Forestry Commission

Bulletin 121

Forest Tree Seedlings

Best practice in supply, treatment and planting

John Morgan

FORESTRY COMMISSION BULLETIN 121

Forest Tree Seedlings - best practice in supply, treatment and planting

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Forestry Commission, Edinburgh

ISBN 0 85538 404 2

Morgan, John L. 1999. Forest Tree Seedlings – best practice in supply treatment and planting. Bulletin 121.

FDC 232.41:232.412:453:414.12:(410)

KEYWORDS: Forestry, Insecticide treatment, Plant handling, Plant quality, Plant storage, Plant supply, Planting operations, Planting stock.

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Forest Tree Seedlings - best practice in supply, treatment and planting

Summary

This Bulletin gives guidance about choosing plants for the establishment of different types of woodland in Britain. Recent research has identified the best practices for handling and planting trees to ensure high rates of survival and good growth following planting. Recommendations cover the range of activities from plant supply through to monitoring the success of establishment.

The main categories of planting stock are described and the most appropriate size specifications are recommended for different situations. Physical and physiological condition of plants are discussed and techniques for assessing damage are described. Guidance is given about choosing dates for lifting, storing and planting trees in order to avoid deterioration in their physiological condition. Techniques for the insecticide treatment and handling of treated trees are reviewed and the supervision of planting operations is described.

This Bulletin is recommended reading for forest managers, woodland owners, students, and all others concerned with establishing woodlands in Britain.

Semis d' arbres forestiers - les meilleures pratiques à suivre pour l' approvisionnement, le traitement et la plantation

Résumé

Ce bulletin donne des conseils sur le choix des plantes en vue de l' implantation de différents types de forêts en Grande Bretagne. Des recherches effectuées récemment ont identfié les meilleures façons de manipuler et planter les arbres pour assurer un pourcentage de survie élevé et une bonne croissance après plantation. Les recommandations données couvrent un éventail d'activités allant de la fourniture des plantes au contrôle régulier de leur bonne implantation.

Les principales catégories de stock de plantation sont décrites et on y recommande les spécifications de taille les plus appropriées à différentes situation. Les états physique et physiologique des plantes sont examinés et les techniques permettant l'évaluation des dégates décrities. Des conseils sont donnés pour choisir les dates où effectuer la sortie de terre, l'entreposage et la plantation des arbres afin d'eviter que leur état physiologique ne se détériore. Les techniques utilisées pour le traitement insecticide des arbres et la manipulation des arbres traités sont passées en revue et la conduite des opérations de plantation s'y trouve décrite.

La lecture de ce bulletin est recommandée aux gestionnaires de la forêt, aux propriétaires de bois, aux étudiants et à toute autre personne concernée par l' implantation des bois en Grande Bretagne.

Waldbaumsetzlinge - die besten Verfahren zur Beschaffung, Behandlung und Pflanzung

Zusammenfassung

Dieses Bulletin gibt Richtlinien zur Pflanzenwahl für die Etablierung der verschiedenen Waldtypen in Britannien. Neue Untersuchungen haben die besten Verfahren zur Handhabung und Pflanzung von Bäumen festgestellt, um hohe Anwuchsraten und gutes Wachstum nach der Pflanzung zu sichern. Die Empfehlungen behandelten Aktivitäten von der Pflanzenbeschaffung bis zur Überwachung des Etablierungserfolges.

Die hauptsächlichen Pflanzgutkategorien werden beschrieben und für unterschiedliche Verhältnisse werden die geeignetsten Größenangaben vorgeschlagen. Der physische und physiologische Zustand der Pflanzen wird diskutiert und Verfahren zur Schadensbegutachtung werden beschrieben. Es werden Richtlinien zur Wahl des Ausgrabungszeitpunktes, Lagerung und Pflanzung der Bäume gegeben, um eine Verschlechterung ihres physiologischen Zustandes zu vermeiden. Verfahren zur Insektizidenbehandlung und zur Handhabung von behandelten Bäumen werden betrachtet und die Überwachung der Pflanzarbeit wird beschrieben.

Dieses Bulletin ist vorgeschlagenes Lesematerial für Forstwirte, Waldbesitzer, Studenten und all denen, die sich mit der Etablierung von Wäldern in Britannien beschaffen.

Chapter 1

Introduction

Trees are planted for a wide range of objectives. The techniques for establishing different types of woodland have been comprehensively reviewed in previous publications, e.g. restocking, farm woodlands, reclamation sites, urban areas and new native woodlands (Tabbush, 1988; Williamson, 1992; Moffat and McNeill, 1994; Hodge, 1995; Rodwell and Patterson, 1994). Most sites should be cultivated before planting and the trees must be protected from vegetation competition for good survival and vigorous growth (Davies, 1987).

Each of these publications stresses the importance of using high quality nursery stock unless natural regeneration is available. Aldhous and Mason (1994) describe most nursery systems and the techniques used in plant production. Their text is the main reference for nursery managers.

This Bulletin gives guidance about choosing plants for different planting situations. Recommendations on best practice are based on the latest information from research experiments. Figures from earlier publications have been redrawn and in some cases, simplified to assist presentation. The forest nursery trade has been consulted about the content of this guide and we are very grateful for the comments that we received. There are references to publications produced by members of the Committee on Plant Supply and Establishment and by the Horticultural Trades Association.

There is wide variation between the specifications and costs of plants offered by different nurseries (Plate 4). A recent survey of nursery stock found a total of 15 plant types and sizes for six species of tree (Britt *et al.*, 1996). Prices varied according to the size of tree and the nursery concerned so customers were advised to shop around. However, savings should not be sought at the expense of plant quality and customers are advised to find good quality plants before negotiating prices.

The overall cost of establishing woodlands will vary according to the objectives, site factors and the size of the scheme to be planted. Small, lowland amenity plantings are more costly than large upland plantations (Mitchell *et al.*, 1994). The purchase of plants only represents 12–20% of the total establishment cost (Aldhous and Mason, 1994; Britt *et al.*, 1996). However, if plants fail to survive and grow well, they will cost more to replace and maintain. It is a false economy to save money on plants that do not meet the recommended specifications. The value of good quality plants will be realised if they are handled carefully and planted well.

This Bulletin covers the important points for those concerned with buying and planting trees. We recommend reading the Bulletin before planning planting programmes and ordering trees from nurseries.

Chapter 2

Types of planting stock

Description of plant types

Forest nurseries are widely distributed across the UK. Nursery managers must adopt production systems that match the environmental conditions in their nursery to the growth requirements of different tree species. Some nurseries can produce only a limited range of species, others use specialised techniques such as the use of containers or the rooting of cuttings. It is worth making arrangements to visit your local nursery to find out what they grow.

Nurseries normally hold stocks of the trees that are commonly used in forestry planting schemes. Sales catalogues are normally produced each autumn, and list for each species the types, size and price of plants offered for sale. In some cases the seed origin of plants will also be specified and this is a statutory requirement at the point of sale for species covered by EU Forest Reproductive Material Regulations. Most nurseries are happy for their customers to inspect plants before placing orders. Many nurseries will also buy in plants from other nurseries if preferred choices are not grown on site.

It is important to understand the definitions of the different plant types and the size classes that are given in nursery catalogues. The age of plants is given as the sum of time spent under different regimes in the nursery (Table 2.1). Particular growing regimes are represented by letters and symbols that are fully defined in the Horticultural Trades Association National Plant Specification (1997). The first number in any description is the time spent undisturbed as a seedling or as a cutting. This may be prefixed by a letter describing how it was produced for example, C for cell-grown. Subsequent figures represent the number of years spent undisturbed after operations such as transplanting, undercutting, wrenching and stumping back.

Table 2.1 Nomenclature for different plant types (HTA, 1997)

Code	*Growing regime*
O	plants raised from cuttings
C	cell-grown stock
+n or n	n years after transplanting
u n or = n	n years after undercutting
w n	n years after wrenching
S n	n years after stumping

Plate 1 *Inserting cuttings into holders of a mechanical transplanter. (38222)*

Plate 2 *Undercutting pine seedlings. View showing the reciprocating blade which is pulled beneath the seedlings. (Forest Life Picture Library 1008272020)*

Plate 3 *Cell-grown oak seedlings growing in containers in a polyhouse. (R.L.Jinks)*

Plate 4 *Range between plant types and prices (£ 1997) for oak. From left to right: 1+0 @ £160 per 1000 plants, 1u1 @ £190 per 1000 plants,* $^{1}/_{2}$ *u* $^{1}/_{2}$ *@ £130 per 1000 plants, 1u1 @ £180 per 1000 plants, P1+0 @ £180 per 1000 plants and P1+O @ £400 per 1000 plants. (51485)*

Plate 5 *1u1 Japanese larch undercuts. Note lack of root distortion compared with transplants. Quality improves from left to right. (51169)*

Plate 6 *Comparison between age and size of Sitka spruce plants. From left to right: 2+0, 1u1, 2+1 and C1+1* $^{1}/_{2}$ *cutting. (51214)*

Plate 7 *C* $^{1}/_{2}$ *+ 1* $^{1}/_{2}$ *Sitka spruce cuttings. Quality improves from left to right; note plagiotropic growth of plant on the left. (51166)*

Plate 8 *Cell sizes for P1+0 cell-grown seedlings. Birch grown in 110 cc Rigipots and oak grown in 250 cc Bowmonts. Note the difference in spacing and the size of the plugs. (51171)*

Plate 9 *P1+0 and C1+0 hybrid larch plugs. Seedlings on left and cuttings on the right. Note looser growing medium which is used for cuttings. (51188)*

Plate 10 *5-year-old Sitka spruce planted on a cultivated restocking site. The trees on the right were large 3-year-old transplants, those on the left were small 1+1 transplants. The larger plants have retained a height advantage and have slightly better survival. (51153)*

Plate 11 *J rooting in 1+1 Scots pine transplants. Left plant is unacceptable, middle is borderline and right is acceptable. (51168)*

Plate 12 *1+1 beech transplants. Plant to left of sample has unacceptable J rooting and few fibrous roots, all others are acceptable. (51170)*

Plate 13 *Grading line in a commercial nursery. Fresh plant are delivered by forklift from a humi-cold store. Graded plants are placed in bags in boxes for direct cold storage or delivery to the customer. (51154)*

Plate 14 *Bundles of 1u1 Sitka spruce. Both have suffered slight root desiccation, the right-hand bundle has unacceptable amounts of soil on foliage which may lead to fungal infection. (51163)*

Plate 15 *Bundles of Sitka spruce and larch 1u1s. The spruce has flushed during storage in bags and mould is beginning to grow on foliage. Larch are in good condition (despite buds swelling). (51189)*

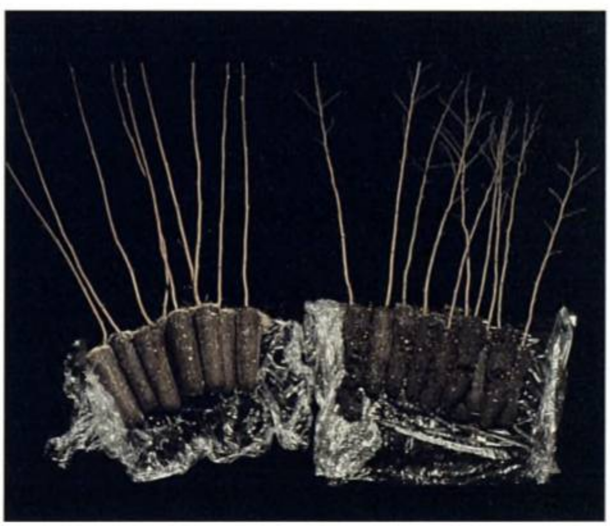

Plate 16 *Cell-grown birch; left P1+0, right P2+0. Plants on left are in good condition, those on right contain dead roots and have more broken plugs than should be accepted. (51164)*

Plate 17 *Root growth potential of P1+0 Scots pine. (50800)*

Plate 19 *Plant quality testing laboratory at Bush nursery. Plants are routinely tested for RGP, electrolyte leakage and root moisture content. Physical measurements compare plants against British Standards. (51221)*

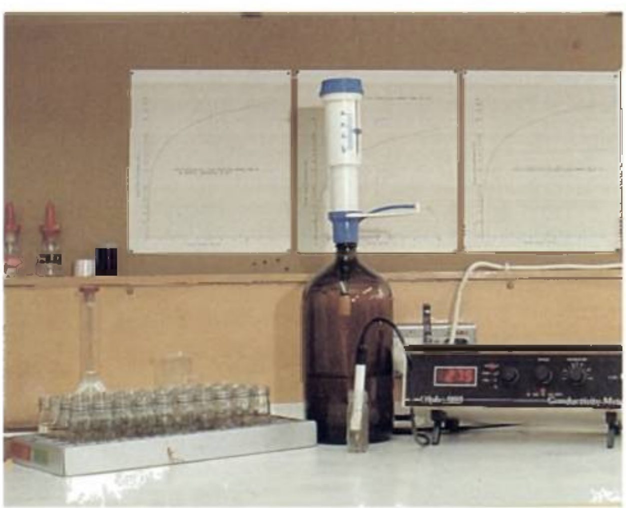

Plate 18 *Equipment used to measure root electrolyte leakage. Sample of fine roots in a distilled water solution and a conductivity meter. (Helen McKay)*

Table 2.2 Examples of descriptions and definitions for different types of plants

Description	*Definition*
1+0 or 1/0	A 1-year-old seedling which has not been transplanted
1+0 = or 1/0 =	A 1-year-old undercut seedling
1u1	A 2-year-old undercut seedling that has not been transplanted
2+1 or 2/1	3-year-old transplanted seedling, 2 years in a seedbed, transplanted and grown on for 1year
O/ 1+1	2-year-old cutting transplant, 1-year in cutting bed, transplanted and grown on for 1year
CO/1	1-year-old cell-grown cutting
C2+0 or C2/0	2-year-old cell-grown seedling

Bare-root plants

Plants that leave the nursery without any rooting substrate are described as bare-root stock. These can be raised from either seedlings or cuttings (Plate 6). A cell-grown seedling is also described as bare-root after it has been transplanted into a nursery bed and grown on before lifting.

Seedlings

Seedlings remain undisturbed in nursery beds until they reach a size that is suitable for lifting. The height of seedlings will depend on when they were sown, how they were irrigated and whether they were grown under some form of seedbed cover. The diameter of a seedling increases as it is given more room to grow. High density seedbeds (>400 m^{-2}) are normally broadcast sown and seedlings are used for transplanting in the nursery. Seedlings grown at low density can be broadcast sown, drilled or precision sown to remain in the same beds before lifting for sale. It is rare for seedlings to be offered for sale for forest planting unless they have been undercut (see later). Some species of tree produce deep tap roots, even as seedlings. If these roots are allowed to grow undisturbed then a large proportion of the root system will be broken off when plants are lifted.

Transplants

Seedlings can be grown for 1 or 2 years before they are transplanted or lined-out to provide more space for plants to develop. Root systems should become more compact and fibrous after transplanting so these plants develop more root in proportion to shoot than undisturbed seedlings. In some cases seedling roots are pruned to encourage regrowth and to assist transplanting.

Lining out is carried out by hand or, more commonly, by machine (Plate 1). Correct placement of plants is important for both methods to prevent plants becoming deformed: 'hockey stick' stems develop when seedlings are set at an angle; 'J rooting' occurs when roots are bent or swept along the transplant line (Plates 11, 12 and Chapter 3, 'condition of roots'). Good quality plants are produced when they are lined out at the correct depth and are given sufficient space to grow. Broadleaves generally need more space and less time to grow than conifers. Overcrowding of any species causes drawn and spindly plants, correct spacing produces sturdy plants with good root:shoot ratios (Chapter 3, 'root:shoot ratios').

Undercuts

Undercutting seedling roots is another way of increasing root fibre and improving the balance between root and shoot. A sharp blade is passed through the seedbed to cut the tap root at a predetermined depth (Plate 2). Certain broadleaves and larches are large enough to be undercut in the same year as sowing, other species are generally undercut early in the second growing season.

Undercut plants must be given sufficient time to regenerate new roots before they are lifted. Repeated wrenching with a different blade and sidecutting using discs between rows will continue to improve root form. Transplanted seedlings will also benefit from wrenching. As well as improving the structure of root systems (Plate 5), undercutting and wrenching have been shown to benefit the physiology of conifer seedlings and this can result in greater tolerance of stress during handling and storage. Undercuts also become dormant earlier than transplants and may be ready for lifting earlier in the year (Chapter 4).

Adequate spacing is as important to undercuts as it is to transplants. Seedlings must be sown at low densities to allow sufficient space for development. Sidecutting lateral roots is only possible when seed has been drilled or precision sown.

Cuttings

Rooted cuttings

Cuttings are the main method of producing plants from the superior genotypes that are selected by tree breeders. Production costs are higher than those for conventional seedlings, so cuttings must be sold for a premium.

The main conifer species propagated by cuttings in Great Britain is Sitka spruce. Approximately 7 million cuttings will be produced annually at the turn of the century. Seed for stock plants is produced using controlled pollinations between families of trees that have been selected for vigour, straightness and branching characteristics. Improvements in vigour will more than compensate for the additional costs of these plants. Very few broadleaved trees are grown as rooted cuttings, although some poplars and willow cuttings are sold unrooted (see below).

Sitka spruce cuttings are rooted in mist houses and then transplanted into nursery beds like conventional seedlings. All subsequent operations follow the same practices as for transplants. Some Sitka spruce cuttings have poorer stem form than seedlings because shoots exhibit plagiotropic or branch-like growth in the nursery beds (Plate 7). Good nursery practice can minimise plagiotropism by using juvenile cuttings taken from tips of shoots. All forms of spruce cuttings resume upright growth between 2 and 4 years after planting in the forest. It is impossible to distinguish between seedlings and cuttings once they are fully established.

Unrooted cuttings and sets

Poplars and willows are commonly sold as 20–25 cm unrooted hardwood cuttings. Large 10–20 mm diameter cuttings root and grow better than smaller material. The minimum midpoint diameter for a cutting should be 8 mm for willow and 10 mm for poplar (Tabbush and Parfitt, 1999). Large cuttings are described as 'sets' and can be 3–4 m in length.

Cell-grown plants

Seedlings grown in small containers (<500 cc) are generally referred to as 'cell-grown' stock. They are generally produced inside plastic tunnels or glasshouses (Plate 3). The containers or cells are usually combined to form modular trays made from plastic or polystyrene. The plants are grown in an artificial growing medium; seedlings that are removed from the tray with the medium are referred to as plugs. In some systems, plants are lifted and planted together with paper pots in which they were grown (JPPs). It was these systems that led to the older description 'containerised planting stock.'

Cell-grown stock is normally sold after one year because seedlings have faster germination and growth inside plastic tunnels and glasshouses compared with open-grown seedlings. Slower growing species benefit from being sown during the previous summer (e.g. native Scots pine) or may even need two full growing seasons to reach marketable size (e.g. noble fir and Macedonian pine). Most cell-grown plants will be hardened off outdoors by the end of the growing season.

The rate of growth of different species should be taken into consideration when choosing cell size (Plate 8). For example, one-year-old pines can be grown in 80–100 cc cells whereas oak of the same age requires at least 150 cc volume. There are a wide range of cell designs available; most were originally designed for growing conifers in Canada or Scandinavia and have been modified and manufactured to suit the needs of British planting stock production. Growers select those cell designs that produce high quality seedlings, which consistently have uniform size and a good balance between root and shoot.

Absence of root spiralling and root deformation are critical requirements for cell-grown seedlings. Spiralling occurs in designs such as paper pots or plastic cells that have smooth, cylindrical walls. Most modern cells have features that control the root form of seedlings. When seedling roots reach the cell walls they are directed downwards by ridges or grooves. These stop the roots spiralling around the plug, which avoids the risk of self-strangulation after planting.

Roots are prevented from growing out of the drainage hole at the bottom of cells by the action of air pruning. Trays must be raised at least 15 cm above the ground to ensure good air circulation for root pruning. Properly air-pruned seedlings have a characteristic cluster of roots at the bottom of the plug. The best quality root systems are produced by growing seedlings in an appropriate cell design for the correct length of time.

Cuttings can be rooted in cells and lifted with rooted plugs (Plate 9). This system is cheaper than producing bare-root cuttings because there are no transplanting costs; however, the plants tend to be smaller. Cuttings must be well rooted to ensure plugs remain intact after lifting. This can be a problem since the rooting medium for cuttings is less cohesive than that used for cell-grown seedlings, to ensure good drainage under the intensive watering regimes used in mist houses.

Cuttings raised in cells can grow plagiotropically like bare-rooted material. Hybrid larch is particularly susceptible to plagiotropism when collected as softwood cuttings or hardwood cuttings from the base of shoots.

Chapter 3

Plant specifications

Plant size

Plants are normally graded within height ranges that are specified by the customer or the nursery (Plate 13). The root collar diameters of plants should meet standards that are described in the British Standard for Nursery Stock (British Standards Institution, 1984a). The Standard specifies minimum diameters for different height classes of the commonly produced forestry species (examples are given in Table 3.1).

British Standard specifications for cell-grown seedlings are less comprehensive than for bare-root material. However, an updated guide has been produced by the HTA Forestry Group (Horticultural Trades Association, 1995; Table 3.1). The guide describes minimum root collar diameters and minimum cell volumes for different height ranges of broadleaves and conifers.

The ratio of root collar diameter to height is described as the sturdiness of a plant. Sturdy plants normally have better developed root systems in proportion to their shoots than tall and thin plants (Aldhous, 1989). Many studies have shown that survival and growth of trees can benefit when sturdiness is improved (Edwards and Holmes, 1951; Mason *et al.*, 1989; Mason, 1991).

Root:shoot ratios

The ratio between the root and shoot dry weight of plants is widely used as an index of plant quality. Plants need adequate water supply for photosynthesis and subsequent growth. Seedlings with large fibrous root systems are better able to supply shoots with water from the soil and a high root:shoot ratio enables them to withstand moisture stress after they are planted. If root:shoot ratios are too small then shoots may die back due to desiccation before roots are able to regenerate.

Uptake of water is mostly through fine roots with a diameter of less than 2 mm. However, these roots are most susceptible to damage and desiccation. Large woody roots can withstand more exposure to desiccation but must regenerate new fine roots to improve their water uptake efficiency.

Trees differ in their ability to withstand root damage and to regenerate new roots. Amongst conifers the pines, firs and larches are considered to be sensitive to damage. These species produce few adventitious roots (roots from the base of the stem), so young plants must rely on nursery roots for water uptake and root regeneration after planting. Spruces and most broadleaved species produce adventitious roots more readily and so are better able to regenerate new root systems to replace nursery roots.

Plants with high root: shoot ratios are considered as being of good quality because they have better relative height growth rate[1] than plants with low root:shoot ratios (Mason, 1991). However, plants with good root:shoot ratios can still suffer damage if they are handled or planted poorly. Figure 3.1 compares first year growth of 1u1 Sitka spruce, which were either roughly handled or carefully handled, and then planted. Sturdy plants tend to grow better than weaker plants irrespective of handling treatment.

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[1] Relative height growth $= \dfrac{1}{\text{height}_0} \times \dfrac{\text{height}_1 - \text{height}_0}{\text{year}_1 - \text{year}_0}$

Table 3.1 Examples of size specifications from British Standard BS 3936 (Part 4) and the HTA guide for cell-grown trees and shrubs

British Standard Specification: Bare-root

		Height band (cm)						
		10	15	20	30	40	50	60
Minimum root collar diameters (mm)	birch	-	-	3	4	4.5	5.5	6.5
	beech	-	-	4	5	6	7.5	9
	oak/ash/gean/lime	-	-	5	6.5	8	9.5	11
Minimum root collar diameters (mm)	pine (not Corsican)	3	4	4.5	6.5	8	9.5	-
	Sitka spruce	-	2.5	3	4	5	6	7
	Douglas fir	-	-	3	4	5	6	-
	noble fir	5	5	5	6.5	8	9.5	-

HTA Specification guidelines: Cell-grown

		Height band (cm)			
		10 – 20	20 – 40	40 – 60	60 – 90
Minimum root collar diameter (mm)	broadleaf	4	4	6	8
	conifer	3	4	6	8
Minimum cell volume (cc)	broadleaf	50	100	150	200
	conifer	50	100	150	N/A

Condition of shoots

Most conifers and some broadleaves (e.g. cherry and ash) should have single leading shoots if they are planted for timber production. Other species readily establish apical dominance so may be accepted with more than one leader (e.g. oak or larch). Singling of shoots by cutting off laterals is an acceptable means of improving shoot form during grading. Alternatively, plants for hedging or amenity planting will be grown with vigorous lateral branches, promoted by clipping leading shoots back in the nursery (e.g. hawthorn and blackthorn).

Plants must not be supplied with shoot damage or disease. Broken leaders, frost damage, discoloured foliage, stem lesions and mould are all unacceptable. Nursery managers should ensure that plants are lifted in dry weather to avoid getting excessive amounts of soil on the shoots. Wet shoots are more susceptible to infections from mould fungi when plants are stored in bags.

Bare-rooted plants will normally be lifted before buds begin to burst. Shoots begin to grow as plants are coming out of dormancy. It is acceptable for buds of some species to begin swelling during cold storage (e.g. larch, Plate 15)

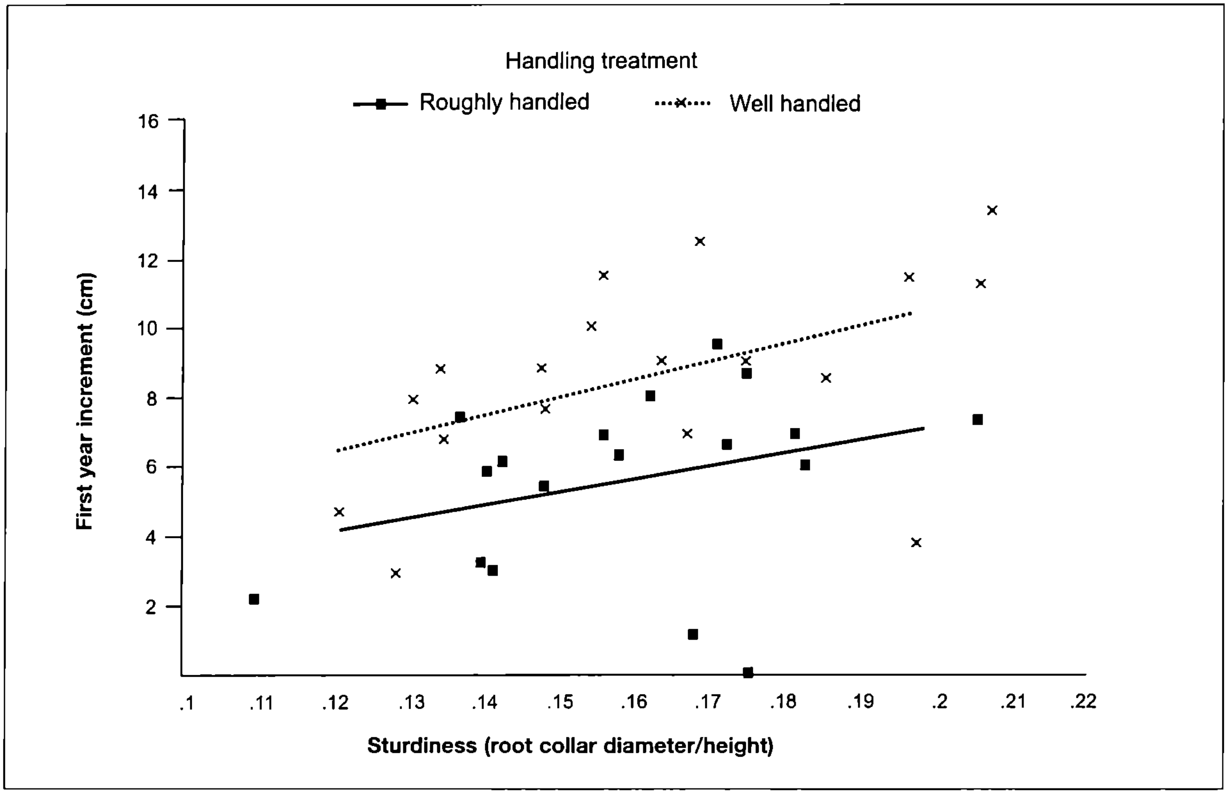

Figure 3.1 *Effect of rough handling on first year growth of 1u1 Sitka spruce. Height and diameter were measured before planting.*

but trees should never be supplied after budburst. Although cell-grown plants can be successfully established when they are in leaf there is a risk that seedlings will become desiccated if they are planted into dry soils in this condition. Planting before budburst allows roots to grow into the surrounding soil before water is lost through new foliage.

Condition of roots

The form of a seedlings root system will depend on the condition of the nursery soil and any symbiotic associations formed between micro-organisms and the plant (Aldhous and Mason, 1994). Development of fine roots benefits from a loose soil structure and pH within the prescribed range for that species. Mycorrhizal associations promote root branching and species of *Frankia* will form nodules on alder roots.

Various operations can be used to manipulate the root form of seedlings. Transplanting, undercutting and wrenching can increase the production of fibrous roots. However, these operations must not cause unacceptable root distortion (Plates 11 and 12). Plants with severe J rooting take longer to plant correctly and are more prone to early instability. Poor root form is most detrimental to early stability for species like pines and firs, which do not produce adventitious roots.

Undercutting and wrenching must be carried out in time for seedlings to regenerate new roots before lifting. This generally requires the first undercut to take place before the middle of August since it takes 4–6 weeks for new roots to regenerate. Late undercutting will reduce root mass and can be detrimental to root form. It is recommended that most conifers are wrenched on at least three subsequent occasions (Aldhous and Mason, 1994).

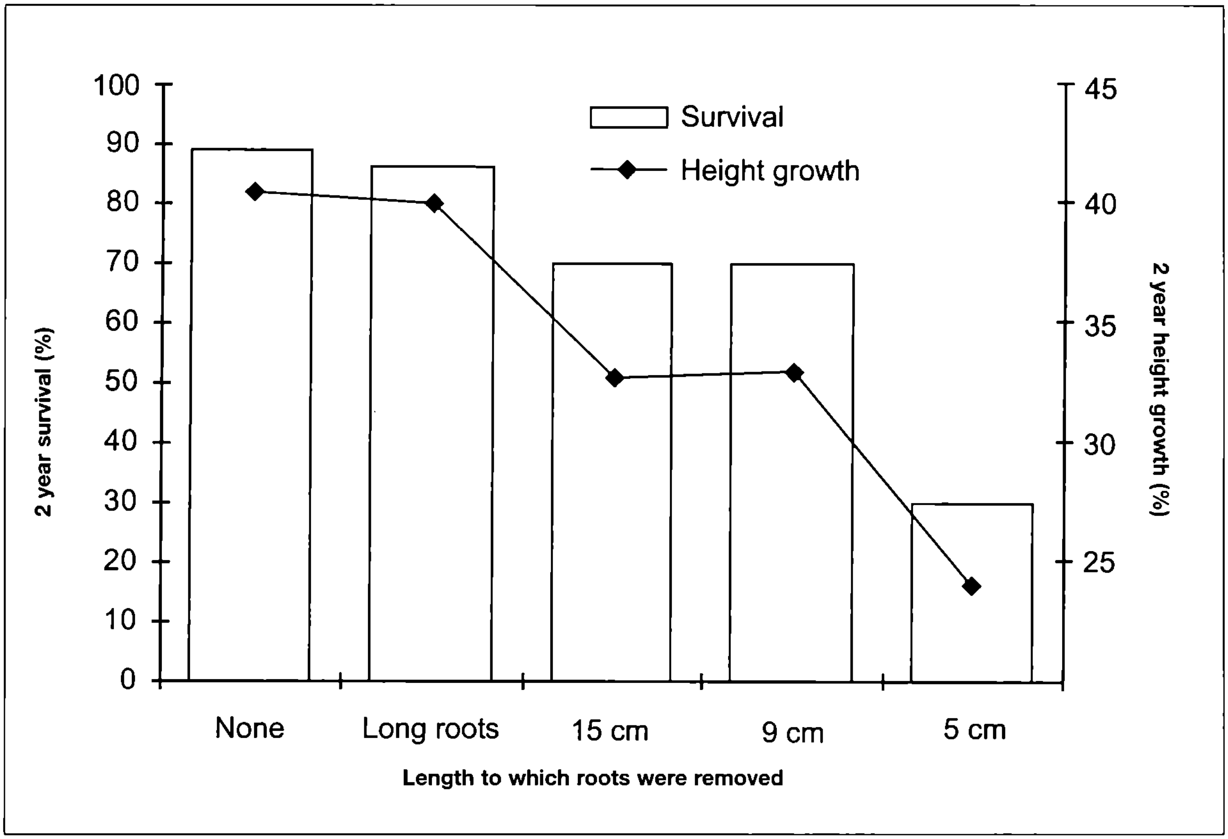

Figure 3.2 *Effect of root pruning on survival and growth of 1u1 Douglas fir. Treatments: none (control) = untreated, long = long roots outside root ball removed,15/9/5 cm = pruning the root ball to different lengths.*

In some species, such as pines, undercut seedlings develop long lateral roots despite being side pruned in nursery beds. These roots can extend beyond the main root ball making trees difficult to plant properly. Experiments have shown that these long roots can be pruned prior to planting without any detrimental effect on survival or growth. Removal of any of the root ball can significantly reduce survival and growth (Figure 3.2). Root pruning should be carried out by the nursery where specifications can be closely controlled. Under no circumstances should planters be allowed to cut roots on site.

The condition of tree roots has a large influence on potential survival and growth. Any roots that are damaged or removed during lifting will adversely affect root:shoot ratios. Lifting damage is only apparent on close examination; large roots can be torn or broken; fine roots can be stripped (where the brown exterior or cortex is removed and exposes the white centre or steele).

Root form of cell-grown plants is influenced by their growing conditions. There should be no roots spiralling around the plug, which could lead to root strangulation. Roots should be air pruned at plug bases and not fused into clusters. Plugs should be well rooted and intact with no breakages and only small amounts of loose growing medium (Plate 16).

Roots are much more susceptible to physiological damage than shoots (Chapter 4, 'root electrolyte leakage'). Fine roots that have been allowed to dry out will be irreversibly damaged (Plate 14).

Species with large tap roots can withstand some surface drying but normally all roots should have a fresh, moist appearance. Dry soil on bundles of plants does not always mean that roots have dried out and a true value for root moisture content can only be obtained by measurement in a laboratory (Chapter 4, 'root moisture content').

Waterlogged soil can be just as damaging to tree roots as exposure to drying. Plants should be lifted with very little soil remaining on roots. Large clods of wet soil can restrict oxygen supply to roots, particularly when bags are stored in warm temperatures. Most nurseries will avoid lifting when soil is wet to prevent root damage.

Root diseases occasionally occur in nurseries and it is possible to find dead roots or roots which have been damaged by pathogens on plants. Symptoms of root diseases are normally noticed on shoots when they are in the nursery and these plants will be destroyed. If a disease is suspected then samples should be sent to a pathologist for diagnosis. It is important not to confuse mycorrhizal hyphae, which are beneficial to plants, with root rots or moulds.

Chapter 4

Assessing the physiological condition of plants

Onset of dormancy

The physiological condition of a plant can be modified by exposure to different physical and environmental factors. Physical treatments are used to manipulate growth in the nursery, such as fertilizing and wrenching. Environmental factors change according to climate and the time of year. Development of dormancy occurs as physiological condition changes towards the end of a growing season, including an increase in hardiness which improves resistance to frost damage.

The onset of dormancy is influenced by seed origin, nursery treatments and seasonal conditions. Southern provenances of north temperate species can develop dormancy 2–3 weeks later than northern provenances, e.g. Oregon v. Queen Charlotte Islands Sitka spruce. Undercutting and wrenching both induce dormancy, whereas fertilizing can prolong plant growth. Seed origin and cultural treatments can interact with climatic conditions. Plants become dormant earlier in the north of Britain because of cooler temperatures than in the south.

Dormancy of shoots is a response to day length and air temperature whereas root activity is affected by soil temperature and soil moisture. Roots can continue to grow for up to one month after shoot growth has stopped and buds have set. In Britain it is rare for shoots and roots to be fully dormant before the beginning of December. Roots of some species are quiescent and it can not be assumed that they will remain dormant throughout the winter period (e.g. Douglas fir, McKay, 1993).

Plants are most tolerant to stresses caused by lifting, cold storage and handling when they are fully dormant. This has been taken into account in the recommendations for lifting and cold storage dates (Chapter 6). Actual lifting dates may be delayed or brought forward depending on the climatic conditions of a particular season. The most accurate way to determine safe lifting dates is by physiological testing of plant dormancy status.

Release from dormancy

Release from dormancy, or dehardening, follows a period of exposure to cold temperatures during winter. This chilling requirement differs between species and seed origins. Plants take less time to break bud the longer they have been exposed to low temperatures. Trees only begin to grow when dormancy is released and temperatures increase during the spring.

Root growth potential

Root growth of most species begins as soon as soil temperatures exceed 6°C. Shoot growth follows bud burst when there is an associated decline in root activity. The ability of a plant to grow new roots is described as root growth capacity or potential (RGP) (Ritchie, 1984). Less roots are produced as conifers deharden and get close to bud burst so RGP can be used as a physiological test to measure depth of dormancy (Tabbush, 1988).

RGP is used to assess dormancy status and plant vitality in this country (Tabbush, 1988; Aldhous and Mason, 1994). RGP measurements have been used to determine safe periods for lifting and storing species such as Sitka spruce and Douglas fir (Tabbush, 1988). RGP can also be used to assess physiological damage caused by physical and environmental stresses (Tabbush, 1986; Sharpe and Mason, 1992; McKay *et al.*, 1993).

Plants with high RGP are expected to survive and grow well after planting. However, there is no simple relationship between RGP, survival and growth because of variation in RGP values between species, plant types and plant dormancy status. RGP tests are slow to use because trees need at least 14 days to express RGP in a warm environment with supplemental lighting. These limitations mean that use of RGP testing is restricted to small-scale applications for research and advisory testing (Mason, 1991) rather than routine testing of trees when they are despatched from the nursery.

It is important for all plants to produce new roots as soon as they are planted into warm soils during the spring. RGP testing has resulted in better understanding of root periodicity and the ability of different species to regenerate new roots after planting. Sitka spruce and Douglas fir have maximum RGP in January when plants are fully dormant (Tabbush, 1988). Larches have two RGP peaks when roots are still growing, one in October and another in March (McKay and Howes, 1994). Birch has high RGP values similar to those of spruces whereas other broadleaves have low values similar to larches.

Different techniques for physiological testing have been evaluated by research in the UK (Mason, 1991; McKay and Mason, 1991). RGP testing is too slow and expensive for routine analysis as successful methods need to be quick, reproducible and to give good correlations between survival and growth (Figure 4.2). Root electrolyte leakage testing has been shown to be the most appropriate method for routine testing (McKay, 1991).

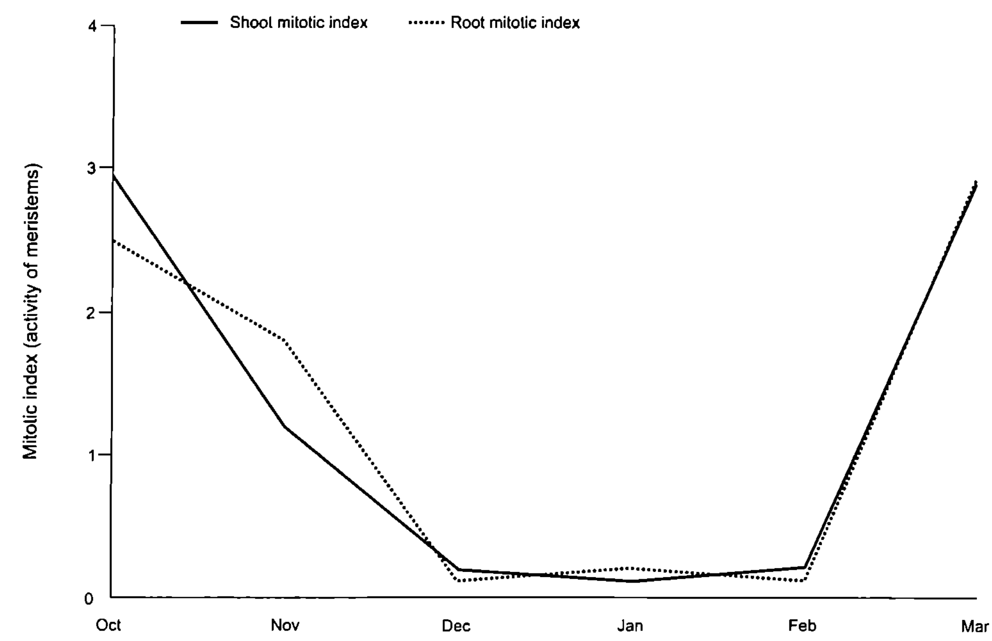

Figure 4.1 *Overwinter changes in shoot and root dormancy of Sitka spruce 1u1s. Expressed using mitotic index which is a measure of cellular activity (from McKay and Mason, 1991)*

Root electrolyte leakage

Plant cells contain salt solutions with charged ions that can move or leak out from cells when they are active, or if they become damaged. Root electrolyte leakage (REL) is used to describe the rate of salt movement from samples of roots into distilled water. Roots are more leaky when they are active or damaged and this can be detected by measuring the electrical conductivity of the leachate in distilled water. The test procedure takes only 48 hours and is fully described by McKay (1991).

REL tests can be used to monitor the change in plant dormancy throughout winter in the same way as RGP. The test also detects damage caused by desiccation, rough handling, overheating and freezing. Values for REL fall and rise according to similar trends as found for root activity at the end of the growing season (Figure 4.1). Typical REL values for dormant plants are shown in Table 4.1. There should be very little deterioration in condition if plants are handled carefully and stored correctly before planting.

REL tests are very good predictors for survival and growth for a wide range of species (e.g. Figure 4.2). Forest Research has a large database containing information from experiments and advisory testing where samples with known REL values have been assessed after planting. It is possible to make precise estimates for survival when sites and planting dates are known. Maximum acceptable REL values are those associated with ≥90% survival for spruces and ≥80% survival for other species (Table 4.1). Actively growing plants will exceed these values; dormant plants should be closer to the baselines for each species. Dormant plants which are above REL maxima have suffered physiological damage.

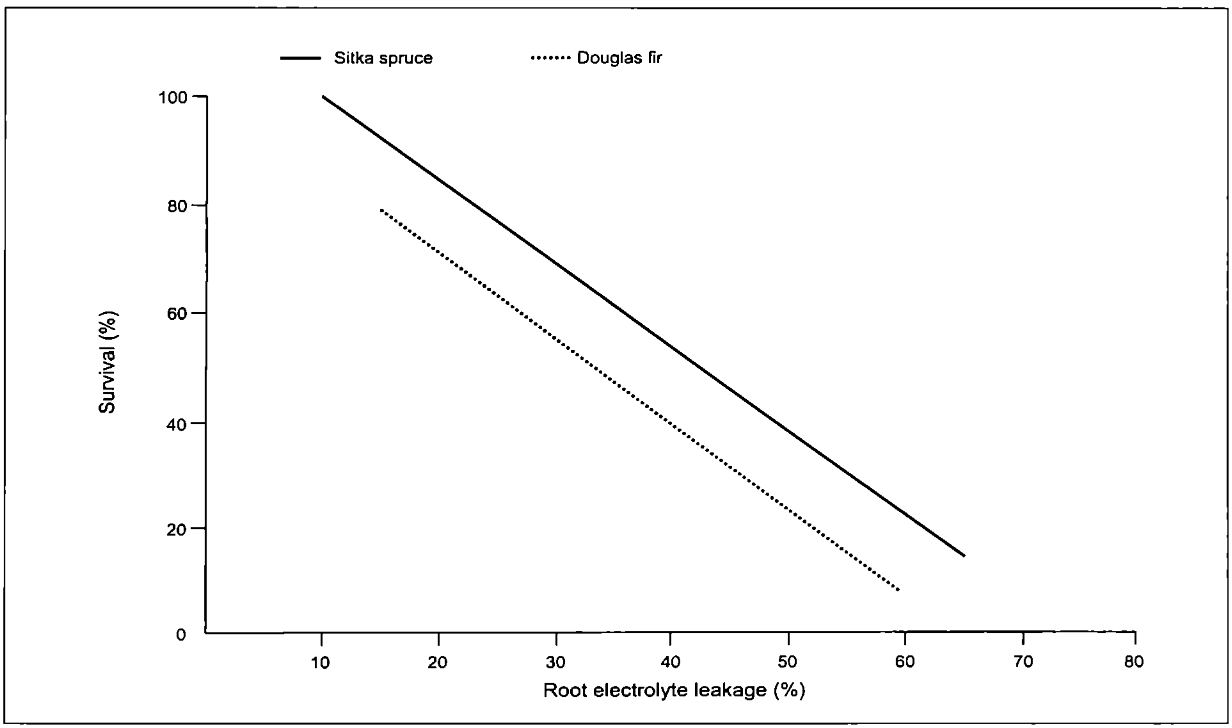

Figure 4.2 *Relationship between root electrolyte leakage and 2-year survival of Sitka spruce and Douglas fir 1u1s (from McKay and Mason, 1991).*

Table 4.1 Baseline root electrolyte leakage values expected for major species when fully dormant. Maximum REL values should predict more than 90% survival

Species	*Baseline when fully dormant (%)*	*Maximum acceptable REL values for different plant types*	
		Bare-root with good root:shoot ratios	*Cell-grown*
Pines	10–15	25	30
Spruces: QSS, VPSS, NS	10–15	25	30
Spruces: RSS, WSS	15–20	30	35
Douglas fir	15–20	30	35
Larches	10–15	30	35
Firs: NF, GF	15–20	30	35
Ash	5–10	25	30
Rowan, oak, beech, lime	10–20	30	35
Birch, cherry, Norway maple	20–30	35	40

The REL levels associated with good survival and growth in Table 4.1 have been taken from datasets derived from experiments on cultivated and fenced restocking sites in the North York Moors. These sites are prone to spring drought and poor quality plants readily become desiccated and die. Sites in wetter, western areas are less prone to drought and poor quality plants are more likely to survive than they would be in the east. Consequently the maximum acceptable REL values are pessimistic – they assume trees will be planted and then exposed to spring drought (McKay and White, 1997).

Some commercial nurseries carry out testing to monitor dormancy of plants during the lifting season. The test is fast enough to assist decisions on time of lifting and suitability for cold storage. REL can also be used as a form of quality control on large batches of plants as they leave the nursery.

Electrolyte leakage testing has been used to determine the frost hardiness of shoots and roots for different species (Figure 4.3, Figure 4.4). There is considerable variation between species and even between provenance within the same species (McKay and Perks, 1997).

Further testing may be desirable if a problem with plant quality has developed during transportation and storage between the nursery and the planting site. Plants with physiological damage often look healthy until dieback and losses become evident after planting. It is too late to measure REL and identify reasons for plant failure after planting.

An independent service has tested planting stock quality at the Forestry Commission's Northern Research Station since 1993 (Plate 19). Samples of 10 or 15 plants are sent in by customers using overnight postal delivery. Reports can be provided within 2 days of receipt for urgent cases

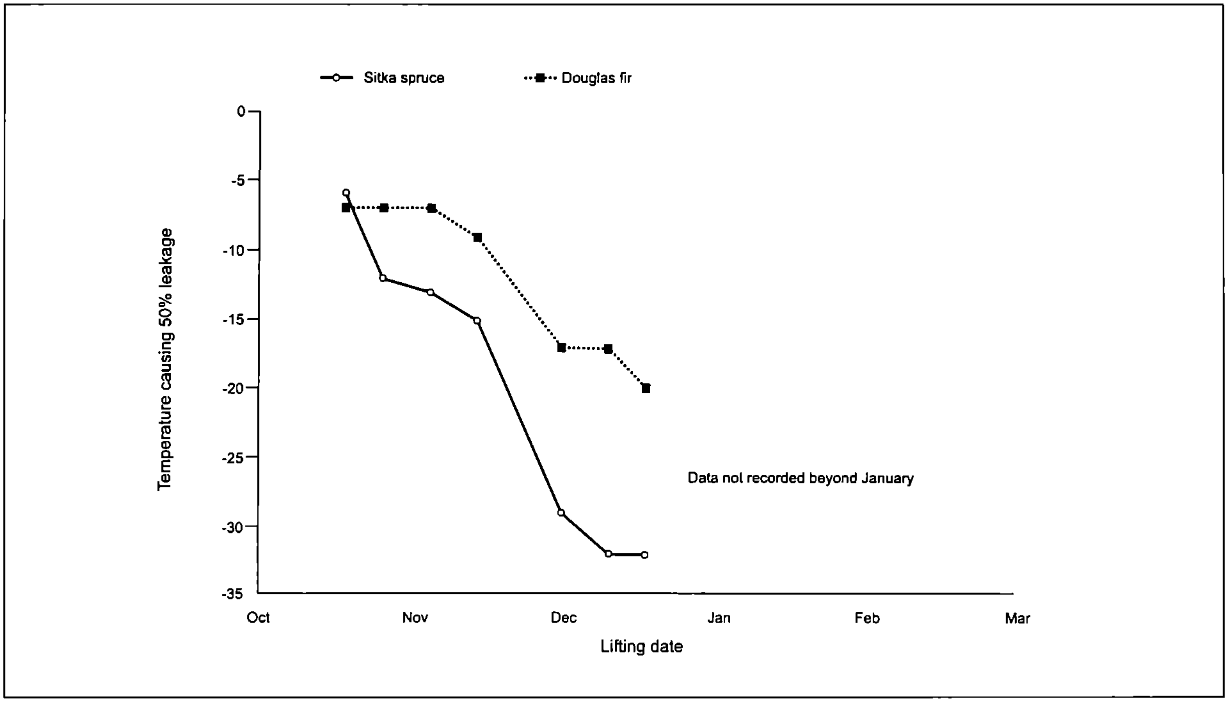

Figure 4.3 *Shoot frost hardiness for Sitka spruce and Douglas fir.*

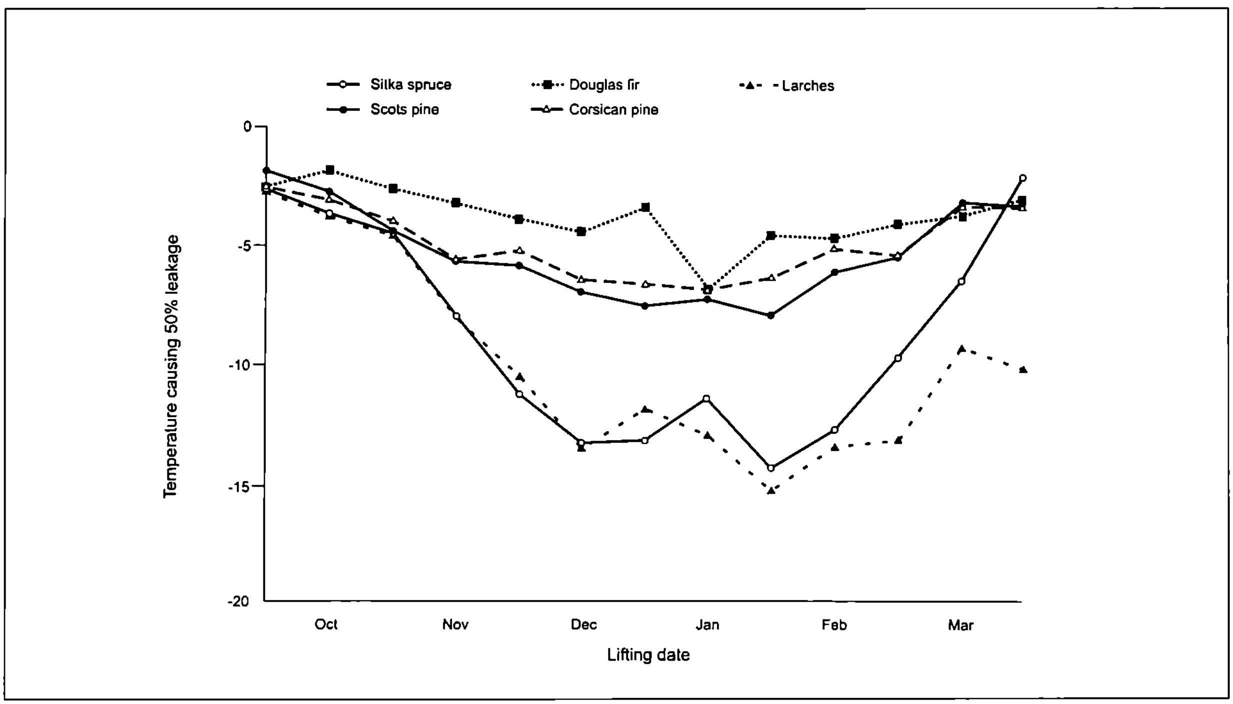

Figure 4.4 *Root frost hardiness for a range of conifer species (after McKay, 1996).*

(Edwards, 1997). Managers can use reports on plant quality to make decisions about whether trees should be planted. It is be better not to plant damaged trees which could have poor survival and lead to increased beating-up and weeding costs.

Needle and shoot electrolyte leakage

REL testing only provides information about root condition. Roots are most susceptible to physiological damage so normally they are the best part of plants to use as a predictor for survival. However, early frosts can damage shoots without affecting the condition of roots when trees are in the nursery; needle and shoot electrolyte leakage can be used to detect frost damage.

Electrolyte leakage is measured using samples of needles and shoots in the same way as for roots. Needle and shoot leakages are much lower than REL values, typically between 1 and 9% for undamaged plants.

Needles can be damaged by overheating, frosting or deterioration during storage. Leakage tests can be used to predict whether needle loss is likely to occur, values >15% are associated with severely damaged needles.

Conifers can recover from needle loss so long as the remaining buds flush and produce new shoots. Damage to buds and shoots usually results in dieback of plants. This form of damage is normally quite obvious but should be confirmed by sectioning stems.

Root moisture content

The fine roots of seedlings lose moisture very rapidly, much faster than shoots. Root moisture content (RMC) is therefore a much more sensitive measure of desiccation damage than shoot moisture content or shoot water potential. Several studies have shown that RMC can be closely associated with survival and growth after planting (Figure 4.5) (Tabbush, 1987a; Sharpe and Mason, 1992; McKay, 1996). The drawback of using RMC as a predictor for survival is that it does not detect any other form of root damage and cannot distinguish between roots which have been desiccated and then rewetted (e.g. through dipping in soil and water slurries).

Fine root moisture content is usually between 350 and 450% of oven dry weight when seedlings are lifted from nursery beds. Roots begin to lose moisture seriously as soon as they are exposed to air which has less than 95% humidity. Moisture loss is rapid when conditions are windy and dry. Polythene bags and containers are used for storing plants because humidity inside rapidly increases above 95% and so prevents further moisture loss from plants. If any of the shoot remains exposed, or, if bags are torn, then moisture loss will continue.

The length of exposure time before irreversible damage occurs differs between species of tree. Sitka spruce can recover from up to 3 hours exposure to outdoor conditions whereas Douglas fir is damaged after only 20 minutes. Broadleaved species with tap roots are generally more tolerant of desiccation damage than conifers and broadleaves with fine roots (e.g. birch and alder). Ash can withstand long periods of exposure causing death of fine roots and regeneration of new roots from the tap root (e.g. Kerr and Harper, 1994).

Plant quality testing

Plant quality testing compares the condition of plants against predetermined standards for size specifications, physical condition and physiological quality (Edwards, 1998).

REL tests give most information about potential survival and growth for plants so these are most commonly requested. Little extra time is needed to describe height, root collar diameter and usability for a sample of plants. These assessments can be compared against specifications given in the British Standard. In some cases these measurements are

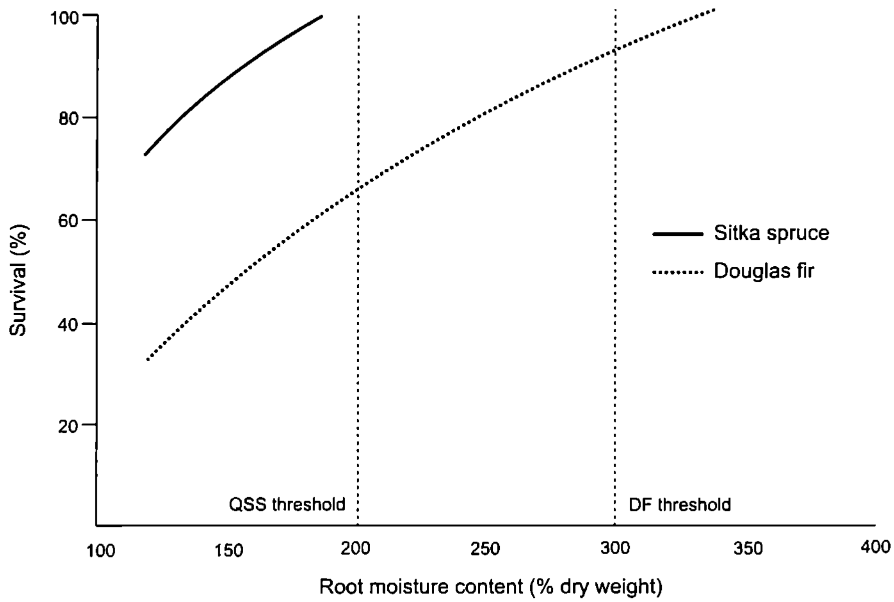

Figure 4.5 *Relationship between root moisture content and 2-year survival of Sitka spruce and Douglas fir 1+1s (from Tabbush, 1987a).*

important, plants with damaged shoots or few roots can have acceptable REL values but may not be suitable for planting.

Needle leakage, root moisture content, root:shoot ratios and root growth potential can all be carried out on request. Information about the full range of tests that are available can be obtained from the Northern Research Station. Some commercial nurseries have now begun their own testing and may be willing to test samples of plants for their customers.

Chapter 5

Suitability of various plant types for different planting sites

The suitability of different types of planting stock will be constrained by their size, physiological condition and cost:

Table 5.1

Constraint	*Example*
Planting site conditions	Small seedlings would not be suitable for planting sites with strong weed competition; use larger transplants instead
Planting date	Bare-root plants should not be used for planting in September; cell-grown stock should be used instead
Cost	Large broadleaved whips are expensive to buy from nurseries; smaller transplants are less expensive and give better survival and growth

The examples above present straightforward decisions about single constraints. Real situations will involve a number of constraints that must be evaluated together. For example, the cost of handling and planting will increase as plant size increases, however, this should be a lesser consideration than choosing the correct plant type for the site.

Nurseries normally charge a premium for larger planting stock (e.g. 1u1 v. 1+0=, Plate 4). Taller plants must be sturdy and have root systems which have grown well in proportion to shoots. When this is the case (Chapter 3), taller stock should retain a height advantage over smaller plants after outplanting (Plate 10).

Tall plants tend to have lower root:shoot ratios than small plants. Consequently, the relative height growth of shorter plants (as a % of initial size) will actually be better than with tall plants. The initial size difference between forestry transplants and tall whips (≥1 m) will even out during the establishment phase (Hodge, 1991).

Nursery managers should choose appropriate growing regimes to achieve sturdy plants with good root:shoot ratios (Chapter 2). Not all plants in a nursery bed match the specifications required for height, root collar diameter and root form. Substandard plants should be culled during the grading process. Many studies have shown the disadvantages to survival and growth from using culled plants (e.g. Rikala, 1989; Figures 5.1 and 5.2). Buyers should satisfy themselves that nurseries achieve the correct standards of grading (Chapter 7).

Large root systems take longer to plant properly by hand; good soil:root contact is necessary to realise full growth potential of larger plants. Machine planting normally benefits from a

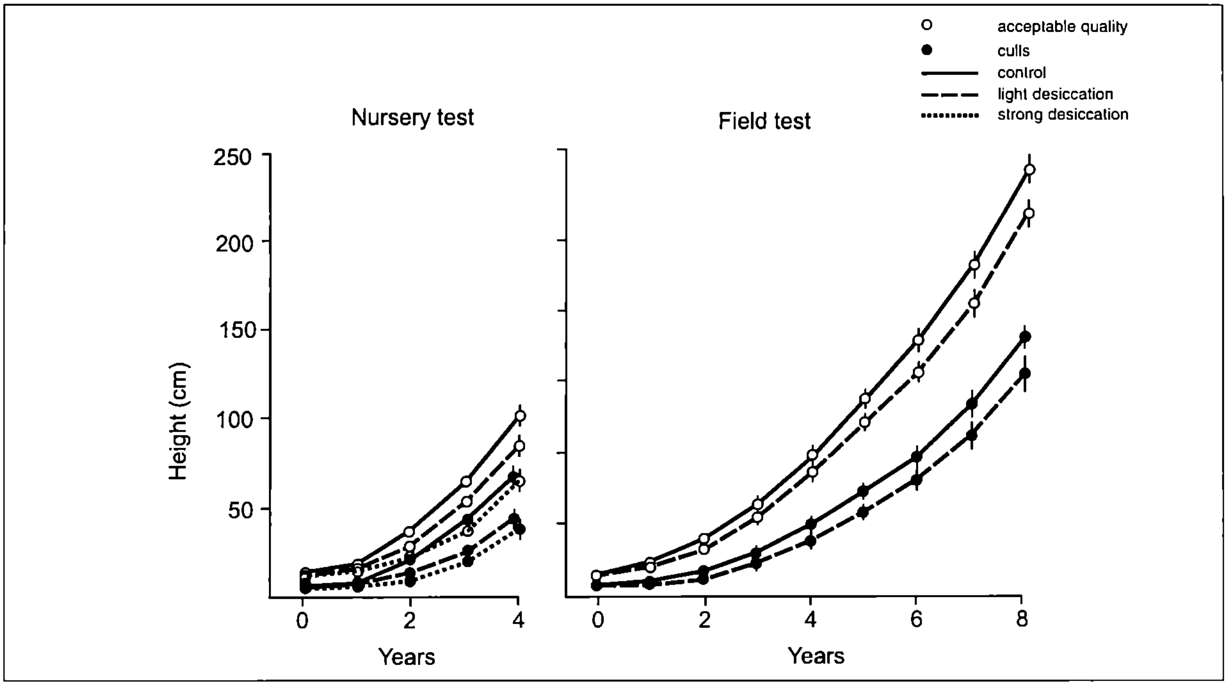

Figure 5.1 *Height growth of Scots pine transplants graded as acceptable quality or culls and exposed to desiccation treatments (from Rikala, 1989).*

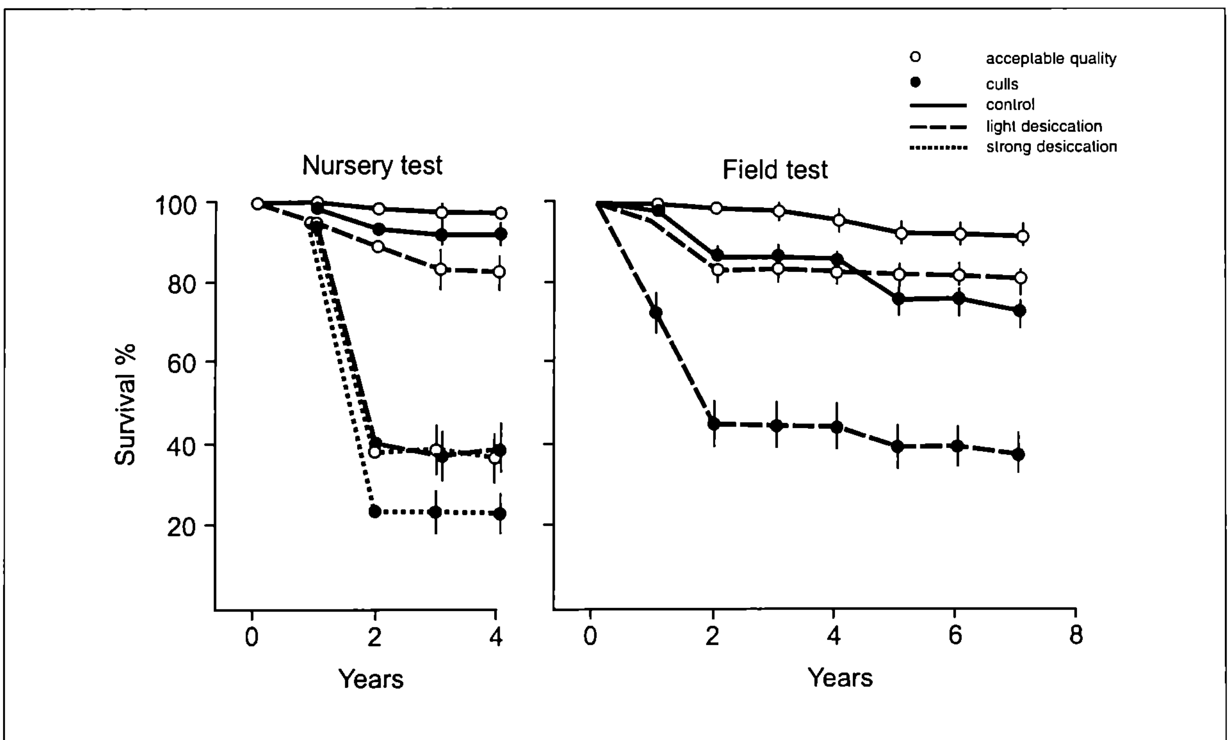

Figure 5.2 *Survival of Scots pine transplants graded as acceptable quality or culls and exposed to desiccation treatments (from Rikala,1989).*

standard stock size to ensure correct planting depth (Drake-Brockman, 1995). Buyers should check on machine specifications before ordering plants from the nursery.

The following recommendations assume that nurseries have achieved the best size specifications and physiological quality for the following plant types.

Bare-root seedlings up to 1 year old

One-year-old seedlings are only appropriate as planting stock for fast growing broadleaves or larches. The plants are smaller than 2-year-old stock and should have been undercut and wrenched during the summer (i.e. 1+0=). There can be significant benefits to survival and growth from undercutting and wrenching broadleaves that produce substantial tap roots, such as oaks and ash. The smaller seedlings may be preferred to larger plants on exposed sites but they can be more susceptible to deaths from browsing, *Hylobius* damage and weed competition. All sites planted with small sized plants should be cultivated and weed-free to ensure high levels of survival and good rates of growth.

Bare-root transplants and undercuts up to 4 years old

Transplants and undercuts are better plant types than undisturbed 2-year-old seedlings because they have better root:shoot ratios. Transplanted seedlings and undercuts both benefit from wrenching, which improves their physiological condition and root:shoot ratio. There are significant survival and growth benefits to be gained from using Douglas fir, larches and pines that have been undercut and wrenched. Undercutting and wrenching is less critical for spruces and fine rooted broadleaves (e.g. birch and alder).

The size of plants depends on the species and the nursery in which they were grown. Smaller size classes (20–40 cm) should be chosen for drier and exposed sites to avoid desiccation. Choose larger size classes (40–60 cm) for wetter, less exposed and fertile sites to withstand weed competition. Where soils have high water tables they should be cultivated to avoid planting large plants into anaerobic conditions.

Older plants have large root collar diameters (>5 mm) that can withstand browsing and *Hylobius* damage more readily than smaller seedlings. Larger size classes (e.g. 40–60cm height, >5 mm diameter) should be preferred for upland restocking sites, particularly when browsing damage is expected.

Cuttings

Unrooted poplar and willow cuttings are normally chosen for planting short rotation coppice. Cuttings are relatively cheap and can be machine planted. Large rooted poplar cuttings and willow sets are preferred for wide spaced stands of poplar and cricket bat willow.

Planting sites for poplar and willow are typically moist and fertile with rank vegetation growth. Ground must be cultivated and kept weed-free for short rotation coppice. Larger cuttings and sets are less susceptible to weed suppression and may be pit planted and spot weeded. Specifications for plants are described in the British Standard for poplars and willows (1984b).

Genetically improved Sitka spruce should be planted on better quality sites with low Windthrow Hazard Class to realise the full potential from gain in vigour (Lee, 1992). Bare-rooted cuttings grow well on these sites and tend to be less susceptible to browsing and *Hylobius* damage than smaller C1+0 rooted plugs. One-year-old cuttings are normally 15–25cm tall whereas 18-month-old C$1\frac{1}{2}$+0 will be taller (25–40 cm) and should be ordered as larger z rooted plugs (e.g.110–175cc cells). The larger rooted cuttings should be used for restocking and weedy areas where cultivation and spot weeding is essential. On uncultivated ground, plagiotropic shoots can become entangled with brash or suppressed by vegetation, which has a detrimental effect on tree form.

Cell-grown seedlings

Cell-grown plants are particularly suitable for situations when it is necessary to extend planting seasons beyond the recommended period for bare-root stock. Cell-grown seedlings offer better survival and growth than bare-root material when they are planted between July and October.

Good quality bare-root plants will have just as good survival and growth as cell-grown plants when they are carefully planted at the correct time of year (Hodge, 1991; Kerr and Jinks, 1995). Cell-grown plants grow to similar sizes as large one-year-old bare-root seedlings. Because they are the same size, the same disadvantages apply as to bare-root seedlings and one-year-old undercuts; they are more susceptible to death from browsing and *Hylobius* damage than large bare-root plants. Cell-grown plants suffer less from the shock of transplanting than bare-rooted plants, root systems remain undisturbed in plugs and regenerate rapidly following planting. As a consequence, the relative height growth of cell-grown plants is better than bare-root stock in the year following planting.

Several studies have shown that cell-grown stock is more resistant to rough handling and desiccation than bare-rooted material (Kerr, 1994; Kerr and Jinks, 1995). However, plugs are slightly more expensive to buy and transport than bare-root material. Prices depend on the size of order and the nursery concerned.

Cell-grown cuttings tend to have larger diameters than cell-grown seedlings with equivalent height. This can allow cuttings to recover more successfully than seedlings from damage caused by *Hylobius*.

Chapter 6

Choice of planting date

Planning plant delivery and planting

Plant requirements should be determined before the beginning of the planting season. It is recommended that delivery dates are agreed with the nursery when plants are ordered. Procedures for ordering plants are covered in Chapter 7. However, managers must first understand the best combination of lifting date, storage treatment and planting dates to ensure maximum survival for their conditions.

Planting dates can now be chosen by using a decision tree based on research recommendations (Figure 6.1). It will be necessary to adapt these recommendations to local experience with sites and climatic conditions (Chapter 10, 'planting conditions'). The decision tree was produced to assist with the *planning* of planting programmes. There should always be flexibility to allow some departure from the recommendations if planting is delayed by unseasonal weather.

Choice of planting dates

Back-end planting should only be considered for moist, sheltered and frost-free sites. Trees should be planted into warm soils (>6°C) which allow at least 4 weeks of root growth before the beginning of winter. Back-end planting is appropriate for those bare-root stock that are suitable for lifting and planting between late October and mid-November (Figure 6.1) otherwise it is better to choose cell-grown stock. Avoid planting cell-grown plants before Christmas on peaty sites as they can be susceptible to frost heave during the winter. Temperatures in mounds often fall well below temperatures in the original ground surface (Lindström and Troeng, 1995).

December and January planting is only recommended for a limited range of species in milder, sheltered areas of Britain where frost and cold-induced desiccation are rarely experienced (Figure 6.5,). Spring planting should begin when soil temperature begins to increase in February or March. Fresh lifted or cold-stored stock are both suitable for planting before April (Figure 6.4). Plant exposed, high elevation sites from mid-March onwards.

Cold-stored and cell-grown stock should be used from early-April until mid-May depending on region and storage recommendations. Cell-grown stock can be cold stored safely so long as it is fully dormant. Only cell-grown stock should be considered for planting beyond the middle of May and then only when site conditions are appropriate.

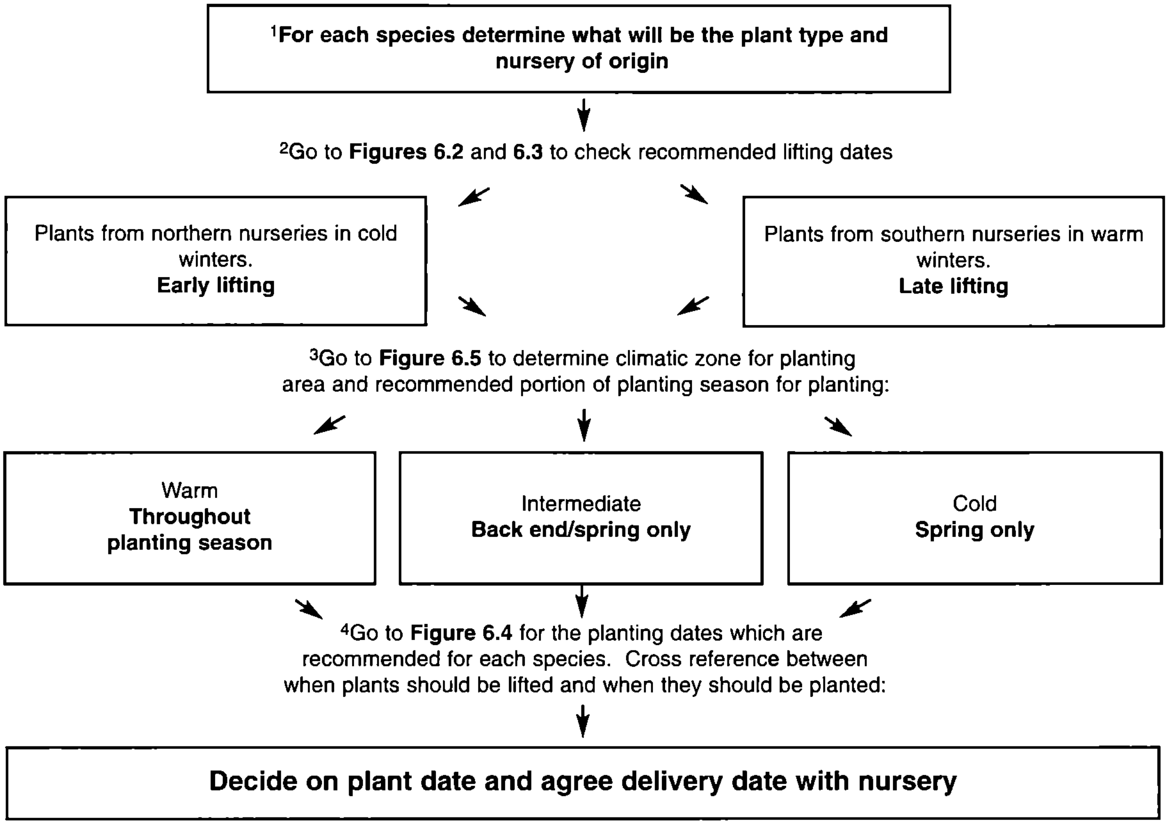

Figure 6.1 *Decision tree for best choice of planting date.*

Notes:

1. It is critical for bare-root plants to be lifted when they are dormant. There is no restriction on lifting cell-grown trees so long as safe handling and storage can be guaranteed. Southern nurseries tend to have longer summers and milder back ends than northern nurseries. Onset of dormancy will be at least 2 weeks earlier in the north, although this may be modified by unseasonally warm back ends. It is assumed that northern nurseries are located above the Mersey/Humber line.

2. Recommended lifting dates have been determined from experiments using physiological tests to measure dormancy. Safe periods assume average years when a specific species has become sufficiently dormant for direct planting or cold storage. REL testing at the nursery gives greater precision than recommended dates. The roots of some species can remain active throughout very mild winters and plants can not be freezer-stored in this condition (Chapter 8, 'cold storage').

3. The potential for survival and growth of trees depends on when they are planted. Timing is more critical for some species than others. The risk of damage increases as trees are exposed to longer periods of cold weather. Regional differences between the warmth of the growing season (>6°C) are shown in Figure 6.5. These are relevant to planting because soils in areas with longer growing seasons tend to warm up earlier and cool down later. The figure shows generalised climatic zones for Great Britain, more detailed maps are available from the Macaulay Institute (Scotland) or Rothamsted Experimental Station (England).

4. Recommended planting dates are based on experimental evidence collected over a number of planting seasons with bare-rooted plants. Recommendations for specific species must be tailored to meet the regional differences in the planting season shown in Figure 6.5. The choice of planting date should also be determined by referring back to suitable dates for fresh lifting and cold storage. Local knowledge of site variability is essential for deciding final planting dates (see next section). Cell-grown plants can be planted outside the periods recommended for bare-root plants but site conditions are still critical for good plant survival (Chapter 5, 'cell-grown seedlings').

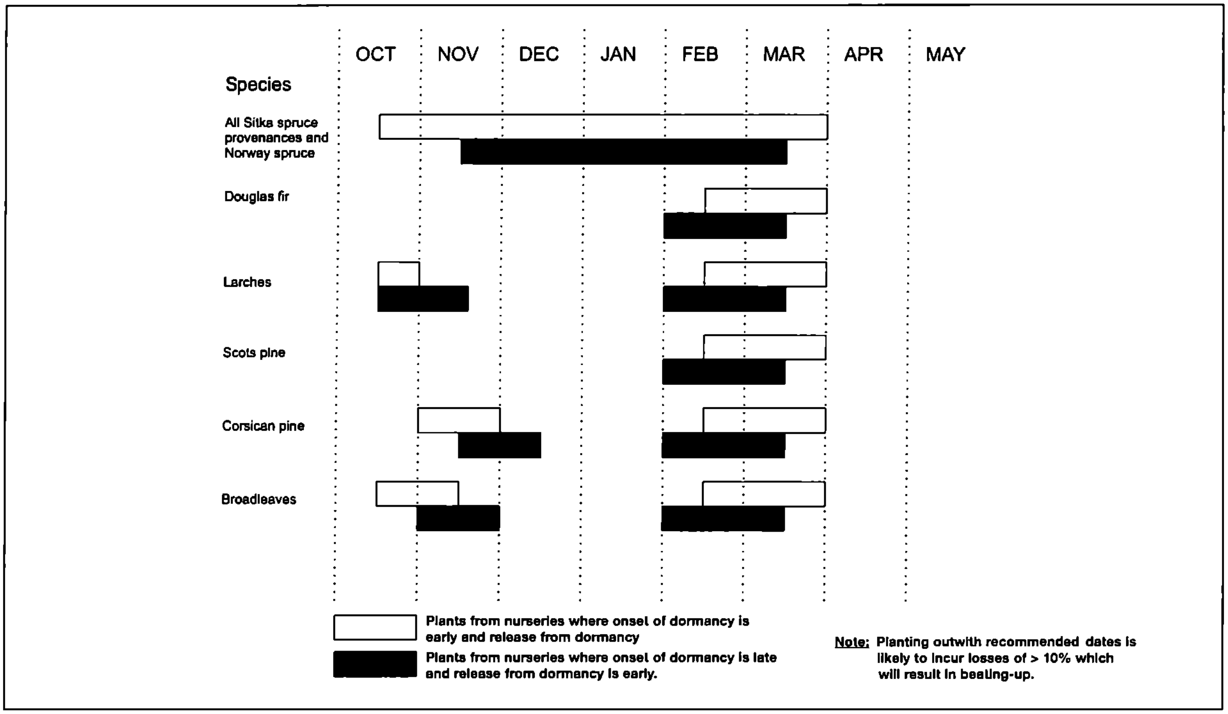

Figure 6.2 *Recommended dates for fresh lifting and immediate planting.*

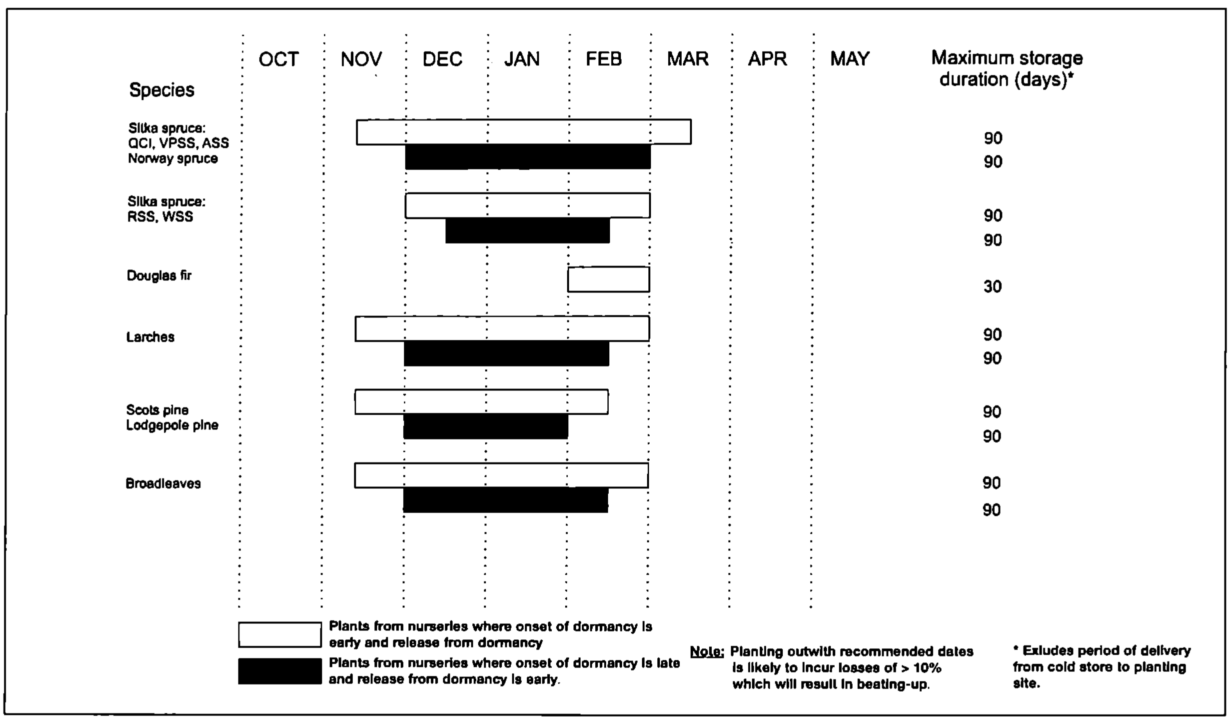

Figure 6.3 *Recommended dates for lifting for cold storage.*

Table 6.1 Planting dates recommended for different climatic zones

Climatic zone (Figure 6.5)	*Back-end plant dates*	*Spring plant date*
Warm	mid-October throughout winter to mid-April	
Intermediate	mid-October to mid-November	February to May
Cold	not recommended	March to mid-May

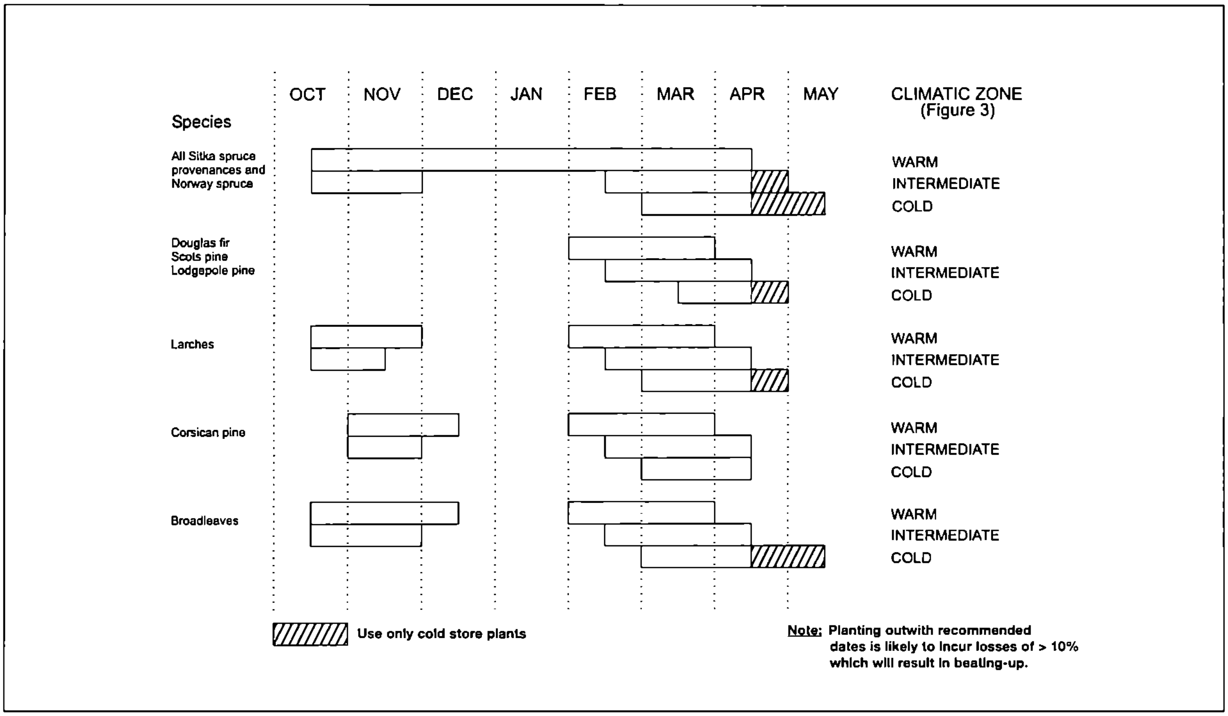

Figure 6.4 Recommended planting dates for bare-root stock.

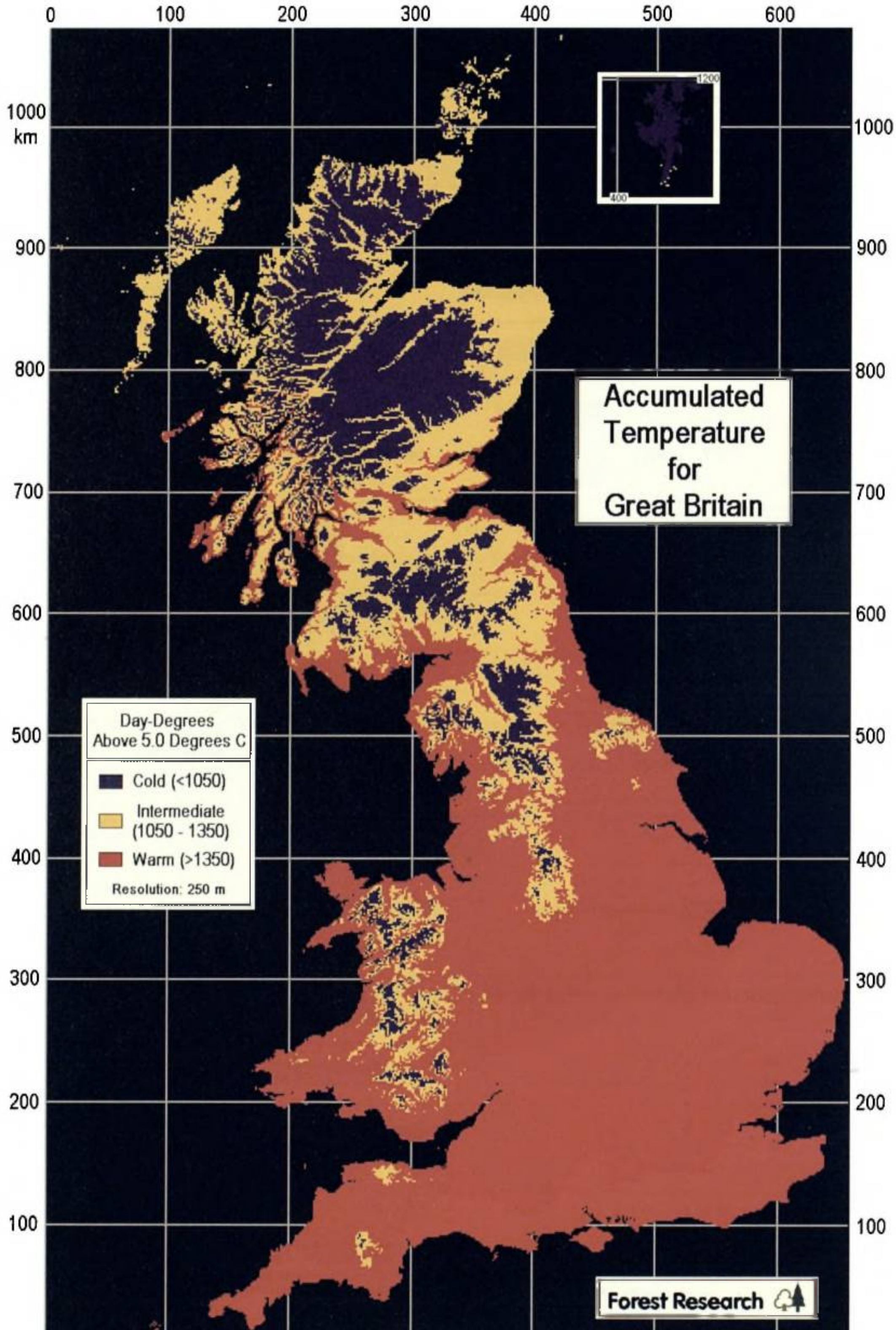

***Figure 6.5** Recommended dates for planting bare-root stock in different climatic zones.*

Chapter 7

Ordering plants and receipt of deliveries

Ordering plants

Nursery catalogues are normally available by early September and plants should be ordered as soon as possible thereafter when nurseries still have good supplies of stocks. Specialised seedlots will need to be sown to order. Those nurseries which regularly sow small, specialised seedlots can arrange seed collections. Common species and origins will be listed in catalogues.

Plants should be inspected in the nursery before placing any orders. Nurseries will normally welcome visitors or may agree to send samples of plants to customers for approval. The price and conditions for delivery of small orders of plants may be agreed at the nursery. Larger orders can be tendered using standard forms provided by the HTA and these forms should specify all details necessary to guarantee that good quality stock is supplied.

These include:

- specifications for size and condition (BS3936, Part 4);
- country where grown;
- notice of delivery sites and dates and times for delivery;
- plant handling (in accordance with recognised procedures and publications);
- complaint procedure and right to return;
- payment conditions.

Special requirements may be added depending on facilities provided by the nursery:

- seed origin;
- insecticide treatment;
- packaging and type of pallets (assume always in co-extruded bags unless cell-grown);
- labelling (lift, grading and storage dates);
- root pruning;
- other requirements (e.g. inoculation of alders for planting on reclamation sites with *Frankia*).

Plants will only be supplied when tenders have been accepted and an order is received by the nursery.

Advice notes

Nurseries will issue advice notes to accompany deliveries of plants. Before deliveries are unloaded checks should be made to ensure that the description and quantity of plants matches the order. Any discrepancies must be clarified with the nursery before a decision is made whether to accept or reject loads.

Points to check on advice notes:

- quantities for different species and seed origins;
- plant type and size specification;
- insecticide treatment;
- plant passport number (when applicable).

Packaging and transport systems

The nursery trade considers that black plastic bags are the minimum requirement for packing bare-root seedlings (Anon., 1996). However, these bags only offer protection against drying out and do not stop overheating. Most forestry operations now specify co-extruded black and white bags; these offer most protection from overheating (Tabbush, 1987b). Bags must be sealed and free from damage to ensure moisture is retained within the plants. Large broadleaves often have exposed shoots and roots wrapped in bags. Plants will lose moisture through their shoots even without foliage (Insley, 1979) so this form of packaging is only suitable for short-term transportation. Large bags are available or a second, standard-sized bag can be inverted over shoots for longer-term storage.

The best handling systems have been designed to minimise rough handling and mechanical damage. Loose bags are still the standard means of loading and unloading plants from lorries. However, it is possible to request some loads in crates or potato boxes since plants are at least risk from damage when they are transported in bags inside boxes. Individual boxes can then be stacked on pallets which will need to be unloaded by forklift. Risk of damage to plants becomes greater as the amount of manual handling increases during unloading. Managers are advised to minimise manual handling for this reason.

The Forestry Commission tested a number of box designs for packing systems during the mid 1980s (Dauncey *et al.,* 1989). Two systems remain in operation and, examples of boxes used at Wykeham nursery are shown in Plate 21. Bags should not be stacked in layers more than four deep to prevent plants becoming crushed. The numbers of layers will depend on the size and weight of plants delivered, heavy bags can be separated using steel cages with shelving to pack several layers of bags.

Cell-grown plants are normally supplied as cling-wrapped bundles in flat packs or inside boxes (Plate 26). Cages may be used to carry plants when they are too large for boxes. The cages may be cling-wrapped when actively growing plants are transported to avoid moisture loss. Some Scandinavian box systems are used to support plants on planting harnesses for cell-grown plants.

It is very important for supervisors to ensure that boxes and bags are passed, never dropped or thrown. The same principles apply to cell-grown plants, although there is less likelihood that heavy packs of cell-grown plants will be thrown around.

Unloading deliveries

Deliveries of plants should be expected well in advance of arrival so that managers can arrange sufficient manpower and equipment to unload deliveries safely and without roughly treating plants. The nature of the loads should come as no surprise to the recipient because the system for packaging should have been agreed at the time plants were ordered.

Checking deliveries

Bags should be counted as they are unloaded and checked against the advice note for the load. All bags should be in good condition with no tears or signs of being crushed. There should be sufficient air space in bags to cushion plants and there should be no obvious signs of damage such as boot marks or severe creasing of the polythene.

Many nurseries use a system of labelling bags so that plants can be checked back to lifting and grading dates. Information accompanying the bags should be recorded at the time of receipt of plants and quoted to nursery managers in event of any queries.

As soon as is practicable, bags should be randomly sampled to make checks on the planting stock. A minimum of five bags per consignment will give a good overall impression of condition. The condition of plants should meet British Standards and any others agreed when plants were ordered.

Checks on deliveries provide a subjective impression about plant quality. Detailed reports on the size specifications and physiological condition can be obtained by sending samples for Plant Quality Testing at the Forestry Commission's Northern Research Station or to other nurseries who offer this service. An outline checklist for deliveries is provided on page 30. This can be amended to meet particular needs, e.g. if planting alders on a reclamation site, check that the roots have nodules present to ensure good early growth.

Samples from the same batch of plants can be planted in an observation plot to provide a check on vitality, a comparison with subsequent deliveries and a link with eventual forest performance. A fenced area of cultivated ground close to delivery points should be chosen for this purpose. The samples should be given labels which correspond with checklists and advice notes.

Complaint procedure

Complaints should be rare. Nurseries should supply plants according to the specifications that were given at the time of ordering. If stock is unavailable then substitute plants may be accepted by mutual agreement.

Written complaints to nurseries should be made within 7 days from receipt of the plants. The purchaser has the right of return when plants are not supplied to the agreed specification. Rejected plants are returned at the supplier's expense.

CHECKLIST FOR DELIVERIES OF PLANTS

Date

Advice Note number				
Name and address of nursery				
Plant	species			
	origin			
	number			
Check for bag from each species: 3 = satisfactory, x = poor				
Are bags in good condition? comment:				
Is inside of bag dry and cool? comment:				
Is bundle in good condition? comment:				
Check on numbers of plants in each bundle ✓ = satisfactory, x = poor				
Are numbers of plants correct? comment:				
Are sizes what were ordered? comment:				
Do plants have good fibrous roots in proportion to shoots? comment:				

Chapter 8

Conditions for temporary storage

Types of temporary stores

Plants are commonly stored between lifting and planting. Large numbers of plants can be safely stored for long periods in nurseries to provide the flexibility to lift plants when they are dormant and to despatch them when conditions are suitable for planting. Plants may be held at the nursery of origin or by secondary nurseries that have bought in plants.

The condition of plants must not be allowed to deteriorate during storage. Plants are most resistant to storage and handling damage when they are fully dormant. Safe lifting dates for cold storage are given in Figure 6.2, during this period some species can tolerate up to 90 days of cold storage without significant changes to their physiological condition.

Plants are much more susceptible to damage when they are stored in ambient conditions such as sheughs or bags under canopy. Both these types of store are exposed to fluctuations in climatic condition.

Plants in sheughs undergo the same changes in dormancy as plants in nursery beds. Plants in bags may begin to flush earlier than plants in the ground if they are allowed to heat up.

Cold storage

Large nurseries normally invest in a facility for cold storing plants. Stores can be installed at the nursery or hired from fruit and vegetable wholesalers. Temperatures in cold stores should be maintained between +2° and -2°C. Freezer stores (-2°C) are preferable to +2°C stores for certain species (Table 8.1). Plants continue to respire above freezing and they will deplete carbohydrate reserves when stored for long periods. Deterioration is slower below freezing, but there is a risk from damage caused by freezing if temperatures are allowed to drop below -4°C (Figure 4.4).

There is very little margin for error with sensitive species, which must only be stored between -2° and 2°C (Table 8.1). If managers cannot guarantee these conditions then these species should not be freezer stored.

Storage at 2°C is recommended for those species that can be badly damaged by mild exposure to freezing (e.g. -3°C, Figure 4.4). The temperature in freezer stores fluctuates depending on how often they are opened and how many plants are contained in the store. Stores normally operate between -3° and -1°C for freezer storage or 0° to 2°C for storage above freezing.

Fluctuating temperatures should be avoided to prevent condensation and freeze-thawing in bags. Good air circulation is essential for stores to operate effectively. Refer to Figure 6.2 for the maximum periods of storage for untreated plants. Different recommendations are available for plants treated with insecticide (Chapter 9).

Direct cold stores have low relative humidity which will cause a loss of water from uncovered

Table 8.1 Temperatures recommended for cold storage. For species not listed, use cold storage unles experience shows freezer storage is acceptable

Freezer storage (-3 to -1°C)	*Freezer storage (-2 to 0°C)*	*Cold storage (0 to 2°C)*
All spruces,	Scots pine	Douglas fir
larches	lodgepole pine	noble fir
birches	ash	corsican pine
beech	maple	cherry
oak		
lime		
rowan		

plants and consequent desiccation. Plants must be stored in bags in this type of store (Plates 21, 23). Unprotected plants can be stored for short periods in jacketed or humified stores (Plate 20; Aldhous and Mason, 1994). Bags should always be used for long-term storage (Sharpe and Mason, 1992).

The safe period for cold storage depends on species and the condition of plants when they are lifted. Plants are generally most dormant in January when they have been conditioned by short days and low soil temperatures. It is safe to lift plants for short-term storage over a much wider period (Figure 6.2). Long-term storage is only suitable when plants are fully dormant and this will depend on climatic conditions at the nursery (Chapter 4). Some species can be safely cold stored for up to 3 months when they are fully dormant. For example, lift spruce in January and plant them in April, or, lift in February and plant in May.

Recommended lifting and storage windows are shown in Figure 6.2. Recommendations differ according to the amount of chilling and the rainfall experienced by plants between October and January (Chapter 4). Plants take longer to become dormant during mild, wet back ends. Plants also break dormancy earlier in milder winters when temperatures are warmer and rainfall is greater. Safe lifting dates need to be adjusted accordingly (Figure 6.2).

Good labelling helps cold store managers to decide on how long batches of plants should remain in cold storage. It should be possible for nurseries to provide lifting and storage information on each batch of plants that is sold.

Ambient storage

Ambient storage describes arrangements other than cold stores used to keep plants for short periods prior to planting. Outdoor storage in sheughs, where plants are heeled into trenches, used to be common practice. Plants are now more likely to be stored in sheds or under canopy in co-extruded polythene bags. Ambient storage should not last for more than 3 weeks, cold stores should be used for longer periods of time.

Heeling in or sheughing

Broadleaves are still commonly sheughed in bundles during November. This allows senescent foliage to fall in the nursery before plants are cold stored or placed in bags. It is very important that plants should be heeled in correctly to avoid unnecessary damage (Plates 24, 25). Part of the nursery should be chosen which has light, freely-drained soil. Waterlogged soil can damage roots of some species and bundles of plants should never be placed in drainage ditches. Wet, heavy soil causes more damage to roots when plants are lifted.

Trenches should be dug to the correct depth for the root system with a sloping back. Good soil-root contact is very important, air spaces allow roots to dry out, especially when they are in the middle of large bundles. Plants will undergo normal changes in dormancy when they are heeled in. The same recommendations for safe lifting dates will apply as for fresh lifted plants (Figure 6.2). Cold stored material can be planted later in the season than plants from sheughs.

Storage in sheds

Estate buildings can provide valuable cover for plants before they are planted. Sheds should be unheated and well-ventilated with good access for deliveries. Untreated, fully dormant plants can be stored in good condition for 3 weeks by following basic principles:

- plant the most sensitive species immediately upon delivery (e.g. Douglas fir before Norway spruce);
- always place bags upright, spaced singly with gaps of about 25 cm between. Do not stack or place in heaps;
- inspect bags regularly for signs of overheating, check by opening bags and examining bundles (ventilate bags if necessary).

Canopy storage

If no buildings are available, then some form of canopy store is preferable to leaving plants in the open. Stores in plantations give some protection from overheating and frost damage but are less secure than estate buildings. Untreated plants will remain in good condition for 3 weeks by following two additional principles to storing in sheds:

- always turn down necks to avoid rain running into bags;
- choose a dense canopy with low risk from frost and preferably on a north facing slope.

Storage in the open

Plants should only be stored in the open as a last resort. Only take enough bags from indoor/canopy stores for a days planting and return unused plants at the end of the day. Temperatures inside bags fluctuate with ambient temperature, irrespective of storage conditions. Respiration rates depend on temperature, so plants generate more heat and moisture as temperatures rise outside. Risk of fungal infection and depletion of carbohydrates is greatly increased by storage outdoors.

Some species are particularly susceptible to frost damage in bags due to low root cold hardiness. A relatively mild frost of -5°C for 3 hours can kill pine and Douglas fir during periods when they are routinely stored in bags (Figure 4.4). Hardy species can tolerate freezing but separation of frozen plants is likely to cause physical damage to roots and shoots.

The roots of cell-grown plants can suffer serious cold damage if they are stored in the open. There is less chance of freezing when bundles or trays are placed in contact with the ground. Plugs provide a certain amount of insulation to roots in the centre of bundles of plants. The trays should be arranged with no air space between them and should be surrounded by bales of straw or other insulating material.

Cell-grown plants need additional protection when they are supplied in open trays. They must be held in fenced enclosures if there is a risk of browsing damage. Enclosures should be well drained and plugs should be checked regularly and watered when needed. Boxes of cell-grown plants offer better protection from animal damage.

The same principles for canopy storage apply to stores on the hillside. Additional protection can be provided by foil laminate sheeting to reflect sunlight. This should not be draped across tops of bags but should be suspended above bags like a tent with no sidewall.

Tarpaulin covers give some degree of night frost protection if plants have to be stored in the open. Covers should be suspended over bags to avoid contact with tops of bags and then removed during the day.

Plate 20 *Humified cold store where open boxes of graded plants are stacked on pallets in the foreground. Cages of plants in the background are waiting to be graded. (51155)*

Plate 21 *Boxes used for storing plants in cold stores. The open box is only suitable for short-term storage in a humified or jacketed cold store. The bag in a box should be used for long-term storage to prevent desiccation. (51175)*

Plate 22 *Bags of plants stored in an unheated shed for a short period before planting. Note that bags are stacked upright in a single layer to prevent crushing. (51177)*

Plate 23 *Boxes containing co-extruded polythene bags stacked on pallets in a freezer store. The boxes of plants can be loaded directly by forklift as soon as they have been ordered. (39390)*

Plate 24 *Good example of heeling in. Freely drained soil, correct trench depth and profile but plants beginning to flush. (51173)*

Plate 25 *Bundles of whips heeled in ready for despatch. Waterlogging and compaction in the tractor ruts will cause root damage. (Forest Life Picture 1013288020)*

Plate 26 *Box used for delivery of cell-grown plants. Closed, waxed cardboard boxes are resistant to rainfall and desiccation. (51172)*

Plate 27 *Co-extruded bags in a canopy store. Necks of bags are turned down to prevent waterlogging. Spacing around trees is to allow air circulation. (51174)*

Chapter 9

Insecticide treatment

Methods of treatment

All trees planted on restocking sites should be treated with insecticide for protection against *Hylobius abietis*, the large pine weevil. If trees are not treated before planting then post-planting sprays can be used to apply insecticide. Post-planting sprays do not give the same consistency of protection offered by electrodyn or dipping treatments. Electrodyn treatment (e.g. Permethrin 12 ED) and dipping (e.g. 0.8 % permethrin) should give the same amount of protection for the first growing season after planting. There are six Research Information Notes (268–273) that describe current forms of protection against *Hylobius* (Heritage, 1996, 1997; Heritage and Johnson, 1997; Heritage, Johnson and Jennings, 1997 a, b; Brixey, 1997).

The full range of products with current approval for *Hylobius* protection are listed by Heritage (1996a). There has been a reduction in use of organophosphates such as gamma HCH over recent years. Synthetic pyrethroids such as permethrin offer better operator safety than organophosphates and are less phytotoxic. Experiments have shown that products containing permethrin are just as effective as products with gamma HCH. The approval of all pesticides is subject to continuous review by regulatory bodies in the UK and it is quite possible that permethrin will be withdrawn from use at some time in the future.

This Chapter will only consider how insecticides affect plant physiology and how treated plants should be handled. All recommendations assume plants have been treated with formulations of permethrin.

Handling and storing treated plants

The foliage of treated plants should be completely dry before bagging. Moisture in bags should only appear as a result of transpiration and subsequent condensation. All treated plants should be clearly identified by labelling bags with wording to the effect that plants have been treated with permethrin-based insecticide.

All personnel involved with handling treated plants should wear recommended protective clothing and observe necessary standards of hygiene. A full description of recommended practice is covered by Forestry Safety Council Guide 103. Protective clothing for dipping and planting is shown in Plates 28 and 29.

Permethrin is very toxic to aquatic invertebrates and must never be applied in the proximity of watercourses. Great care should be taken to recover all used pesticide containers, including bags used for plants, and then to ensure safe disposal in accordance with manufacturers recommendations. Dye markers are now recommended for use with permethrin during post-planting spraying. Dyes improve targeting of the insecticide and should improve the efficacy of these treatments.

Effect of insecticides on plant physiology

Insecticides must only be applied when bare-root plants are sufficiently dormant to be lifted (Figure 6.1). Treatments cause damage outside this period and cell-grown plants have been similarly affected. There is a separate, off-label approval for spraying cell-grown plants with 0.8% permethrin (Heritage, 1996a).

Some insecticides are more phytotoxic than others. Dipping in gamma HCH (lindane) prevented most root regeneration when Sitka spruce and Douglas fir were stored for only 2 weeks under canopy (Tabbush and Heritage, 1988). Dipping in permethrin was much less phytotoxic but still caused a slight reduction in plant vitality.

The electrodyn formulation of permethrin is slightly more phytotoxic than that used for dipping. It is thought that damage is caused by the cyclohexanone carrier for the insecticide. Electrodyn treated plants suffer more damage if they are cold stored prior to planting. Plants dipped in permethrin can be safely cold stored during recommended periods for lifting (Figure 6.2).

There is limited evidence to suggest that permethrin based insecticides may reduce the frost hardiness of Sitka spruce needles although this requires further investigation. However, if the recommendations in this Bulletin are adopted then insecticide treated trees would not normally be exposed to temperatures associated with freezing damage.

Recommendations for plants treated with permethrin

- **Store dipped or sprayed plants according to recommended practice for untreated plants.**
- **Never cold store electrodyn treated plants.**
- **Store electrodyn treated plants for a maximum of 14 days under ambient conditions.**

Chapter 10

Planting operations

Establishment objectives

Establishment operations must achieve desired stocking densities for the minimum amount of expenditure. This does not mean that the cheapest operation should always be chosen. It is cheaper to buy poor quality plants but they are unlikely to survive and grow well. Cash saved on plants will not cover additional costs of beating-up, protection and weeding.

Some form of site preparation is normally recommended. All ex-agricultural sites will require some form of weed control using cultivation or herbicides (Williamson, 1992; Willoughby and Moffat, 1996). Most restocking sites will need to be cultivated to achieve satisfactory stocking (Tabbush, 1988). Site preparation provides benefits to survival and growth of newly planted trees. Planting is easier on cultivated ground and subsequent operations will be cheaper (Morgan and McKay, 1996). Detailed recommendations on cultivation can be found in Paterson and Mason (1999). All establishment operations should comply with the *Forests & water guidelines* (Anon., 1999).

Managers need to have a good understanding of their sites and conditions to plan effective establishment systems. Planning should begin by July/August in the year before planting. More notice is needed in parts of the country where contractors are scarce or when large numbers of specialised planting stock are required.

Planting conditions

Planting dates should be planned according to recommendations for lifting, storage and planting (Chapter 6). Planting should begin as soon as plants are delivered. Unseasonal weather will delay planting in some years due to heavy snow or frozen ground. Under these circumstances it is better for plants to remain in cold storage at the nursery than to be delivered to the site. Not many nurseries have the flexibility to offer this facility so alternative types of storage should be considered (Chapter 8).

It is better to plant trees on ground that is clear of harvesting residues and weeds. Quality of planting has a major affect on the survival and growth of trees. There is more choice of planting position and better opportunity to ensure good soil:root contact on cultivated sites. Cultivated soil furrows should not present a barrier to planting operations and distribution of plants on scarified and mounded ground is easier than sites crossed by plough furrows.

Transporting plants

No more than a day's planting requirement should be transported to the planting site unless canopy stores are available (Chapter 8). Good handling practice should be observed during transport to the site. Transportation damage is more likely to occur on rough forest roads than on public highways. Plants transported by all terrain vehicles are especially at risk from physical damage. Bags should not be packed more than one layer deep and ties should not crush bags.

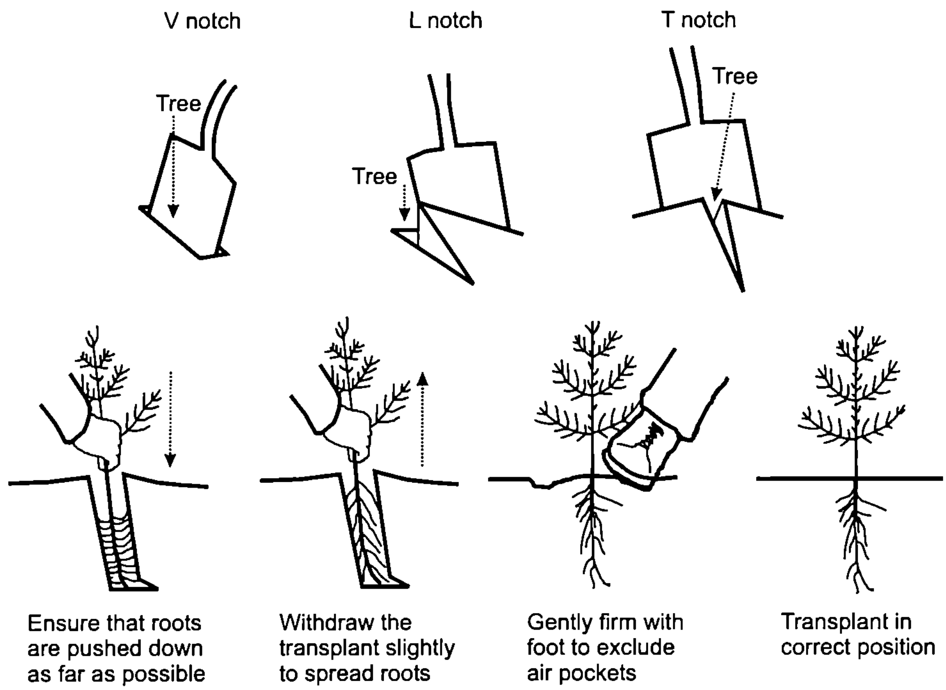

Figure 10.1 *Diagram to illustrate notch planting of trees (from Dobson and Moffat, 1993).*

Torn bags should be replaced or sealed with tape as soon as they are noticed.

Freshly lifted bare-root plants are especially sensitive to physical damage and desiccation in October and March. Supervisors must ensure that plants are handled carefully at all times of the year.

Planting tools

There is a wide range of planting tools designed for alternative plant types and different planting techniques (e.g. Plate 30). Most trees can be planted with a well-worn garden spade but it is sometimes possible to plant trees faster and more effectively by using specialised tools.

The size of spade for bare-root stock should reflect the depth and width of notch that is needed (Figure 10.1). The wide, shallow, pointed spade is suitable for plants with large root systems to be planted in stony soils (Plate 30). The deep, narrow spade is better for planting conifers on cultivated mineral soils and peats. Other types of tool may be preferred for different planting conditions (e.g. a mattock for very stony ground).

There is a wide range of tools available for planting cell-grown trees. These range from simple devices such as planting spears through to Scandinavian designs of planting tubes (Plate 30). Planters can achieve high outputs with these tools, so long as they have been correctly matched with the size of plug.

Planting bags or harnesses should match the size and type of planting stock. Choice of bag usually depends on personal preference although some handling systems require specialised harnesses and frames to hold boxes of plants from the nursery (Adam, 1996a, b). The planters in Plate 29 have used co-extruded bags as linings. Planting directly from co-extruded bags should be discouraged. Some bags are available with rigid bases that provide support to the bag walls and prevent roots getting crushed against the planter's side. This type of bag is particularly suitable for cell-grown plants as is protects plugs against breakage.

Planting technique

The first edition of *Forestry practice* in 1933 devoted 8 pages to discussion about planting techniques. Single notch planting is the most commonly used technique for planting bare-rooted trees today. This is the fastest and simplest method, and will result in good quality planting when done correctly. Other methods take longer for little gain on cultivated sites but do have a place when trees are planted directly into vegetation.

Exposed root systems are the first sign that trees have been poorly planted. All roots should be buried in the planting notch otherwise trees will suffer desiccation damage in early summer. It is critical that the notch is wide and deep enough to accommodate all the roots. It is important to choose a spade which suits the type of plant that is being planted. Root pruning by planters should not be permitted (any pruning should be requested at the nursery).

Planting depth is very important, particularly on cultivated ground. The transplant root collar should be planted 2–3 cm below ground level under normal conditions. If soil is likely to erode (e.g. fresh mounds) or to compensate for imbalanced plants then depth should be increased to 5–10 cm below ground level. Deep planting is not appropriate when there is a high water-table as this will kill the nursery root system, for example, direct planting into peaty gleys; cut turves or shallow mounds can be used to raise plants above water-table levels on these types of soils. It is important that trees are planted through shallow mounds to provide contact with the original ground surface in case of spring drought.

Transplants with J rooting or swept stems take longer to plant properly than upright plants with symmetrical root systems. The planting notch needs to be wider and more attention is needed to straighten stems. Stems should be pulled upright before the notch is firmed. Leaning stems are more prone to socketing and loosening of plants, which can lead to toppling and basal sweep of some species later in the rotation (Edwards *et al.*, 1963; Lines, 1996). Plants should be properly firmed so that there is good soil:root contact and no air spaces left in the slot.

Improvements in survival and growth can be gained by intelligent choice of planting position. Ground prone to waterlogging or desiccation should be avoided, as should stumps, rocks and brash. The top of large mounds should be avoided because this position is more exposed to desiccation, erosion and socketing. The side of mounds in the lee of the prevailing wind should be preferred when sites are exposed.

The role of the supervisor is to check and maintain the quality of planting during planting operations.

Evaluation of planting operations

The consequences of good plant care and planting are apparent at the end of the first growing season. The first beating-up assessment should be carried out in September/October of the year after planting and replacement plants should be ordered accordingly. Plants with good physiological quality and correct size specifications will survive and should grow well in their first year.

A number of surveys of restocking success have shown that quality of planting and the condition of plants were the two main reasons for poor growth and survival in the first year. Pre-planting treatments with insecticide prevent *Hylobius* damage on the majority of sites during the first year. These treatments are not effective in the second year; plants are better able to withstand subsequent damage if they have grown well in their first year.

Table 10.1 Numbers of plots required for 2 x 2 m planting sites with different areas

Area of planting (ha)	*Number of plots*
<3	10
3–9	15
10–15	23
20–30	30
>30	1 per ha

This Bulletin describes establishment systems which regularly achieve more than 90% survival for Sitka spruce and more than 80% survival for other species on difficult restocking sites. If managers follow these recommendations they should not expect to beat-up sites unless severe browsing or weevil damage had occurred.

Desiccation damage, plant failure and poor growth can be minimised by adopting best practice for plant selection, storage, handling and planting. Losses of at least 10% must be expected if recommendations are ignored. Losses will be cumulative; if a number of recommendations are ignored then more plants are likely to fail.

Additional costs will be incurred as soon as losses exceed 10% and sites need beating-up. Beating-up is usually accompanied by additional weeding and supervision. If no beating-up takes place then the value of timber can suffer from uneven spacing. Understocked sites produce lower volumes of wood and poorer quality timber than fully stocked sites.

Survey methods

The success of establishment can only be judged by systematic surveys of planting sites. Beating-up requirements are commonly assessed towards the end of the first and second growing season. The number of survey plots will depend on the area that has been planted (Table 10.1). Circular or square 0.01 ha plots are suitable for 2 m spacing (25 planting positions); larger plots will be required for wider spacing.

It is better to lay out positions of plots along transects on a map before visiting the site. This ensures that the whole site is surveyed without bias. Walk along the transect and record the number of trees at regular intervals according to the number of plots required.

Surveyors should record details about species present in mixed plantings. Other information can be collected to identify the main reasons for understocking. It is necessary to know whether understocking was caused by plants dying or by incorrect plant spacing. Gaps in crops can be rectified but it is impossible to adjust wide spacing by beating-up.

Managers should decide whether natural regeneration can be accepted as a replacement for planted trees where it occurs. Suitability of different species will depend on what objectives have been agreed for the site. Regeneration sometimes causes overstocking and respacing may be required.

Beating-up will be necessary where losses exceed 10% across the whole of the site. Sometimes losses are unevenly distributed and beating-up is only necessary in certain areas of the site. In these cases the numbers of plants needed must be adjusted accordingly.

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