving the survival and early growth of larch.

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IMPROVING HYBRID LARCH PRODUCTION: CUTTINGS AND FUTURE STABILITY

Propagation problems

Traditionally, HL seed has been produced in open-pollinated seed orchards that contain a mixture of EL and JL trees. As there is a degree of breeding incompatibility between the two species, in particular because JL tends to flower earlier than EL, the resultant seed contains a high proportion (>50%) of either pure EL or JL, depending upon the mother tree from which the seed was collected.

There are only two ways to ensure production of 100% hybrid seed: either controlled pollination between the two species or a seed orchard planted with dioecious mother trees of one species in mixture with males of the other (Morgan, 1992). Only controlled pollination is used in the UK and the amount of HL seed so produced falls well short of the potential demand for plants (Morgan, 1992). Added to this is the high unit production cost (>£1.00 per viable seed). This renders the direct use of seed to produce planting stock, even if it were available, prohibitively expensive.

Vegetative propagation from cuttings is used to maximise the number of plants produced from each seed thus increasing plant availability and reducing the cost of the seed per plant. In research trials, conducted in an unheated polytunnel with mist irrigation, this method of plant production has proven to be a dependable system of propagation with both summer (softwood) and spring (hardwood) cuttings (Mason, 1989). In the UK, large-scale production of rooted cuttings of HL began in 1990 at the Forestry Commission's Delamere Nursery in Cheshire, striking both hardwood and softwood cuttings in cells. At its peak, 150 000 HL cuttings were inserted per year but low rooting percentages (<40%) and poor plant quality, particularly plagiotropic growth, caused the system to be abandoned in 1996. However, recent experiments in the UK and other parts of Europe have highlighted and refined some of the requirements for successful economic production.

Plagiotropism

There is a tendency for HL cuttings taken from side shoots to initially retain their branch habit as a rooted cutting, i.e. they grow more horizontally than vertically. This is termed plagiotropic growth. Although there is good evidence that such plants revert to vertical growth during the post-planting establishment phase, however, the form of the nursery product can be so poor as to be unmarketable. To reduce this effect tip cuttings should be used in preference to base cuttings.

Stock plant yields

A series of experiments examined the effects of applying a general fertiliser boost to stock plants in varying amounts at various times during the growing season (Harrison *et al*., 2002). A June application was found to promote fascicular bud growth resulting in the production of many short shoots (2–6 cm). However, these failed to root successfully and no benefit was evident in the number or rooting of standard (>8 cm) shoot cuttings. Foliar nutrient status and height growth were also unaffected by boost additions, leading to the conclusion that fertiliser manipulation does not improve stock plant cutting yield.

There is an age-induced decline in cutting rootability that may occur as early as 5 years from seed. Other studies indicate a slightly longer period, at age 6–7 (Yang *et al*., 2002). To ensure continuing yield, a cycle of stock plant propagation and replacement, within this time frame, needs to be established.

Rooting

The effects of clonal variation, substrate type and bud status (flushing) on rooting of softwood and hardwood cuttings (from the same stock plants) were investigated.

These studies showed a very wide clonal variation in cutting rootability between stock plants (range 0–100%), though most were in the 60–80% range. This variation also proved unpredictable from year to year, making the selection of good rooting clones impossible.

Freely draining rooting substrates were found to be beneficial when mist irrigation watering systems were used. Substrates containing a minimum volume of one-third grit or perlite were found to perform best, with pure grit doing equally well. A relative humidity (RH) of 80% was found to be optimal for the rooting phase of 8–12 weeks, after which RH could be reduced to ambient over the following four weeks (Harrison *et al*., 2002).

There is evidence that the addition of slow release fertiliser to the rooting substrate can be beneficial to the survival and subsequent growth of cuttings. It is thought to offset the nutrient leaching effects that can be observed during the rooting phase, particularly under intermittent mist irrigation.

Unflushed hardwood cuttings rooted better than flushed ones (15% increase in survival) in UK trials. However, other studies have found the reverse to be true (Verger, 2002). Overall, hardwood cuttings exhibited higher rooting percentages than softwood cuttings. Nevertheless, the use of softwood cuttings is an option that should not be dismissed as it allows more flexible use of nursery resources.

The use of various rooting hormone treatments gave inconsistent results. Nevertheless, it can be concluded that hormone application is unlikely to be a cost-effective operation.

Remaining problems

Despite significant progress in the development of the vegetative propagation production system, some problems remain. In particular, variability in rooting, poor root structure, fungal attack to soft shoots and the low proportion (<60%) of marketable plants produced relative to the number of cuttings rooted (Harrison *et al.*, 2002).

Economics of production

This relatively low rooting success (compared with Sitka spruce) may simply be a characteristic of the species but it may still be economic to produce HL cuttings if the market will support a higher priced product (Table 1).

Table 1

Estimated variation in HL production costs (£ per 1000 plants) dependent on number of cuttings produced per stock plant, relative to rooting potential.

Rooting level	60 cuttings per stock plant	100 cuttings per stock plant
50%	400	388
60%	346	335
70%	308	300

It is evident that, compared with HL transplants (e.g. 1+1 @ £175 per 1000 plants), the cost of producing cuttings is approximately double (Table 1). However, genetic gains of 15–20% for 10-year height and 20–25% for stem straightness are predicted with genuine hybrid stock (Lee, 2003), which would largely offset the cost differential of the two nursery systems. Furthermore, predicted height (>20%) and straightness (>30%) gains are possible by selection of outstanding hybrid material using controlled pollination and vegetative propagation methods (Lee, 2003).

IMPROVING THE ESTABLISHMENT OF LARCH

Nursery practice

Transplanting rooted cuttings within the nursery stimulates new root growth resulting in a more fibrous root system (Aldhous and Mason, 1994; Morgan, 1999). French studies have compared treatments that can influence the growth and quality of transplanted cuttings for bare-root production (Verger, 2002). The factors investigated included:

- the time and density of transplantation;
- the root quality and size of the rooted cutting;
- the effects of root pruning.

Results showed that transplanting in October at a density of 60 plants per m^2 is the most successful. The initial quality of the rooted cutting is also important. Those with a radially symmetrical root distribution and a height >20 cm grew best, resulting in 90% survival, with 55% of these graded as marketable plants. Root pruning did not show any benefit to transplanted cuttings.

Irish studies suggest that transplanted larch seedlings should be undercut in June of their second growing season and wrenched early if height control is required, whilst more than one wrenching may be necessary to improve fine root production (Morrissey and O'Reilly, 2002).

Undercutting and wrenching help to improve subsequent plant growth in conifers by:

- modifying seedling morphology by increasing root:shoot ratio and the proportion of fine roots;
- improving the fine root membrane function.

Nursery techniques for undercut stock production, e.g. sowing density, timing, fertilisers, are discussed in detail by Mason (1994).

Undercutting and wrenching significantly improved survival of larch (EL and JL) after outplanting and greatly improved the ability of bare-root larch to withstand cool storage (McKay and Howes, 1994; McKay and Morgan, 2001; Morrissey and O'Reilly, 2002).

Physiological indices of plant quality

One possible reason for the recent poor establishment of larch in Britain is its apparent sensitivity to cold-storage (McKay and Morgan, 2001). Desiccation and poor handling of stock has also been shown to reduce survival (McKay and Milner, 2000). Therefore, careful handling is essential to improve out-planting survival. Physiological testing of plant vitality should also be used to aid the identification of correct lifting times (McKay and Morgan, 2001).

Commonly used physiological tests include:

- root growth potential (RGP);
- root membrane function (by assessment of root electrolyte leakage, REL);
- shoot and root frost hardiness (REL in conjunction with artificial freeze tests).

We summarise the results and validity of these tests for informing operational procedures for nursery production of larch.

Identification of lifting windows

Lifting windows for bare-root larch can be identified most accurately by analysis of REL in conjunction with artificial freeze testing*. It has been found over many years that once short-term exposure to –7 °C causes only 50% damage to fine roots (artificial freeze-test (REL) LT50) larch can be lifted for cool storage (+1 to +2 °C). Freezer storage (–2 °C) is possible once the threshold for 50% fine root damage has dropped to –12 °C. Baseline (non-freeze) assessments of REL can also be used operationally with a threshold value for lifting of 30% leakage for bare-rooted stock and 35% for containerised stock. Fully dormant seedlings exhibit REL leakage values of 10–15%. This second method is quicker but less accurate. These recommendations compare favourably with thresholds obtained under Irish conditions (O'Reilly *et al.*, 2001).

Storage

The optimum time for lifting bare root seedlings to storage is usually mid-November to the end of February (Morgan, 1999). In general cool storage (+1 to +2 °C) is the preferred option for seedlings lifted in November whilst freezer storage (–2 °C) is equally good from December to February. The latter period coincides with the optimum time for plant handling. Material lifted over this period can be freezer stored at –2 °C for out-planting as late as April.

Post-storage assessments of REL can be used to assess the detrimental effects of cold storage. Experience has shown that plants with an REL of <30% are still of sufficient quality to justify out-planting.

*The Forest Research Plant Quality Testing unit offers an artificial freeze testing service (Edwards, 1998).

Out-planting and establishment

The general sensitivity of larch to establishment practice was confirmed through experiments with direct-planted stock (i.e. stock that had not been cold stored). Survival of >80% after two years was possible only by planting during two relatively short periods, in autumn (October) and spring (March). This finding is peculiar to larch among commercial conifer species (McKay and Morgan, 2001). Survival of plants lifted and planted during the intervening winter months from November to February was poorer (McKay, 1998; McKay and Morgan, 2001). This pattern may be related to periods of active root growth (as indicated by RGP), with the bimodal peaks of survival possibly influenced by the deciduous habit of larch, deciduous broadleaf trees having a similar RGP pattern. RGP values >5 are indicative of good direct-planted stock (root) vitality during these two periods.

Spring planting may have the further advantage that seedlings that flush a few weeks after planting will generate current photosynthate. Although there is no information concerning the ability of larch to utilise any stored photosynthate for root production, the availability of current photosynthate will benefit root growth (Philipson, 1988).

Results from field trials show that rooted tip cuttings achieve the same height and diameter growth as transplants of the same genetic origin. There is no evidence to suggest that there are any differences in stem straightness and basal sweep between the two plant types.

In one study, winter weed control applied over the first two seasons of growth improved survival by 8% (to 94.5%) and growth by 9%. The current stocking density target for larch is 2500 stems ha^{-1} at year five.

It is recommended that plantings of improved family mixtures of HL should target sites with deeper rooting soils where soil nutrient regime (SNR) is poor to rich, and soil moisture regime (SMR) is moist to slightly dry (Pyatt *et al.*, 2001). Sites should also have a low windiness score (DAMS <13) and an accumulated temperature >1000 day-degrees (>5°C).

The stability of stands derived from cuttings

It has been suggested that increased shoot growth in cuttings from improved clonal stock may come at the expense of root growth, with a resulting loss of stability. Stability is influenced by the size of the root system in relation to the shoot, the number and size of structural roots, and their radial distribution (Coutts, 1983; Coutts *et al.*, 1999). Stability improves with increasing root:shoot ratio and root number, size and symmetry.

General concern exists over the long-term stability of commercial plantations in view of the windy climate in Britain (Gardiner and Quine, 2000). Selection of the parent material and the stock propagation method may adversely affect future stability. For stock produced by vegetative propagation, the number and symmetry of roots, though strongly influenced by genotype, is likely to be less than for conventionally produced seedlings. Nicoll *et al.*, (1995) found that clonal cuttings of Sitka spruce had fewer but larger roots than transplants. Uneven allocation between roots, particularly if there are a smaller number in the root system, affects other components of tree stability (Coutts, 1983) which may further exacerbate stability problems later in the rotation.

Scant information is available on larch root architecture and subsequent tree stability in the UK. However recent analysis of two 11-year-old larch experiments (in Shiplaw, south Scotland and North York Moors) suggest that there may be some reason for concern. At Shiplaw some cuttings had significantly asymmetrical structural-root architecture and there was a trend for the main structural roots to become less evenly arranged over time. At North York Moors significant asymmetrical structural-root architecture was also evident in places. However, caution should be used when interpreting these results due to the limited sample size.

CURRENT BEST PRACTICE GUIDELINES

Vegetative propagation

- The first crop of cuttings can be taken after two years' growth of the stock plants from seed. Stock plants should be replaced after 5–7 years.

- Both hardwood (spring) cuttings and softwood (summer) cuttings can be utilised but hardwood cuttings are easier to handle, store and insert.

- Cutting size should be 8–10 cm long with a minimum basal diameter of 2 mm. Tip cuttings are preferred.

- Free draining rooting substrates (>30% grit or perlite content) are beneficial when propagating under mist irrigation systems. Addition to the mix of slow release fertiliser is also beneficial.

- For hardwood cuttings 80% relative humidity is optimal for the rooting phase (8–12 weeks).

- Hardwood cuttings should be transplanted in the autumn, softwood cuttings should be held over until the following year.

Nursery operations

- Larch seedlings should be undercut in June and wrenched at intervals to control height and improve root:shoot ratio.

- Direct lifting and planting of larch should ideally be confined to October and March though the most appropriate window is dependent upon the climatic zone of the planting site.

- Artificial freeze-test (REL) thresholds are accurate predictors of cool and cold storage windows. Baseline (non-freeze) REL thresholds can be used operationally for identification of lifting windows but, although slightly faster, are less accurate.

Establishment

Where larch planting with the objective of quality timber production occurs it should be noted that:

- Survival of HL cuttings should be the same as conventional stock types provided good handling practices are followed.

- During early establishment some poor form may be evident but initial differences will be minimised with tip cuttings. Plagiotropism will not usually be evident five years after planting given a cultivated weed-free planting position.

- Winter weed control, e.g. propyzamide ('kerb') when the trees are dormant (November–February) is recommended to improve survival rates.

- Plantings of improved family mixtures of HL should target sites of high yield potential.

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