A Guide to Forest Tree Species Selection and Silviculture in Ireland

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Foreword

The last fifteen years have seen dramatic changes in the forestry sector in Ireland, with the private sector now the dominant force in afforestation with 12,000 new forest owners. Over this period more than 180,000 ha have been established in the private sector. This and other changes have created an enormous need for research, training and information services.

This publication is the first comprehensive guide to species selection in an Irish context since M.L Anderson's *Selection of Tree Species* in 1950. The authors, all employees of Coillte, have enormous experience in species selection and silviculture. They have done an excellent job in bringing together this experience and in distilling the associated literature in this work. Such in-depth knowledge is a tremendous resource for the thousands of new forest owners in Ireland. With a national target of a further 600,000 ha of afforestation by 2030 this publication will greatly assist the achievement of the national afforestation programme and greater species diversification. In addition, the guidelines presented will help to inform species selection decisions on the 6-8,000 ha of reforestation undertaken in Ireland every year.

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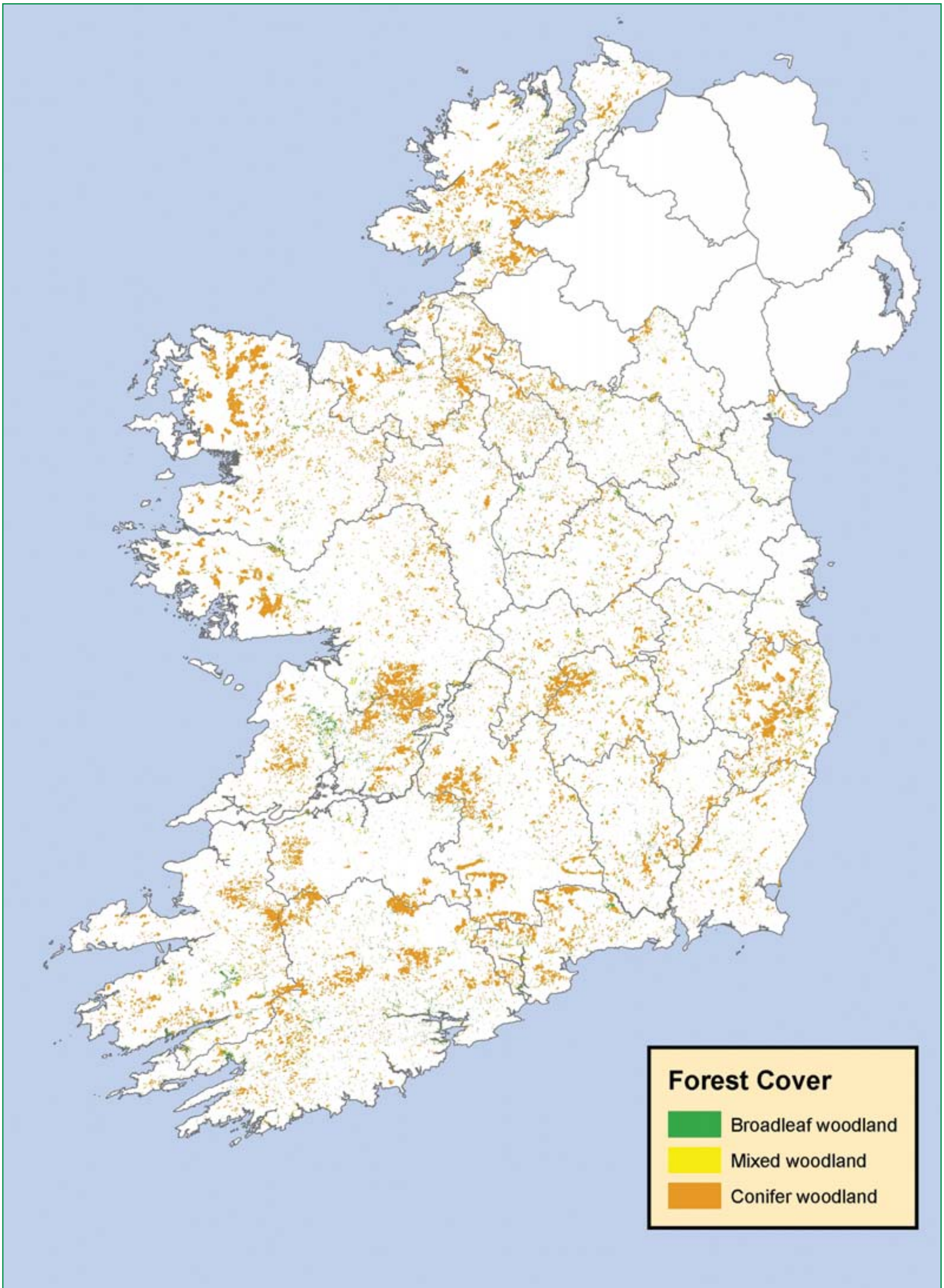
Section 6.3 on native trees and shrubs is based on *Our Trees: A Guide to Growing Northern Ireland's Native Trees*, compiled and edited by the late Dinah Browne and published by Conservation Volunteers, Northern Ireland, on behalf of the Northern Ireland Trees of Time and Place Group. The original publication was edited and reproduced as part of the outreach programme of the People's Millennium Forests project. Coillte manages this initiative, financed by AIB, the National Millennium Committee and the Department of the Marine and Natural Resources, in association with the Woodlands of Ireland Group.

The text on native species and shrubs in Chapter 6 was revised and edited by Dr Marian Coll with help and advice from the following:

The late Ms Dinah Browne, Mr John McLoughlin, Dr Declan Little, Dr Aileen O'Sullivan, Mr Mick Doyle, Mr Derek Felton, Dr John Cross, Mr Pat Doody and Ms Monica Murphy.



Distribution of coniferous and broadleaved forests in Ireland (2003).

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Ireland’s climatic conditions are ideal for the growth of many species.

chapter 1
INTRODUCTION

Due to its location in the path of the Gulf Stream, Ireland experiences a mild and moist oceanic climate that is unique for countries at similar latitudes. Extremes of temperature and precipitation are rarely experienced and favourable climatic conditions occur throughout the growing season. This equitable climate allows a wide range of native and exotic species to be grown, as can be seen from the great diversity of both herbaceous and woody species that grow successfully side-by-side in Ireland's gardens and arboreta. The ability to grow many species of trees presents foresters with opportunities to use different species, not only to maximise site productivity for the production of specific wood products, but also to enhance the amenity, landscape and biodiversity values of the forests.

Irish foresters are fortunate in being able to select from a range of species, depending on the objectives of a plantation and site conditions; however, the many options available can also present problems in knowing which species to use. Matching appropriate species to a given site is one of the fundamental principles by which sustainable forests are established. Species selection is sometimes regarded as more of an art than a science, as many variables must be taken into account, such as soil type, fertility, exposure, and drainage. This publication has been compiled by collating the results and experience of field experimentation and extensive planting over many decades, ensuring that species are ecologically well adapted to sites. In some cases there has been limited experience with large-scale plantings of some species; these are highlighted in the text.

The purpose of this manual is to provide the reader with the necessary background information on species that are suitable for Irish forests and to provide a methodology for selecting appropriate species depending on site characteristics and objectives of the plantation.

1.1 NATIVE AND INTRODUCED SPECIES

Ireland's forest cover was reduced to approximately 1% of the total land area of the country by the turn of the 20th century. To redress this situation, a State forestry programme was established in 1903 with the objective of recreating a forest resource that would provide a sustainable supply of home-grown timber to reduce the country's dependency on imports. In order to rapidly reduce the gap between wood supply and demand, foresters looked to exotic species, particularly conifers, which had proven to be substantially more productive in arboreta than native species.

In 1904, when the Avondale estate in County Wicklow was purchased, its first director, A.C. Forbes, began a planting programme designed to "*...turn it into a forest experimental station along the lines of a Continental forest garden...*" and "*...as a demonstration and experimental area which might prove of service not only for educational and training purposes but as one which tree planters throughout Ireland could inspect at any time.*" He established plots of over 40 different native and non-native species at Avondale in the period 1906 to 1909.

On the basis of these trials, and subsequent extensive operational plantings, the merits of introduced species, particularly conifers from the Pacific Northwest, were proven. A wide range of species was now available which would provide high yields of quality timber. The economic benefits of these new species are illustrated by a comparison of average productivities (Yield Classes) for some of the main native and introduced species (Table 1.1). Indeed, it is the use of non-native conifer species that has permitted the development of the Irish forest products industry to the extent to which it exists today. The use of non-native species has permitted the establishment of forests on sites and under conditions that would not have been possible with the limited number of native Irish tree species.

Many of these non-native species originate from regions with a climate similar to that in Ireland. Sitka spruce, Douglas fir, western red cedar, western hemlock and lodgepole pine are native to Northwest America, while others such as European larch and Norway spruce originate from the European mainland.

Forestry in some countries is based mainly on a single species. Ireland is fortunate that its suitability for a wide range of species makes it possible to provide a wide range

TABLE 1.1: Yield classes for a range of broadleaf and conifer species (Source: Coillte inventory).

	YIELD CLASS		
SPECIES	**MINIMUM**	**MAXIMUM**	**AVERAGE**
Oak	2	8	4
Beech	4	8	6
Ash	4	10	6
Douglas fir	4	24	16
Western red cedar	4	24	17
Sitka spruce	4	30	17

of products and end uses, as well as providing added protection against catastrophic failure due to disease or environmental factors.

1.2 SPECIES DIVERSIFICATION

For many decades government policies confined the planting of forests to marginal and sub-marginal agricultural land. This had the effect of limiting the range of tree species that was grown in Ireland. Sitka spruce proved to be the most successful, being best adapted to the soils and climate of these poor sites, while at the same time producing a high quality white wood with many end uses. This species proved so successful that by the early 1990s it formed 85% of the annual planting programme. Concerns that the composition of the national forest estate was becoming dominated by Sitka spruce (Figure 1.1) led to a questioning of the wisdom of this strategy. As it is difficult to predict what will be needed from our forests in the future, the planting of a more diverse range of species was seen as an insurance against the risk created by this uncertainty. Consequently, in 1996, the Forest Service introduced the requirement of planting diverse species in its strategic plan for the development of the forestry sector (Anon. 1996). The plan outlined changes in policy with regard to species composition in afforestation and required a reduction in the national annual planting of Sitka spruce to 60%, with a corresponding increase in diverse conifers and broadleaves.

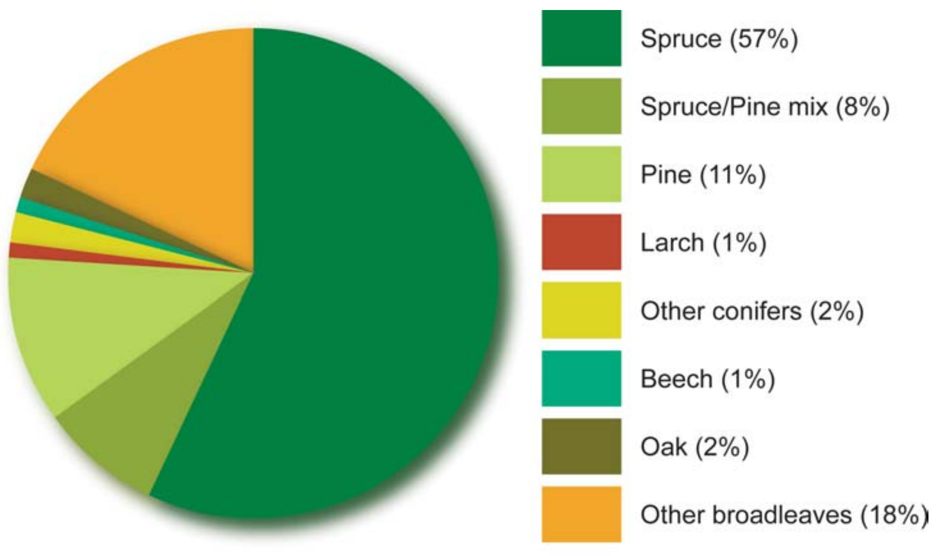


FIGURE 1.1:
Species composition of the national forest estate (2001).

Four types of risk are created by relying excessively on one species. These risks and the questions they raise can be summarised as follows:

1. Economic risks – Will the future income generated from wood and fibre be sufficient to return a profit on the cost of production?
2. Marketing risks – Will a single species satisfy a maturing market for diverse wood products?
3. Biological risks – Can we realistically expect to remain free of major insect, disease and animal pests in the future?
4. Environmental risks – Will the potential environmental impacts of commercial plantation forestry, based on a single species, be acceptable to society?

Diversifying the range of species in the national forest estate can help to avoid or minimise these risks. However, while there are very good economic, environmental and social reasons for planting a range of species, it is vital that the species planted are compatible with the site and soil types available.

At the end of 2001 the national forest estate stood at 665,277 ha, representing over 9% of the total land area of the country – up from a mere 1% in 1900. About 21% of the national forest estate is estimated to be broadleaves (Figure 1.1).

chapter 2
SPECIES and FOREST PLANNING

Forests have three main functions:

1) Economic (timber production)
2) Environmental (soil protection, landscape, biodiversity, and water quality protection and enhancement)
3) Social (recreation, employment and rural development)

Each of these functions must be taken into consideration in the planning and management of a forest, in keeping with the principles and aims of sustainable forest management. Species selection, which is an important aspect of forest planning, impacts to a greater or lesser extent on all three functions.

2.1 ECONOMIC ASPECTS

2.1.1 Introduction

Before considering site characteristics and species demands, it is essential to have a clear understanding of what the objectives of the plantation are. Historically, forestry in Ireland has been geared towards maximising wood production. In recent years, however, a wider appreciation and awareness of the need to balance economic goals with environmental and social needs has developed. Notwithstanding these changes, the economic production of wood is likely to remain the main source of income from most of our forests. Indeed, forest management costs, including those that relate to conservation, recreation, amenity and landscape, have to be covered by the income from wood sales and other income generating forest activities.

It would be remiss to ignore the grants and premiums that have been available to private growers in any forestry investment analysis. However, the longevity of forestry investments and the reality that government policy can change should not be overlooked. Nevertheless, successive governments have committed to the strategic plan *Growing for the Future* (Anon. 1996), which outlines a target level of afforestation of 20,000 ha per year.

Forest investment is quite unique in terms of the length of time between investment and return. This period is between 35 and 90 years for most species, but even greater for some broadleaves. This makes forestry quite different from industrial or agricultural enterprises. It is relatively simple to compare possible investment alternatives where the cycle between investment and return is only one year. With forestry, the expected rotation length of different species can vary by many years. Associated costs can also vary greatly, while forecasted revenues must be based on assumptions of future values for long rotation crops, such as oak.

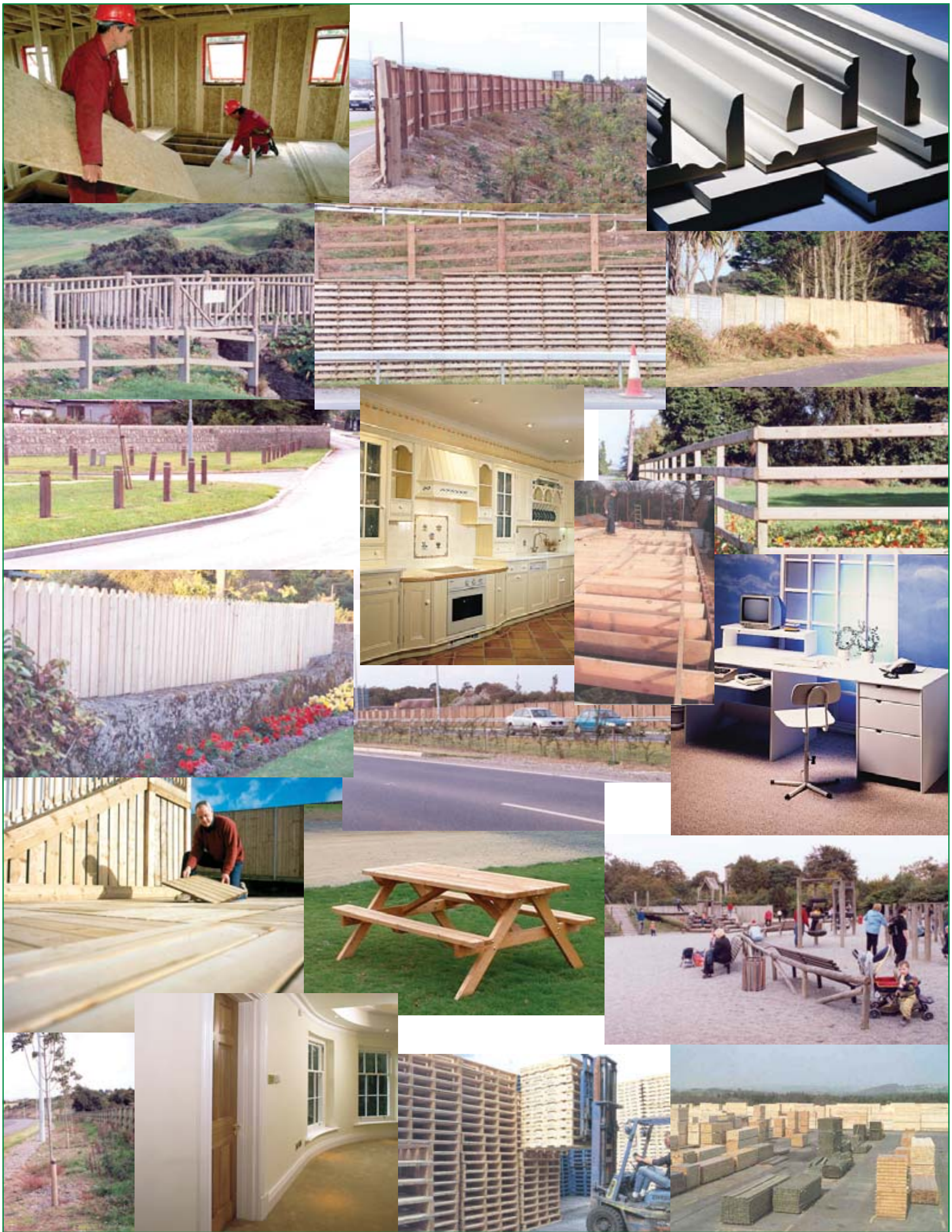
The commodity nature of most wood products and the increasing globalisation of markets for these products have tended to favour low cost producers. Maintaining a low cost base is therefore fundamental to remaining competitive in the world market. Ireland has a natural advantage in having conditions favouring the growth of a wide range of species. The processing sector has invested heavily to ensure that the most modern equipment is used to optimise the current roundwood resource. Typically, home-grown softwood is used for panelboard production (medium density fibreboard (MDF), oriented strand board (OSB) and chipboard), packaging, pallets, fencing and construction.

This country imports substantial volumes of hardwood timbers, of which a large proportion could be replaced by home-grown species. Although the hardwood industry is small and fragmented in Ireland, there is a strong interest in using home-grown material, provided that sustained supplies of quality material can be made available. There is strong consumer awareness of tropical deforestation and this is leading to a greater specification of temperate hardwoods from sustainably managed forests. Most of our hardwood imports now come from the USA and many of the species used can be readily grown in this country. Ireland is one of the largest importers of hardwoods per capita in Europe. These factors support the case for more broadleaf planting in Ireland.

Production costs will largely determine the financial feasibility of many forestry investments. The cost of production is determined by the availability and cost of land, labour and capital.

To analyse the potential returns from any forestry investment four factors need to be considered:

1. Land: price, productive capability, ownership category and State support.
2. Site preparation and establishment costs.
3. The cost, frequency and extent of management activities.
4. An estimate of the future value of the investment.



A wide range of end use applications can be serviced with home-grown timber.
Photos courtesy of Weyerhaeuser Europe Ltd, Coillte, SmartPly Europe Ltd, Woodfab Timber Ltd, Buffalo Structure (Irl.) Ltd.

2.1.2 Land: price, productive capability, ownership category and State support

The real rate of return of any forestry investment is dependent on the price of land. State subsidisation of various land uses has resulted in a distortion of the price of land, such that the market price is no longer a true reflection of the opportunity cost of using the land. Typically, where an investor has to purchase land a rate of return of between 4.5% and 7% can be expected from commercial forestry, exclusive of current grant and subsidy levels[1]. Where the investor is already a landowner, and eligible for the grant-aid to farmers, a rate of return in the region of 8% to 12% is attainable.

Growing for the Future (Anon. 1996) estimates the rate of return from forestry (Sitka spruce) as 5%, exclusive of grants and subsidies. The productive capability of land is intrinsically linked with price. Traditionally, forestry in Ireland has been confined to land considered marginal for agriculture. However, with many agricultural products in oversupply and with substantial increases in forestry subsidies, the planting of more productive land is increasing. Good quality land is key to growing commercial forests, and this is particularly true for broadleaved forests. Land suitable for commercial broadleaf production can cost significantly more than that required for conifers.

Due to our mild climate and long growing season, Ireland has higher tree growth rates than other European countries. Growth rates can be estimated with a high degree of accuracy based on certain site parameters. The productive potential of forestry land is measured in yield class (YC). Yield class is defined as the maximum potential volume of wood (overbark) of a given species that a site can produce per ha per annum. Once this has been determined, future wood yields can be predicted from yield tables. Actual yields will vary according to stocking, frequency and intensity of thinnings, and the expected or desired rotation length.

Improved levels of State support available to investors and farmers have dramatically increased private sector afforestation activity in recent years. State and European Union support is currently provided in the CAP Afforestation Programme (2000-2006) and is administered by the Forest Service of the Department of Communications, Marine and Natural Resources. The current Afforestation Grant and Premium Schemes are the two most important financial incentives for forestry, both aimed at promoting forestry as an alternative use of agricultural land.

The Afforestation Grant Scheme is designed to cover all the costs of establishing a plantation up to a maximum prescribed level based on species selected and land type planted. The variation in grant levels is largely attributable to the significantly higher cost of establishment of certain broadleaves over that of conifers. Typically, it takes four

1 The Forest Service shold be contacted for up-to-date details on available support schemes.

years to successfully establish a plantation and consequently the grant is paid in two instalments, 75% after the initial work is completed and the remaining 25% after four years, provided the plantation is successfully established.

Running in tandem with the Afforestation Grant Scheme is the Premium Scheme. This scheme was introduced to provide farmer and non-farmers with a short-term income from forestry to compensate for any lost revenue resulting from the change in land use. Both the Afforestation Grant Scheme and Premium Scheme are aimed at encouraging greater species diversification.

A number of other grant schemes may be available for private forestry, such as pruning, woodland improvement, reconstitution of woodland and roading[2]. All available grant aid should be included in any financial appraisal. The level of grant currently available depends on the species chosen, and qualification for such payments may dramatically affect the choice of species.

A further grant scheme for Native Woodlands was announced by the Forest Service in 2001. The Native Woodland scheme provides support to landowners to enhance and protect existing native woodland and to establish new native woodlands in an ecologically sensitive manner.

2.1.3 Site preparation and establishment costs

Species choice will have a significant effect on establishment practices and costs. In general, coniferous species tend to cost substantially less to establish than broadleaved species. The individual cost of plants, site preparation, vegetation control, fencing requirements, and associated management and labour costs are higher for broadleaves and some diverse conifers.

Site preparation costs largely depend on the condition of the site to be planted and the species chosen. Afforestation sites are generally less expensive to prepare than restocking sites. Low cost methods of site cultivation, such as scarifying and ripping, tend to be suited better to afforestation sites, where the problems associated with brash and stumps do not arise as they do on reforestation sites. On reforestation sites, the species previously grown will often dictate the methods and extent of preparation required. For example, windrowing is often not required on sites previously planted with Scots pine prior to cultivation; however, it is almost a prerequisite with heavy crowned species like Sitka spruce. The requirement for a greater number of mounds per unit area, to facilitate increased planting densities for some broadleaves and conifers, will also increase the cost of site preparation.

2 The Forest Service shold be contacted for up-to-date details on available support schemes.

Increased mechanisation of establishment operations is helping to control the costs of afforestation and reforestation.

The price of plants of different species varies greatly, with some minor conifers and broadleaves costing up to 150% more than commonly used species (Figure 2.1). In addition, higher planting density leads to higher labour and planting stock costs.

Most plantations will require some form of vegetation control in the early years, with broadleaves and slow-growing conifers requiring a more intensive regime. The factors that will determine the cost of such control include site fertility, vegetation type, method of cultivation, species, and the frequency and method of control required. Of the three effective methods of vegetation control - manual, mechanical, and the use of herbicides - the latter tends to be the most cost-effective. Some sites will require inputs of fertiliser, regardless of the species chosen. However, for others the addition of fertiliser will often depend on which species is planted. Any consequent requirement for fertiliser application will increase establishment costs. In some instances, the use of a less site-demanding species or mixture will be justified on the basis that the cost of frequent fertiliser application for the initially preferred species would probably not be

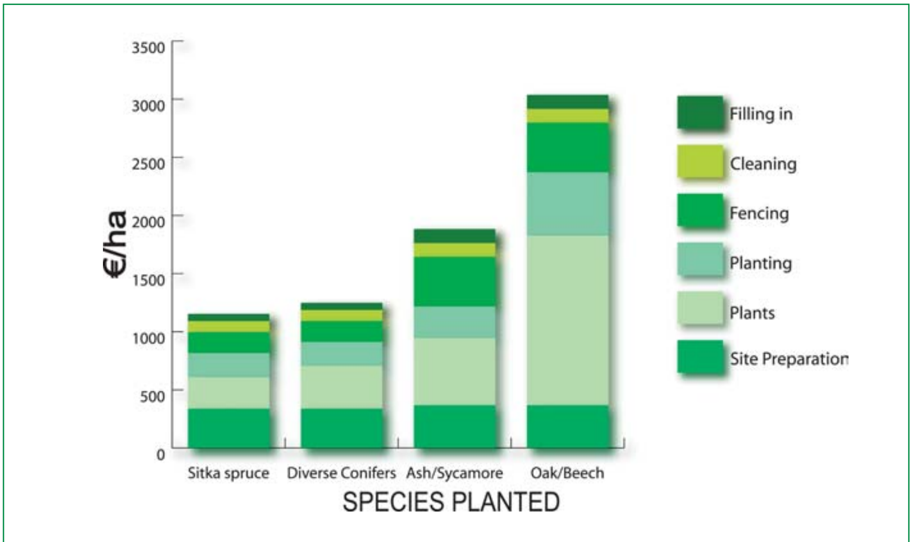


FIGURE 2.1:
Relative afforestation establishment costs (€/ha) for different species - based on average contract costs (Coillte: 1998 to 2000).

financially justifiable. This is illustrated by the use of lodgepole pine (either pure or in mixture) on impoverished Old Red Sandstone sites, as opposed to planting pure Sitka spruce with its need for frequent applications of fertiliser nitrogen.

The threat posed by certain wild and domestic animals, insect pests, fungal and bacterial diseases should also be considered, and may limit the planting of certain species. The cost of providing adequate protection for species against specific pests, such as erecting deer or rabbit fencing, can often be prohibitively expensive. An assessment of the risk, protection costs and potential losses should be completed before a decision on species is made. The species notes in Chapter 6 outline some of the typical pests encountered by each species.

2.1.4 The cost, frequency and extent of management activities

Pure coniferous crops generally require the least amount of management and do not have as high a management cost as broadleaves and mixtures. Mixtures can enhance economic return through improved crop quality, productivity, and stability. However, it is important to realise that additional species can make management of these areas more complex and costly. Conifer mixtures tend to cost less to establish and manage than broadleaf mixtures. The third alternative of conifer/broadleaf mixtures is often a good

The expansion of the forest estate has greatly extended the natural range of deer populations. In some instances, this now necessitates the erection of deer fencing. The cost of this operation may be prohibitive and can limit selection to species not susceptible to deer damage.

financial compromise if the inclusion of broadleaves is important, but compatibility problems can occur if the site/species match is not correct. When considering the use of conifer/broadleaf mixtures bear in mind the additional cost of more complex designs, and the fact that the primary species often may have to be planted several years before the companion species. Chapter 5 (*Mixed Species Plantations*) gives further information on mixtures.

Forest plantations are initially planted at close spacing and subsequently thinned regularly to enhance the form and productivity of remaining trees. Species selection will have a direct effect on the timing, type, intensity, cycle of and returns from thinnings. While thinning is silviculturally necessary, harvesting and extraction costs of early thinnings are relatively high, and the value of wood yield is generally low due to the small diameter of the trees removed. After second thinning, the profitability of each subsequent thinning should improve. The cost of early thinnings should be regarded as an investment in the plantation that will improve the value of the remaining crop in successive thinnings and eventually at clearfell.

The timing of the first thinning largely depends on the species and growth rate and ideally all crops should be assessed for the need and timing of thinning between 10 and 12 years of age. The decision of whether or not to thin, and the timing of thinning, will also be influenced by the risk of windthrow or by the desire to take advantage of favourable roundwood prices and markets. Table 2.1 gives the normal average age of first thinning for some major coniferous species with varying yield classes. From a

Harvesting in Irish forests is now almost completely mechanised. Most forest owners pursue a thinning policy except where there is a high risk of windthrow.

silvilcultural viewpoint the optimum time for first thinning is often earlier than indicated. First thinning is often delayed to ensure that the produce is more marketable.

The frequency of thinning is referred to as the thinning cycle. The number of times a crop will be thinned largely depends on its rotation length, which is directly influenced by the management objective. In vigorous coniferous crops the thinning cycle is about 4-6 years whereas for slower-growing broadleaves it is generally 8-10 years.

Species choice will affect the type of thinning carried out. Line thinning removes all trees in selected lines with no regard taken of the quality of individual trees. Selective thinning does consider the merits of individual stems, but it is a more expensive method. Currently a combination of line and selective thinning is practiced for conifers. Normal practice is a 1 in 7 line thinning, with the removal of a selection of poorer stems from the remaining 6 lines.

Following establishment young broadleaved stands should be checked regularly for forking and double leaders. Formative shaping should help to ensure that young broadleaved trees produce single straight stems. Particular attention should be paid to stem quality over the first four years, as the lower section of the stem is the portion of the tree that potentially yields the most valuable logs. It is desirable to select the potential final crop trees as early as possible, particularly in broadleaved stands. Thinning of broadleaves begins when the trees are 8-10 m in height when grown at conventional spacing. For closely spaced groups this will differ (see section 5.2.7, page 86). This involves removing trees that are dominant, rough-branched or malformed, while favouring the crown development and growth of final crop trees. The costs associated with access, intensive shaping, selection and management are high, but these operations are critical to optimise the overall return on investment from the crop.

Mensuration is normally the final management intervention before harvesting. This measurement activity is vital to ascertain the volume and value of the crop. The marketability of roundwood from a given species at any given time is affected by many factors: average tree size, lot size, location, road access, harvesting costs, stem and wood quality, and macroeconomic factors.

TABLE 2.1: Normal average age of first thinning for some major coniferous species with varying yield classes.

SPECIES	YIELD CLASS			
	10	14	18	22
Sitka spruce	-	23	21	19
Norway spruce	31	26	23	21
Douglas fir	27	22	19	17
Japanese/hybrid larch	18	15	-	-
Scots/lodgepole pine	26	21	-	-

2.1.5 An estimate of the future value of the investment

Discounted cash flow (DCF) analysis is the principal tool used to estimate the current value of future costs and revenues. In DCF analysis, costs and revenues are equated to present day values. The discount rate used (typically 3% to 7%) should reflect the opportunity cost, risk and the required real rate of return over inflation of the investment. While roundwood yields can be estimated through the use of yield tables, prices have to be estimated based on past trends and future predictions.

The sum of the discounted revenues minus the sum of the discounted costs is termed the net present value (NPV) of the investment. The NPV is used as a measure of the profitability of the investment. The internal rate of return (IRR) is the interest rate at which the discounted expenditure balances discounted revenue. It is the earning power of the investment in terms of the rate of interest it can bear. The IRR for a number of species is given in Table 2.2.

Tax benefits are also important incentives for choosing to invest in forestry. All individuals and companies engaging in forestry in this country are currently exempt from tax on income from this activity, regardless of residency status. This exemption includes all profits from roundwood sales. Consequently, species choice has no effect on exposure to tax. Growth increment of forests is exempt from Capital Gains Tax and Stamp Duty, but the underlying land is not.

TABLE 2.2: Estimated internal rate of return (IRR) for Sitka spruce, Norway spruce, Scots pine, Japanese larch, ash/sycamore, oak/beech.

SPECIES	LOW YIELD CLASS			HIGH YIELD CLASS		
	IRR No Grant %	IRR Grant* %	Investment Period years	IRR No Grant %	IRR Grant* %	Investment Period years
Sitka spruce	4.7	8.6	50	6.9	11.8	40
Norway spruce	3.9	8.0	65	5.3	10.0	50
Scots pine	3.1	8.3	80	4.2	9.2	65
Japanese larch	2.5	7.6	55	3.9	8.8	45
Ash or sycamore	<0	<1	70	2.3	5.8	60
Oak or beech	<0	<1	170	1.4	5.1	120

*Assumptions - 5% discount rate, including land price, spacing as per Chapter 6, average costs and timber prices used (Coillte: 1998-2001). *Afforestation and premium grants (2001) for enclosed land – farmer category*

2.2 ENVIRONMENTAL CONSIDERATIONS

2.2.1 Landscape

New forests should be established and maintained in a way that enhances the landscape. Therefore it is essential to consider, at the planning stages, the effect the proposed forest will have on the surrounding area. The Forestry and the Landscape Guidelines (Anon. 2000b) provide useful information on the key criteria that are used to assess the impact of new plantations on the landscape.

The species composition of a forest can greatly influence the character of a landscape. The large-scale planting of evergreen conifers, just as with any other large-scale, single land-use can lead to a bland, uniform landscape in the absence of careful planning. Slight differences between crown shape and colour are obvious to foresters and the trained eye, but often not to the general public, for whom the contrast of deciduous species may be necessary to give an impression of diversity. Introducing contrasting species alone will not improve landscape diversity unless the principles of good design are applied. In establishing a forest there are a number of basic design principles that relate to the choice of species:

1. One species should appear to dominate the landscape composition by about two-thirds.
2. Margins between species should be irregular.
3. Species related to ground vegetation should follow its shape at an approximate scale and in harmony with the landform.
4. Mixing adjoining species at the boundary is no substitute for a well-designed shape, but can enhance its appearance.

Mixed woodland enhances the aesthetic appeal of landscapes.

In planning the forest the basic rule is that species layout should be designed within shapes of well-formed external margins and open spaces. Poorly shaped external margins and felling coupes cannot be improved by species layout alone. Contrasting species can be selected to increase diversity, introduce seasonal change and reflect the surrounding pattern of the vegetation. A broad strategy of species distribution will improve the unity of the overall design and can help to blend the forest into the landscape.

The choice of species is one of the major tools available to the forest planner in designing the appearance of a forest in the landscape. The subject of landscape design is, however, beyond the scope of this book. Some useful references are listed in the bibliography for further reading.

2.2.2 Biodiversity

Biological diversity, or biodiversity, is concerned with the total variability of all living organisms and the habitats in which they live. It encompasses diversity at the ecosystem, species and gene level.

The establishment of new forests in the countryside has the potential to provide habitats for flora and fauna that might not otherwise exist. Biodiversity will be enhanced by planting a range of species, and incorporating diverse habitats within the forest by

The increase in afforestation in Co Wicklow led to an increase in the population of hen harriers, shown here nesting in thicket Sitka spruce. However, open space is also vital for many bird and mammal species.

retaining specific habitat types, such as hedgerows or wetlands. These issues are best addressed at the planning stage.

The *Forest Biodiversity Guidelines* (Anon. 2000a) should be consulted. Areas contained within or adjacent to Special Areas of Conservation (SACs), Special Protection Areas (SPAs), or Natural Heritage Areas (NHAs) are subject to restrictions. Any local biodiversity factors should be considered in planning the forest, such as unique habitats (hedgerows, areas of scrub, pockets of native broadleaves, old individual trees, aquatic zones, wetlands, woodland glades, unimproved grassland and wildflower meadows), and plant and animal species.

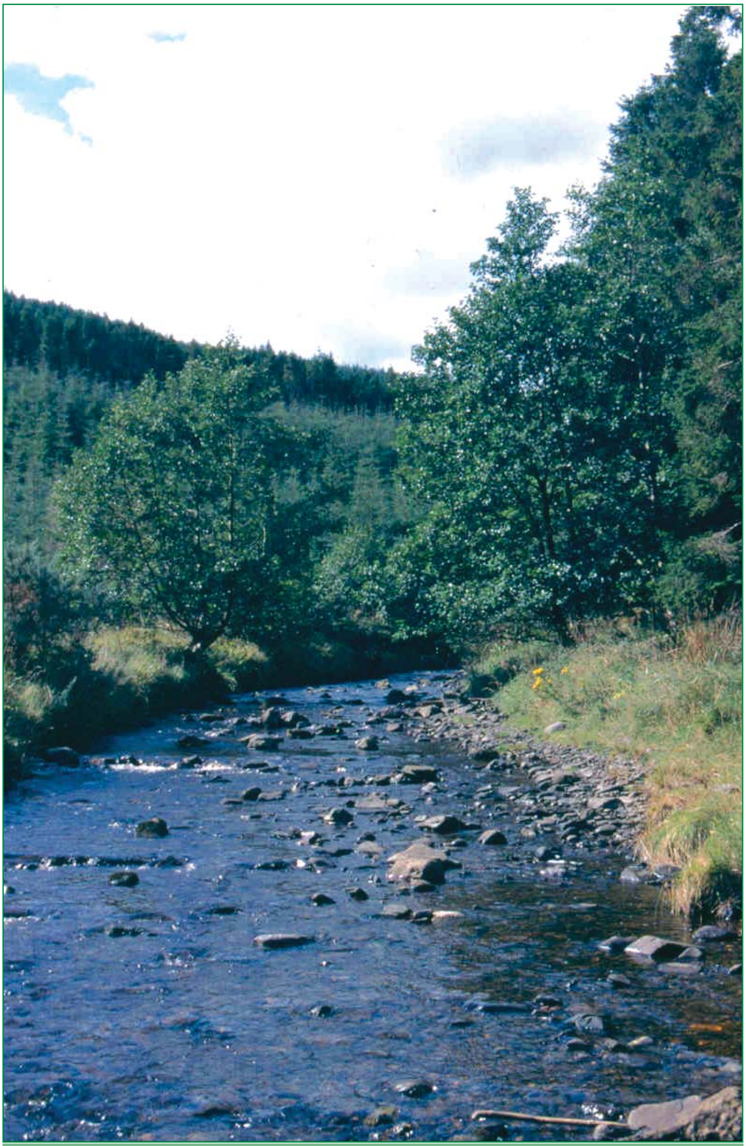
Species diversity can also contribute to the habitat value as well as the biodiversity of a forest. Mixtures between native and non-native broadleaves and conifers, if silviculturally compatible, can encourage the formation of native shrub and ground cover layers. Native broadleaf species should be planted where suitable conditions prevail. Local or native seed sources should be used when and where possible. The retention of existing hedgerow trees, pockets of native scrub, and old individual trees, can help in providing age diversity, although this is more easily established in existing forests. The retention of over-mature trees and deadwood on the site can also promote biodiversity, especially for insects and birds. The provision of open spaces (5 to 10% of the total area) help to promote biodiversity, as in ride-lines, firebreaks, forest roads, turning bays, landing bays, buffer zones along aquatic zones, exclusion zones around archaeological sites, and areas left unplanted for landscape purposes.

2.2.3 Riparian zones

In recent years the establishment of aquatic or riparian zones along watercourses has become an important feature of forest design. These areas, which are generally managed for water protection, also act as undisturbed corridors for wildlife and provide a natural link between the uplands and lowlands. Vegetation is generally encouraged in these areas as it is more conducive to in-stream flora and fauna. In creating a well-managed riparian zone the aim should be to have an irregular distribution of trees, with about 50% of the stream in full sunlight, the rest receiving light dappled shade from native broadleaves.

On any site that borders on watercourses, buffer zones adjacent to aquatic zones are required to protect both the water quality and the resulting aquatic ecosystems. Within the buffer zone natural vegetation should be permitted to develop and the planting of some suitable riparian tree species, such as willow or alder, may be permitted. Sizes of buffer zones depend on the average slope leading to the aquatic zone and on the erodibility of the site. The *Forestry and Water Quality Guidelines* (Anon. 2000c) should be consulted.

Any proposed planting site with rivers, streams or drains with continuously flowing water, or sites contiguous with lakes, rivers or streams, are subject to these regulations.



The Forest Service's *Forestry and Water Guidelines* sets out recommendations on how to protect water courses and manage riparian zones.

chapter 3
SITE PRODUCTIVITY

3.1 INTRODUCTION

To be in a position to select suitable species for a site, it is necessary to have a good understanding of the major factors influencing growth potential, and consequently species selection, namely climate, site and soil.

One of the most important lessons to be learned in dealing with climate, site and soil as factors affecting site quality and productivity is the fact that all three are interdependent (Figure 3.1). For example, increases in wind speed and rainfall with elevation generally lead to a decrease in soil quality and temperature. It is not possible, therefore, to examine these factors in isolation when evaluating sites for planting.

In this chapter, temperature, precipitation and wind are discussed under 'Climate', whilst other factors, such as topography, exposure and aspect, are discussed under 'Site'.

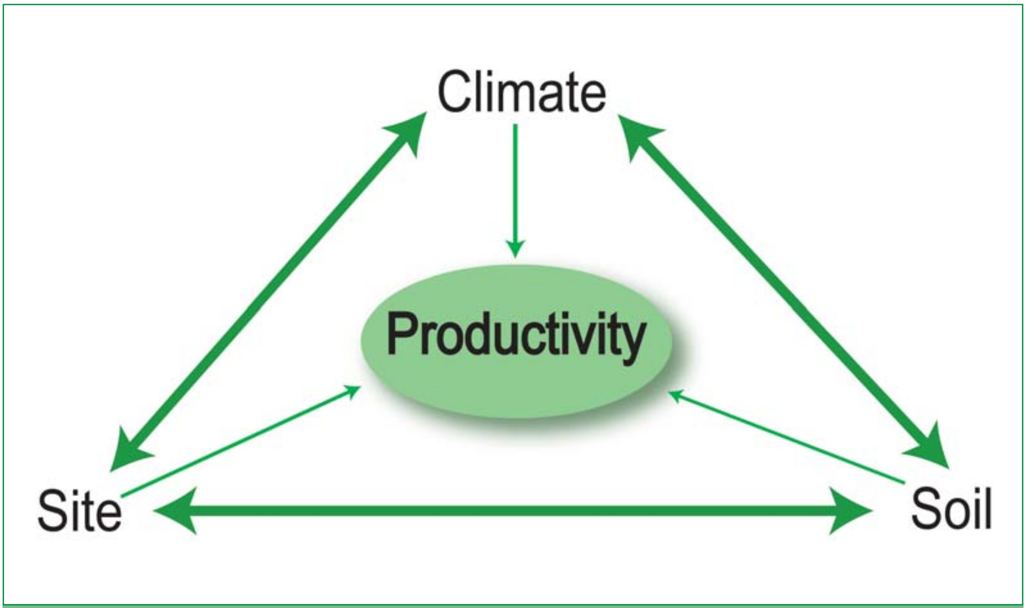


FIGURE 3.1:
The interaction of climate, site and soil with productivity.

3.2 CLIMATE

Three levels of climate determine the environment in which trees grow (Major 1963):

Regional:	This level is characteristic of large areas (greater than 10 km^2) and is not affected by topography or local vegetation.
Local:	This level (1-10 km^2 in extent) is affected by local topography, which can modify the regional climate.
Microclimate:	Soil, vegetation and topography can also modify climate in the vicinity of a planting location.

3.2.1 Temperature

As a result of its location in relation to the Gulf Stream, Ireland enjoys a moist temperate climate. The grass-growing season (when temperatures are at or above 5-6ºC) for Ireland varies from 330 growing days/year on the southern tips of Cork and Kerry, to 240 in the northeast (Collins and Cummins 1996; Figure 3.2). Although our winters are relatively mild, we do not, however, get the high summer temperatures experienced in continental Europe.

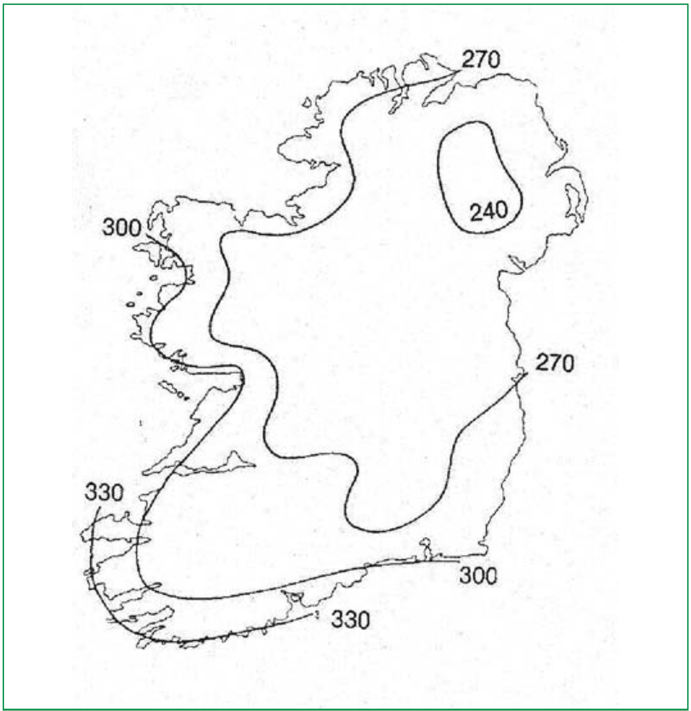


FIGURE 3.2:
Median length of the grass-growing season, days/year (Collins and Cummins 1996).

Due to these conditions, the growing season for tree species can be quite long in this country. For example, Kelly (1977) examined the patterns of height growth in a range of tree species in the southeast of the country. He found that some *Pinus* species began height growth in mid-March, while others began four weeks later. Some species of *Picea* and *Abies* began in early April, while others did not begin height growth until mid- to late May. Most of the broadleaves examined (*Fagus* and *Quercus* species) began height growth in mid-April.

Choice of species and subsequent growth of forests are both affected by temperature. In Northern Ireland, researchers have found that temperature alone (rainfall, within the ranges experienced, was not important) influenced leader growth in lodgepole pine and Sitka spruce (Kilpatrick and Seaby 1990). The air temperature in both current and previous growing seasons influenced leader length in the pine, while in spruce only the temperature in the previous season had an influence. Similarly, in northern Britain, workers have found that accumulated temperature and windiness were the main factors determining productivity in Sitka spruce (Worrell and Malcolm 1990). Both studies were carried out in areas that do not experience any appreciable drought.

3.2.2 Frost

In spite of our generally mild climate, frost is quite common during winter, particularly in areas removed (at distances of 10-20 km) from our coastline. This type of frost rarely damages young forest seedlings or mature trees in this country. In spring (and to a lesser extent in autumn), however, frost can have a far greater effect on survival and early growth of trees. Frost damage represented over 60 percent of all incidences of damage recorded by the Forest Service under the ‘Reconstitution’ scheme in the mid-1990s (Anon. 1998).

Figure 3.3 shows the mean date of the last air frost in spring over the period 1944-68 (Collins and Cummins 1996). This map shows that, on average, frosts in mid-May are not uncommon in many parts of the country and, in exceptional years, severe frosts as late as early June have been recorded. There are areas of the country however, where the likelihood of late spring frost damage is low. Damaging late spring frosts often coincide with the time of flushing, and in recent years many species have been badly affected. Choosing the correct species on these site types can be difficult as frost occurrence varies from year to year.

The extent and intensity of these spring frosts have had a major effect on species selection in many midland areas. Sitka spruce (whose newly emerged shoots are damaged at temperatures below $-3^{o}C$) has been replaced by late-flushing provenances of Norway spruce on both afforestation and reforestation sites following high incidences of frost damage to the former species during the late 1980s and 1990s. However, while

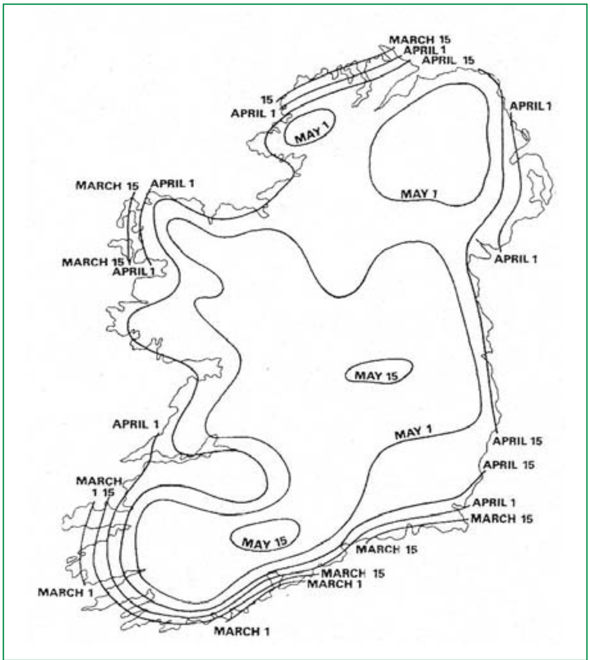


FIGURE 3.3:
Mean date of the last air frost in spring, 1944-1968, reduced to mean sea level (Collins and Cummins 1996).

choosing Norway spruce may make initial savings, in the longer term Sitka spruce offers a higher financial return. Research is currently underway in the Midlands to assess the possibility of using birch as a nurse to shelter spruce from these damaging frosts.

Although the initial effects of autumn frost may seem very dramatic, long-term damage is generally not a problem. These frosts occur after shoot elongation is complete and result in a distinctive browning of the current years needles. Sitka spruce is the main tree affected, but noble fir, Scots pine and Douglas fir can also be damaged. Southern provenances are affected more than northerly ones.

Frost is the main climatic factor causing damage in young forest plantations in Ireland.

3.2.3 Precipitation

The vast majority of Ireland's precipitation falls as rain. Much of the variation in rainfall is due to elevation. Although the rainfall in the lowlands varies from 750 mm in the east to 1,200 mm in the west, some uplands receive over 2,600 mm. The country's rainfall tends to be spread evenly throughout much of the year, with even the east and south east (the driest regions) receiving some precipitation on more than 200 days in the year.

Drought is rarely a limiting factor to forest growth in Ireland or Britain (Kilpatrick and Seaby 1990; Waring 2000). The only recent evidence of drought damage was to newly planted crops in the very dry springs and summers of 1976 and 1995. The indirect effects of drought can also be seen, particularly in the establishment of many species, where competing vegetation (especially grasses) must be controlled for satisfactory growth of the trees.

3.2.4 Wind

Wind is the most important climatic factor affecting forestry in Ireland. This fact was reinforced by the storms of December 1997 and 1998, both of which left vast tracts of windthrow in their wake.

Severe exposure is one of the factors that can lead to basal sweep in some species.

Wind can also have more subtle effects on forest growth and development. Certain species will not establish and grow well when planted in large blocks on very open ground (e.g. ash, European beech, western hemlock and Norway spruce). When trees are exposed to strong winds over their lifetime, they react by changing their form. Trees on the edges of plantations have greater taper and larger root systems than those from the centre of the plantation. In extreme cases, individual trees can take on a form where the branches are swept to the leeward, resulting from the death of buds on the windward side. All of these results of wind damage will decrease the economic value of the crop.

This reaction to the wind is also species-dependent, with certain species such as Sitka spruce, lodgepole pine, Monterey pine, Monterey cypress, sycamore and rowan being

Wind is the most important climatic factor affecting forestry in Ireland.

more tolerant to exposure than many other species. It is thought that the complex phenomenon of top-dying of Norway spruce is also partly linked to extreme transpiration losses following exposure of plantations, after heavy thinning or removal of side shelter.

Even on moderately exposed sites, away from coasts, exposure can cause even young trees to lean away from the wind or be blown over. This lean can have a permanent negative effect on wood quality, with serious financial implications. As trees subsequently straighten, a permanent curvature of the stem remains, resulting in 'basal sweep'. This is a common phenomenon in lodgepole pine and in some stands of Douglas fir and larch. Juvenile instability in pines, larches and Douglas fir also occurs when the trees in very young plantations (less than five years old) are blown over or loosened soon after planting.

A range of climatic, site, stand and silvicultural factors influence the occurrence of windblow. Many of these are taken into account in windthrow risk classification models, and work is currently underway to develop a new model to predict the probability of windthrow throughout Ireland (Ní Dhubháin *et al.* 2001). Significant site factors in the model include stand location in relation to windzones (Figure 3.4) and soil type.

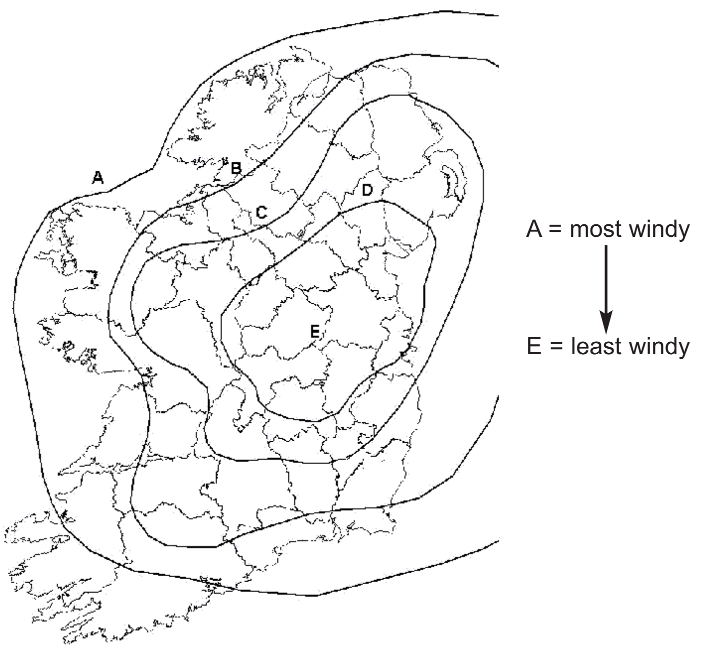


FIGURE 3.4:
Windzones are used to assess windthrow risk in Ireland (Miller 1986).

3.3 SITE CHARACTERISTICS

3.3.1 Topography/elevation

Although Ireland is not really considered mountainous, its tree line is situated at quite a low elevation compared to other countries. The absence of tree cover at higher elevations is related to exposure levels and temperature, as tree growth generally becomes scrubby at elevations at which the average temperature of the four warmest months is <10°C (Pears 1967).

Other climatic variables also change rapidly with increasing elevation. With every increase of 100 m, average temperatures drop by 1°C and windspeed increases by 30 percent. A recent examination of the Coillte inventory database has shown an expected relationship (Figure 3.5) between compartment elevation and yield class. The relationship incorporates the expected change of soil type with elevation. For afforestation sites, current Forest Service guidelines (Anon. 2000d) suggest that land over 300 m (in the west) and 400 m (in the east) is 'unplantable', although this relates more to economic limitations rather than to a true 'tree line'.

3.3.2 Exposure

The term exposure combines many of its related components, such as, elevation, windiness and aspect. In forestry, it is often expressed by what is known as 'topex',

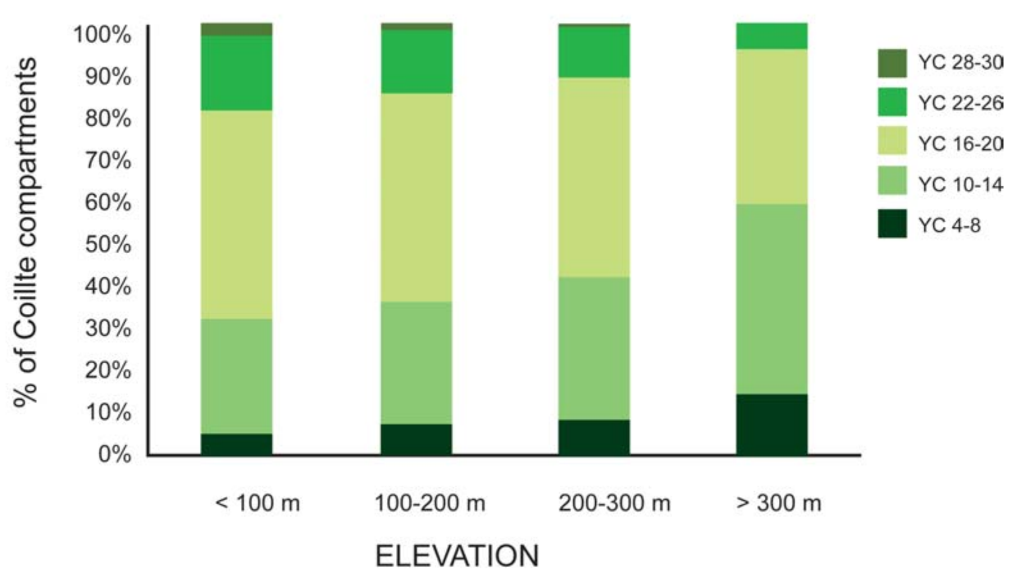


FIGURE 3.5:
Relationship between the yield class (for all species) of Coillte compartments and their elevation (Coillte Inventory/GIS 2003).

which is an index of topographic exposure, measured in the field using angles to the horizon at cardinal points. It is primarily used in calculating windthrow risk. Modern computer mapping systems now allow topex to be measured directly from Ordnance Survey maps (Mills and Cory 1998).

3.3.3 Aspect

Although perhaps not as immediately obvious as exposure, aspect can have an important effect on growth of various species. South-facing slopes are warmer than others, but south to southwest aspects are also generally exposed to the prevailing winds in this country. Crops growing near the foot of southeastern slopes, or those exposed to early morning sunshine, are often at risk through damage to recently-flushed growth by early morning sunshine after clear, frosty nights.

North or northeastern slopes, although sheltered from most prevailing winds, are often cold and may be less productive. For example, at 55ºN on the summer solstice, a south-facing slope of 10º would receive 50% of possible solar energy, while a north-facing slope would only receive 20% (Reifsnyder and Lull 1965). Species from warmer climates, such as European beech, Spanish chestnut and coast redwood, do best in these warmer microclimates.

3.4 VEGETATION

An t-ór fén aiteann, an t-airgead fén luachair agus an gorta fén bfraoch.

(Gold under furze, silver under rushes and famine under heather.)

Folklore has recorded this saying, which classifies soils according to the vegetation they bear. The vegetation occurring on a site was also commonly used as an indicator of species choice in early afforestation programmes in this country. At that time, the modest scale of the operation enabled foresters to have more time to acquire in-depth knowledge of sites, and to be in a position to be aware of subtle changes in the composition of the vegetation cover.

Today, forestry is a much more extensive operation, encompassing a large variety of site types. By virtue of the better quality of land now being planted and increased desire for greater species diversity, the forester also has to deal with a much larger choice of tree species than heretofore. Sound species choice depends fundamentally on knowledge of the relationship between all the relevant site factors and the silvicultural requirements of the various species. Important differences in site types can be determined by studying correlations between the physical site characteristics and the nature and composition of relatively undisturbed vegetation. Table 3.1 outlines vegetation communities and their associated soil types.

Generally, the larger the variety of plants present in the natural vegetation the more suitable the site is for a wide range of tree species. The underlying principle is that some plants are highly sensitive to variation in site factors. Such plants have a high indicator significance, whereas others, those with a broad environmental tolerance, have a lower indicator significance. Common among the latter are bracken, bramble, purple moor grass, heather and rosebay willow-herb (fireweed).

Another problem in many areas is that human intervention has made it very difficult to know what the natural composition of the vegetation may have been. Burning or cultivating a heather-dominated site can at least temporarily favour colonisation by species, such as, purple moor grass, tufted hair grass and bent-grass. Vegetation as an aid to species selection has therefore limited application in areas that have been disturbed,

TABLE 3.1: Summary of vegetation communities and their associated soil groups.

INDICATOR SPECIES	SOIL TYPE
Because of their desirable physical characteristics, brown earths, free-draining grey-brown podzolics, acid brown earths and brown podzolics are devoted extensively to cultivated crops and pasture. Natural vegetation is therefore confined to derelict sites, and the variety of plant species that grow on these soils can be very wide, characterised as follows:	
Medium to high fertility: Lady's bed straw, hart's tongue fern, wild parsnip, dog's mercury, herb Robert, wood sanicle, stinging nettle, garlic, broad-leaved dock, cow parsley, broad-leaved willow herb, wood sorrel, male fern, cocksfoot, hog-weed.	Alkaline brown earths/ Free-draining deep grey-brown podzolics
Low to medium fertility: Yorkshire fog, wavy hair-grass, bent-grass, fescue, crested dog's tail, bracken, bramble, bilberry, foxglove, honey suckle, Irish and European furze.	Acid brown earths/Brown podzolics
Old pastures: These include a wide range of grass and weed species, the more characteristic being sweet vernal grass, red clover, red fescue, plantain, and cowslip. Waste ground: Hazel, holly, blackthorn, hawthorn, buckthorn, spindle tree, and juniper are among the most common.	Shallow brown earths/ Rendzinas/Free-draining shallow grey-brown podzolics
Bramble, bracken, bilberry, Irish and European furze, mat-grass, bent grass, wood rush, wood sage, purple moor grass, ling and bell heather.	Podzols/Peaty podzols (often with a weakly developed iron pan).

TABLE 3.1 (continued): Summary of vegetation communities and their associated soil groups.

INDICATOR SPECIES	SOIL TYPE
Ling and cross-leaved heather, deer grass, Irish furze, purple moor grass, lichen.	Indurated iron pan podzols
Ling and cross-leaved heather, Irish furze, bracken, bilberry, lichen	Lithosols
Purple moor grass, deer grass, heath rush, ling and cross-leaved heather, lichen.	Peaty podzolised gleys
Yorkshire fog, tufted hair grass, mat-grass, soft rush, jointed rush, hard rush, rough stalked meadow grass, meadow sweet, creeping buttercup, great willow herb, silverweed, marsh thistle, march marigold, water lily.	Surface- and Ground-water gleys/Peaty gleys (Fertility class A)/Gleyed grey-brown podzolics
Purple moor grass, ling and cross-leaved heather, heath rush, cotton-grass, sedge, and mosses.	Peaty gleys (Fertility class C)
Mosses, deer grass, cotton grass, bog orchid, bog rush, bog asphodel, purple moor grass, sundew, butterwort, tormentil, milkwort, ling and cross-leaved heather.	Unflushed blanket bogs/Intact raised bogs (Fertility class C)
Purple moor grass, bog rush, soft rush, jointed rush, bog myrtle, bog asphodel, birch and willow.	Flushed blanket peats (Fertility class B or B-C)
Pasture crops, purple moor grass, bog rush, fen thistle, bog bean, bog orchid, common comfrey, guelder rose, birch, willow, and reed.	Fen peats
Ling and cross-leaved heather, purple moor grass, soft rush, rose-bay willow herb, male fern, cotton grass, birch and willow.	Hand-cutaway blanket bogs and machine-cutaways (sod-peat, prior to 1980)
Ling and cross-leaved heather, purple moor grass, soft rush, bulrush reeds, royal fern, meadow sweet, birch, willow, bracken and a wide variety of grass species.	Hand-cutaway raised bogs and machine-cutaways (sod peat, prior to 1980)
Soft rush, bulrush, royal fern, purple moor grass, cotton grass, birch and willow.	Machine-cutaway raised bogs (milled peat, post 1980)

such as sites where burning, cultivation and/or herbicide or fertiliser application has taken place.

Even where relatively undisturbed vegetation is present, it should not be used in isolation as an indicator of species suitability. However, when combined with all other site characteristics, it is useful at a local level to indicate site variations, and as supporting evidence of where a particular tree species might do best.

Chemical analysis of the soil is very useful in accurately determining the exact proportions of the elements present, but it can only give an indication of the extent to which these are available to trees planted. The composition and vigour of vegetation cover is often a better indication of nutrient availability (Anderson 1950).

3.5 SOILS AND FORESTRY POTENTIAL

An awareness of the characteristics of the soils to be planted is of fundamental importance if a good matching of species with site is to be made. This is best done by observation of soil profiles or cuttings, obtained through digging with spade or machine. The cuttings should be deep enough to expose the subsoil and upper section of the parent material (the material from which the topsoil and subsoil are developed). Investigations of topsoils only are insufficient, since the characteristics of the soil below the topsoil will largely determine both the suitability of the site for tree growth, and the relative suitability of the site for conifer and broadleaf species. Some soil characteristics to note when investigating soil cuttings are:

- the nature of the parent material (marl, glacial drift, etc.) and its depth from the ground surface, and
- the permeability of the topsoil, subsoil and parent material layers.

Soil testing of samples in a laboratory allows for a more comprehensive understanding of the soil characteristics, particularly in terms of fertility. (Guidelines for soil sampling are given in Appendix IV).

Whilst the range of soils found in Ireland may not be broad, the arrangement and distribution of them is exceptionally complex. The reason for this complexity is the result of repeated glacial episodes and the variety of the soil parent material left behind, as well as the nature of their disposition, particularly relief or slope. The resultant variability of our soils can be daunting to the land-manager, who has to plan without either the availability of a simple, practical soil classification system, or the means to recognise the different soil groups. This section on soils is an attempt to provide these aids to decision-making in regard to species selection and, indeed, other forestry activities.

3.5.1 Soil classification

The soil classification system proposed (Table 3.2) is a modification of that used for upland Britain by the Forestry Commission (Pyatt 1982), which has the basic requisites for the purpose of species selection, namely, that it is simple and practical. Soils in this system are conveniently divided into two broad divisions: (I) mineral soils, including shallow peaty soils (peat depth less than 45 cm), and (II) peatland soils (with peat depth greater than 45 cm).

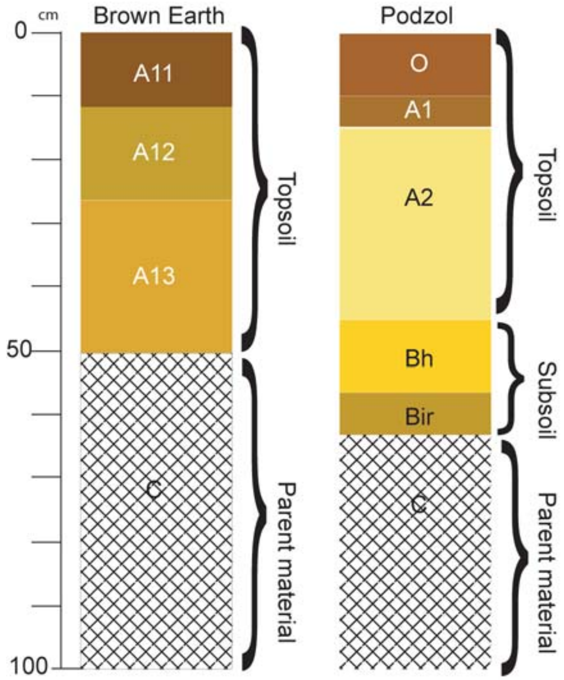
3.5.2 Description and identification of soils

Each soil is the result of processes, such as, weathering (physical and chemical breakdown of rocks), leaching (removal of soluble materials from upper to lower parts of soil), podzolisation (removal of less soluble materials, such as, iron, from upper to lower parts of soil), and gleying (the loss of iron under low aeration conditions). The nature and intensity of the processes is conditioned by six factors of soil formation: parent material, climate, topography, living organisms, time, and human activity. The operation of soil processes and the interplay of soil factors lead to a multiplicity of possible soil types. Soils can be described, and subsequently identified, by the

TABLE 3.2: Soil classification.

I. Mineral Soils	1) Dry Mineral Soils	Brown Earths Acid Brown Earths Grey-Brown Podzolics Rendzinas Brown Podzolics Podzols/Peaty Podzols (+/- weak pan) Indurated Iron Pan Podzols Lithosols
	2) Wet Mineral Soils	Surface-Water Gleys Peaty Podzolised Gleys Ground-Water Gleys Peaty Gleys
II. Peatland Soils	1) Raised Bogs	Intact Raised Bogs Hand- and Machine-Cutaway Peats (sod and milled) Fen Peats Fen-marls
	2) Blanket Bogs	Flushed (*Molinia*) Peats Reclaimed Blanket Peats Unflushed (*Sphagnum*) Peats Machine-cutaway Blanket Peats

elaboration of the soil into layers (horizons), which are characteristic of particular combinations of soil processes and factors. The main soils found in Ireland, and included in the classification above, are described below, largely on the basis of differences in the nature and arrangement of the soil horizons. The O, A, B, C system of naming horizons is used in this manual. This is illustrated in a schematic soil profile in Figure 3.6.



O horizon - contains more than 20% organic matter, and is present in podzols, peaty podzols, peaty gleys and peats.

A horizon - represents the topsoil (the upper mineral horizon), which is brownish-coloured due to the presence of organic materials. The lower part of the horizon can be paler in colour due to loss of iron and humus through leaching and podzolisation.

B horizon - represents the subsoil (the mineral horizon between the topsoil (A) and parent material (C)). The colour is usually different from the A and C horizons, being somewhat darker than both, through accumulation of iron and/or humus.

C horizon - represents the parent material, which consists of unconsolidated material from the upper portion of the bedrock or glacial drift. It is less developed than the A and B horizons, being paler and more poorly structured or lacking in crumb structure (crumb is defined as a soft, porous, more or less rounded natural unit of structure from 1 to 5 mm in diameter).

FIGURE 3.6:
Schematic diagram and explanation of the O, A, B and C system of naming soil horizons (after Joyce *et al.* 1998).

3.5.3 Soil groups

Typical locations for the various soils described are given below to aid the reader in soil identification (Gardiner and Radford 1980).

3.5.3.1 Mineral Soils

Dry Mineral Soils (Table 3.3)

TABLE 3.3: Dry mineral soil groups and characteristics.

SUBSOIL CHARACTERISTICS	SOIL GROUP	CHARACTERISTICS
Permeable to water/good aeration	Brown Earths	Lack of soil horizons. Derived from nutrient-rich materials. Medium-high fertility.
	Acid Brown Earths	Brown Earths derived from acid parent materials. Low-medium fertility.
	Grey-Brown Podzolics	Calcareous parent material. Accumulation of clay in subsoil.
	Rendzinas	Shallow version of Brown Earth.
	Brown Podzolics	Moderate leaching. Less pronounced horizons than in Podzols.
	Podzols/Peaty Podzols (with/without weak iron pan)	Extreme leaching. Pronounced series of horizons.
	Indurated Iron pan Podzols	Very extreme leaching, giving Podzol with iron pan.
	Lithosols	Very shallow stony soil over solid or broken rock.

Alkaline Brown Earths and Acid Brown Earths

These are free-draining mineral soils possessing a brownish-coloured profile, with little differentiation into horizons. There is no O horizon. The A and B horizons have a good crumb structure, and usually contain enough stones to make them favourably friable (a soil consistency term relating to the ease of crumbling of soils). There are two types of brown earth soils: firstly, those referred to simply as Brown Earths and secondly, the Acid Brown Earths, which are more common in Ireland.

Alkaline Brown Earths (known also as Brown Earths) are derived from nutrient-rich materials, such as, limestone and limestone glacial drift, conferring on them a high fertility status. They would have a mull type humus (mixed organic and mineral matter found in best soils) and medium (loamy) textures. They are found at lower elevations, but are not extensive in this country (Table 3.4).

<u>Forestry potential</u>: These are high fertility forest soils, suitable for a wide range of species, but particularly broadleaves, such as pedunculate oak, ash, European beech, sycamore, wild cherry, alder, and silver birch. However, their high fertility can promote

TABLE 3.4: Locations and parent material of alkaline brown earths.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Limerick: Ballingarry and Rathkeale	Limestone glacial drift	Gleyed Brown Earths and Gleys

coarse growth, poor form and instability in some species. At greatest risk are lodgepole pine (south coastal), Monterey pine, Scots pine, Corsican pine, Douglas fir, and Japanese, European, and hybrid larch.

The high pH associated with these soils also predisposes tree crops planted on them to *Fomes* butt rot (*Heterobasidion annosum*).

Brown earth.

Acid Brown Earths are derived from more acidic parent materials (sandstones, granites, mica schists, and non-calcareous shales), conferring on them a low to medium fertility status, and can be found at higher elevations than the Brown Earths, especially in low rainfall areas (Table 3.5). Humus may be mull or moder (intermediate between mull and mor, i.e. incomplete mixing of organic and mineral material), and textures are normally sandier than the (Alkaline) Brown Earths.

Forestry potential: These are prime forest soils, suitable for a wide range of species. However, ash and, to a lesser extent, sycamore, Norway maple and European beech, are more suitable for soils developed on limestone parent material (Alkaline Brown Earths and Grey Brown Podzolics). Form and stability of lodgepole pine (south coastal), Japanese and hybrid larch may be adversely affected by excessive growth rates on these soils. This can lead to poor stem form. Despite the very favourable physical and chemical characteristics of Acid Brown Earths, phosphorus levels are frequently low. However, trees usually respond to phosphorus fertilisation (250 kg/ha of rock phosphate is recommended).

Gleyed or slightly gleyed brown earths (indicated by some grey mottling) represent a group of soils between the Brown Earths and the Gleys.

TABLE 3.5: Locations and parent material of acid brown earths.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Carlow, Wicklow, Waterford and Louth	Granite and granite drift	Gleys and Podzols
Cork, Waterford, Kilkenny, and south Tipperary valleys	ORS/Limestone drift	Grey-Brown Podzolics and Gleys
Wexford, Waterford, Wicklow, Kilkenny, Tipperary, east Clare, Louth, Meath, Cavan and Longford	Shale glacial till	Gleys and Brown Podzolics
Monaghan, Cavan, Longford, Meath, Louth, and Clare	Drier drumlins on shale glacial till	Inter-Drumlin Peats and Peaty Gleys

Grey-Brown Podzolics

These soils are derived from calcareous parent materials (Table 3.6), which chemically prevent the leaching of iron while at the same time encouraging the movement of clay particles from the A horizon to the B horizon. The B horizon therefore has a substantially

TABLE 3.6: Locations and parent material of grey-brown podzolics.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Widespread in Limerick, Tipperary and Kilkenny	Loose glacial till, mainly limestone, some sandstone	Gleys and Brown Earths
Tipperary (Thurles-Cashel, Cloughjordan), Offaly (Tullamore and Ferbane), Roscommon (Castlerea-Roscommon), Meath (Oldcastle and Rathmoylan)	Limestone glacial till	Gleys, Brown Earths and Basin Peats
Galway (Portumna), Sligo–Mayo (Crossmolina, Ballyhaunis)	Compact limestone glacial till, gravelly in Galway, and with some sandstone in Sligo- east Mayo	Brown Earths, Gleys, and Podzols
Widespread as minority soil (to areas of shallow brown earths) in south Mayo (Claremorris), Galway and Clare (Corofin)	Shallow limestone glacial till	Shallow Brown Earths (majority soil), Gleys and Peats
Midlands: Kilbeggan, Ballinasloe, Birr	Limestone gravels and sands, e.g. eskers	Brown Earths, Gleys and Peats
Athboy (Meath) Mullingar (Westmeath)	Limestone glacial till, with some shale	Gleys and Brown Earths
East Meath and Dublin	Mostly Irish Sea glacial till	Gleys
Laois (Stradbally) Carlow (north of Tullow)	Mainly limestone glacial till, some granite/sandstone	Gleys
Kildare (Rathangan) Laois (Durrow)	Compact and stony limestone glacial till	Brown Earths and Gleys
Drier drumlins in Monaghan (Clones), Cavan (Belturbet), Meath (Nobber), Longford (Edgeworthstown), Sligo (Ballymote), Mayo (Castlebar), Roscommon (Strokestown to Elphin) and Clare (Ennis)	Limestone glacial till	Gleys, Inter-Drumlin Peats and Peaty Gleys
Hill areas in west Wicklow (Stratford-Dunlavin) and east Kildare (Kilcullen)	Mixed glacial till of limestone, shale and sandstone	Gleys and Brown Earths

Grey-brown podzolic.

higher clay content than the overlying A horizon and underlying C horizon. A wide range of Grey-Brown Podzolics exists because of the variability in the texture of the B horizon produced. The lighter-textured soils in the group have a wider potential of uses (similar to the Brown Earths), having a better drainage status than the heavier-textured ones. A common feature between the Grey-Brown Podzolics, Brown Earths and Brown Podzolics is the mull humus in the topsoil.

Forestry potential: Assuming the soil is the deeper (>70 cm) version of the Grey-Brown Podzolic, the forestry potential would be the same as described above for the Alkaline Brown Earths.

Rendzinas

Rendzinas are very shallow soils, best known in the Burren where they are generally less than 30 cm deep. They occur over limestone (Table 3.7). The typical Rendzina has a dark brown A horizon which directly overlies the limestone bedrock. If a B horizon is present, it is usually weakly expressed.

Rendzinas invariably exist in close association with Shallow Brown Earths and Shallow Grey-Brown Podzolics, all three soils often being found even within the small confines of a soil pit.

Forestry potential: (including Shallow Brown Earths, Shallow Grey-Brown Podzolics): These soils are generally sub-optimal for forestry, rarely enabling species planted on them to reach their full potential. Species best adapted to these conditions are European beech, sycamore, Norway maple, Italian alder, Corsican pine, Monterey cypress, and Serbian spruce. Other species to show promise on these soils include Lawson cypress,

Rendzina.

TABLE 3.7: Locations and parent material of rendzinas.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Extensively in north Clare (Burren) and to a limited extent in Galway, Sligo, Leitrim, Mayo and Tipperary	Limestone	Lithosols and Shallow Brown Earths, often in a matrix with outcropping rock

larch, lodgepole pine (north coastal), Monterey pine, Scots pine, Sitka spruce, western red cedar, lime and birch. Good crops of ash and Norway spruce can be found in pockets where the soil is deeper and more moisture retentive. On very difficult sites (shallow soils with rock outcrop) Austrian pine is the best option. *Fomes*, which causes mortality in pines and butt rot in many other conifer species, is usually very prevalent on these soil types.

Brown Podzolics

These are intermediate between Brown Earths and Podzols. Brown Podzolics (Table 3.8) have been subject to a milder intensity of leaching and podzolisation (due in part to lower rainfall) than the Podzols, resulting in a weaker expression of horizons. A typical profile would have a shallow peat layer (mull type) on the surface, overlying an A1 horizon which, compared to the Podzol, is thicker and has a more thorough mixing of organic and mineral material. A leached A2 horizon will be faint if present. Underlying the A horizon is a red-brown B horizon, the colour indicating the accumulation of iron, and sometimes humus. Brown Podzolics are very good forest soils, due to their favourable physical and chemical characteristics.

Forestry potential: Same as for Acid Brown Earths described above.

TABLE 3.8: Locations and parent material of brown podzolics.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Ridges of Munster valleys	Mixed drifts of sandstone, shale and slate	Acid Brown Earths and Gleys
Upper slopes of Boggeragh, Nagles, Knockmealdowns and Monavullagh Mountains (south Cork and south Waterford)	Sandstone	Gleys and Podzols
East Wicklow, Wexford and Tipperary	Shales and mica schist	Gleys and Podzols
Donegal, Carlow, Wexford and Wicklow	Mica schist drift	Acid Brown Earths and Gleys
Lower slopes of Leinster Mountains: west Wicklow, Wexford, Carlow and south Dublin	Granite	Gleys, Podzols and Blanket Peats

Brown podzolic.

Podzols/Peaty Podzols (with/without weakly developed iron pan)

These soils are derived from acid parent materials, and are found mainly on upper and middle free-draining slopes (Table 3.9). They are strongly acid, coarse-textured, free-draining soils, with a distinct sequence of horizons. Leaching is a dominant process in the formation of these soils, resulting in loss of humus (from O and A horizons) and iron (from the lower part of the A horizon, giving rise to a pale-coloured A2 sub-horizon) and deposition in a B horizon, with humus at the top of the B horizon. With more intense leaching, particularly on flattish areas at high elevation, organic matter accumulates at the surface giving a peaty podzol. Both podzols and peaty podzols have a mor type

TABLE 3.9: Locations and parent material of podzols/peaty podzols.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Mountains in Cork, Kerry, Waterford, Tipperary, Limerick, Wicklow and Donegal	Sandstone, granite and some shale	Lithosols, Indurated Iron Pan Podzols, Peaty Podzolised Gleys and Blanket Peats

humus (raw forest humus layer of organic matter without incorporation of mineral matter) at the surface. Heather and furze are the dominant vegetation types.

Forestry potential: These soils generally have low levels of available phosphorus and nitrogen. Cultivation aimed at rupturing the organic surface seal, plough pan and weakly developed iron pan, if present, followed by an application of phosphate, will stimulate

Peaty iron pan podzol.

furze development on many sites. The pan can be an obstacle to downward water movement, but usually not seriously so, because the pan is usually discontinuous. Where the pan is continuous, the soil above the pan is often saturated. This is evident in the gleyed appearance of the soil immediately above the pan. Disruption of the pan transforms this poor forest soil into a very good one, since the only obstruction to water movement has been removed. Furze, by virtue of its root nodules, ensures a regular supply of nitrogen to the tree crop. Growth of European furze has to be controlled to prevent suppression of the tree crop. A wide range of species can be grown where exposure is not a problem, with the following being best adapted: Sitka spruce, Serbian spruce, Douglas fir, hybrid and Japanese larch, western hemlock, western red cedar, Scots pine, Corsican pine, Monterey pine, Lawson cypress, Spanish chestnut, European beech, southern beech, red oak, silver birch, and rowan. On more exposed sites, and/or where heather dominates, confine selection to Sitka spruce, or mixtures of Sitka spruce and Japanese larch, and Sitka spruce and lodgepole pine (see Table 6.2, page 183). Pure crops of Macedonian pine also show promise in these situations.

Indurated Iron Pan Podzols

These share many of the characteristics of the Podzols/Peaty Podzols, but the existence of an iron pan (an indurated soil horizon in which iron oxide is the principal constituent) in the B horizon confers an important distinguishing feature.

This soil is commonly found in the Old Red Sandstone hills of the south (OCarroll and Carey 1972) (Table 3.10). It has a surface peat (mor) layer, about 15-20 cm thick. The underlying highly leached A horizon is generally thicker than found in the Podzols/Peaty Podzols described above. Likewise, the iron pan is much more strongly developed and generally lies at a deeper depth (50-60 cm from the surface) than any iron pans found in Podzols/Peaty Podzols. Other points of difference are the very compact and indurated (soil material cemented into a hard mass that will not soften on wetting) nature of the B horizon, and its yellowish brown colour, which is less striking than in the Podzols/Peaty Podzols. These soils have a poor structure (absence of crumb aggregates), due largely to their low organic content.

TABLE 3.10: Locations and parent material of indurated iron pan podzols.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Upper slopes and flats of Old Red Sandstone hills in the south.	Sandstone	Peaty Podzolised Gleys Peaty Iron Pan Podzols Lithosols

Indurated iron pan podzol.

The pan is a serious obstacle to downward water movement, with the result that the soil above the pan is often saturated, so that the A horizon is gleyed, especially the lower part (that part immediately above the pan). A minimum requirement for planting would be that the pan be broken during site cultivation. In their natural condition, the surface layer is usually dominated by heather.

<u>Forestry potential</u>: Above the iron pan, these soils are waterlogged and anaerobic for much of the year, and are unfavourable for growing most tree species. Where the surface layer of peat and/or the iron pan are not too deep the soil can be improved by a combination of ripping and mounding (ripping to rupture the iron pan to allow vertical drainage, and mounding to provide a favourable environment for survival and early growth). Where this is not possible, careful alignment and increased intensity of mound

drains can achieve good lateral drainage. Typically, these soils are low in available phosphorus and nitrogen. This condition is further exacerbated by high levels of iron and aluminium, causing chemical fixation of phosphorus, requiring perhaps second applications in the crop rotation.

Pure crops of Sitka spruce could be planted in areas where the surface layer of peat has not been removed, or where Irish furze is expected to colonize following cultivation and phosphorus application. Elsewhere, and where exposure is not too severe, mixtures of Sitka spruce and Japanese larch could be considered, as also could western red cedar, western hemlock and Lawson cypress in mixture with Japanese or hybrid larch. Downy birch, common alder, red oak, rowan, and European beech if planted, should be confined to the more favourable locations such as glens and stream edges. On more exposed situations confine selection to mixtures of Sitka spruce and lodgepole pine (see Table 6.2, page 183). On sites where the surface layer of peat has been removed (scrawed), pure lodgepole pine is the best option (see Table 6.2, page 183).

Lithosols

These are very shallow stony soils over solid or broken rock, found usually on steep slopes and mountain tops (Table 3.11). A typical lithosol will be up to 10 cm deep, and will either have a thin cover of acid (mor) peat over coarse mineral material/bedrock or be mixed with coarse mineral material. These soils are subject to rapid water loss, and are therefore prone to drought.

Forestry potential: By virtue of their location (usually near the summit of hills and mountain ridges), exposure is nearly always an additional factor in limiting species choice to lodgepole pine, or perhaps to lodgepole pine/Sitka spruce mixtures (see Table 6.2, page 183). Macedonian pine is also showing promise in these situations. Where conditions are more favourable Sitka spruce/Japanese larch mixtures could be considered.

TABLE 3.11: Locations and parent material of lithosols.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Cork, Kerry, Galway, Mayo, Donegal and Wicklow	Granite, sandstone, mica schist and quartzite	Brown Podzolics, and Peaty Podzols amongst outcropping rock and Blanket Peats

Lithosol.

Wet Mineral Soils

This category of soils, referred to as gleys, is dominated by conditions of water-saturation (Table 3.12). The main gleys are described below, but there are several other soils with gley characteristics, which intergrade with the freer-draining soils described in 3.5.3.1 above: Gleyed Brown Earths, Peaty Podzolised Gleys, Gleyed Iron Pan soils, and Gleyed Alluvial Soils (an alluvial soil is one produced from recently deposited river deposits, with little or no horizons developed). Of these intergrade soils, only the Peaty Podzolised Gleys are described, since they only represent an important forest soil in this country.

TABLE 3.12: Wet mineral soil groups and characteristics.

SUBSOIL CHARACTERISTICS	SOIL GROUP	CHARACTERISTICS
Impermeable to water/poor aeration	Surface-Water Gleys	Formed on clay-rich or compact materials. 'False' water table from surface water.
	Peaty Podzolised Gleys	Raw peat over greyish leached layer that overlies red-brown mottled subsoil; no iron pan. Peat may have been removed.
	Ground-Water Gleys	Impervious material below soil. 'Real' water table from ground water, seepage and springs.
	Peaty Gleys	Black or dark brown amorphous peat over surface or ground-water gleys.

Surface-Water Gleys

Water saturation in Surface-Water Gleys (Table 3.13) is due to a restriction of drainage, either from materials with high clay contents and/or from materials that are compacted. This impermeable material (especially that due to high clay content) can occur at any

TABLE 3.13: Locations and parent material of surface-water gleys.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Widespread on plateaus in Abbeyfeale, Castlecomer and Clare; north Cork and north Kerry	Upper Carboniferous glacial till	Acid Brown Earths and Peats
Galway (Woodford), Roscommon (Strokestown), Tipperary (Newport) and Limerick (Cappamore)	Mixed sandstone-shale till	Peaty Gleys
Wet drumlin areas of Cavan (Bailieborough-Arvagh-Cootehill), and Monaghan (Newbliss-Clontibret)	Ordovician/Silurian shale and sandstone till	Acid Brown Earths and Peaty Gleys
Wet drumlin areas of Cavan (Ballinamore), Leitrim (Mohill, Drumsna), north Roscommon, Sligo (Drumcliff) and south Donegal	Extremely high silt and clay content glacial till mostly of Upper Carboniferous limestone and Ordovician/Silurian shale	Peats and Peaty Gleys
Wet flats of Meath (Kilcock –Dunshaughlin-Balbriggan), Louth, Dublin (Ashbourne), north Kildare (Naas), south Wexford (Bridgetown), southeast Waterford (Fethard-on-sea)	Calcareous till from Irish Sea mixed with land-sourced limestone and shale	Grey-Brown Podzolics (sometimes gleyed)
Wet flats of eastern Wexford and Wicklow (Enniscorthy to Brittas Bay)	Calcareous muds from Irish Sea	Grey-Brown Podzolics (sometimes gleyed)

depth of the soil, and indeed throughout the soil also. The development of Surface-Water Gleys is facilitated by high rainfall on flattish ground. The topsoils are generally acid, but the pH increases with depth, the extent of the rise dependent on the nature of the parent material.

The soil profile has a dominant grey colour, which is due to the lack of aeration, which in turn is due to a lack of pores in the soil material. Blue colours dominate where water saturation is permanent or semi-permanent. Where there is some aeration of the soil (zone of fluctuating water table), as in old root channels and soil cracks, there will be small areas of red-brown colour (mottles). The more mottled a gley soil is, the more favourable it is for tree growth and wider species options.

Surface-water gley.

Surface-Water Gleys, due to high clay materials, typically have a profile with horizons as follows: the humified and gleyed upper part of the soil (A1) may be underlain by an A2 horizon, also gleyed and mottled, but paler in colour due to lack of humus and slight removal of iron. The underlying B and C horizons get progressively more gleyed, and poorer in soil structure.

Soils intermediate between Brown Earths and Gleys would be the Gleyed Brown Earths, Gleyed Grey-Brown Podzolics, Podzolised Gleys and Peaty Podzolised Gleys.

These intermediate soils would be freer-draining than the true gleys. The Gleyed Brown Earths have only minimal gleying in the topsoil. The Peaty Podzolised Gleys have coarse-textured and pale-coloured A2 horizons, below which are humified B horizons.

Surface-Water Gleys developed on compact materials (not necessarily clay-rich) have profiles similar to those developed on high clay materials, with the exception that they normally do not have a B horizon. Soils intermediate with these would be the Gleyed Iron Pan Podzols, where the pan is located directly above the compact material.

Forestry potential: Soil nutrient status is generally good. Anaerobic conditions are the main limiting factor to tree growth. Where this condition is less severe (significant red-brown mottling of the profile) and/or if the anaerobic conditions can be alleviated by intensive drainage, the following species can be used: Sitka spruce, Norway spruce, Serbian spruce, western red cedar, western hemlock, Lawson cypress, Grand fir, pedunculate oak, Norway maple, sycamore, ash, common alder, grey alder, downy birch, and hornbeam. Where anaerobic conditions are severe (yellow or grey/blue soil profile, with little or no mottling) and/or it is not possible to keep the winter water table 45 cm below the surface, silvicultural options are significantly reduced. Species choice would then be reduced to common alder, Sitka spruce, Norway spruce, and where landscape enhancement is a priority, groups of Japanese larch could be added. Crop stability is also a major problem on gley soils, but the use of self-thinning mixtures can do much to alleviate this problem (see Chapter 5).

Peaty Podzolised Gleys

Such soils have podzol and gley features. Their sandy loam to sandy clay textures, and their typical location in the high rainfall sandstone hills of the south, allows a degree of leaching and podzolisation on an otherwise imperfectly drained soil. Where the soil has been undisturbed it is covered by a raw, mor-type peat of less than 45 cm depth, which overlies a greyish leached layer (A), which in turn overlies a layer (B) that has been variously coloured due to enrichment with humus and iron from above and red-brown

Peaty podzolised gley.

mottles due to aerated pockets. The peat layer is often much less than 45 cm, and may even be absent if previously harvested as a fuel source, the resulting soil being a podzolised gley rather than a peaty podzolised gley.

Forestry potential: Where the site is exposed species selection is limited to Sitka spruce/lodgepole pine mixtures (see Table 6.2, page 183). On less exposed and better-drained sites these mixtures may be supplemented with Sitka spruce/Japanese larch mixtures. Western red cedar, western hemlock and Lawson cypress also show promise on these sites, and are suitable for planting in mixture with larch. Where the peat has been removed, a pure crop of lodgepole pine is the best option (see Table 6.2, page 183).

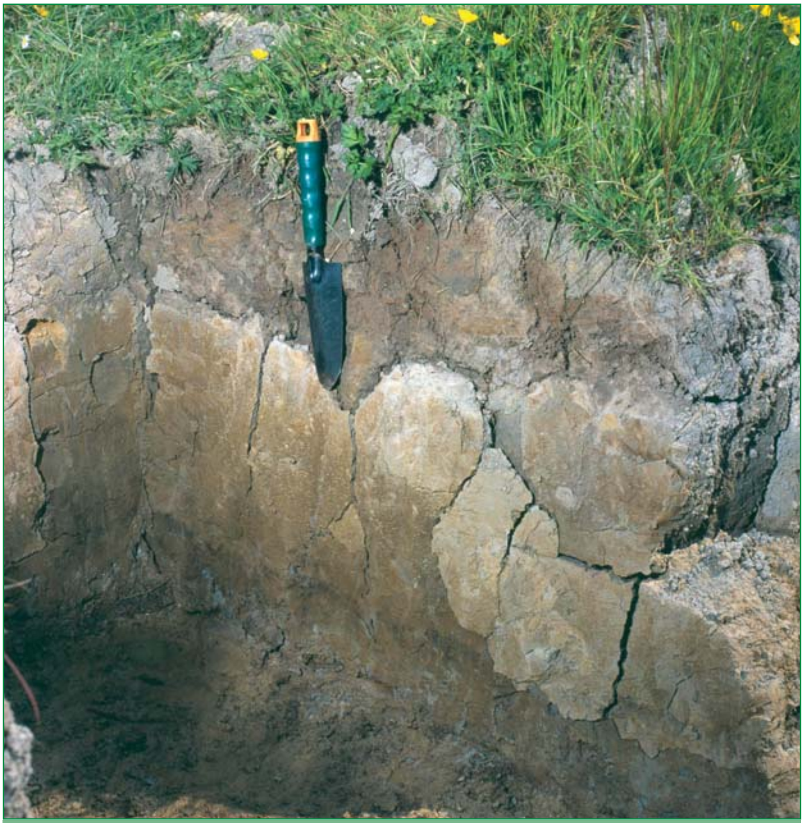
Phosphorus fertilisation is required at planting, and a second application may be needed later in the rotation. Nitrogen fertiliser may also be required where mixtures are proposed to maintain growth of the spruce prior to the nurse species becoming effective.

Ground-Water Gleys

Water saturation in Ground-Water Gleys (Table 3.14) is due to drainage being restricted by a high water table, caused by impervious material below the soil parent material. Thus, it is possible for ground-water gleys to have coarse-textured topsoils, in contrast to surface-water gleys.

The soil profile has a dominant grey colour, which is due to the lack of aeration that in turn is due to a lack of pores in the soil material. Blue colours dominate where water saturation is permanent or semi-permanent. Where there is some aeration of the soil (zone of fluctuating water table), as in old root channels and soil cracks, there will be small areas (mottles) of brownish colour. The more mottled a gley soil is, the more favourable it is for tree growth and wider species options.

Ground-Water Gley profiles generally have an organic-rich topsoil (A) with slight gleying, overlying a much-mottled B horizon, which overlies a saturated grey to blue C horizon. Textures are often coarser than in Surface-Water Gleys, at least in the A and B horizons. Soil pH is usually acidic in the topsoil, but the pH increases with depth, the extent of the rise dependent on the nature of the parent material.



Ground-Water Gley.

TABLE 3.14: Locations and parent material of ground-water gleys.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Limerick, Tipperary, Laois, Kilkenny, Kildare, Roscommon and Galway	Limestone till	Grey-Brown Podzolics and Brown Earths

Soils closely related to Ground-Water Gleys would be the Gleyed Alluvial Soils.

Forestry potential: Same as for Surface-Water Gleys.

Peaty Gleys

These are defined as soils with less than 45 cm peat over gley subsoil. They are more commonly found within the Surface-Water Gleys, since drainage tends to be more restricted in their topsoils than in those of the Ground-Water Gleys.

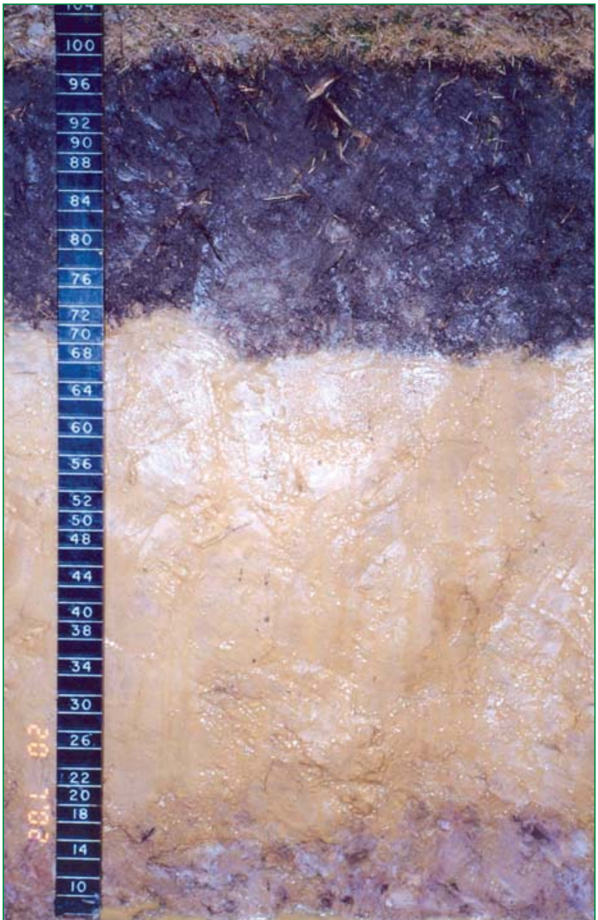
Peaty Gleys (Table 3.15) developed on high clay materials have a profile with a black amorphous peat, overlying a two-part A horizon, the upper organic-mineral part (A1) weakly expressed and the lower leached part (A2) strongly expressed. The soil reaction patterns would be as noted above for the Gleys, i.e. rising from acid at soil surface towards neutral at the bottom of the soil profile.

Peaty Gleys developed on compact materials have profiles similar to those already described for the Gleys on such materials.

Forestry potential: Peaty Gleys – Fertility Class A or B: Same as for Surface- and Ground-Water Gleys.

TABLE 3.15: Locations and parent material of peaty gleys.

TYPICAL LOCATIONS	PARENT MATERIALS	ASSOCIATED SOILS
Wetter drumlins of east-mid Cavan and Monaghan	Ordovician-Silurian shale and sandstone glacial till	Surface-Water Gleys and Inter-Drumlin Peats
Wetter drumlins of Leitrim and west Cavan	Upper Carboniferous limestone and shale/sandstone glacial till	Surface-Water Gleys and Inter-Drumlin Peats
Drier drumlins of Monaghan and Cavan (Emyvale to Cavan town)	Limestone glacial till	Grey Brown Podzolics, Surface-Water Gleys and Inter-Drumlin Peats
Drier drumlins of east Monaghan and Cavan	Ordovician-Silurian shale glacial till	Brown Earths (acidic) and Inter-Drumlin Peats



Peaty gley.

Forestry potential: Peaty Gleys/Gleys – Fertility Class C: Generally, species choice is rather limited on these sites. Sitka spruce often develops a condition known as 'check' (retarded growth), eight to ten years after planting. This is brought about by nitrogen deficiency, the affected crop frequently requiring repeated nitrogen applications and, in some cases, a second phosphorus application, for satisfactory crop development. While the economic benefits of nitrogen application are clear, an alternative and preferred option, on sites where nitrogen problems are anticipated, is to plant Sitka spruce in mixture with a nurse species (see 5.1.2.1, page 74). Lodgepole pine is best suited to this purpose, having the capacity to adapt to diverse and often adverse growing conditions associated with these sites (see Table 6.2, page 183). Japanese larch, common alder and downy birch could be planted in more favourable locations, such as along the banks of streams and flushed areas.

3.5.3.2 Peatland Soils

Raised Bog Group

The raised bog group (Table 3.16) are found in the Midlands on mineral-rich ground.

TABLE 3.16: Peatland soil classification.

Raised Bogs	Intact Raised Bogs Hand- and Machine-Cutaway Peats (sod and milled) Fen Peats Fen-Marls
Blanket Bogs	Flushed (*Molinia*) Peats Reclaimed Blanket Peats Unflushed (*Sphagnum*) Peats Machine-Cutaway Blanket Peats

Intact Raised Bogs

Undrained raised bogs can have a peat depth of 9-12 m. There are two main types of peat present. The type found at the base of the bog was developed under the influence of mineral-rich, alkaline ground waters, forming a fertile fen peat. The peat overlying the fen peat was developed under the influence of rainfall, thus forming a nutrient-poor, acidic peat.

Three layers of peat are usually evident: a surface layer of poorly humified mosses, an intermediate layer of humified mosses, and a bottom layer of residues from woody and fen species.

Surface vegetation is dominated by mosses, with varying occurrences of heather, cross-leaved heath, bog asphodel, deer grass and bog cottons, their frequencies being dependent on drainage status.

Intact or virgin raised peatlands have considerable conservation value and this should be borne in mind when considering their forestry potential.

Forestry potential: Raised bogs are generally confined to the central plains. Intact or virgin raised bogs are generally unfavourable for tree growth, the major disadvantages being infertility and the frequency of severe frosts. Lodgepole pine (see Table 6.2, page 183) performs relatively well because of its low nutrient requirements and its resistance to frost, whilst Sitka spruce would require repeated applications of fertiliser and is susceptible to frost.

Hand- and Machine-Cutaway Raised Bogs

The main feature of the hand-cutaway raised bog is its disturbance by man, which results in the existence of a highly acid (pH 3.5-3.8) surface layer (0.3-2.0 m), consisting mostly of non-humified mosses. This layer ('acid strippings') was stripped from an adjacent bog surface (discarded due to its low calorific value) and removed to rest on an adjacent, previously harvested bog surface.

Peat depths vary, depending principally on (1) the original depth, and (2) the amount of peat that has been removed and harvested.

Surface vegetation typical of shallow hand-cutaway peats would be reeds, rushes and meadow sweet. Deeper peats tend to be dominated by heather, with also bracken or moss and *Molinia*. The greater part of the deeper peat profile is composed of relatively non-humified, nutrient-poor material.

Prior to 1980 there were two peat harvesting systems, known as sod peat and milled peat systems because of the nature of the material produced. There were three important differences between the systems:

- the sod peat has a two-part profile, having the acid strip layer on the surface, whilst the milled peat profile has no acid strip layer,
- drains are at 250 m intervals on sod peat bogs and 15 m on milled peat bogs, and
- sod peats are generally deeper than milled peats.

<u>Forestry potential</u>: (Hand and Machine Cutaway Raised Bogs (*sod peat, pre-1980*): Due to a layer of acid strippings left behind after the peat harvesting, free calcium carbonate is less of a problem than on milled peat sites. The highly acid and nutrient-deficient nature of the strippings, usually favours the development of heather dominant vegetation types. With the exception of lodgepole pine (see Table 6.2, page 183), and to a lesser extent Scots pine, chemical heather control and/or nitrogen applications may be required for the satisfactory establishment of many species. Phosphorus fertilisation is essential at planting on all sites; potassium fertilisation is also advised, although application may be deferred to the second or third year after planting. Application of copper should only be considered following confirmation of copper deficiency by foliage tests.

Spring frost damage is the main limiting factor to the planting of Sitka spruce. Apart from being multi-stemmed (most likely the result of frost), the performance of western hemlock is impressive and appears unaffected by peat depth. Conversely, the performance of western red cedar, Japanese larch, grand fir and Douglas fir declines rapidly with increasing peat depth. The performance of Monterey pine is typical, that is, very large individual specimens in poorly stocked stands. Lawson cypress is multi-stemmed, but remarkably healthy. For sheer consistency of performance, lodgepole pine, Scots pine and, where heather is not a problem, Norway spruce, are the best among the conifers, with oak and birch being the most promising broadleaf species.

After 1980, harvesting by Bord na Móna has been by the milled peat system only, resulting in a major part of the peat being harvested or cut away (i.e. no acid strippings), leaving behind a variable depth of basal peat. The depth of peat left behind will vary according to the depth at which the underlying bog floor occurs. Peat depth affects species options.

Forestry potential: (Machine-Cutaway Raised Bogs (*milled peat, post-1980*): Problems being encountered include the adverse effects on tree growth of free calcium carbonate (see discussion below on marls in section on fen peats), exacerbated by winter waterlogging and a fluctuating water table, frost and vigorous vegetation competition. Phosphorus and potassium (and sometimes copper) are also usually required on these sites. Current indications are that where the underlying mineral material is weathered to some degree and is overlain by at least 50 cm of peat with a relatively stable water table, the following species may be grown: Norway spruce, Scots pine, lodgepole pine (see Table 6.2, page 183), Corsican pine, birch, common alder and oak. Experience with hybrid larch, Grand fir, Macedonian pine, western hemlock, western red cedar and Lawson cypress is limited, but is sufficiently promising to justify further planting. Sitka

Cutaway milled peat.

The BOGFOR project is researching silvicultural practices and species selection on cutaway bogs.

spruce would perhaps be the first choice, but for the frost problem. These are relatively new man-made soils, with many gaps in our understanding of their many complexities. Their silvicultural potential is the subject of the BOGFOR project, which involves University College Dublin, Bord Na Móna and Coillte and has been funded in the past by COFORD and the Forest Service. Factors under investigation by this project include, appropriate cultivation methods, most suitable species, and nursing mixtures. Definitive silvicultural prescriptions will have to await the findings of this comprehensive investigation.

Fen Peats

Fen peat is found at the bottom of raised bogs, and also in valleys and basins bearing mineral-rich (alkaline) ground waters.

The surface peat is black, with depths up to about 0.5 m, usually with a good drainage status, especially where it was previously cultivated (which most of them were in periodic reclamations). The black layer is underlain by a reddish-brown peat composed of a mix of humified and non-humified materials (wood and herb residues).

The depth of fen peats can extend beyond 1.5 m. The fertile nature of the fen peats is reflected in the pH status, which is typically pH 5.0-5.5 at the surface and even higher at the base.

There are two types of fen peat, reedswamp peat and wood or woody fen peat. The topographical position in which the peat was formed determines which peat it is. Reedswamp peat usually develops in the lowermost areas, over marl, whilst wood or woody fen peats are formed on more upland areas, over less calcareous material.

<u>Forestry potential</u>: Many of these sites have been considerably altered by arterial drainage schemes. There is also evidence of field boundaries, localised drainage, cultivation, lime and fertiliser application. For this reason wide variations can be found between sites and in the performance of the tree crops growing on them. The forestry potential of fen peats will depend to a great extent on the depth of peat left behind, particularly where the fen is underlain by highly calcareous marl material (see Fen-Marls below). Free (excess) calcium carbonate, frost, potassium deficiency and, in some cases, copper deficiency, are the main limiting factors to satisfactory tree growth on these sites. Phosphorus requirements can vary from site to site, some sites requiring none. Species options would be similar to those for machine-cutaway raised bogs (post-1980).

Fen-Marls

The nature of the bog floor beneath the fen peat ranges from marls (lime-loving plants absorbed lime from the highly calcareous freshwater lakes following the glacial period, eventually leaving an accumulation of lime-rich material, or marl, on the lake bottom) to glacial drift materials, the pH and free lime content of which can vary enormously, depending on their source and degree of weathering.

<u>Forestry potential</u>: Marl is inherently unfavourable for growth of most species, particularly conifers, and in many cases in which it occurs the site will be unsuitable for any species, at least for normal commercial purposes. The suitability of marl soils for tree growth depends on a range of factors, which can have a separate or collective effect. The most important of these factors are: the free lime content of the marl, depth to the marl layer, thickness of the marl layer itself (thin veins are inconsequential), presence/absence of organic material, depth of organic material overlying marl, and drainage conditions. The inevitably complex interaction of these factors makes sites frequented by marls very difficult to assess in terms of suitability for growing trees. Thus, it is advisable to seek expert advice when marl soils are being evaluated for their forestry potential. Soils developed from glacial drift material tend to be more favourable for tree growth than those on marl material, which highlights the need for recognition of the difference between the two types of lime-rich material.

Fen-Marl.

Blanket Bog Group

The blanket bog group is found on nutrient-poor ground and in high rainfall areas of the northwest, west, southwest, and mountains in other parts of the country. Blanket peats occur at all elevations, and have been classified into two types for soil survey purposes (Hammond 1979), the high-level blanket peats, occurring at elevations above 150 m, and the low-level blanket peats, occurring at elevations below 150 m.

Both types are similar, the main point of difference between them being the dominance of black bog rush in the surface vegetation of low-level blanket peats, in contrast to its relative infrequency or even absence on high-level blanket peats. Another point of difference may be the depth of peat, which is often greater in the low-level blanket peats, due to their occurrence on flatter terrain than the high-level blanket peats.

The profile usually has three recognisable layers: (1) a surface layer of relatively fresh non-humified plant materials, (2) an intermediate layer of moderately humified plant materials, and (3) a bottom layer of very humified plant materials, which is characteristically greasy and black.

Whilst the classification of blanket peats into low-level/high-level types is useful, it is important for forestry purposes to also recognise fertility differences within the blanket bog group, by separating flushed (relatively fertile) from unflushed (infertile) peats.

Reclaimed blanket peat.

Some blanket peatlands have conservation value and this should be borne in mind when considering their forestry potential.

Flushed Blanket Peats

These are often referred to as *Molinia* peats, due to the dominant status of *Molinia caerulea* (purple moor grass) in the surface vegetation. Heather is often frequent in flushed blanket peats also. The texture of the peat is well to moderately humified.

<u>Forestry potential</u>: Though enriched by waters from adjoining slopes, these soils normally require an application of 350 kg/ha of rock phosphate. Sitka spruce is the obvious first choice on these sites, whilst Lawson cypress, Serbian spruce, Monterey pine, western hemlock and Japanese larch, can also be successful. However, their performance naturally varies according to the characteristics of the site.

Reclaimed Blanket Peats

These are the result of improvement by man through a variety of practices over a long period of time. Such practices include burning of the indigenous bog vegetation, drainage, cultivation and addition of natural (e.g. farm-yard manures, sea-sand, seaweed and lime) and/or artificial fertilisers. Such reclamation is generally confined to shallower, more drainable peats and/or following the removal of the upper part of the peat bog for fuel purposes. A feature of the reclaimed blanket peats is the replacement of the original or native bog vegetation by species (e.g. soft rush) introduced naturally as a result of the improved conditions. Vegetation composition is dominated by grass-rush as long as the basic fertility of the site is maintained. However, in the absence of inputs many sites revert to almost their original condition, or at least to a *Molinia*-dominated state, indicating less favourable conditions.

<u>Forestry potential</u>: Considerable variations in both character and fertility status of these peats are not uncommon due to having developed from very diverse backgrounds. Notwithstanding this, species options are similar to those given in Table 4.1 for flushed blanket peats. However, cognisance should be taken of local factors and, where appropriate, the species ranking adjusted to reflect the actual conditions of the site. It is possible that the site has been abandoned for many years and has reverted to close to its original condition, in which case many species should be downgraded to a lower level than shown in Table 4.1. Conversely, if the site has been managed to a very high standard over a protracted period, many species could safely be upgraded to a higher level than shown in Table 4.1. In these circumstances additional species, such as grey alder and sycamore, could be considered.

Unflushed Blanket Peats

These are often referred to as *Sphagnum* peats. As well as the mosses (*Sphagnum*), other important components of the surface vegetation would be bog cotton and deer grass. The upper part of the peat tends to be non-humified (plant remains are obvious), with some humification in the lower part.

Forestry potential: Blanket bogs are the most common peat types found along a coastal belt from Cork to Donegal. Unflushed blanket peats are generally regarded as hostile areas for tree growth, with the blanket peatlands of north Mayo being regarded as the most difficult and infertile. After drainage and phosphorus application, Sitka spruce can be established, but rarely is growth sustained in the absence of a second application of phosphorus and repeated applications of nitrogen. Due to economic forces and environmental constraints these options are unlikely to be available in the future and will have to be substituted by prudent species choice. Pure lodgepole pine (see Table 6.2, page 183) is therefore the best option on the more exposed knolls, featuring deer grass and heather, and also on the frequently pool-studded, fibrous and pseudofibrous peat flats, which are dominated by deer grass and cotton grass. Nutritional mixtures are not considered to be an option on such sites (see 5.1.2.1, page 74). However, mixtures of Sitka spruce/lodgepole pine (see Table 6.2, page 183) could be considered on the adjoining slopes of shallower and better-drained peats. Birch and common alder could also be considered in more favourable locations, such as along the banks of streams, with Japanese larch being planted on bracken-colonised knolls.

Machine Cutaway Blanket Peats

Forestry potential: The only information about species options on this site type comes from an experiment established in 1984 on a milled peat site at Bellacorick, Co Mayo. Following peat harvesting to within about 0.5 m of the underlying mineral material, the area was ploughed to a depth of 1 m. The site was then given a broadcast application of 350 kg/ha rock phosphate and planted with the following species: Sitka spruce, lodgepole pine (south coastal), Monterey pine, Sitka spruce/Japanese larch and Sitka spruce/common alder. After 18 years, lodgepole pine is the most promising species (full stocking, healthy, and general yield class (GYC) 14), followed by Sitka spruce (full stocking, reasonably healthy, and GYC 14) and larch (good stocking, looks healthy, and GYC 6-8). The Sitka spruce planted in mixture with Japanese larch has an improved colour and a GYC of 16, evidently benefiting from the larch nurse. Alder is moribund, and the Monterey pine is all dead.

3.6 PREVIOUS LAND USE AND SITE FERTILITY

Most of this section is taken from Research Communication No. 13 (OCarroll 1975). Amendments have been made, firstly, to fertiliser recommendations, reflecting changes in form and rate of fertiliser to accommodate environmental concerns, and secondly, to include an additional site fertility class.

The influence of man (previous land use) on site fertility is well recognised, as manifested by the symbols or ornaments seen on the 1:10,560 scale (six inches to one mile) Ordnance Survey (OS) maps.

By examining the ornament on the maps, sites can be separated into three fertility classes, based on varying intensities of agricultural use. The fertility classes are denoted as A, B and C, with A the most fertile and C the least fertile.

3.6.1 Class A (Fields and ornamental grounds)

These are areas that have been in intensive agricultural use up to relatively recent times, so that they still carry characteristic agricultural vegetation (Figure 3.7). They are among the most fertile site types made available for forestry, and fertilisation is not normally required. Vegetation usually consists of pasture grasses and herbaceous plants, often with a high proportion of rushes.

Species choice is not limited by fertility on Class A sites.

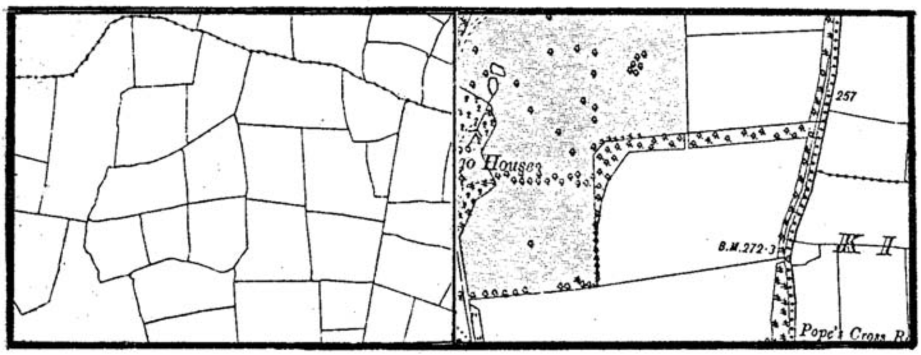


FIGURE 3.7:
Class A (fields and ornamental grounds) as seen on 1:10,560 OS map.

3.6.2 Class B (Furze)

These areas were once enclosed by banks, walls or ditches (Figure 3.8). This indicates that they were considered sufficiently fertile at some time to justify bringing them under

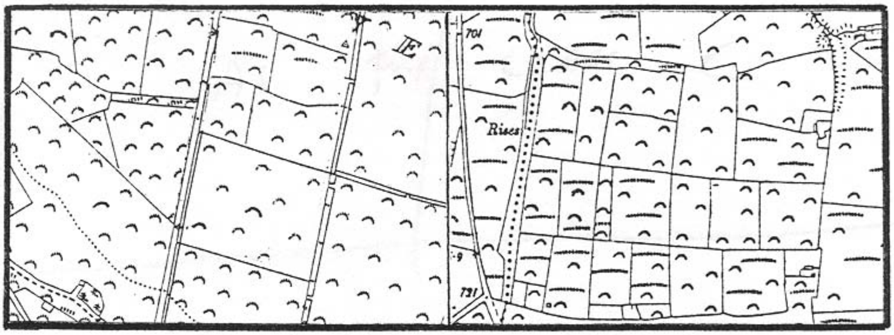


FIGURE 3.8:
Class B (Furze) as seen on 1:10,560 OS map.

agricultural use, and were probably cultivated. The presence of furze species indicates that these areas have not been intensively managed for a long time. They were first abandoned when less land was required for agricultural production as a result of either decreasing population pressure, or increasing productivity on the better land due to improved technology. The basic fertility of these sites will generally have been improved by past cultivation and the use of manures, but will have remained unchanged, or may have deteriorated somewhat since their withdrawal from intensive management.

This class would include all long-abandoned agricultural land, even though it appears to have reverted almost to its original condition. It may also be extended, on the basis of local knowledge and experience, to include unenclosed areas on mineral soils derived from parent materials of shale and mica-schist or granitic origin, i.e. to include areas inherently not of the lowest fertility, but which, because of other local factors, were never enclosed for agricultural usage. These sites are intermediate in fertility between those in A and C, requiring an application of 250 kg/ha of rock phosphate.

Species choice on these sites is usually dictated by considerations other than fertility.

3.6.3 Class C (Rough pasture, with or without outcropping rock).

These are areas of unenclosed ground (Figure 3.9), which have never been cultivated or brought under any form of intensive agricultural use. In most cases the reason for this was that the inherent fertility of the soil (as a result of the combined effect of soil and site factors) was so low that any investment in reclamation would not have been practical or financially justified. Sites included in class C are those on unenclosed land, usually in the uplands or on bogland, typically carrying unimproved heathland or peatland vegetation. Mineral land in this class will normally be derived from quartzite or sandstone. The class will include all unflushed virgin deep peats. Trees planted on class

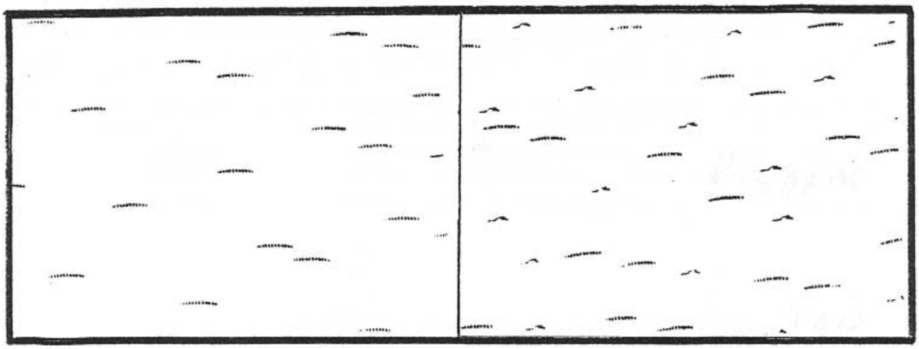


FIGURE 3.9:
Class C (rough pasture, with or without outcropping rock) as viewed on 1:10,560 OS map.

C sites will fail unless given phosphorus fertiliser. An application of 350 kg/ha of rock phosphate is recommended at planting. In some situations this may have to be repeated, in addition to nitrogen application, to maintain satisfactory growth.

Species choice on these sites is usually very limited, on occasions confined to lodgepole pine and Sitka spruce, or mixtures of those species on mineral soils.

3.6.4 Class B-C

Class B-C represent sites that have been improved in the recent past, at least since the OS maps were completed. The OS maps, having been prepared prior to the site improvement, have included sites in this relatively fertile class in class C. On the ground however, they are clearly more fertile than class C sites, resembling class B, or even A,

Fertility Class B-C site (area within the outlined zone).

depending on how intensively and how recently they have been managed. Notwithstanding this, fertility and general silvicultural suitability can be taken as intermediate between classes B and C, due to the impoverished nature of the material they have been derived from and their often exposed locations. An application in the range 250-350 kg/ha of rock phosphate is recommended.

On class B-C sites, species choice is more likely to be governed by exposure levels rather than by site fertility.

3.7 INDICATOR VALUE OF TREE CROPS IN LOCALITY

Forests or individual trees in the vicinity of afforestation sites can often serve as useful guides to species choice. However, this can only occur when the conditions under which they are growing are comparable with the planting site in question. Very often remnants of woodland or scrub owe their existence to the fact that they are atypical of the surrounding area. In an agricultural setting, such areas were often considered either too steep, or perhaps too wet, to be brought under intensive agriculture. It must also be borne in mind that, in this country, soils may vary dramatically even over short distances, so the apparent health and vigour of nearby tree crops should not be used as an isolated indicator for species selection.

3.8 REFORESTATION

On reforestation sites, the performance of the previous crop can be a reliable indicator of the suitability of the site for that particular species. Where the proposed replacement species already exists on the site and performance is satisfactory, it can be assumed that the species is well adapted to the site. If, on the other hand, the previous crop has performed poorly, the reasons why need to be established and, where appropriate, an alternative species may have to be chosen. On certain very poor site types, it may not be economically or environmentally desirable to replant the site at all. This option, however, would have to take cognisance of the Forestry Act, 1946, and other appropriate legislation.

Ascertaining the reasons why the previous crops have performed poorly may involve intensive assessments, such as stem analysis of tree rings and where possible the findings may have to be substantiated by local enquiries, unless detailed records are available over many decades. It is possible that the site may have been planted with the incorrect species or provenance, or the site preparation methods used may have been inappropriate. At the beginning of the rotation, the crop may have suffered frost damage, 'check' due to heather competition and/or nutritional problems, or been the victim of any one of a wide range of damaging agents.

Even where the desired second rotation tree species was not previously grown on the site, strong inferences on the major site factors can usually be obtained from the performance of the existing species. However, the success of this method in highlighting these features, is dependent on the sensitivity of the indicator tree species and, in some cases, also the availability of stand records. For example, Sitka spruce is very sensitive to late spring frosts, ash is sensitive to low fertility levels, and Douglas fir is sensitive to exposure, salt-laden winds and excessive soil moisture. Conversely, lodgepole pine (south coastal) is very undemanding with regard to site conditions; hence little can be learned from observing its performance. Inland provenances of lodgepole pine, which become moribund between 20 and 30 years of age, and Lulu Island provenances, where the growth begins to decline after about 10 years of age, are equally unreliable site indicators.

Cognisance should also be taken of the possible ameliorative effect on the site of previous tree crops, particularly in stands consisting of species with known soil-improving qualities. This is very evident on some nutrient-poor Old Red Sandstone soils, where the species options for the first rotation were limited to lodgepole pine. Pioneer crops of lodgepole pine are now enabling successful second rotation mixed species crops of Sitka spruce/lodgepole pine, Sitka spruce/Japanese or hybrid larch and, in some cases, pure crops of Sitka spruce, to be grown successfully on many of the sites.

Recommendations for species selection on a given soil type may vary from the first rotation to the second. Large fissures in peat, the effects of shrinkage and irreversible drying, are common in plantations established on cutaway bogs, being most prevalent in well humified peat less than 2 m deep. As a consequence, lateral drainage is provided together with a lowering of the water table, producing aerobic conditions, at least in the upper peat horizons. Excessive drying out, however, can result in the development of hard lumps of peat, no longer capable of rewetting, a material clearly unfavourable for roots (Malcolm 1979). The long-term effects of the drying process are still unknown. On the other hand, this phenomenon is very rare in plantations growing on blanket bogs, which shows little evidence of being physically or nutritionally altered by the tree crop.

On peaty gleys the position is unclear. Very impermeable gleys result in tree roots being totally confined to the peat layer (sometimes less than 20 cm in depth). Reforestation of these sites normally involves mounding, exposing the peat to drying and destruction, perhaps further exacerbating an already poor situation.

Brown earths, which invariably carry high-yielding conifer or broadleaf plantations, are unlikely to be significantly altered by the tree crop. Consequently, species options would be expected to be as wide as that available for the first rotation.

chapter 4
SPECIES SELECTION GUIDELINES

Most of the considerations which govern the choice of species (climate, soil, biodiversity, landowners' objectives, economics, etc.) have already been covered in Chapters 2 and 3. Another major determinant of species selection, the specific silvicultural requirement of the tree species itself, will be addressed in Chapter 6. Having matched species to the site, a further vital decision is the selection of the most suitable provenance. A trade-off may have to take place between productivity and provenance. The species notes in Chapter 6 recommend the most suitable provenances for Irish conditions. It is often difficult, however, to combine these many considerations and select a species that will grow well, enhance the environment and be profitable for the landowner for a particular site. Even in purely financial terms, species choices that initially appear attractive (because of grants and premiums) may, in the longer term, prove to be less so because of changing market conditions.

The selection of the correct species can be best achieved by clearly determining:

1. The plantation objectives (Chapter 2)
2. Site characteristics (Chapter 3, Sections 3.2, 3.3, 3.4, 3.6, 3.7, 3.8)
3. Soil characteristics (Chapter 3, Sections 3.5, 3.7, 3.8)

It is only after determining these that the full potential of Tables 4.1 and 4.2a can be captured. These tables have been compiled in an effort to simplify the matching of tree species to sites, and they attempt to bring together some of the information contained in other parts of this manual. Table 4.1, while being an extension of the forestry potential for each of the soil groupings given in Chapter 3, presents the information in an easy to read format, highlighting the species options for each of the soils in question. Table 4.2a, which ranks silvicultural characteristics and site suitability factors for each species on a scale of 1-5, further streamlines the species selection process. **Notwithstanding this, these tables are not intended as a 'quick fix' and should not be read in isolation.** When read in conjunction with other chapters, however, they provide a sound basis for species selection.

TABLE 4.1: Species and soil table.

	Soil Types - See Table 4.1a																
SPECIES	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Alders: Common alder																	
Grey alder																	
Italian alder																	
Ash																	
Beech: European beech																	
Southern beech																	
Birches: Downy birch																	
Silver birch																	
Cherry: Wild cherry																	
Chestnut: Spanish chestnut																	
Hornbeam:																	
Lime:																	
Maple: Norway maple																	
Oaks: Pedunculate oak																	
Red oak																	
Sessile oak																	
Rowan:																	
Sycamore:																	
Cedar: Western red cedar	x																
Cypress: Lawson cypress																	
Monterey cypress																	
Firs: Douglas fir	x																
Grand fir																	
Hemlock: Western hemlock	x																
Larch: European larch	x																
Hybrid larch	x																
Japanese larch	x	x															
Pines: Austrian pine	x	x		x													
Corsican pine																	
Lodgepole pine (NC)*																	
Lodgepole pine (SC)*	x	x	x	x	x					x	x		x			x	
Macedonian pine																	
Monterey pine	x																
Scots pine	x																
Redwood: Coast Redwood																	
Spruces: Norway spruce																	
Serbian spruce																	
Sitka spruce																	
Sitka spruce/Douglas fir	x																
Sitka spruce/Japanese larch	x	x															
S.spruce/Lodgepole pine (NC)*	O	O	O							O	O						
S.spruce/Lodgepole pine (SC)*	O	O	O	O	O	O	O	O	O			O	O	O	O	O	O

X Denotes a species/site interaction which would predispose the crop to coarse growth, poor form, instability or excessive growth rates, or *Fomes* butt rot caused by high soil pH.

O Denotes inappropriateness of the mixture either through incompatibility between the species on some sites or through unsuitability of the site for one or both species.

Colour Key

** For more detailed discussion of lodgepole pine provenances, including interprovenance hybrids, see Table 6.2, page 183.*

TABLE 4.1a: Soil type definitions (as described in Section 3.5).

A	Alkaline brown earths and free draining deep grey-brown podzolics	**J**	Gleys/peaty gleys (mottled profile) and gleyed grey brown podzolics (fertility class A or B)
B	Acid brown earths and brown podzolics	**K**	Gleys/peaty gleys (blue/grey profile) (fertility class B)
C	Rendzinas/shallow brown earths/shallow grey-brown podzolics	**L**	Gleys/peaty gleys (fertility class C)
D	Podzols/peaty podzols +/- weakly developed iron pan	**M**	Flushed blanket peat
E	Indurated iron pan podzols (organic layer or furze present)	**N**	Unflushed blanket peats and intact raised bogs
F	Indurated iron pan podzols (scrawed - with heather)	**O**	Cutaway blanket bogs (milled peat)
G	Peaty podzolised gleys (organic layer present)	**P**	Cutaway raised bogs (milled peat, post 1980) and fen peats
H	Peaty podzolised gleys (scrawed)	**Q**	Cutaway raised bogs (hand and machine – sod, pre 1980)
I	Lithosols		

In reforestation sites, and particularly in the case of soils D, E, F, G and H, the ameliorative effect of the previous/pioneer crop will result in the upgrading of many species to a higher level than that shown in the above table.

Where free calcium carbonate is present in the topsoil, most species will suffer from lime-induced chlorosis. Soils most at risk are A, C, P and Q.

Table 4.1 colour codes the suitability of a species or mixture from ‘optimal’ to ‘unsuitable’. Using this colour code, certain species can be disregarded immediately as not being suitable for a particular site. The species that are deemed more suitable can then be evaluated, based on additional information from Table 4.2 and 4.2a.

For reforestation sites on many podzols and peaty podzolised gleys, the potentially suitable species range may be expanded due to the ameliorative effect of the previous crop. In addition, it should be noted from Table 4.1 that some species might grow too rapidly on certain fertile sites, leading to coarse growth, poor form or instability. The suggested combinations of site and species where this may occur are marked in the table with an ‘X’. Also, on some sites certain mixtures may be inappropriate due to the unsuitability of either species to the soil type in question. Such mixtures are marked in the table with an ‘O’.

Finally, it must be noted that the ‘suitability’ of most of the tree species listed in both tables relates to their suitability in relation to timber production. The tables are not a definitive listing for suitability under, for example, the current Native Woodland Grant Scheme where other goals and objectives may be more important.

TABLE 4.2: Silvicultural characteristic rating used in Table 4.2a.

CHARACTERISTICS RANGE ON A SCALE OF 1 TO 5 (the exception being 0/1 for I, soil improver)						
A	Establishment*	1	Easy	→	5	Very difficult
B	Spring frost	1	Tolerant	→	5	Very intolerant
C	Exposure	1	Tolerant	→	5	Very intolerant
D	Salt spray	1	Tolerant	→	5	Very intolerant
E	Soil moisture requirements	1	Low	→	5	Very high
F	Soil nutrient requirements	1	Low	→	5	Very high
G	Shade/Light	1	Shade bearer	→	5	Light demander
H	Rooting depth	1	Deep	→	5	Very shallow
I	Soil improver	0	Inconclusive	→	1	Yes

* *Characteristic ‘A’ (ease of establishment) includes a number of factors in the first five years following planting. These include survival, ability to compete with vegetation, growth rate and juvenile instability.*

TABLE 4.2a: Species silvicultural characteristics.

		CHARACTERISTICS – See Table 4.2								
Species		A	B	C	D	E	F	G	H	I
Alders:	Common alder	1	1	3	4	5	4	5	1	1
	Grey alder	1	2	3	4	4	4	4	2	1
	Italian alder	3	4	4	3	3	4	5	2	1
Ash:		2	5	4	3	4	5	5	4	0
Beech:	European beech	2	4	4	4	3	4	1	1	1
	Southern beech	2	4	4	4	3	3	4	3	0
Birch:	Downy birch	3	1	3	4	4	3	3	4	1
	Silver birch	3	2	4	4	2	4	5	4	1
Cherry:	Wild cherry	2	4	5	4	3	5	5	5	0
Chestnut:	Spanish chestnut	2	5	5	5	3	4	4	1	1
Hornbeam:		2	1	4	4	2 -4	3	1	1	1
Lime:		2	3	4	4	3	4	3	2	1
Maple:	Norway maple	3	3	5	2	2	4	4	2	0
Oak:	Pedunculate oak	3	5	5	3	4	5	5	1	0
	Red oak	2	3	4	3	3	3	3	1	1
	Sessile oak	3	5	5	3	3	4	4	1	0
Rowan:		1	1	3	2	3	4	5	2	1
Sycamore:		2	2	3	2	3	5	4	1	0
Cedar:	Western red cedar	3	2	4	3	4	4	2	3	1
Cypress:	Lawson cypress	3	2	4	3	4	3	1	4	0
	Monterey cypress	4	3	1	1	3	3	4	3	0
Firs:	Douglas fir	3	3	5	5	2	3	4	2	1
	Grand fir	2	2	5	4	3	5	2	2	1
Hemlock:	Western hemlock	3	4	4	3	3	3	1	3	0
Larch:	European larch	3	5	4	5	3	4	5	2	1
	Hybrid larch	2	3	3	2	4	3	5	2	1
	Japanese larch	2	3	3	2	4	3	5	2	1
Pine:	Austrian pine	3	2	3	2	2	3	3	3	0
	Corsican pine	3	2	3	5	2	4	5	2	1
	Lodgepole pine	1	1	2	1	1-4	1-3	5	1	1
	Macedonian pine	4	1	1	3	3	3	4	1	1
	Monterey pine	4	2	4	1	2	2	5	1	1
	Scots pine	1	1	4	4	2	3	5	1	1
Redwood:	Coast Redwood	4	5	5	2	3	5	3	3	0
Spruce:	Norway spruce	3	3	5	5	4	4	3	4	0
	Serbian spruce	3	2	3	3	2-4	2-4	3	3	0
	Sitka spruce	1	4	2	2	2-4	3-5	5	3	0

The use of mixtures enhances the aesthetic appeal of forests.

chapter 5
MIXED SPECIES PLANTATIONS

5.1 WHY MIXTURES?

There are growing concerns about the protection of the environment and an increased awareness of the importance of forests in this context. The predominance of pure crops of non-native species (Sitka spruce in particular) has been the subject of much comment in recent years. However, given the outstanding performance of Sitka spruce in this country since the early nineteenth century, much of this criticism is unjustified (Joyce and OCarroll 2002). It also ignores the fact that substantial tracts of natural temperate forests are made up of single species. However, where sites are suitable, opportunities for the creation of more diverse forest types should be encouraged. This would involve a wider range of species and an increase in mixed species plantations. Though more difficult to manage than single species stands (requiring much skill and attention to detail to achieve their given objectives), there are many sound reasons for planting mixtures. These include:

- aesthetics and environment
- nursing
- self-thinning
- crop quality improvement
- soil enhancement
- improved stability
- better and earlier financial returns
- spreading the risk of over-reliance on one species

5.1.1 Aesthetics and environment

Mixed species forests are generally considered visually more appealing than single species plantations. They are also regarded as being more sustainable, more socially acceptable, and more biologically diverse. Benefits also accrue for recreation, and wildlife. For example, a study in north Wales on the implications of using broadleaves in conifer forests to improve bird communities has indicated that one hectare of broadleaves within a larger conifer area would support about six time more birds of certain species if it were distributed in a hundred small patches rather than concentrated in one (Currie 1984).

5.1.2 Nursing effect

In silvicultural terms, 'nursing' is described as the beneficial effects of one species on another growing in close proximity. This can occur in three ways:

5.1.2.1 Nutritional

Nursing can help by enabling more site-demanding species to grow satisfactorily on nutrient-poor soils. The improved growth, or so called 'nurse effect', is related to greater availability of soil nitrogen, thus reducing the potential for possible negative environmental impacts associated with repeated applications of fertiliser nitrogen. While the exact mechanisms behind the nursing effect are not fully understood, it is believed to be closely related to root activity and interactions between roots of the species comprising the mixture. The nurse species has an innate capacity to absorb nitrogen from a scarce resource and to pass it on to the nursed species through root-contact. The effect becomes obvious about 10 years after planting. Sometimes, in the case of mixtures involving Sitka spruce, the nurse species may out-grow the Sitka spruce in the early years of establishment. However, as the nursing effect becomes evident, the nursed species generally recovers, and often does so with such vigour that it will self-thin the nurse species from the stand.

The most successful nutritional nursing in Ireland is to be found on mineral and peaty mineral soils deficient or marginally deficient in nitrogen. Such soils would normally have at least moderately free-draining subsoils, and would include a wide range of soils from among the following soil types and peaty variants of them: podzols, iron pan podzols, gleys/podzolised gleys, peaty gleys (Fertility Class C) and shallow peats.

The nutritional nursing of Sitka spruce by Japanese larch and lodgepole pine (north coastal) on infertile/marginally infertile mineral/peaty mineral soils has been evident for many years (OCarroll 1978). More recently evidence has emerged of the successful nursing of Sitka spruce by Douglas fir on nutritionally-marginal peaty mineral soils derived from Old Red Sandstone (McCarthy and Horgan 2003).

Whether (nutritional) nursing occurs on deep peats in Ireland is a debatable point. Whilst examples of the nursing of Sitka spruce by larch and pine on deep peat have been

Nutritional nursing effect of Japanese larch in alternate line mixture with Sitka spruce compared to pure Sitka spruce (foreground) which is in check, at Banteer Forest.

Nursing effect of lodgepole pine on Sitka spruce on an infertile Old Red Sandstone site at Ballyhoura Forest.

recorded in Britain (Taylor 1985 and Garforth 1979), such occurrences are unsubstantiated in Ireland - at least in the nutritional form - despite some anecdotal references to the nursing of Sitka spruce by lodgepole pine on Irish peatlands. Research is planned to resolve the role of mixtures on the range of deep peats. Until such research is completed the current advice would be that the use of lodgepole pine as a nurse species in mixture with Sitka spruce cannot be relied on to enhance the nitrogen status of the latter on deep peats in Ireland. However, this not to overlook the other benefits that may accrue from the use of lodgepole pine/Sitka spruce mixtures on deep peats, such as the provision of shelter (5.1.2.2, page 76) and frost protection (5.1.2.3, page 76), the lowering of the water table, and the spreading of risk. Nonetheless, problems can arise, particularly where the Sitka spruce fails to develop adequately, frequently due to phosphorous deficiency.

Another example of nursing which has proved successful, involves the interplanting of checked crops of Sitka spruce with lodgepole pine (south coastal provenance). This has been demonstrated conclusively in an experiment established on a nutrient-poor peaty podzolised gley in Avondhu Forest, Co Cork. The objective of the experiment was to compare the response of checked Sitka spruce to fertiliser nitrogen with that which could be achieved by interplanting the crop with lodgepole pine (south coastal). As would be expected the growth response to fertiliser nitrogen was very impressive for a number of years after applications. However, by the twelfth year after interplanting, the annual height increment of Sitka spruce in the lodgepole pine interplanted treatment exceeded all of the other treatments, even compared to where nitrogen had been applied on three occasions. This enhanced growth was maintained at least up to the eighteenth year after interplanting, when the experiment was last assessed.

5.1.2.2 Shelter

Nursing can help by providing side shelter, so essential to the growth of quality broadleaf species. If coppice is present on the site, it can be utilised to good effect by leaving it *in situ* around cleared and planted groups, or bands of broadleaf species. Where this is not available, planting groups or bands of broadleaf species in a matrix of compatible conifers can provide side shelter. However, to be effective, the conifers in some situations need to be planted 2-4 years ahead of the broadleaf species.

Ash performs well in group mixture with Sitka spruce, illustrating the importance of shelter. This stand is on a mineralised peaty gley soil at Ballyhooley Forest.

5.1.2.3 Frost protection

Nurse crops can be used to bring more valuable species through a difficult establishment phase. One of the more common circumstances in which they are used is in the provision of an overhead screen to help alleviate late spring frost damage to sensitive species (Anon. 1947). Birch or common alder are suited to this purpose, but unless already present, they need to be planted well in advance of the main species. When they have reached a height of about 6 m, the crop should be opened up and underplanted with the main target species. To prevent causing damage to the main crop by 'whipping', the nurse species can be removed once its sheltering effect is no longer required.

5.1.3 Self-thinning mixtures

Self-thinning mixtures are those in which one species or provenance of species dominates the other and ultimately becomes a single-species (or provenance) final crop. As mentioned earlier, stands of Japanese larch, lodgepole pine and Douglas fir in mixture with Sitka spruce can often inadvertently develop into self-thinning mixtures.

However, self-thinning has its greatest appeal on unstable fertile sites, which have the potential to produce high-yielding crops. Many of these crops rarely reach maturity however, due to instability (often exacerbated by mechanised thinning operations). Mixtures of Sitka spruce and lodgepole pine (inland provenance) have worked very well in such situations in the past. The Sitka spruce, having suppressed the pine, carries on to maturity. This success has been replicated with mixtures involving Sitka spruce and lodgepole pine (south coastal provenance) on similar site types. Mixtures of Sitka spruce provenances can also be successful, e.g. Alaska/Washington, where over time the Washington provenance outgrows the Alaska provenance, resulting eventually in an almost pure crop of the Washington provenance. Alaskan Sitka spruce is not readily available and may need to be ordered in advance.

Ten year old Sitka spruce/lodgepole pine (south coastal) intimate mixture on a fertile gley site at Banteer Forest.

5.1.4 Crop quality improvement

Planting an understorey of beech or hornbeam (both shade tolerant species) can control lateral branching, epicormic shoot development, and undesirable undergrowth in oak stands. Beech also benefits from the microclimate created by the oak overstorey. Form and height growth of broadleaf species is also improved when planted in a matrix with conifers.

5.1.5 Soil-enhancing mixtures

When selecting species, particularly for sites vulnerable to soil degradation, consideration should be given to mixtures which include species recognised as having soil-improving properties, e.g. beech, Spanish chestnut, birch, red oak, larch, Douglas fir and grand fir. The deep-rooting attributes of many of these species also allow them to tap nutrients in the subsoil and deposit them at the surface in their litter. Their leaves and needles also break down more easily and provide a better environment for microfauna and flora, which are the main agents for converting litter to organic matter in the soil (Wormald 1992).

Sitka spruce showing improved performance (background) when interplanted with lodgepole pine following a period in check (caused by nitrogen deficiency), compared to pure Sitka spruce (foreground). These trees were planted on a nutrient-poor site at Ballyhooley Forest.

5.1.6 Improved stability

There is much observational evidence that some coniferous species are more stable when grown in mixture with deep-rooting broadleaf species, such as oak. Although rooting depth is usually determined by the water table, there are also considerable variations in rooting depths between coniferous species. Examples of lodgepole pine roots penetrating to a depth of up to 1.5 m on free-draining sites are not uncommon. There is also evidence of lodgepole pine roots growing deeper than those of Sitka spruce on peaty gleys and deep peats. Root penetration by grand fir into the calcareous sub-peat layer on a midland cutover bog at Clonsast, Co Offaly, has also been observed (Carey 1975). All other factors being equal, mixing shallow-rooting species with those having deep-rooting characteristics should enhance the overall crop stability.

5.1.7 Better and earlier financial return

Many broadleaf species grow slowly and hence have longer rotations. By planting in mixture with compatible conifers, establishment costs are reduced by virtue of having fewer broadleaf trees to plant and maintain, as conifers are generally planted at wider spacings. Earlier and enhanced financial returns are also attained (less low value thinnings of broadleaf species).

5.1.8 Spreading risk

Where doubts exist as to what species would grow best on specific sites, or if there is a risk of frost, drought, or ‘check’ due to heather competition, or the possibility of serious damage by insect, fungi or animal pests, a number of species is often planted. On some very difficult sites this has resulted in the development of successful crops of one or more species.

5.2 GUIDELINES FOR THE USE OF MIXED SPECIES

5.2.1 Objective

A clear understanding of the objectives for the mixture on each site is fundamental to the success of mixed species plantations. It is only in the presence of clear objectives that appropriate decisions can be made on the spatial arrangement and species composition and proportions which best meet the requirements of that site.

5.2.2 Mixture types

At least five different mixture types are recognised: intimate, alternate line, group, band, and two-storey. It is vitally important, before embarking on the establishment of mixed species plantations, that the advantages and disadvantages of each mixture type are fully understood.

5.2.2.1 Intimate mixtures

These consist of two or more species mixed within lines, with considerable variations in the species proportions. Such mixtures are desirable in stands which constitute a prominent feature of the landscape. They also have application for self-thinning mixtures, and in situations where there is a desire to spread risk. In these situations the expanding crowns of the more successful species quickly occupy the spaces left by failures or unthrifty trees. However, they are difficult to manage and their long-term existence as mixed species plantations is largely dependent on the degree of compatibility between the different species and the level of skill and commitment in their management. Their use is totally inappropriate for mixtures of conifer and broadleaved species.

Four year old intimate mixture of Sitka spruce, hybrid larch and Douglas fir at Banteer Forest.

5.2.2.2 Alternate line mixtures

These mixtures, which consist of full lines of alternate species, are easy to establish, but like intimate mixtures, can be difficult to manage, unless the species used have a high level of compatibility. In general compatibility between broadleaved species is less of a problem than between broadleaves and conifers. Alternate line mixtures (or a variant, such as one line of the nurse species to two lines of the primary species) are commonly used in nursing mixtures of Sitka spruce/Japanese larch or with suitable provenances of lodgepole pine, thus enabling the spruce to be grown on nutritionally marginal mineral/peaty mineral soils, without the need for repeated nitrogen fertiliser applications. Early dominance by the nurse species is often reversed later in the rotation, with the nursed species - having suppressed the nurse species - going on to form the final crop.

Japanese larch/Sitka spruce (centre) line mixture at Ballyhoura Forest.

5.2.2.3 Group mixtures

These mixtures involve the planting of groups of broadleaved species at 10-12 m centres in a matrix of a compatible conifer species. The group size, which is governed by species and desired spacing, can vary from 4 - 25 plants (see Figure 5.1). Group mixtures are more robust in design than either intimate or alternate line. Provided there is compatability between species, and the site is suitable to both components, these mixtures can coexist for several years without intervention. However, the key to the success of this system is punctual and effective management, involving weeding and thinning to favour the broadleaf species.

5.2.2.4 Band mixtures

These mixtures essentially consist of 3 rows of conifer species (at conventional spacing) and (depending on species and desired spacing) 2-5 rows of broadleaved species. Broadleaf rows adjacent to the conifers are planted 2 m from the conifers (see Figure 5.2). The advantages associated with the band system include their ease of establishment and the robustness of their design (each species is able to survive with the minimum intervention). Nevertheless, it should be recognised that the management of mixtures is a more delicate operation than that of single species crops. Progress should, therefore, be regularly monitored and, where necessary, prompt remedial action taken.

Five year old ash in a group mixture of nine year old Sitka spruce at Ballyhooley Forest.

Given the regularity of their pattern, band, group and alternate line mixtures are sometimes considered incompatible with good landscape design. Their use can therefore be confined to flat areas and/or areas of low visual impact. In areas of high visual sensitivity, it is better to plant each species in larger groups, with species following the pattern of soil type and topography (Bulfin 1998). Alternatively, consideration could be given to intimate mixtures in such situations.

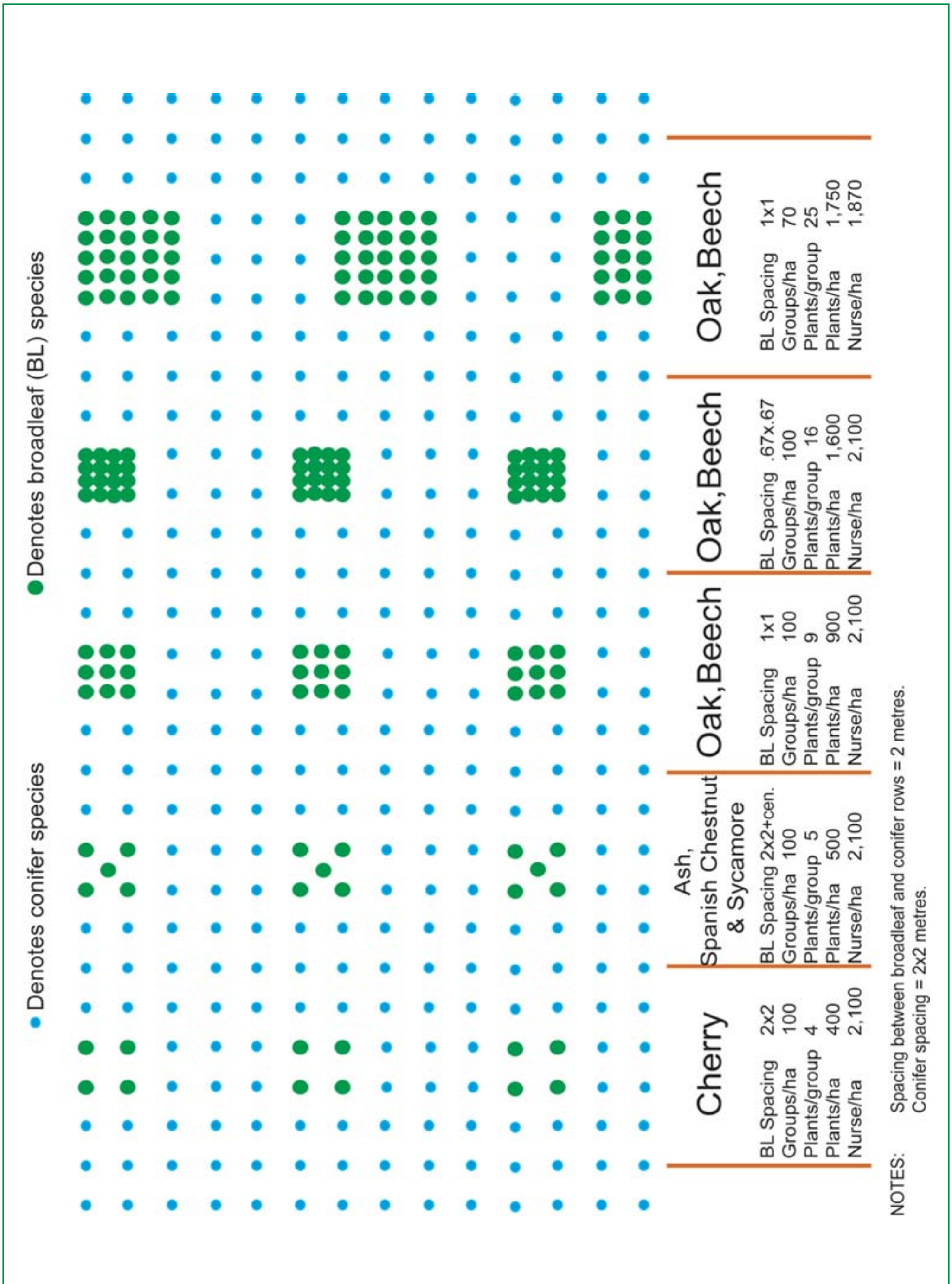


FIGURE 5.1:
Group options for conifer/broadleaf mixtures.

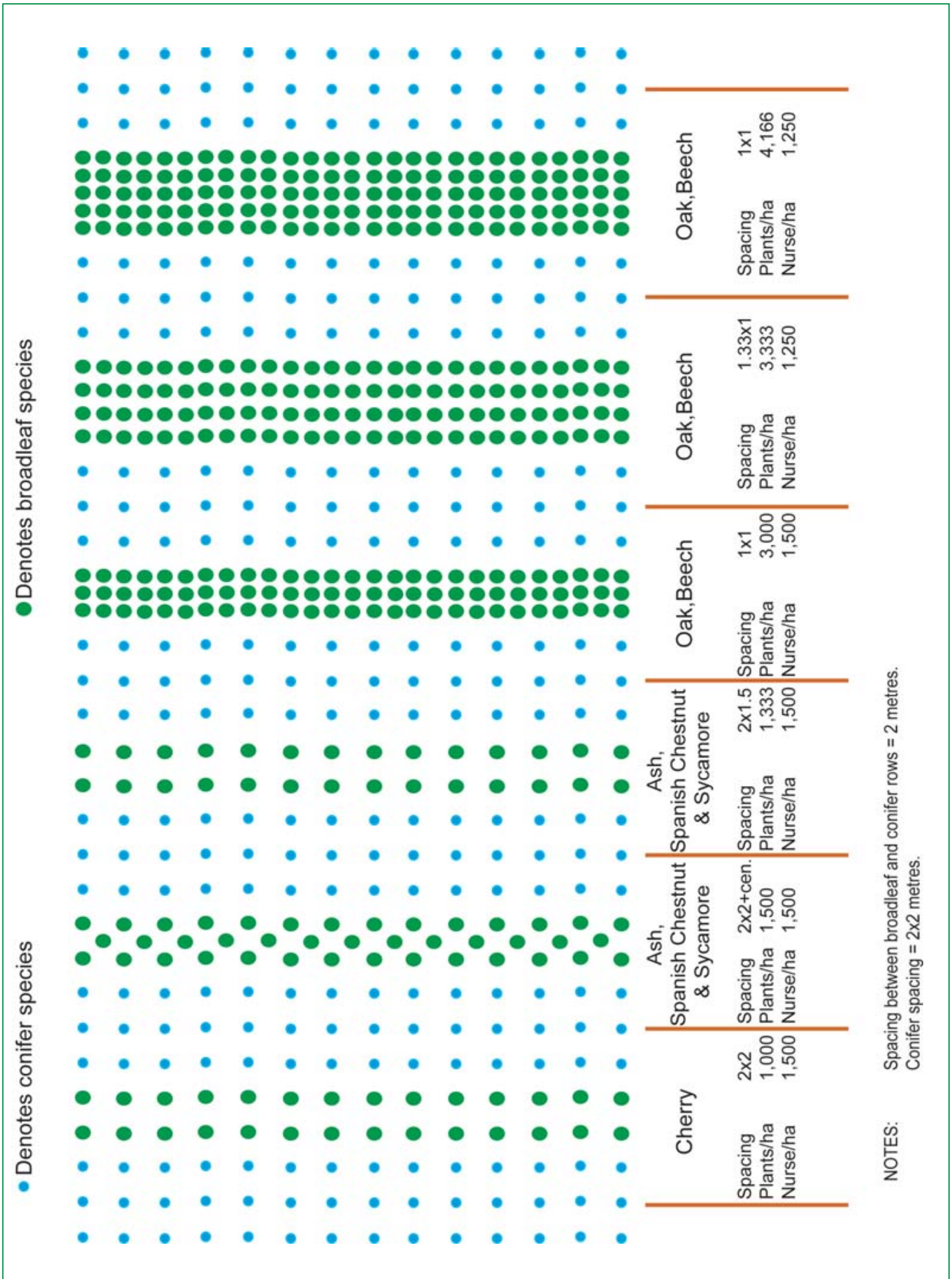


FIGURE 5.2:
Band options for conifer/broadleaf mixtures.

5.2.2.5 Two-storey mixtures

These mixtures involve the growing of one species under the canopy of another species, for example Sitka spruce planted beneath a birch screen as possible protection against frost damage, or the introduction of a beech understorey under a semi-mature oak crop as a successor crop and also to reduce epicormic shoots in the oak. Though generally relatively easy to manage, skill is needed in determining the correct density of the overstorey. The timing and method of removing the overstorey is also important to facilitate the development of the understorey species.

Two-storey mixture of mature Scots pine plantation underplanted with western hemlock at Killanne Forest.

5.2.3 Matching species to site

The choice of species, whether for pure or mixed plantations, is determined in the first place by the soil and site conditions. Planting species which are ill-adapted to the site cannot fulfil any of the objectives for which the plantation is established. It should, however, be remembered that sometimes species, which are considered unsuited to a site as a pure crop, can be grown quite successfully on that site when planted with a nurse species. Examples of this include Sitka spruce/Japanese larch mixtures on nutritionally marginal sites, or a beech understorey in a semi-mature Scots pine stand on an exposed site.

5.2.4 Compatible species

Species and provenances within species vary greatly in terms of their growth pattern over their rotation. It is therefore very important to use compatible species when planting mixtures. For instance, Japanese larch grows very quickly for about the first twenty years; thereafter the increment is more modest. In contrast, growth of Norway spruce is extremely slow for about the first five years. It then enters a phase of very fast growth, which in turn is followed by more moderate increments. All of these factors have an impact on compatibility between species.

5.2.5 Continuity of management

In some countries it is common for a forest to be successively managed over many decades by generations of one family. In this way experience is built up and passed on. In Ireland, however, this scenario is rarely encountered, making it more difficult for detailed silvicultural knowledge to be obtained or retained. Good management plans and records and the discipline to enforce their prescriptions can go some way to offsetting the shortcomings arising from this lack of continuity in forest management and silvicultural expertise (Wormald 1992).

5.2.6 Early selection of final crop trees

In conifer/broadleaf mixtures it is imperative that a potential final broadleaf crop density of 300-400 trees/ha is selected by the time the crop has reached 6 m. These trees should be favoured in all subsequent operations, bearing in mind that only about 100 trees/ha will ultimately remain as the final crop.

5.2.7 Timely intervention

Even where great care has been exercised in selecting compatible species, and robust mixture patterns used, difficulties can arise. In conifer/broadleaf mixtures difficulties often arise when the conifers nearest the broadleaf species threatens to suppress the latter prior to first thinning stage. These conifers may have to be removed, or cut to waste, to prevent them from smothering the broadleaves.

Cognisance should also be taken of inter-broadleaf competition, especially where close initial spacing has been adopted. Species such as ash, cherry and Spanish chestnut are very intolerant of crown competition. Where competition is excessive and crowns become small, response to thinning is poor. The aim should therefore be to ensure that the crowns of the potential final crop trees remain unimpeded. This is best achieved by frequent crown thinning to perpetuate a live crown of at least one-third the height of the tree. While sycamore has good powers of crown recovery following suppression, best performance is achieved when it is managed in a similar manner to ash, cherry and Spanish chestnut. Oak and beech, by virtue of their poor apical dominance, require stocking levels to remain high, until the objective of single straight stems is achieved. The species, plantation stocking and growth rate will dictate the time of first intervention. At very close initial spacing (1 x 1 m or less) potential final crop trees should be selected by the time the crop reaches a mean height of 5 m. Subsequent respacing/thinning, favouring these trees, should be frequent and light. At wider initial spacing, final crop selection and respacing can be delayed.

Where birch or alder are used as an overhead screen for frost-prone species, it is imperative that they are removed once they have fulfilled their objective, to prevent whipping of the main crop. Chemical injection with a suitable herbicide can be used for this, thus avoiding damage to the main crop during felling operations, while also eliminating potentially troublesome coppice regrowth.

5.3 CONIFER MIXTURES

Although the primary objective of many of these mixtures is to enhance the performance of the more site-demanding species, they also increase diversity, and, particularly where larch is involved, they enhance environmental and landscape values. These mixtures normally take the form of two lines of the main crop species to one line of the nurse species, though examples of alternate line and fully intimate mixtures can also be found. Table 5.3 lists conifer mixtures with recognised potential on suitable sites.

Alternate line mixture of Douglas fir and Sitka spruce (centre) on an Old Red Sandstone site at Banteer Forest.

TABLE 5.3: Recommended conifer mixtures on suitable sites.

SPECIES IN MIXTURE	COMMENTS
Sitka spruce (provenance mixtures)	Mixtures of different Sitka spruce provenances, e.g. Alaska/Washington (if Alaskan material is available), result in high stand variability, thus facilitating the self-thinning process. This has much merit on unstable sites, where thinning operations could otherwise induce windblow.
Sitka spruce/lodgepole pine (south coastal - see Table 6.2, page 183)	In the past, this mixture was very popular on infertile soils, but in nearly all cases the lodgepole suppressed the Sitka spruce. However, on fertile sites, the Sitka spruce later dominates (having kept pace in the earlier years), and ultimately suppress the lodgepole pine. As is the case of the pure Sitka mixture, it has application on unstable sites.
Sitka spruce/lodgepole pine (north coastal - see Table 6.2, page 183)	On nutrient-poor mineral soils, the lodgepole pine out-performs the Sitka spruce for about the first ten years, then the desired nursing effect generally begins to manifest itself in improved growth of the Sitka spruce, which goes on to suppress the pine.
Sitka spruce/Japanese larch	Early dominance by the larch often poses problems for the spruce on nutrient-poor mineral soils. However, after about ten years, nursing by the larch begins to take effect, becoming evident in improved growth of the spruce. This usually leads to a reversal of dominance later in the rotation.
Sitka spruce/Douglas fir	Nursing of Sitka spruce by Douglas fir is a phenomenon first observed in 1985 at Mallow forest, Co Cork. This performance has since been replicated at a number of sites, demonstrating conclusively that on free-draining mineral soils, nutritionally marginal to pure Sitka spruce, planting in mixture with Douglas fir enables the spruce to be grown successfully. Early dominance by the Douglas fir is usually reversed later in the rotation.
Sitka spruce/western hemlock	This mixture occurs in the native range of both species, the west coast of North America. The western hemlock benefits from the microclimate created by the Sitka spruce during the establishment phase. The pliant, pendulous leading shoot of the hemlock is not easily whipped, and it has very strong powers of recovery after being suppressed.

TABLE 5.3 (continued): Recommended conifer mixtures on suitable sites.

SPECIES IN MIXTURE	COMMENTS
Sitka spruce/western red cedar	This mixture occurs in the native range of both species, the west coast of North America and may have application here on heavy soils, where species options are limited.
Norway spruce/Scots pine	This mixture was very popular in the past, when Scots pine was used as a nurse to Norway spruce on frost-prone sites. However, on damp sites the spruce has a tendency to dominate, whilst frosty or infertile conditions favour the pine.
Norway spruce/European larch	On sites suitable to both species this mixture works well, but where soil conditions are heavy the Norway spruce usually becomes dominant.
Douglas fir/Japanese larch	These species are generally compatible. However, Japanese larch is much more flexible in terms of site suitability. These stands have a high amenity value.
Douglas fir/Hybrid larch	Mixtures of these species are generally compatible, although Douglas fir is much more site-specific. By judicious thinning, the final crop composition is easily manipulated to favour the most promising species or indeed the best stems of both species.
Western hemlock/Douglas fir or western red cedar	These species often grow in mixture or in close association in their native range. Drier areas favour the Douglas fir and western hemlock, with western red cedar becoming dominant on the banks of watercourses and on marshy valley bottoms.
Scots pine/European larch	Mixtures of these species were much favoured in the past. The larch, being valuable in small sizes for the production of fencing stakes, was gradually removed as thinnings, leaving the pine to form the final crop. On fertile sites the larch has a tendency to dominate, whilst infertile or frosty conditions favour the pine.
Japanese larch/western hemlock or western red cedar	These form plantations with a high amenity value, as well as a nursing effect and early returns from the larch, in combination with enhanced production from the hemlock or cedar. The pliant, pendulous leading shoot of the hemlock is not easily whipped, and it has very strong powers of recovery after being suppressed. By virtue of its narrow crown and shade tolerance, western red cedar is well set to cope with the early dominance of the larch.
Hybrid larch/western hemlock or western red cedar	These form plantations with a high amenity value, a nursing effect, and early returns fom the larch, in combination with enhanced production from the hemlock or cedar.

5.4 BROADLEAF MIXTURES

Generally, broadleaf mixtures have fewer problems with compatibility and visual impact than conifer/broadleaf mixtures, affording scope for greater flexibility in design. Table 5.4 lists broadleaf mixtures with recognised potential on suitable sites.

Table 5.4: Recommended broadleaf mixtures on suitable sites.

SPECIES IN MIXTURE	COMMENTS
Birch in mixture with oak, beech, ash, Spanish chestnut and/or cherry	Birch, because of its frost-hardiness, is ideal as an overhead screen against spring frost damage for more delicate species during the establishment phase. However, unless already present on the site, the birch needs to be planted well in advance of the other main species. When it reaches a height of about 6 m, the main species is introduced as an understorey following a heavy thinning of the birch. These plantations must be carefully managed to prevent whipping of the main crop leaders by the birch. Further thinning of the birch, as required, can provide additional relief to the main crop.
Alder in mixture with oak, ash, and cherry	On heavier soils, common or grey alder can be substituted for birch as an overhead screen. Alder's ability to make direct use of atmospheric nitrogen can be beneficial to the ash on many sites.
Oak/beech	It is not recommended to mix these species at planting. It's best to introduce beech as an understorey at the time of first thinning of the pure oak crop. Beech will benefit from the microclimate created by the oak, while controlling epicormic shoots in the oak.
Oak/hornbeam	On heavy soils, following thinning of an oak crop, hornbeam can be introduced as an understorey to control lateral branch development, epicormic shoots and undesirable undergrowth.
Beech/ash	Following a number of thinnings to the ash, beech is best introduced as an understorey to control unwanted vegetation, to act as a soil-improver and as a successor crop to the ash.
Beech/sycamore	Although this mixture is initially compatible, the beech has a tendency to suppress the sycamore later in the rotation.
Beech/alder	Italian alder may be used as a nurse to beech on alkaline soils.
Ash/sycamore	These species are generally compatible. The ash, however, is more site specific, and is also more sensitive to frost and exposure than the sycamore.
Ash/Spanish chestnut	These species have many similarities, i.e. sensitivity to frost, exposure and growth rates. However, ash prefers soils with a higher pH and a higher soil moisture regime than does Spanish chestnut.
Spanish chestnut/ sycamore	Growth rates of these two species are generally compatible. Spanish chestnut, being very sensitive to frost and exposure, should benefit from the sycamore nurse.

Mature oak plantation with beech understorey.

Group of nine oak trees in a mixture with birch at Newmarket Forest.

5.5 CONIFER/BROADLEAF MIXTURES

These mixtures are usually established with three main objectives in mind, the production of:

1) quality broadleaf crops

2) cost effective pure broadleaf crops

3) aesthetically enhanced crops.

Ideally, conifer/broadleaf mixtures should be of robust design, i.e. band or group, where each species is able to survive with the minimum intervention. To be fully effective in the provision of side shelter, so essential to the satisfactory establishment of quality broadleaf crops, the conifer nurse should, in some instances, be planted ahead of the broadleaf species. Alternatively, both species can be planted at the same time, and if after 2-3 years the general form of the broadleaf crop is less than satisfactory, it is 'stumped back' (cut back to within 10 cm of ground level). The resultant vigorous regrowth will not only have improved form, but also benefit from the side shelter now available from the conifer nurse. However, it should be remembered that not all broadleaves lend themselves to stumping back. It works very well in the case of oak, ash, Spanish chestnut and sycamore, but not for beech. Table 5.5 lists conifer/broadleaf mixtures with recognised potential on suitable sites.

TABLE 5.5: Recommended conifer/broadleaf mixtures on suitable sites.

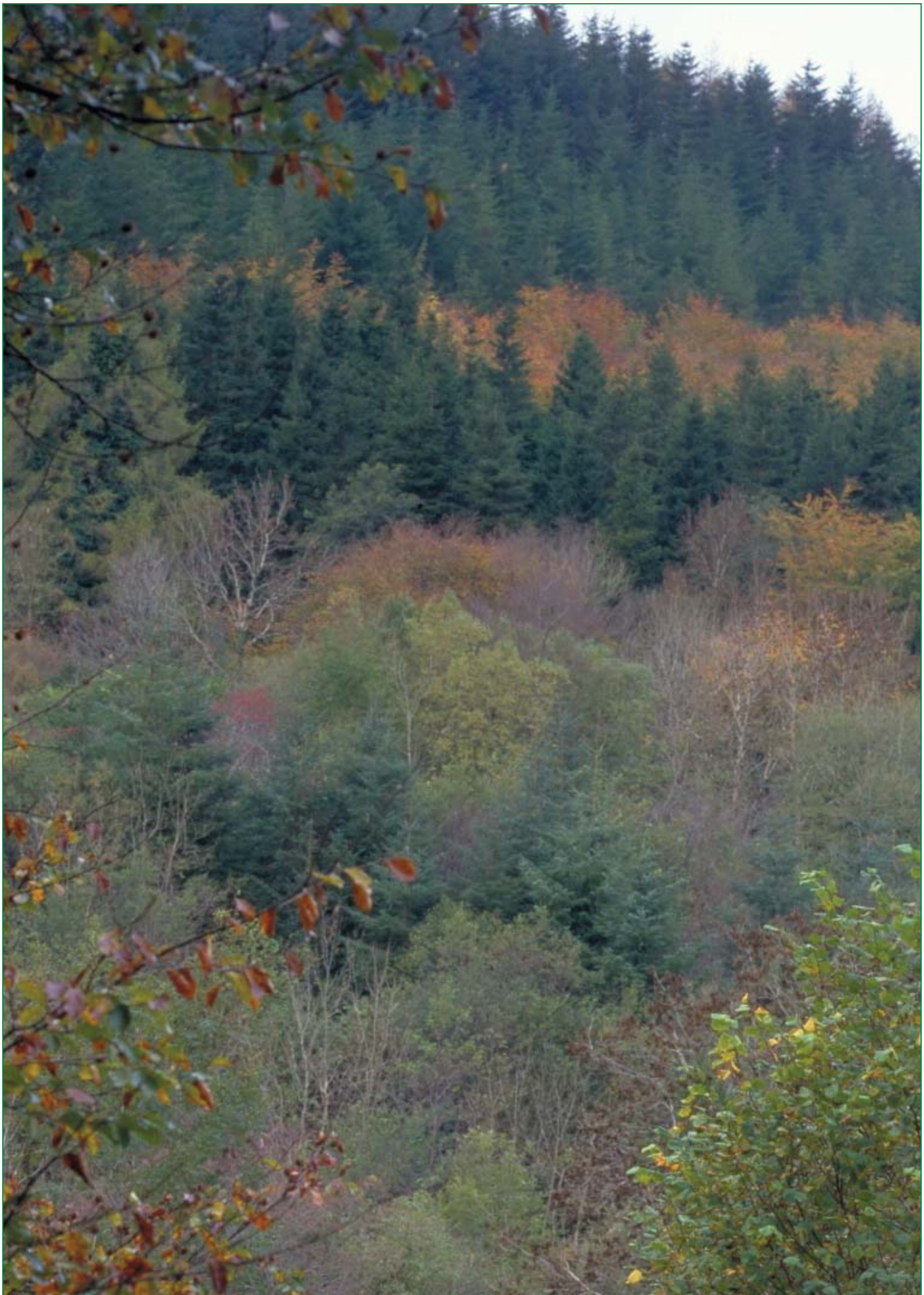
SPECIES IN MIXTURE	COMMENTS
Norway spruce/oak	Traditionally Norway spruce was used to nurse oak. However, this practice has been questioned, due to the slow early growth of Norway spruce compared to oak. Oak responds to chemical vegetation control more positively in terms of enhanced growth than Norway spruce. This can result in the oak being twice the height of the Norway spruce four to five years after planting. In later years, the spruce is usually too vigorous for the oak.
Norway spruce/ash	Prior to the advent of chemical vegetation control these species were regarded as having compatible growth rates. However, due to their very differing responses to chemical vegetation control, this is no longer the position, at least in the earlier years. **Mixtures of these species are therefore not recommended.**
Scots pine/oak	Well-managed oak, pedunculate in particular, can make rapid height growth in the early years. Therefore, to be in a position to provide the necessary side shelter to the oak at establishment, and to avoid the danger of suppression by the oak, the Scots pine should ideally be planted 2-3 years ahead of the oak. Scots pine is not ideally suited to heavy soils that are often considered as good pedunculate oak sites.
Scots pine, European larch and oak	Provided the soil and site are suitable, these mixtures have the advantage of yielding an early return from the thinnings of the conifer, whilst also providing a space in which beech or hornbeam can be introduced as an understorey to control the occurrence of epicormic shoots. The larch is removed in earlier thinnings, whereas the Scots pine may be allowed to grow until half way through the oak rotation. These mixtures are also much cheaper to establish than pure oak. However, such mixtures need careful and skilful management.
Scots pine/beech	To be in a position to provide the necessary shelter to the beech at establishment, Scots pine should ideally be planted 2-3 years ahead of the beech. A better system is to introduce beech as an understorey, after the Scots pine has been opened up by a number of thinnings.
Corsican pine/beech	This is a frequently used mixture on calcareous soils, the Corsican pine being less liable to lime-induced chlorosis than other compatible species.
European larch/oak	Generally compatible, however European larch is not ideally suited to heavy soils that are often considered as good pedunculate oak sites.
European larch/beech	On some soils, the rapid early growth of the larch can pose problems for the beech. On the other hand, the beech is likely to outgrow and suppress the larch later in the rotation. A better system is to introduce the beech by underplanting half way through the rotation of the European larch.

TABLE 5.5 (continued)**:** Recommended conifer/broadleaf mixtures on suitable sites.

SPECIES IN MIXTURE	COMMENTS
European larch/ash	Where the soil and site are suitable to both species, compatibility between these species is generally good. Nevertheless, to be effective in the provision of side shelter essential for quality ash production, the larch would need to be planted 3-4 years ahead of the ash. However, care is needed to ensure that the larch does not restrict crown development in the ash, which once lost is not easily increased again.
European larch/sycamore	Where the soil and site are suitable to both species, these mixtures are successful. Nevertheless, there is a need for vigilance to prevent dominance by either species.
European larch/Spanish chestnut	It is recommended to plant the Spanish chestnut in groups in a matrix of European larch, stump back the Spanish chestnut about 2-3 years after planting, and reduce the resulting coppice to a single stem one year later.
Hybrid larch/sycamore or ash	Hybrid larch provides early side shelter and controls heavy branching in the broadleaf species, whilst also providing early returns from thinnings. However, timely intervention is required to favour the broadleaf species from undue competition from the larch.
Western hemlock/oak	Western hemlock can be planted as an understorey in semi-mature oak stands (60-80 years old) to control lateral branch development, epicormic shoots and undesirable undergrowth. It is envisaged that both species would be harvested simultaneously.
Western hemlock/ash	Western hemlock can be introduced as an understorey to control undergrowth and to provide a successor crop.
Western red cedar/ash	Its narrow crown makes western red cedar the ideal nurse species that is effective in the provision of side shelter to the ash; ideally it needs to be planted 3-4 years ahead of the ash.
Western red cedar/beech	Provided the soil and site are suitable to both species, this mixture should be successful. The narrow crown of the western red cedar enables it to provide the necessary shelter without suppressing crown development of the beech. Ideally it needs to be planted 2-3 years ahead of the beech.
Western red cedar/oak	Its narrow crown makes western red cedar the ideal nurse species, but, in common with some other nurse species, ideally it needs to be planted 2-3 years ahead of the oak. Western red cedar can also be introduced as an understorey where it will also control lateral branch development and undesirable undergrowth.

TABLE 5.5 (continued)**:** Recommended conifer/broadleaf mixtures on suitable sites.

SPECIES IN MIXTURE	COMMENTS
Sitka spruce, Norway spruce, western hemlock in mixture with birch	As previously stated, birch is ideal as an overhead screen against spring frost damage for more delicate species during the establishment phase. However, unless already present on the site, the birch needs to be planted well in advance. When it reaches a height of about 6 m, the main species is introduced as an understorey following a heavy thinning of the birch. These plantations must be carefully managed to prevent whipping of the main crop leaders by the birch. Further thinning of the birch, as required, can provide additional relief to the main crop.
Sitka spruce, Norway spruce, western hemlock in mixture with alder	On heavier soils, common alder as an overhead screen can substitute for birch. Alder's ability to make direct use of atmospheric nitrogen can be an additional nutritional benefit to the main crop on many sites.



Mixed woodlands provide a range of habitats which support a wide variety of plant and animal species.

chapter 6
SPECIES NOTES

This chapter provides notes for each tree species referred to in previous chapters. It also (Section 6.3) provides basic information on other native trees and shrubs not previously discussed. Growth and yield figures are based on information available from Coillte Forest Estate.

6.1 BROADLEAVES

6.1.1 Common/black alder

Climatic requirements

Common alder has no serious climatic limitation in Ireland. Even though it flushes early, it is resistant to spring and autumn frost. However, it does not grow well on very exposed sites (often manifested by leader damage) and it is susceptible to salt spray.

Suitable sites

Common alder is very undemanding and will grow on all but the most infertile soils. However, it shows a definite preference for the moist fertile soils that occur at valley bottoms, frequently being found growing near lakes and streams. It will tolerate having its roots immersed in running water, but will not grow where the soil water is stagnant. It tolerates a wide soil pH range but does best where pH is greater than 6.

Unsuitable sites

It does not grow well on acid peats, dry sandy soils, exposed sites and coastal areas.

Other silvicultural characteristics

Common alder is an indigenous species and is our only native nitrogen-fixing tree. Nodules attached to its roots, containing bacteria (*Frankia* spp), enable the tree to make direct use of atmospheric nitrogen. It is useful as a nurse for oak on heavy soils and for ash, where its role in fixing nitrogen is often beneficial. It is a light-demanding pioneer species, which regenerates freely from seed and coppice. It is deeply rooting, even in poorly aerated soils, and is therefore generally windfirm. It is a short-lived species, especially when planted on poor sites, where its life span may only be 20-25 years. It is very sensitive to shading and does not respond to delayed thinning, particularly later in its rotation. Alder provides the principal habitat for many insects and, when alder is planted along the banks of rivers and lakes, these insects can provide an important source of food for fish (Savill 1992). Seed remains on the tree over winter and is an important source of food for several species of birds.

Diseases and pests

Common alder is relatively free of serious pests and disease problems, only occasionally suffering from leaf rust disease. The species has been affected recently by *Phytophthora cambivora* root rot in Britain and Ireland. It is seldom damaged by squirrels, and is less subject to attack by hares and rabbits than many other broadleaf species.

Provenance

Native Irish material is the preferred choice. Otherwise British, northern French, Belgian, Dutch, northern German, and Danish stands are recommended.

Plants and planting

Common alder is one of the easiest species to establish, requiring no special treatment. Best results are achieved with sturdy, well-balanced plants, 40-50 cm in height and with a root collar diameter of at least 7 mm.

Spacing and stocking

Common alder is normally planted at a spacing of 2 x 1.5 m, equivalent to a stocking of 3,300 plants/ha

Vegetation control

Due to its fast early growth very little vegetation control is usually required.

Fertiliser

Fertiliser is not required on most sites where common alder is grown. However, when planted on nutrient-poor sites an application of 250 kg/ha of rock phosphate should be applied.

Growth, yield and rotation length

Productivity is unlikely to exceed 8 m^3/ha/yr and, as it is such a short-lived species, it seldom grows to large sizes. Typical rotation lengths are 30-50 years.

Common alder at Killavullen Forest. Age 15 years; height 13 m; DBH 22.5 cm.

BROADLEAVES

Wood properties and uses

The timber is light and not very strong. It dries fairly rapidly and is stable in service. It is easy to work and finishes well. One of its main attributes is its resistance to decay when submerged in water, but it is not otherwise resistant. Uses include general woodturning and the furniture trade, with current demand for top quality logs greatly exceeding supply.

6.1.2 Grey alder

Climatic requirements

Grey alder is not as frost-hardy as common alder, otherwise it has no serious climatic limitations in this country.

Site requirements

Grey alder tolerates a wide range of soils, and is better adapted to slightly drier and more alkaline soils than common alder.

Other silvicultural characteristics

It is more shade-tolerant than common alder. It produces root suckers, often at great distances from the main stem. These root suckers are often initiated when the tree is as young as 3-5 years. This is a useful characteristic when planted on industrial and other waste sites, but may be a nuisance when the alder is planted as a nurse for oak or ash. Grey alder is similar to common alder in all other respects.

6.1.3 Italian alder

Climatic requirements

Italian alder is susceptible to damage by spring frosts.

Site requirements

It is an adaptable species and will grow on a wide range of soils, including dry and calcareous sites such as thin soils over limestone, but does best on deep alkaline soils. It can act as a nurse for European beech on dry alkaline soils.

Unsuitable sites

Italian alder should not be planted on soils that are very acid. On exposed sites it suffers from juvenile instability, but once established it tolerates exposure well.

Grey alder.

BROADLEAVES

Other silvicultural characteristics

It will grow on relatively dry sites and tolerates pollution well. It is a strong light demander, with variable ability to coppice. When planted on exposed situations, it is susceptible to being blown over in the first few years after planting. This is partly due to rapid early growth and heavy crown development.

Growth, yield and rotation length

It grows more rapidly and is a larger volume producer than either common or grey alder. On favourable sites height increment in excess of 1 m/year can be achieved. A comparison of the performance of the three alder species planted on an acid brown earth at JFK Arboretum, Co Wexford is given in Table 6.1.

Based on the data in Table 6.1, the biological rotation length for Italian alder on this site is estimated at 35-40 years.

These data are based on a single site. This site is perhaps better suited to Italian alder than to grey, and it is certainly drier than the optimum for common alder. These results must therefore be interpreted with caution.

Information is very scarce on the silviculture of Italian alder, but it is likely to be similar to that for common and grey alder.

TABLE 6.1: Growth performance of three alder species.

PARAMETER	COMMON ALDER	GREY ALDER	ITALIAN ALDER
Age	34	33	34
Top height (m)	not available	not available	22.0
Mean DBH (cm)	15.5	16.1	28.2
Standing volume (m^3/ha)	159.0	218.7	398.8
Thinning (m^3/ha)	12.6	32.4	143.9
Total volume (m^3/ha)	171.6	251.1	542.7
MAI (m^3/ha)	5.0	7.6	16.0
CAI (m^3/ha)	18.0	18.3	26.7
* LYC	6	8	16

Source: C.P.Kelly, JFK Arboretum, New Ross, Co Wexford. Measurements taken in 2001 by M. Doyle. IWS Associateship Dissertation.

**Current mean annual increment estimates, and a comparison with Forestry Commission yield tables for sycamore/ash/birch, suggest the above local yield class (LYC) for each species.*

Italian alder stand at the JFK Arboretum.

6.1.4 Ash

Climatic requirements

Apart from late spring frosts and exposure, climate is not a major limiting factor to the growth of ash in Ireland.

Suitable sites

Ash is one of the most exacting species with regard to site. Having the highest nutrient requirements of any of the more commonly planted trees species in Ireland, very careful choice of planting site is essential for quality timber production. It does best on moist, deep, well-drained fertile soils, whose soil reaction is near neutral (pH 7) and which have a high content of available nitrogen. Vegetation indicators of potentially good ash sites are dog's mercury, garlic and to a lesser extent nettle. Meadow sweet is an indicator of wet soils that are suitable for ash provided they are properly drained.

Unsuitable sites

Avoid frost hollows, as well as poor, dry or shallow soils, exposed sites, poorly drained sites and very heavy soils.

Other silvicultural characteristics

Ash is generally not suitable for large-scale planting or for use on exposed ground. It is rare to find suitable conditions except in small areas, but the opportunity should be taken to plant ash on these sites. Owing to its frost-tender nature, ash benefits from shelter during its early growth stages. Often the best trees are found in mixed woodland, particularly with oak, European beech, sycamore and cherry.

Diseases and pests

Ash is relatively free of serious disease and pest problems, though the incidence of bacterial canker and infestation by the ash bud moth can result in considerable stem degradation.

Provenance

Native Irish material is the preferred choice. Otherwise registered British, Belgian, Dutch, and northern German, Danish and northern French stands are recommended.

Plants and planting

Large plants (greater than 1 m) confer no early growth advantage; they are also expensive to buy and plant, and often 'check' after planting. Although height is the most

Twelve year old naturally regenerated ash/sycamore plantation, two years after respacing, at Ballyhooley Forest.

common method of size grading, root collar diameter is of equal importance. For plants 60 - 90 cm tall, root collar diameter should be at least 12 mm. Ash responds better than many broadleaf species to stumping back, with regrowth of up to 2 m possible in the first growing season following cutting back to 10 cm from ground level. Because the form of the regrowth is superior to conventionally raised trees, the technique offers a cheap means of getting a second start with plants where initial form is poor.

Apart from drainage to some sites, and the erection of a stock and rabbit-proof fence in all cases, suitable ash sites rarely require further site preparation.

Spacing and stocking

The current recommendation is to plant ash at 2.0 x 1.5 m (3,300 plants/ha).

Vegetation control

Ash responds very positively in terms of height growth to chemical weed control. An added benefit of weed control is that exposed mineral soil is usually more effective at absorbing heat than soil covered with vegetation. A warmer soil will improve plant root growth and overnight re-radiation may reduce frost damage. However, great care is required when applying herbicides to ash plantations, particularly outside the dormant

Twenty-four year old ash plantation at Clonmel, showing good form.

season when some herbicides can be absorbed through the bark, often proving fatal. It is far better to leave a few weeds around the base of the stem than endanger the plant with spray drift. It should however be borne in mind that chemical weed control does not always have a positive effect on ash crops. Some data show a correlation between intensive chemical weed control regimes and the incidence of stem sinuosity and/or stem breakage.

Fertiliser

Ash is well-known to be a very site-demanding species, an important part of which is its need for a relatively high uptake of nutrients. Suitable ash sites will therefore not need or benefit from fertiliser, provided weeds are controlled adequately. It is important to bear in mind also that fertilisation will not compensate for any site characteristic that is unfavourable for ash, such as where ash is planted in poorly-drained soils.

Formative shaping

Ash will benefit from intervention, especially if damaged by frost or insect attack. Formative shaping should start soon after establishment and ideally continue annually until the objective of a single straight stem of at least 6 m is achieved. However, care should be taken to avoid the removal of more than 40% of the live crown as this can lead to significant increment loss. To reduce costs, shaping should, wherever possible, be confined to trees that are likely to form the final crop. Shaping of ash may take place from June to August or during mid winter.

Thinning

Ash is a strong light demander, except when very young. Therefore, the successful management of ash plantations involves allowing trees full access to overhead light, while still providing some side shelter. Thinning should have commenced by the time the stand's top height has reached 10 m. The best trees should be allowed plenty of light and space with only side shade. Under-thinning restricts crown development, which for ash (unlike oak) is not easily increased again when the stand is opened up. Conversely, sudden opening of a stand by heavy thinning can cause stagnation of growth. The best approach involves selecting and permanently marking 350-400 potential final crop trees/ha. Subsequent thinnings should favour these trees, bearing in mind that some will need to be removed, as only 120-150 trees/ha are required for the final crop.

Growth, yield and rotation length

Yield class ranges from 4 to 10, averaging 6. The economic rotation length for ash is 60-80 years. After this age staining of the wood tends to occur, which adversely affects its value.

Wood properties and uses

The more rapidly ash grows the better its flexibility and bending ability is. This is an important attribute where shock resistance is required, for example when used for sports goods, such as hurleys, and tool handles. Ash dries relatively quickly and has medium movement in service. The wood is non-durable and is vulnerable to attack by the common furniture beetle. Ash works well with both hand and machine tools and has good resistance to splitting when nailed. There is a constant demand for good quality ash, which usually exceeds supply thus maintaining a strong price for growers. Uses include veneers, sports equipment, furniture, and tool handles. Boat builders and wood turners also use ash. It is particularly suited to applications where strength is required. It should be remembered that although hurley ash prices are currently buoyant, the market is finite, requiring only 50-60 ha/yr to supply the hurley market. Therefore, 3,000 ha of ash managed on a 50-year rotation would be adequate to meet all hurley ash requirements.

6.1.5 European beech

Climatic requirements

European beech prefers moist, mild and sunny areas. It is susceptible to damage by frost, especially late spring frost, and can be difficult to establish on exposed ground without a nurse. Once established, European beech is relatively tolerant of exposure. It is one of the best trees for shelterbelts, although the quality and quantity of its timber is much lowered when planted in full exposure or at high elevations. It can suffer from sun scorch if planted on exposed slopes with a southern aspect.

Suitable sites

European beech grows on a wide range of soils, but only grows well on certain soils. It grows best on moist, free-draining soils of pH 6.0 - 7.5, with a moderate to good fertility, but it will tolerate a lower pH level if the moisture regime and nutrient status are adequate.

Unsuitable sites

Avoid frost-prone sites, heavy clay soils, peaty soils, poor sandy soils, shallow soils, and soils with free calcium carbonate to the surface.

Silvicultural characteristics

European beech is not a good pioneer species. It benefits strongly from side shelter or even light overhead cover when young. However, severe shading (less than 25%

daylight) reduces total biomass and causes flattening of side branches, though it usually survives and eventually breaks through the overhead cover (Evans 1984). While stem form is a highly heritable trait, significant improvement is possible by establishing under a mature overstorey.

European beech is often referred to as the 'mother tree' of the forest, because of its shade-bearing and soil-improving properties. Its shade-bearing capacity, however, is largely dependent on soil moisture availability. It is sensitive to drought, and on dry sites young European beech can be relatively intolerant of shade. It regenerates freely from seed, but has less ability to regenerate from stool shoots than other broadleaves, such as oak or ash. It is prone to coarse growth and forking, with only medium ability for natural pruning. European beech is wind-firm under favourable growth conditions. Trees under stress from competitors tend to develop epicormic shoots.

Provenance

Registered Irish, British, northern French, Belgian, Dutch, northern German, and Danish stands are best.

Diseases and pests

Beech bark disease, often in conjunction with the beech scale insect, can cause mortality in pole stage stands. Mature European beech is susceptible to considerable internal rot,

Sixty year old beech plantation at Emo forest.

caused by the fungus *Ganoderma applanatum*. Occasionally, newly planted European beech may be infested by the beech woolly aphid. European beech is very susceptible to squirrel damage, resulting in serious defects in the stem wood by stripping and gnawing the bark. A defect known as 'red heart' can occur at age 100 to 120 years. While this condition does not significantly reduce strength properties in will significantly reduce the value of the timber (Joyce *et al*. 1998).

Site preparation

On most sites a rabbit proof fence will be required. It is unlikely that any long-term advantage can be expected from cultivation on a typical European beech site. However, ripping or shallow ploughing can often be justified where a plough pan is present, or as an aid towards reduced planting costs.

Plants and planting

Plants should be well balanced (good root/shoot ratio) and sturdy (good root collar/height ratio), with a fibrous root system. While individual site conditions will have a bearing on the optimum plant size, plants 60-90 cm tall, having a root collar diameter of 12 mm, should meet the requirements of most sites. Provided good plant-handling procedures are in place, bare-rooted transplants can be successfully established from November to March. The planting season can be extended to mid-May without any adverse effect on survival if planting takes place within two weeks of plants being removed from the cold store. It responds well to planting in tree shelters. Except where conditions are particularly favourable, pure planting of European beech should not be attempted without shelter. Furthermore, given sufficient growing space, European beech has a tendency to adopt a coarse habit of growth, with outward rather than upward crown development. To curb this tendency it should be established at close spacing, requiring 6,000-7,000 plants/ha if planted as a pure plantation. Such plantations are not only extremely expensive to establish, but have little or no value in early thinnings. The profit from such plantations is greatly enhanced if European beech is planted in mixture with some of the following species: European larch, Scots pine, Corsican pine or western red cedar, which are not only marketable as small diameter logs but also mature much earlier than European beech.

Vegetation control

European beech responds positively in terms of height growth to chemical weed control. The aim should therefore be to maintain a weed-free zone of about 1 m diameter around each plant for up to four years after planting to maximise water and nutrient availability to the plant. An added benefit of weed control is that exposed mineral soil is usually more effective at absorbing heat than soil covered with vegetation. A warmer soil will improve root growth and overnight re-radiation may reduce frost damage.

Good beech stand at the JFK Arboretum.

BROADLEAVES

Fertiliser

On suitable sites fertiliser is rarely required, but phosphate should be applied to marginal sites. A foliage analysis should be carried out on unthrifty crops to confirm the need for phosphorus fertiliser (see Appendix V).

Formative shaping

European beech is a species with poor apical dominance and, if grown for timber production, it should benefit from formative shaping. The main priority is to control forking and the development of disproportionately large branches. Formative shaping should start soon after establishment and, if necessary, continue annually until the objective of a single straight stem has been reached.

Pruning

Pruning, which involves the removal of live and dead branches from the lower 6 m of the main stem, is usually performed in two lifts. To ensure no adverse effect on individual tree increment, at least one third of the total height should be live crown. To avoid the risk of providing an entry point for fungi causing heart rot, branches should be removed before they reach 3 cm diameter where they join the main stem. To reduce costs, pruning should wherever possible be confined to the 300-400 trees/ha that are likely to form the final crop. Current recommendations are that shaping and pruning of Europeanbeech is best carried out between June and August or in mid-winter.

Thinning

Stocking should remain high until a clean bole of at least 6 m is achieved. Early thinnings should favour the development of the potential final crop trees by the removal of forked and deformed stems in the upper canopy, while retaining sub-dominants and suppressed trees to assist with natural pruning. Any nurse species threatening to suppress potential final crop trees should also be removed. Once the objective of a branch-free bole of at least 6 m has been achieved, the development of the potential final crop trees (300-400/ha) can be further facilitated by a moderate to heavy crown thinning, removing any trees (main crop or nurse) that threaten to dominate or compress their crowns. The middle storey and understorey should be retained where possible to control epicormic shoots in the final crop trees. Subsequent thinnings should continue to favour the development of the potential final crop trees, bearing in mind that only about 100 trees/ha will ultimately remain as a final crop.

Growth, yield and rotation length

Yield class ranges from 4 to 8. The economic rotation can vary from 100 to 120 years.

Wood properties and uses

European beech has exceptional bending properties and is one of the strongest of all home-grown timbers. It dries fairly rapidly and has a tendency to warp, shrink and split. There can also be some movement in service. European beech is not naturally durable but takes preservatives well. It has a density of about 720 kg/m^3 at 15% moisture.

European beech is the most widely used wood in the furniture industry. High quality logs are used to produce veneer, which is used on plywood and on medium density fibreboard. It is also used for tool handles, sports goods, turnery and domestic flooring.

6.1.6 Southern beech

Of the forty species of southern beech that occur in the southern hemisphere, only two, *Nothofagus procera* and *Nothofagus obliqua,* are considered to have forest potential in this country.

Nothofagus obliqua stand at the JFK Arboretum.

Climatic requirements

Nothofagus procera is better suited to the milder and moister conditions in the south and southwestern parts of the country, whereas *Nothofagus obliqua* can tolerate drier conditions. While both species are susceptible to spring and autumn frosts, lack of winter hardiness is the principal limiting factor to their more extensive planting in this country. Damage may not manifest itself for one or two years after its occurrence, appearing as dieback of shoots and consequent multiple leaders. Frost can also kill the cambium and the resulting damage ranges from irregular swellings to large open fissures, which allow entry to fungal pathogens. This damage may be fatal to the trees.

Suitable sites

Neither species are too exacting and will grow on soils not suited to more demanding broadleaf species. Both species will grow on a wide range of soils, ranging from deep sands to moderately heavy clays, in middle to lower slope positions.

Unsuitable sites

Avoid frost hollows and exposed sites, especially those exposed to cold north and east winds. Poorly drained sites, shallow soils over limestone, and acid peats are also unsuitable. Sites where *Fomes* butt rot is present should also be avoided.

Other silvicultural characteristics

The form and timber properties of *Nothofagus procera* are superior to that of *obliqua*, but it is more liable to be damaged by drought. Both species are best established under a light overstorey, but this must be removed quickly to enable the young, light-demanding Southern beech plants to develop. On exposed sites, even at quite low elevations, growth is poor and the crop is liable to suffer from shoot dieback, due to strong or very cold winds. Both species have poorly developed root systems when grown in plantations at close spacing. They coppice well, provided the shoots have access to full light.

Diseases and pests

Nothofagus is less likely to be damaged by squirrels than common beech. The larvae of winter moths cause some defoliation, but the trees recover quickly and any serious effect on timber production is unlikely. On alkaline sites *Fomes* butt rot can result in the death of some trees. Root systems can be damaged by honey fungus and this can render trees more liable to windthrow.

Provenance

British stands and *Nothofagus procera* imported from Chile (Malleco and Llanquihue) should be favoured. *Nothofagus obliqua* provenances from Chile (Frutillar) are preferred.

Plants and planting

Careful handling is required, as plants are more sensitive to drying out than many other species.

Spacing and stocking

The current recommended planting spacing for southern beech is 2.0 x 1.5 m (3,300 plants/ha). Close spacing results in poorly developed root systems and stem form is

Good form in a *Nothofagus procera* stand at the JFK Arboretum.

unlikely to suffer as a result of wider spacing. Therefore, advocating wider spacing seems a logical step and will encourage a larger root system and hence a more wind-firm plantation.

Thinning

As early height growth tends to be vigorous, thinning may need to start as early as 12 years on fertile sites. Southern beech should be thinned more heavily than common beech, as once crowns are compressed they are slow to recover.

Growth and yield

Southern beech is among the fastest growing broadleaf species. It grows faster than European beech on all but calcareous soils. Yield classes of between 10 and 14 would be expected on most sites, with a corresponding rotation length of between 40 and 50 years.

Wood properties and uses

Though regarded as inferior to common beech, the wood of both species is strong, close-grained, and considered a good general-purpose hardwood. The sapwood is white to rose coloured, while the red heartwood is resistant to decay. Uses include joinery, veneer, flooring, woodturning and pulp.

6.1.7 Birch

Two species of birch are native to Ireland: silver birch, *Betula pendula,* and downy birch, *Betula pubescens*. Downy birch is more widely distributed, occurring in nearly all parts of the country, from exposed mountains to valley bottoms. Silver birch is relatively uncommon, and is generally associated with good soils in sheltered areas.

It is not always easy to differentiate between the two birch species using only characteristics visible to the naked eye. Leaf shape and twig characteristics are the most reliable. Difficulty in species identification has led many to believe that hybridisation between the two species is common. However, downy birch has 56 chromosomes, whereas silver birch has 28, and therefore hybrids would be expected to be fairly rare. Therefore, species identification needs to be carried out with care. A new, simple and accurate chemical method has been developed, proving to be a valuable tool for distinguishing between the species (Lundgren *et al.* 1995). It is based on the colour change of a solution into which a sample of inner bark is placed.

Climatic requirements

Downy birch is extremely frost-hardy, with no major climatic limitations. It can survive at quite high elevations, although its form can be adversely affected, even at quite low levels of exposure. On exposed sites it rarely develops into anything more than scrub. Silver birch is less hardy, and young trees can be damaged by late winter frosts and/or cold winds. This results in dieback of young plants, followed by regrowth from lower shoots, leading to poor stem form and, in severe cases, stem canker (Worrell 1999).


Birch stand showing excellent form.

Suitable sites

Downy birch is an accommodating species, occurring naturally on a wide range of forest soils, including brown earths, podzols, the more fertile iron pan podzols, surface-water gleys, peaty gleys, shallow peats and cutaway bogs. However, optimal growth will only be achieved on moisture-retentive, rich soils in sheltered situations. Silver birch grows satisfactorily only on the better site types. As a timber crop it will only be successful if grown on sheltered sites with free-draining mineral soils of moderate fertility (brown earths, the better podzols, and the drier surface-water gleys) (Worrell 1999).

Unsuitable sites

Unsuitable sites for downy birch are unflushed deep peats, particularly blanket peats, and exposed sites. Unsuitable sites for silver birch are exposed and very frost-prone sites, impoverished soils, and peaty or waterlogged soils.

Other silvicultural characteristics

Both species are attractive, but are rather short-lived, pioneer species. Though light-demanding, downy birch is considerably more shade tolerant than silver birch and can survive as an understorey tree in many types of woodland. Birch regenerates profusely and, due to its invasiveness, it is often regarded it as a weed species (particularly on restocking sites). Such natural crops of birch are normally very dense and expensive to control. Where the naturally occurring birch crop is of good quality, managing the birch (thinning and pruning as necessary), and allowing it to grow on to form a mature crop, may be a more economical option than attempting to grow another species on the site.

By virtue of its frost-hardiness, downy birch can be a valuable nurse for more delicate species on sites prone to frost. However, prompt attention is required to prevent the birch from 'whipping' the main species.

Traditionally, the main silvicultural values of birch is this country were seen as its soil-improving and nursing attributes, as well as its considerable amenity value. However, birch improvement by selection, or by the introduction of better provenances, is now receiving considerable attention. This could significantly enhance the quality of future planting stock and, in conjunction with appropriate management, improve the quality of the timber available.

Provenance

Native Irish material is the preferred choice, otherwise British material may be used.

Diseases and pests

'Witches broom', caused by the fungus *Taphrina betulina*, renders infected twigs more susceptible to frost. Leaf rust is very common but does not result in significant damage. Birch is rarely damaged by rabbits. Hares do browse both species but, when there is a choice, they show a preference for downy birch. The species is also frequently attacked by honey fungus.

Plants and planting

Bare-root birch plants are very susceptible to root damage due to desiccation, resulting in poor growth or high mortality in newly established plantations. It is therefore imperative, when using bare-rooted stock, that the time between lifting and planting is as short as possible and that roots are kept moist at all times.

February to early April is generally the most successful period to plant bare-root stock, except for sheltered lowland sites where November – January planting can be successful. Planting can safely be extended to late May by the use of cold store and/or containerised stock. Containerised stock can also be planted successfully in late summer/early autumn. This allows some root development to take place prior to the onset of winter, thus enhancing survival and growth in the following spring (Worrell 1999).

While the individual planting site can have a bearing on plant size, sturdy well-balanced containerised stock 20-30 cm in height, or bare-rooted stock 40-50 cm in height, should meet the requirements on most sites. Larger plants have a tendency to 'check' after planting.

Spacing and stocking

In Finland, where birch is a major tree species, 1,600 plants/ha is the normal recommendation for planting silver birch on fertile sites. However, the current recommendation in this country is to plant birch at 2.0 x 1.5 m (3,300 plants/ha). In naturally regenerated stands, it is not unusual for stocking levels to reach 10,000 stems/ha. Where timber production is the main objective, it is imperative that the density of such crops is reduced to between 2,000 and 2,500 stems/ha by the time the crop reaches a height of 5 m.

Fertiliser

Birch is very sensitive to phosphate levels. Phosphate deficient sites should therefore be given an application of 350 kg/ha of rock phosphate at planting.

Vegetation control

Birch is very intolerant of competition. Growth is usually poor on grassy sites, where the trees' shallow rooting system is in competition with the grass for soil moisture. Chemical control of the surface vegetation significantly enhances early growth of birch.

Pruning

Pruning is not usually necessary in well-stocked stands as branches are quickly suppressed and die. However, pruning can be carried out if desired, for example, in poorly stocked stands or where forking has occurred. Removal of dead branches can be carried out at any time of the year. Green pruning should only be done just after sap flow in spring (May/June) or shortly before leaf-fall (September) to avoid the risk of discolouration and rot. Pruning should be confined to potential final crop trees, and up to 40% of total tree height should be left as live crown.

Thinning

As birch is strongly light-demanding, prompt attention to thinning is essential to maintain vigorous crowns. If the living crown is reduced below 40% of the tree height, diameter growth will decrease rapidly. In well-stocked plantations, thinning should commence at a top height of about 10 m, at which stage the crop should be reduced to about 1,500 stems/ha. Thinning should be selective, removing poor quality stems. Potential final crop trees (700/ha) should be selected from dominants and co-dominants of excellent form. Subsequent thinning should favour potential final crop trees, thus ensuring that they maintain living crowns of about half their height.

Growth yield and rotation length

Given favourable conditions birch grows rapidly in youth, and for about the first twenty years will keep pace with most conifers, but after that age the rate of growth falls off. Productivity of up to 8 m^3/ha/yr can be expected from silver birch on suitable sites, whereas productivity from downy birch would be closer to 4 m^3/ha/yr. Rotation lengths on the best sites, with appropriate management, can be as short as 35 years. On poorer sites, and/or where thinning has been neglected, rotation lengths can be as much as 60 years.

Wood properties

Birch has a moderately dense wood (600-650 kg/m^3). It is comparable to European beech in most strength properties and to ash in terms of its toughness. Birch wood is fine-textured, white to pale fawn in colour. It works easily and, while not naturally durable, it is easily pressure-treated with preservatives. Its main drawbacks are in its general bland appearance and a tendency to distort on drying. In Finland, it is a very important species for plywood and veneer. Birch pulp is also used in the production of high quality paper. In Ireland, there is a ready market for good quality logs for high-class joinery, furniture and general turnery. However, few trees reach the required standard at present.

6.1.8 Wild cherry

Climatic requirements

Wild cherry is susceptible to damage by late spring frosts and may also suffer from severe winter frosts. It is sensitive to exposure, becoming deformed, often following branch breakage. It shows a marked preference for warm and sunny sites.

Suitable sites

Wild cherry is an exacting species with regard to site requirements. It will grow on moderately acid soils, but it prefers alkaline conditions. It is generally confined to sheltered or moderately sheltered sites, preferring deep, slightly moist soils, of medium to high nutrient status. Deep clay loams over limestone are particularly suitable. Wild cherry is best planted in small groups, wherever fertility and shelter provide ideal growing conditions or as a minor component in existing broadleaf plantations.

Unsuitable sites

Exposed sites should be avoided, and shallow and poorly drained soils give poor growth. Compacted soils, very acid soils and soils with a high water table should also be avoided.

Good stand of wild cherry.

Wild cherry will grow on relatively dry soils, but productivity will be low, and it is also more susceptible to heart-rot on such soils.

Other silvicultural characteristics

Wild cherry is a strong light-demander, except when very young. It has strong apical dominance, usually resulting in trees developing and retaining a single leading shoot. It has a poor capacity for natural pruning, retaining branches for many years after they have died. The tree coppices rather poorly, but suckers well. It is highly valued as an ornamental tree for its characteristic and spectacular flowering. Wild cherry has the potential to deliver better returns than other broadleaf species, due to its rapid growth and more valuable timber. It is a rather short-lived species, with relatively poor rooting ability, rendering it prone to wind damage.

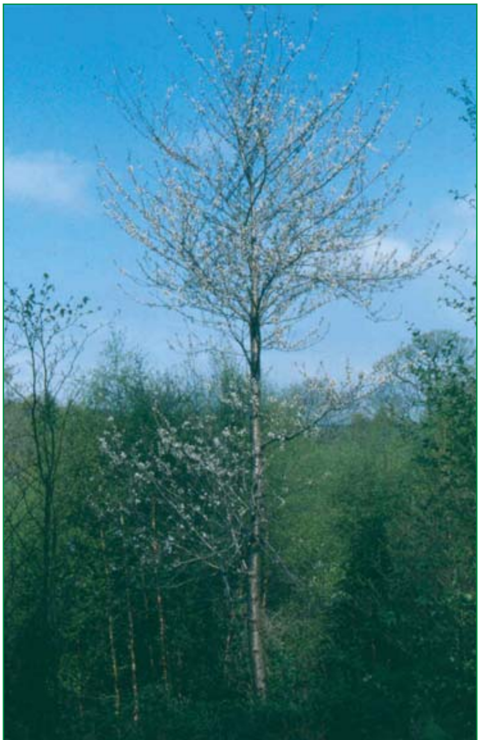
It is rarely grown in pure plantations, as very few suitable sites are available. Where soil and site are suitable, wild cherry is best planted as a single tree or in small groups in mixed broadleaf plantations. However, its intolerance of competition needs to be borne in mind and adequate room for crown development provided.

Provenance

The first choice is native Irish material. Otherwise material from British, northern French, Belgian, Dutch, northern German, and Danish stands can be used.

Diseases and pests

Wild cherry is prone to a number of diseases, bacterial canker being the most serious. This disease is characterised by exudation of gum and cankerous lesions, which may encircle the stem and result in death of the tree. The cherry blackfly can result in the death of the terminal bud and forking in the early years after planting. Heart-rot, caused by *Fomes* and honey fungus, results in timber decay to the most valuable log ends, leading to serious financial loss. Grey squirrels do not damage wild cherry, but deer find the foliage highly palatable and can cause damage.



Wild cherry (*Prunus avium*) at Deputy's Pass, Glenealy, Co Wicklow.

Plants and planting

Plants should be sturdy, well balanced, with a good fibrous root system. Wild cherry is an easy tree to establish, and provided good plant-handling procedures are in place, bare-root transplants can be successfully established from October to April. While individual site conditions will have a bearing on the optimum plant size, plants 60-90 cm tall, having a root collar diameter of 12 mm, should meet the requirements on most sites. Due to its strong apical dominance, wild cherry does not need to be planted at close spacing. It grows faster in tree shelters than almost any other species.

Spacing and stocking

If planted in pure blocks (not recommended), the current practice is to plant at 2.0 x 1.5 m (3,300 plants/ha).

Vegetation control

By virtue of its rapid early growth (up to 80 cm height increment in the second year on suitable sites), cleaning is usually not a problem. It responds positively to chemical vegetation control. An added benefit of weed control is that exposed mineral soil is usually more effective at absorbing heat than soil covered with vegetation. A warmer soil will improve plant root growth and overnight re-radiation may reduce frost damage.

Pruning

As natural pruning is very slow, pruning is required to prevent the formation of dead knots, which result in serious degradation of the timber. To avoid the risk of providing an entry point for fungi, branches should be removed before they reach 3 cm diameter at the base. Pruning should be carried out from June to August to minimise infection risk from bacterial canker and silver leaf disease. To ensure no adverse effect on individual tree increment, the crown should make up at least 40% of the total tree height.

Thinning

Thinning should aim to ensure that the crowns of potential final crop trees are unimpeded. At a top height of about 8 m, competitors should be removed from around the potential final crop trees, ensuring their crowns have adequate growing space to develop. Subsequent thinnings should be heavy (leaving the final crop almost verging on open-grown) and regular, favouring these final crop trees.

Growth, yield and rotation length

Wild cherry has very rapid early growth, culminating between 7 and 15 years, and slowing down appreciably between 30 and 40 years. Yield classes of between 6 and 10 would be expected on most sites, with a corresponding rotation length of between 70 and 80 years.

Wood properties and uses

The timber dries fairly rapidly but has a tendency to distort. Once dry it is fairly stable, moderately hard, with a fine texture and good wood-bending properties. It works easily and polishes exceptionally well. The average density of the wood at 15% moisture content is about 630 kg/m^3. Because of its tendency to warp, cherry is best used in smaller more stable sections. Furniture, decorative joinery and cabinet making are among its uses. Wild cherry is one of the most valuable timber species in Europe for the manufacture of high-class furniture, with demand for top quality cherry timber greatly exceeding supply.

6.1.9 Spanish chestnut

Climatic requirements

As a Mediterranean species, Spanish chestnut is best suited to the south and southwestern part of this country. It is very sensitive to frost and intolerant of exposure.

Suitable sites

It grows best on sheltered sites, with deep, moderately fertile, light soils, pH 4-5, with sufficient but not excessive moisture.

Unsuitable sites

Frosty or exposed sites, very wet or very dry soils, heavy clays, calcareous or nutrient-poor soils are all unsuitable.

Other silvicultural characteristics

Spanish chestnut is shade-bearing for about the first seven years, but then becomes light-demanding. It suffers from ring and star shake. Shake occurs mostly in older trees (over 80 years), growing on light soils which are liable to dry out. Its exacting nature in this respect poses a considerable risk to growing it on unsuitable soils. Spanish chestnut is also windfirm, and it has soil-improving properties. It grows fast when young and coppices very well.

Diseases and pests

A potentially serious disease is chestnut blight, caused by the fungus *Endothia parasitica*, which at present is confined to southern Europe. When planted on wet,

Seven year old group planting of Spanish chestnut at Ballyhooley Forest benefitting from the shelter provided by the eleven year old Douglas fir.

poorly drained soils, especially shallow, compact clays, it suffers from root rot, known as 'ink stain disease,' caused by *Phytophthora cinnamomi* and *P. cambivora*.

Provenance

French seed orchards, where trees have been selected for wood production (not material selected for the production of edible nuts), are preferred.

Plants and planting

Provided sturdy, well-balanced plants with a good fibrous root system are used, Spanish chestnut is generally an easy tree to establish. However, its sensitivity to frost, giving rise to the development of multi-stemmed, bushy trees, is a major hazard. There is evidence that the first stems produced from chestnut seedlings have a twisted grain, and in practice it appears advisable to stump back all plants to within 10 cm of ground level at an age of 5-8 years. Prior to stumping back, it is imperative that all vegetation likely to compete with the development of the new shoots is effectively controlled. Regrowth from the stumps is very rapid (1.5 - 2.5 m) in the first year. Even greater increment can occur in the second year, but thereafter increment becomes closer to normal rates. If the objective is the development of a sawlog plantation rather than a coppice crop, the resultant shoots should be thinned out until the single straightest shoot is left on each stump.

Spacing and stocking

The recommended spacing for Spanish chestnut at establishment is 2.0 x 1.5 m (3,300 plants/ha).

Vegetation control

Spanish chestnut responds positively in terms of height growth to chemical weed control. The aim should therefore be to maintain a weed-free zone of about one metre diameter around each plant for up to four years after planting to maximise water and nutrient availability to the plant. Additional vegetation control may be necessary if a crop is coppiced. An added benefit of weed control is that exposed mineral soil is usually more effective at absorbing heat than soil covered with vegetation. A warmer soil will improve plant root growth, and overnight re-radiation may reduce frost damage.

Fertiliser

Spanish chestnut does not require highly fertile soils. Therefore, apart from phosphate on nutritionally marginal sites, further fertiliser application should only be considered if foliage analysis indicates nutrient deficiencies.

The poor form of this young stand of Spanish chestnut at the JFK Arboretum could be due to provenance or exposure.

Formative shaping

Under favourable growing conditions Spanish chestnut has good apical dominance. However, in practice this rarely occurs. While stumping back and subsequent vigorous regrowth greatly reduces the need for formative shaping, some intervention is usually required. The main priority is the control of forking (which can lead to the development of disproportionately large branches) on up to 400 potential final crop trees/ha.

Pruning

Where artificial pruning is deemed necessary it involves the removal of live and dead branches from the lower 6 m of the stem, and is usually performed in two lifts. To ensure no adverse effect on individual tree increment, at least one third of the total tree height should be live crown. To avoid the risk of providing an entry point for fungi, branches should be removed before they reach 3 cm diameter at the base. To reduce costs, pruning should, wherever possible, be confined to the 300-400 trees/ha likely to form the final crop.

Thinning

Except when very young, Spanish chestnut is a fairly strong light-demander. It should be thinned to the same prescription as for ash, bearing in mind that if crown vigour is lost, response to further thinning will be slow, while sudden opening up of the stand by heavy thinning can give rise to crop stagnation. Thinning should favour potential final crop trees (300-400/ha), allowing them plenty of light and space, with only side shade.

Growth, yield and rotation length

Yield class ranges from 4 to 12, averaging 6. Due to the susceptibility of older trees (over 80 years) to ring and star shake, the rotation length of Spanish chestnut should be limited to 50-70 years.

Wood properties and uses

The main features are its natural durability, even at small dimensions, and the ease with which the wood can be split. The timber of Spanish chestnut resembles oak, but lacks the medullary rays, and is less strong and more easily worked. It has a corrosive effect on metals, and becomes stained in contact with iron. It is a valuable timber if free of shake and spiral grain. Top quality logs are used for veneer and other high quality furniture, panelling and flooring. Lower grades are used for fencing, and other areas where there is a need for decay resistance.

6.1.10 Hornbeam

Climatic requirements

Hornbeam is very frost-hardy, and will survive in frost hollows where many other species succumb.

Suitable sites

It is adapted to a wide range of soils, from wet, heavy clays to light, dry sands. It thrives on both acid brown earths and soils derived from limestone.

Unsuitable sites

Avoid acid and infertile podzols, peaty soils and exposed sites.

Other silvicultural characteristics

Hornbeam is a strongly shade-bearing species. Its main silvicultural value is as an understorey tree on heavy clays and soils prone to waterlogging. It is frequently used as an understorey to pedunculate oak to control epicormic shoots. Hornbeam is generally slow-growing, never reaching large dimensions, but on fertile soils it can reach a height of up to 20 m. Stem form is generally poor, with a high incidence of fluting. It coppices easily, and was once an important coppice species.

Five year old hornbeam (10 year old Sitka spruce in background) on a gley site at Banteer Forest.

Wood properties and uses

Its wood is hard, strong, tough and white, and finishes very smoothly. Its uses include keyboard instruments, carving, and turnery.

Mature hornbeam at Avondale.

6.1.11 Lime

Of the many species of lime that exist, the best known in this country are the small-leaved lime, the large-leaved lime and a fertile hybrid of the two, known as the common lime. The latter is the lime most often seen planted in parks and gardens.

Mature lime tree at Coolattin, Shillelagh.

Climatic requirements

Lime species are moderately susceptible to spring frosts and are sensitive to exposure.

Site requirements

Lime is essentially a tree of the lowlands. Its best performance is on fertile loamy soils, but lime is accommodating and will grow on podzols, brown earths and alkaline soils, provided they are of at least moderate fertility.

Unsuitable sites

These include all infertile soils, as well as poorly drained soils including peats.

Other silvicultural characteristics

Limes are deep-rooting species and are generally wind-firm. They are moderately tolerant of shade and cast a heavy shade themselves. Viable seed production is rare, occurring only in warm summers. Limes coppice freely and can also be propagated from cuttings and layering. They are often planted for their soil-improving properties. The trees and ground beneath are often covered with sticky honeydew in summer from the lime aphids that live in the crowns of the trees.

Provenance

Irish, British, northern French, Belgian, Dutch, northern German and Danish stands are preferred.

Disease and pests

Limes do not suffer from any specific disease and are generally a remarkably healthy species. The species is rarely damaged by squirrels, but is very susceptible to browsing by deer.

Wood properties and uses

The wood is close-grained, pale yellow or white, light, soft, and of medium density. It is regarded as a good general-purpose hardwood. Its ease of working renders it favourable for turnery and woodcarving.

6.1.12 Norway maple

Climatic requirements

Norway maple is tolerant of salt-laden winds. It is frost-hardy but not as tolerant as sycamore and is also much less tolerant of exposure than sycamore.

Norway maple plantation at the JFK Arboretum.

BROADLEAVES

Suitable sites

Norway maple has similar requirements to those of sycamore, that is, moist, free-rooting fertile soils. It grows best on deep soils over limestone, but also tolerates shallow soils over these rocks. It is perhaps less demanding than sycamore and appears to tolerate rather drier soils.

Unsuitable sites

Infertile soils and exposed situations should be avoided.

Other silvicultural characteristics

Norway maple grows well in mixture with European beech, Norway spruce and western red cedar, but due to its rapid early growth it is best planted in groups rather than in intimate mixtures, to avoid suppression of the other species. It has good autumn colour and is valued for this where amenity considerations are important. The species is tolerant of industrial pollution and therefore is much used in streets, parks and gardens. It is fairly deep-rooted, and regenerates freely. It is also a good pollen and nectar producer for bees.

Diseases and pests

The cambium is highly attractive to grey squirrels which, if present, can cause serious damage.

Provenance

Irish and British stands and material from northern French, northern German and Danish stands are preferred.

Spacing and stocking

The recommended planting spacing for Norway maple is 2.0 x 1.5 m (3,300 plants/ha).

Growth and yield

Norway maple grows rapidly for the first 30-40 years, but does not reach dimensions as large as sycamore. On suitable sites, with good management, trees can achieve 40 cm diameter at breast height in 40 years.

Thinning

It is moderately light demanding and therefore needs to be heavily thinned to maintain growth.

Wood Properties and Uses

In most respects the wood of Norway maple resembles that of sycamore, though it is rather harder. The average density at 15% moisture content is slightly greater than sycamore, at about 660 kg/m^3. A hard, strong, smooth-textured wood, it is used for furniture and carving. Wavy-grained maple is in great demand, and is sometimes used for making musical instruments.

6.1.13 Oak (Sessile and Pedunculate)

Climatic requirements

Both species are susceptible to spring frosts, though there is some evidence that pedunculate is less sensitive to frost damage than sessile. However, sessile is damaged less often because it is normally planted in hilly terrain, where late frost is less frequent, and not as severe as in the lowlands, where pedunculate is normally planted. On exposed sites, height growth of oak is impaired, but the more damaging effect is poor tree form.

Suitable sites

Both species will grow over a wide range of site conditions, but as a commercial crop their planting should be restricted to low-elevation, sheltered sites in soils of at least

Fifty-six year old oak stand at Mountbellew Forest.

moderate fertility. Pedunculate oak prefers well-aerated, deep, moist, fertile, heavy soils (pH 4.5-7.0) and can tolerate some waterlogging. Sessile oak is intolerant of flooding, preferring the better-drained acid brown earths (pH 4.0-6.0).

Unsuitable sites

Exposed sites, frost hollows, very infertile soils and badly drained soils should be avoided. Very free-draining soils with a fluctuating water table should also be avoided, as they give rise to a high proportion of trees with ring shake, greatly reducing the value of the timber.

Other silvicultural characteristics

Both species are light-demanding, but sessile oak withstands more shade than pedunculate. Both species are deep-rooting and hence very wind-firm. Sessile oak is said to be less prone to developing epicormic shoots than pedunculate. Shake-prone trees of both species may be recognised by their tendency to flush later in spring (Savill and Mather 1990). Both species lack apical dominance and assume a bushy appearance if given full growing space. Both species coppice freely. The faster oak grows the stronger its timber will be (Knaggs pers. comm. 2003). Oak should not be felled during the growing season as this renders it susceptible to attack by fungi and insects.

Provenance

Registered native Irish material is the preferred choice. Otherwise registered British, northern French, Belgian, Dutch, northern German and Danish seed stands can be used.

Diseases and pests

Apart from occasional damage by the grey squirrel and the occurrence of oak mildew, both species of oak are relatively free of pests and diseases. Of the fungi that attack oak, two are of significance: *Polyporus sulphurens,* which causes brown cubical rot and *Stereum gausapatum,* which causes pipe rot. They enter the tree through branch stubs in which heartwood has developed. The onset of heartwood in side branches occurs when they exceed 3 cm in diameter at the stem. To avoid infection, side branches should not be allowed develop heartwood. This is best achieved by ensuring that branch diameter is kept small by close spacing. The alternative is early and continuous high pruning. A relatively new disease known as ‘sudden oak death’ and caused by the fungus *Phytophthora ramorum* has been identified as killing young plants recently.

Site preparation

The erection of a stock and rabbit proof fence is perhaps the most important operation. Some of the heavier soils may require drainage in conjunction with either ploughing or

Mature oak tree showing excellent stem form.

mounding or a combination of both. On drier sites ripping may be used to provide planting lines, a loosening of the subsoil and a rupturing of plough pans if present.

Plants and planting

Plants should have good root/shoot and root collar/height ratios. They should also have a straight stem with a healthy terminal bud and fibrous root system. Individual site conditions will govern the optimum plant size. However, plants 60-90 cm tall and having root collar diameters of at least 12 mm should meet the requirements of most sites. Oak is not a difficult tree to establish. Provided good plant handling procedures are in place, bare-rooted transplants can be successfully established from November to March. The planting season can be extended with cold-stored stock without any adverse effect on survival, if plants are planted within two weeks of their removal from the cold store.

Early growth can be considerably hastened by the use of individual tree shelters. Oak responds well to stumping back, with regrowth of up to 1.5 m being recorded in the first growing season following cutting back to 5 cm from ground level. With form being superior to conventionally raised trees, this offers an economical means of getting a good second start with plants where initial form is poor. By virtue of its poor apical dominance pure plantations need a stocking of 6,000-7,000 plants/ha to ensure that trees grow upwards rather than spread outwards. Such plantations are not only extremely expensive to establish, their early thinnings are also of little value. The income from such plantations is greatly enhanced if oak is mixed with species such as larch, western red cedar or Scots pine.

Vegetation control

Oak responds positively in terms of height growth to chemical weed control. The aim should therefore be to maintain a weed-free zone of about 1 m diameter around each plant for up to four years after planting to maximise water and nutrient availability to the plant. An added benefit of weed control is that exposed mineral soil is usually more effective at absorbing heat than soil covered with vegetation. A warmer soil will improve plant root growth and overnight re-radiation may reduce frost damage.

Fertiliser

Fertiliser is rarely required on suitable oak sites. On marginal sites phosphate levels should be assessed through foliar analysis (see Appendix V), and fertiliser applied as required.

Formative shaping

All oak grown for timber production will benefit from formative shaping. The main priority is to remove forks and disproportionately large branches. This should start soon after establishment and ideally continue annually until the objective of a single straight stem has been reached.

Pruning

Pruning, which involves the removal of live and dead branches from the lower 6 m of the main stem, is usually performed in two lifts. To ensure no adverse effect on individual tree increment, at least one third of the total tree height should be live crown. To avoid the risk of providing an entry point for fungi causing heart rot, branches should be removed before they reach 3 cm diameter where they join the main stem. To reduce costs pruning should, wherever possible, be confined to the 300-400 trees/ha that are likely to form the final crop. The recommended time for both shaping and pruning oak is during the month of December.

Thinning

Development of epicomic shoots is a major problem in oak, and thinning practices should avoid exacerbating this problem. Sudden changes in the stand density, such as that resulting from heavy thinning, tend to result in the production of epicormic shoots. Conversely, small crowns, which result from neglected or light thinning, also induce epicormic shoots as the trees struggle for survival (Joyce *et al.* 1998). The traditional approach is for frequent, light, intermediate thinnings, maintaining balanced growth of potential final crop trees while avoiding stress or overexposure of the crowns, factors crucial in avoiding epicormics. More recent thinking favours early crown release, following close initial spacing. The rationale is that the early space created allows the potential of the juvenile growth phase for crown development to be exploited (Joyce *et al.* 1998). The crown response of the final crop trees to the increased growing space helps curb the stresses generated in the tree which produce epicormic shoots. Subsequent thinnings should continue to favour the development of 300-400 potential final crop trees per ha, bearing in mind that only about 100 trees/ha will ultimately remain as a final crop.

Growth, yield and rotation length

Yield class ranges from 2 to 8, with an average of 4. The economically optimum rotation length ranges from 130 to 160 years.

Wood properties and uses

The wood of both species is very similar, hard with naturally durable heartwood. The sapwood is perishable unless treated with preservatives. Oak varies greatly in quality, depending on straightness of grain, presence of knots, epicormic branches, shake and stain. Top quality logs are used for veneer and other high quality timber in furniture, joinery, panelling, and flooring. Lower grades are used for fencing and other products where there is a need for decay resistance.

6.1.14 Red oak

Climatic requirements

Red oak is a hardy species, suffering little from severe cold. However, it is occasionally damaged by late spring frosts.

Suitable sites

Red oak is less exacting as regards site than either sessile or pedunculate oak. It will grow on dry acid sites, but it does best on fertile sandy loams.

Unsuitable sites

Exposed areas, alkaline soils, peatlands and very infertile soils are all unsuitable. Except when growing the tree for amenity purposes, very free-draining soils should be avoided as they can lead to timber being badly affected by ring shake.

Other silvicultural characteristics

It is more shade-bearing than either of the native oak species and is immune to mildew.

Young red oak showing very poor form (JFK Arboretum).

It coppices well and is known for its crimson autumn colours for which it is often planted. Unlike the native oak species, epicormic branches are not a serious problem, but the tree has a tendency to fork rather badly, requiring early pruning for quality timber production. It is more prone to damage by hares than almost any other species.

Provenance

Registered Irish, British, northern French, Belgian, Dutch, northern German and Danish seed stands are preferred.

Plants and planting

Red oak is not a difficult tree to establish. Plants 30-60 cm tall, having root collar diameters of at least 7 mm, should meet the requirements of most sites.

Spacing and stocking

The current recommendation is to plant red oak at 2.0 x 1.5 m (3,300 plants/ha).

Growth, yield and rotation

It is a rapid grower, but not long-lived, and will not reach dimensions as large as that attainable by sessile or pedunculate oak. However, productivity is usually higher (3-9 m^3/ha/yr) than native oak. Red oak has an estimated economically optimum rotation length of 70-90 years.

Wood properties and uses

Strength properties of the wood are similar to native oak. The wood is not naturally durable, but it can easily be impregnated with preservatives. The average density of the wood at 15% moisture content is about 790 kg/m^3. Although used extensively for furniture, flooring and interior joinery, it is regarded as inferior to native oak due to its colour and texture.

6.1.15 Rowan (mountain ash)

Climatic requirements

Rowan is resistant to frost damage and is relatively tolerant of exposure.

Suitable sites

Rowan is an undemanding species, which does well on relatively poor, dry, acid soils. However, it grows best on moist, humus-rich sites.

Unsuitable sites

It is rarely found growing on heavy clays and limestone soils, and it does not tolerate waterlogged conditions or infertile peatlands.

Other silvicultural characteristics

Rowan is a valuable pioneer species, and has soil-improving properties. It is a strong light-demander and coppices freely. It grows moderately quickly, but the species rarely exceeds 15 m in height. It is best known for its ornamental value, both in upland areas and in household gardens. Rowan is favoured by deer for browsing.

Provenance

Native Irish material is the preferred choice. Otherwise British material can be used.

Wood properties and uses

Its wood is not naturally durable, but is dense and hard (similar to that of apple). It is suitable for turnery and carving and also makes good firewood.

Rowan.

6.1.16 Sycamore

Climatic requirements

Sycamore is much less sensitive to late spring frosts than most of the other commercially planted broadleaf species in this country. It is tolerant of salt spray and also of exposure on suitably moist and fertile sites. Consequently, it is often used for shelterbelts at high elevations, and in coastal areas. It can suffer sun-scorch on the south side of an exposed trunk.

Suitable sites

Sycamore is moderately exacting and, while it will grow on a wide range of sites, it requires deep, moist, freely drained soils in sheltered localities for best development. Being resistant to lime-induced chlorosis, it grows better than most species on calcareous soils with free calcium carbonate to the surface. Its best growth tends to be on soils in the pH range 5.5-7.5.

Unsuitable sites

Dry or shallow soils, poorly drained ground, podzols, heavy clays and very acid soils (pH 4 or less) are all unsuitable.

Other silvicultural characteristics

In youth, sycamore is a moderate shade-bearer, but requires full light after the sapling stage. It is very wind-firm due to its deep rooting system, and responds well to stumping back. Due to its reputation on fertile sites as an invasive species, it is often regarded as a weed species. Its flowers, which are insect-pollinated, act as a valuable source of pollen and nectar for bees. Sycamore is a longer-lived tree than other maples, and can attain large size, in excess of 30 m in height and 1.5 m in diameter.

Provenance

Irish, British, northern French, Belgian, Dutch, northern German and Danish stands are preferred.

Diseases and pests

Sycamore is very susceptible to damage by grey squirrels. If grey squirrels are present planting of sycamore should be limited. Although frequently affected by tar spot, caused by the fungus *Rhytisma acerinum*, the damage caused is rarely serious. Sooty bark disease caused by the fungus *Cryptostroma corticale* causes wilting of the leaves followed by dieback of affected branches. This disease is mainly confined to warmer areas, with severe outbreaks being associated with hot summers.

Sixty-three year old sycamore at Ravensdale.

Site preparation

On most sites a rabbit-proof fence will be required. Cultivation will rarely be required on a typical sycamore site. However, ripping can often be justified where a plough pan is present, or as an aid towards reduced planting costs. Excavator mounding should be carried out if there is a danger of excess water.

Plants and planting

Plants should be sturdy and well balanced, with a good fibrous root system. Sycamore is a very easy tree to establish, and provided good plant-handling procedures are in place, bare-root transplants can be successfully established from October to April. While individual site conditions will have a bearing on the optimum plant size, plants 60-90 cm tall, having a root collar diameter of 12 mm, should meet the requirements of most sites. It responds well to planting in tree shelters. Though often found growing in association with other species (ash, European beech and larch being the most common), pure plantations can produce excellent quality stems where conditions are favourable.

Spacing and stocking

The recommended planting spacing for sycamore is 2.0 x 1.5 m (3,300 plants/ha).

Vegetation control

Sycamore responds positively in terms of height growth to chemical weed control. The aim should therefore be to maintain a weed-free zone of about 1 m diameter around each plant for up to four years after planting to maximise water and nutrient availability to the plant. An added benefit of weed control is that exposed mineral soil is usually more effective at absorbing heat than soil covered with vegetation. A warmer soil will improve plant root growth, and overnight re-radiation may reduce frost damage.

Fertiliser

On suitable sycamore sites fertiliser is rarely required, but phosphate may be necessary on marginal sites, which should be confirmed by foliar analysis (see Appendix V).

Formative shaping

Sycamore has strong apical dominance, but some intervention is usually required to control forking and the development of heavy branches.

Pruning

Where artificial pruning is deemed necessary it involves the removal of live and dead branches from the lower 6 m of the stem and is usually performed in two lifts. To ensure no adverse effect on individual tree increment, at least one third of the total tree height should be live crown. To avoid the risk of providing an entry point for fungi, branches should be removed before they reach 3 cm diameter at the base. To reduce costs pruning should, wherever possible, be confined to the 200-300 trees/ha likely to form the final crop.

Thinning

Thinning should commence at a top height of about 12 m. A heavy crown thinning is favoured, aimed at removing competitors to potential final crop trees. Subsequent thinnings should take place at 2-3 m height growth intervals, further facilitating the development of the potential final crop trees by the removal of any trees that threaten to dominate or compress their crowns. The middle storey and understorey should be retained where possible to control epicormic shoots in the final crop trees.

Growth, yield and rotation length

Yield class ranges from 4 to 12, averaging 6, with a corresponding rotation length of 50-90 years.

Wood properties

Sycamore wood is moderately dense and has strength properties resembling that of oak. It is hard but not naturally durable, though it takes preservatives well. Its white colour makes it useful in the manufacture of wooden cooking utensils (e.g. butchers blocks and bread boards). It is also used in turnery, flooring and furniture. A special wavy grain, or 'fiddleback' grain, is highly sought after for veneer and musical instruments.

6.2 CONIFERS

6.2.1 Western red cedar

Climatic requirements

In its natural range western red cedar is restricted to areas with abundant rainfall (or snow), high humidity and cool summers. From observations of its growth on a limited number of stands in this country, there is nothing to suggest any limitations imposed by our climate. It can withstand very low winter temperatures and is moderately resistant to late spring frosts. It suffers from cold winter winds (blasting) at high elevations.

Suitable sites

It is clearly an accommodating species, succeeding on a wide range of soils, including some nutritionally marginal, Old Red Sandstone podzols, flushed or reclaimed peats and alkaline soils. However, its performance naturally varies according to the character of the soil. Best development is achieved when planted on sheltered sites, with deep, freely-drained yet moist soils.

Unsuitable sites

Avoid very dry and exposed sites, waterlogged soils, unflushed blanket peats, indurated and very infertile mineral soils.

Mature western red cedar at Avondale.

Other silvicultural characteristics

By virtue of its narrow crown and shade-tolerance, western red cedar is an excellent tree for planting in mixture with many other species. In its natural range it is frequently found growing in association with Douglas fir, becoming dominant on the banks of watercourses and on marshy valley bottoms. It is suitable for underplanting and enriching understocked plantations. It is particularly suitable as a nurse to broadleaf species, as its narrow crown does not interfere with the crowns of the other species. It will keep pace with several species, such as, oak, European beech, ash and cherry, without outgrowing or suppressing them (Savill 1992). It is sensitive to atmospheric pollution. Western red cedar can easily be propagated by cuttings and this affords an opportunity of reproducing clones resistant to shot hole disease. The species can have excessive fluting at the base of the stem and persistent branches can cause wood quality problems.

Diseases and pests

Shot hole can cause serious damage to western red cedar plants at the nursery stage and can also cause defoliation of mature trees. The species is more susceptible than most conifers to attack by heart rot fungi. Western red cedar is more prone to rabbit damage than almost any other species.

Provenance

Irish and British stands, and seed imports from Vancouver Island (British Columbia), coastal Washington and Oregon, are suitable.

Plants and planting

Provided good plant handling procedures are in place, western red cedar is not a difficult species to establish. Sturdy plants (20-30 cm tall) are best.

Spacing and stocking

The recommended planting spacing (Anon. 2000d) for western red cedar is 2 x 2 m (2,500 plants/ha). However, its persistent branching habit and delayed canopy closure make a compelling case for closer initial spacing (1.6 x 1.6 m - 3,900 plants/ha).

Fertiliser

Little is known about the nutritional requirements of western red cedar in this country. However, current recommendations are to apply rock phosphate at 250 kg/ha on marginal sites and 350 kg/ha on more impoverished sites. Soils under western red cedar stands have a higher pH and higher calcium content compared with soils under many other species. Another special nutrient condition associated with western red cedar is the

Fifteen year old western red cedar on a nutritionally marginal Old Red Sandstone site at Ballyhoura Forest.

relatively high rate of nitrification of the litter from this species. This feature of a calcium-rich litter that undergoes nitrification may give western red cedar a competitive advantage in the struggle for a limited supply of soil nitrogen (Bothwell 1998).

Pruning

As natural pruning is very slow, pruning is required to prevent decay of dead knots and to ensure high quality timber. Pruning in conjunction with close spacing may also reduce fluting and extreme taper.

Growth, yield and rotation length

The yield class of western red cedar in Coillte's estate ranges from 8 to 24, averaging 17. Its rotation length varies from 60-75 years.

Wood properties and uses

Western red cedar timber is renowned for the natural durability of its heartwood, particularly timber derived from old growth trees in the Pacific Northwest of the US and Canada. In Ireland, because of its faster growth rate and shorter rotation, the timber has a higher proportion of sapwood, and consequently is less durable. The timber is of exceptionally low density, and has low strength and stiffness. Fluting at the base presents sawing difficulties, and excessive taper can lead to conversion losses. It works easily and has good nailing properties, but corrodes iron and steel. The heartwood is ideally suited to situations where durability is required: roofing, shingles, cladding, decking, glasshouses and garden furniture.

6.2.2 Lawson cypress

Climatic requirements

Low winter temperatures do not damage Lawson cypress. It is sometimes damaged by late spring frosts but has good powers of recovery. It does not grow well where exposure is excessive. It generally seems to grow better in areas of high precipitation, but will grow in drier sites provided soil moisture is adequate.

Suitable sites

Lawson cypress grows best on deep, moist and fertile soils. However, it is generally an accommodating species, growing reasonably well on a variety of soils. It grows slowly but satisfactorily on heavy clays and on the more fertile peats. As part of a species trial established on a peaty podzolised gley/indurated iron pan podzol derived from Old Red Sandstone at Cappoquin, Co Waterford, Lawson cypress outperformed nine other coniferous species in terms of total volume production at forty years of age. The other

Lawson cypress with regeneration at Glenealy Forest.

CONIFERS

species in the trial were: Sitka spruce, Japanese larch, Douglas fir, Scots pine, Corsican pine, noble fir, grand fir, common silver fir and lodgepole pine (inland provenance)

Unsuitable sites

It is unsuitable for planting on dry, heather-covered ground or infertile blanket peats.

Other silvicultural characteristics

Lawson cypress is very shade-tolerant. It is very prone to forking and although closer initial spacing can help alleviate this, significant progress is more likely to be made through genetic selection. Natural pruning is extremely slow, even where closely spaced. Lawson cypress regenerates freely and can be propagated both from seed and cuttings. Numerous named cultivars exist and great care should be taken in selection of these as they have greatly differing characteristics. It is more tolerant of pollution than many other conifers.

Diseases and pests

Lawson cypress does not suffer from any specific disease and is generally a remarkably healthy species. It is less susceptible to *Fomes* butt-rot than many other conifers. It is badly affected by a *Phytophthora* root rot disease in its natural range.

Provenance

Irish and British stands and imports from coastal southern Oregon and northern California are preferred.

Plants and planting

Lawson cypress is an easy tree to transplant, requiring no special treatment. However, except on very sheltered sites, the density of their crowns predisposes plants to juvenile instability. On very exposed sites the risk of instability is reduced by use of smaller plants (20 to 30 cm tall).

Spacing and stocking

The recommended planting spacing (Anon. 2000d) for Lawson cypress is 2 x 2 m (2,500 plants/ha). However, its inclination to fork and delayed canopy closure make a strong case to reduce initial spacing to 1.6 x 1.6m (3,900 trees/ha).

Fertiliser

Lawson cypress does not appear to have a high nutrient requirement. However, rock phosphate, at the rate of 250 kg/ha on marginal sites and 350 kg/ha on more impoverished sites, should be applied at establishment.

Vegetation control

Since height increment of Lawson cypress is relatively slow, dense vegetation, such as, grasses and bracken, needs to be kept under control. However, it is a shade-bearing species and can therefore tolerate some weed growth (bramble/scrub/woody weeds).

Pruning

As natural pruning is very slow, artificial pruning is required to prevent decay of dead knots and to ensure high quality timber. Closer initial spacing may reduce the incidence of forking and branch size, but not the number of branches, which can be substantial. To be economically feasible, pruning would therefore have to be confined to the 500-600 final crop trees/ha.

Thinning

Canopy closure following thinning is very slow in Lawson cypress, suggesting a longer thinning cycle than most other conifers. Pruned final crop trees should be favoured when marking thinnings.

Growth, yield and rotation length

There is no published yield table for Lawson cypress, only a combined one for Lawson cypress/western red cedar. Using this, the average yield class on Coillte's estate is 11. The Lawson cypress plot at Cappoquin (mentioned above) has a general yield class of 12. At age 40 total volume is estimated at 660 m^3/ha, giving a mean annual increment (MAI) of 16.5 m^3/ha/yr. Maximum MAI at Cappoquin can be expected to reach 18 m^3/ha/yr (Lynch pers. comm. 2001). Based on the Cappoquin experience, the average local yield class for Coillte's Lawson cypress is therefore most likely to be well in excess of 11. A rotation length of 60-70 years is recommended. **These results are based on measurements taken at one site and therefore need to be interpreted with caution.**

Wood properties and uses

The wood is light yellow to pale brown, with no clear distinction between sapwood and heartwood. It has a fine, even texture, with a straight grain and fragrant smell. Its heartwood is highly resistant to decay, easy to work to a smooth finish, and stable in service. It has an average density at 15% moisture content of about 500 kg/m^3. It is native to Oregon and California where the wood is used for boat building and joinery.

6.2.3 Monterey cypress

Climatic requirements

Coming as it does from a warm climate, Monterey cypress is susceptible to low winter temperatures. It is therefore best suited to the south and southwestern coastal regions of this country. It is moderately resistant to spring and autumn frosts, and is very tolerant of exposure and salt-laden winds.

Suitable sites

Monterey cypress grows well on a range of well-drained soils (including those derived from limestone), sands and shallow peats of at least moderate fertility.

Unsuitable sites

Avoid very acid and impoverished mineral soils and infertile peats.

Other silvicultural characteristics

Monterey cypress is difficult to raise from seed, having a low germination rate. It is also a very difficult tree to transplant, often with heavy losses being experienced with bare-rooted stock. The species is very variable in shape and size, some specimens being extremely bushy, whereas others have a narrow fastigiate form. Its resistance to salt-laden winds, coupled with its rapid growth and bushy habit, makes it a valuable tree for planting where shelterbelts are required near the coast. It is also a very valuable hedging species, where it grows very fast and bears clipping well. It is very prone to forking and tends to have spiral growth. The ingestion of foliage from Monterey cypress is linked with abortion in cattle (Sloss and Brady 1983).

Provenance

Irish and British stands and seed imports from coastal southern Oregon and northern California are preferred.

Diseases and pests

It does not appear to be seriously affected by fungal or insect attack in this country.

Plants and planting

Containerised stock, which give high survival rates and rapid early growth, are favoured.

Spacing and stocking

The current recommendation (Anon. 2000d) is to plant Monterey cypress at 2 x 2 m 2,500 trees/ha). However, due to the fact that close initial spacing promotes vertical

Monterey cypress at the JFK Arboretum.

growth and narrow, pyramidal crowns (factors crucial to quality timber production), there is a very strong case for plant spacing to be reduced to about 1.8 x 1.8 m (3,100 trees/ha).

Cluster of mature Monterey cypress on sand dunes at Curracloe.

Pruning and thinning

The production of quality knot-free logs of Monterey cypress involves an intensive management regime. The achievement of a 6 m, branch-free bole, requires several pruning lifts, in conjunction with early and frequent selection thinnings.

Growth yield and rotation length

This is a relatively uncommon species in Irish forests. An estimated yield class of 20 and a corresponding rotation length of 60 years are based on data from three stands, whose total area is only approximately 4 ha.

Wood properties and uses

The timber of Monterey cypress has a fine, even texture with excellent working characteristics. Stem fluting and excessive knot size are the main sources of timber degrade. To prevent cell collapse and internal checking, logs should be air-dried to 30% moisture content, prior to kiln drying. It is stable in service and its heartwood is moderately durable. It takes nails and screws satisfactorily, provided care is taken to avoid splitting.

Uses include turnery and interior joinery and the timber is considered particularly suitable where there is a need for decay-resistance.

6.2.4 Douglas fir

Climatic requirements

Although the Irish climate is somewhat similar to that in part of the natural North American coastal range of Douglas fir, higher summer temperatures, including greater levels of water stress, are common in its natural range. It can therefore be concluded that it is better suited to the warmer and drier parts of this country. The species withstands low winter temperatures very well, but can be damaged by late spring frosts in low-lying places. It is also intolerant of exposure, where it becomes badly deformed.

Suitable sites

Particular care is needed in site selection. Douglas fir is best suited to well-drained soils of good depth and of moderate fertility on sheltered, middle valley slopes. On lighter, sandier soils growth can be slower but improved form can often result. Amongst the vegetation types suggesting a good Douglas fir site are grass/herb, fern/grass and bracken. However, bracken, which grows on a wide range of sites, should be treated with caution as an indicator.

Unsuitable sites

Douglas fir is unsuited to heavy soils, where it exhibits very coarse growth and becomes very unstable due to restricted rooting. It is also unsuited to exposed sites, alkaline soils, peaty soils, indurated and infertile soils, and it will not grow satisfactorily in competition with heather.

Mature Douglas fir at Ravensdale.

Other silvicultural characteristics

A major problem with Douglas fir on many sites in this country is stem sinuosity (distorted growth). While this phenomenon appears to be heritable, factors such as nutrient-rich soils, moist sites, and high summer rainfall have the greatest influence on the occurrence of this trait. Its fast growth makes it ideal for planting up areas where heavy weed colonisation is likely to occur, or for the conversion of scrub and coppice areas to productive forest. However, juvenile instability can be a serious problem, particularly when planted on moist, fertile sites. Its litter, which decomposes quickly, has soil-improving qualities.

Nursing

Douglas fir is now recognised as a nurse species for Sitka spruce. This has been demonstrated conclusively on nutritionally marginal Old Red Sandstone soils, where Douglas fir is not only performing well, but it is also having a very significant nursing influence on adjacent Sitka spruce (McCarthy and Horgan 2003). With judicious choice of sites, Douglas fir can play an important role, either as a pure crop or as a nurse to Sitka spruce, on moderately fertile, free-draining podzols, yet nutritionally marginal for pure Sitka spruce.

Young Douglas fir.

Diseases and pests

Apart from parts of the country where deer populations are excessively high, pests and diseases have not proved to be a limiting factor to the growth of Douglas fir in Ireland. Swiss needle cast may be found mainly in the wetter parts of the country, where warm winters and wet summers favour its development. In the past, its presence was believed to cause little damage even where severe defoliation occurred. However, recent observations suggest an increase in the severity of the disease with significant increment loss and mortality now being attributed to the disease. Douglas fir is the alternate host for Cooley spruce gall adelgid. White waxed-covered colonies of this insect cause widespread, but not severe, damage on foliage. The tree is considered to be moderately resistant to heart and butt rot fungus. However, in the early years after planting, the fungus can cause severe root rot.

Provenance

Registered Irish and British seed stands and seed imported under EU derogation from coastal southern Washington and northern Oregon are favoured.

Site preparation

Besides drainage and pre-planting chemical scrub control, little site preparation is usually required on most Douglas fir sites. However, bearing in mind that a raised, warm, weed-free and well-aerated planting position benefits survival and early growth, cultivation, such as mounding, can often be justified.

Plants and planting

Plants should be healthy, sturdy and well balanced. Ideally plants should be 30 cm tall, with a root collar diameter of 6 mm, having a fibrous root system comprising at least 25% of total plant mass. Survival and early growth of Douglas fir are adversely affected by poor plant handling (Sharpe *et al*. 1990). It has also been demonstrated that, while hot-planting of carefully handled plants can be successful throughout the dormant season, the optimum time to hot-plant Douglas fir is during November and December. Best results are obtained from cold-stored plants, if placed in cold storage in January-February, and planted from mid-March to mid-May, within a week of removal from cold storage. However, these are preliminary findings. Further testing is needed because of the wide variation in weather conditions from year to year.

Spacing and stocking

The current recommended planting spacing for Douglas fir is 2 x 2 m (2,500 plants/ha).

Fertiliser

Most typical Douglas fir sites require no fertiliser. However, on marginal sites, it is imperative that phosphate levels are monitored and maintained. Nitrogen fertiliser should only be applied if foliage testing confirms nitrogen deficiency, as an over-supply of nitrogen can adversely affect the stem form of Douglas fir.

Vegetation control

Due to its rapid early growth, cleaning is not usually a major requirement. Bracken, often found growing on Douglas fir sites, is best controlled by herbicide application in late summer/early autumn prior to planting.

Pruning

The branches of Douglas fir tend to be very persistent. This can lead to knotty timber unless pruning is carried out. All final crop trees should therefore be pruned sufficiently early to ensure that the knotty core is as small as is practicable. The timing will depend partly on the rate of branch deaths, as no more than 40% of live crown may be removed without loss of increment. Hence the necessity in many cases for up to three lifts to achieve the objective of a branch-free bole of 6 m. The cost of branch removal above 6 m is likely to be prohibitive.

Thinning

Early intervention is recommended. Due to the limited number of quality trees in many stands, mechanical thinning should be kept to a minimum. First thinning should consist of the removal of one line in nine as extraction racks, with the intervening areas being thinned selectively. Subsequent thinnings should be totally selective. Potential final crop trees (400/ha) should be selected at or before first thinning, and throughout the rotation the stand should be thinned to marginal intensity, favouring the selected stems. Removal of 'wolves' and competing dominants should be carried out as necessary in early thinnings.

Growth, yield and rotation length

The yield class of Douglas fir in Coillte's estate ranges from 4 to 24, averaging 16, with a corresponding rotation length of 50-65 years.

Wood Properties

Douglas fir is a dense and strong timber, and while it is not equal to pine in bending strength, it is comparable in stiffness. It is moderately durable, but is somewhat resistant to chemical treatment; for instance, it is not as permeable as Scots pine. The timber works readily with hand and machine tools, though not as easily as pine. It finishes well, although there is a tendency for it to splinter and break where the cut is across the grain. It takes nails and screws satisfactorily, provided care is taken to avoid splitting. Uses include transmission poles, garden furniture and decking, joinery and interior decoration, plywood, and especially veneer.

6.2.5 Grand fir

Climatic requirements

Grand fir is not limited by low winter temperature in this country, but it is moderately susceptible to damage by spring frosts. It is not as demanding on moisture as Sitka spruce or Japanese larch, and it will grow satisfactorily with rainfall amounts as low as 800 mm. However, the highest yielding stands are found in distinctly moister areas with rainfall in excess of 1,000 mm. Grand fir is very sensitive to exposure.

Suitable sites

Grand fir is best suited to sheltered, well-drained, moist soils of at least moderate fertility. Its performance on heavy clay soils is also very promising.

Grand fir.

Grand fir.

Unsuitable sites

Exposed sites, peaty soils, and infertile soils (particularly where very acid) should all be avoided. It also appears to be unsuited to highly alkaline soils.

Other silvicultural characteristics

Where conditions are favourable, grand fir can be one of the most productive species planted in this country, but due to very poor timber properties it is likely to remain a species of minor importance. It is a strong shade-bearer and is consequently useful for underplanting. The litter, like that of Douglas fir and western red cedar, breaks down quickly, and is relatively high in mineral content.

Diseases and pests

No serious diseases or pests specific to grand fir are known.

Provenance

Olympic Peninsula and Puget Sound origins from Washington State are considered best.

Plants and planting

Apart from sheltered areas, grand fir is best established under partial shade. Sturdy, well-balanced plants (average height 30 cm) are best, as large plants are sometimes blown over. Given suitable conditions it establishes quickly, with very rapid height increment after the second growing season.

Spacing and stocking

The current recommended planting spacing for grand fir is 2 x 2 m (2,500 plants/ha).

Fertiliser

On most sites suitable for grand fir, fertiliser is not required. However, on marginal sites 250 kg/ha of rock phosphate should be applied at establishment.

Vegetation control

Typical grand fir sites carry vigorous vegetation types. Therefore, for the first year or two after planting, appropriate control measures will have to be put in place to prevent plants suffocating.

Pruning and thinning

Pruning is not justified due to the poor structural properties of its timber. First thinning should consist of the removal of one line in seven as extraction racks, with selective thinning between lines. This should take place as soon as the crop reaches a top height of 8 m. Subsequent thinning should be totally selective.

Growth, yield and rotation length

Yield class in Coillte's estate ranges from 4 to 30, averaging 19. These data indicate a rotation length of 50-60 years for grand fir.

Wood properties and uses

Apart from pulp, there are few markets for the timber, which is much inferior than that of most of the other conifers grown in this country.

6.2.6 Western hemlock

Climatic requirements

Western hemlock is susceptible to spring frosts and, while it usually makes a good recovery, there is a high risk of plants developing multiple stems. Moisture is an important factor, but the lower climatic moisture limit is probably not found in our conditions. It is resistant to snow damage.

Suitable sites

Sheltered sites are best, typically the sides of sheltered valleys. It does best on deep, moist and well-aerated soils, but it will grow on well-drained flushed peats and a wide variety of mineral soils of reasonable fertility and depth. It is slow to establish on infertile soils. Performance improves once canopy closure takes place.

Unsuitable sites

Sandy soils, alkaline soils, unflushed blanket peats, frosty sites, heather- dominated sites, and exposed sites are all unsuitable.

Other silvicultural characteristics

Western hemlock is not a good pioneer species and it is difficult to establish on bare ground. It does better when planted with a nurse species, or when underplanted in an existing crop. On exposed sites it develops into a bushy plant with many leaders, subsequently growing into multi-stemmed trees. It responds well to nursing by pine on poor sites and grows well in mixture with larch. It is exceptionally shade-bearing, and it is a valuable species for enrichment and/or underplanting. Its pliant, pendulous leading shoot is not easily whipped, and it has very strong powers of recovery after being

Mature western hemlock.

[illegible] With increased exposure this species can develop pronounced fluting of the stem.

Diseases and pests

Western hemlock is considered to be very susceptible to [illegible] butt-rot and honey fungus.

Provenance

Irish and British stands, and imports from the Puget Sound region of Washington State, as well as the coastal range and Cascade Mountains of Washington and Oregon, are preferred.

Plants and planting

Apart from sheltered locations, it is best established under the light shade of other species. Post-planting check, believed to be related to water stress, is common. Field experiments in Clogheen and Banteer have shown that there is no biological advantage in using containerised stock. Hot-planting with bare-root transplants resulted in very satisfactory levels of survival and early growth, provided the plants were handled with care. These trials have also shown that survival and early growth were enhanced when sites were mounded, when compared to sites with no cultivation.

Spacing and stocking

The recommended planting spacing for western hemlock is 2 x 2 m (2,500 plants/ha).

Fertiliser

Nutritionally marginal sites benefit from an application of 250 kg/ha rock phosphate; this should be increased to 350 kg/ha on more infertile sites.

Vegetation control

By virtue of its shade-bearing characteristics, western hemlock can tolerate some forms of weed growth (bramble/scrub/woody weeds). However, it is unable to cope with dense vegetation, such as that from grass and bracken.

Growth, yield and rotation length

Height growth rates are comparable to Sitka spruce, but diameter growth is slower in hemlock (Aldhous 1974). Western hemlock stands tend to be uniform, having a relatively small range in height and girth. Yield class in Coillte's estate ranges from 4 to 24, averaging 17, indicating a rotation length of 55-75 years.

Wood properties and uses

Western hemlock's wood density is intermediate between Sitka spruce and Douglas fir. In strength and stiffness it is superior to Sitka spruce and similar to Scots pine. To avoid distortion, the timber should be dried slowly. It is non-durable and resistant to preservatives. It is suitable for use in the construction industry, joinery (similar quality to Norway spruce) and pulp manufacture.

6.2.7 European larch

Climatic requirements

European larch is not affected by winter cold, but it is very susceptible to spring frost, which not only kills the newly flushed shoots but also creates conditions favourable to infection by canker. European larch does not [illegible] exposure and is sensitive to salt-laden winds.

Suitable sites

European larch is an exacting species, requiring moist but well-drained, moderately fertile loams for best development. There is a strong correlation between good growth, soil depth and moisture content. It will grow on less fertile sites if planted in mixture with Scots pine.

Unsuitable sites

European larch will not thrive on frosty, badly drained or very dry sites. Equally, optimum growth will not occur on shallow soils, poor podzols, peats, exposed sites and heather-dominated areas. Very fertile soils should also be avoided, as the resultant rapid growth often produces 'cork-screw' leaders and instability.

Other silvicultural characteristics

European larch is a pioneer species and a strong light- demander. Its deep root system is not only well adapted to meet the heavy demands made on soil moisture, but also ensures good anchorage. On wind-swept sites trees develop a pronounced lean and seldom form a commercial crop. Its soil amelioration capabilities have been highlighted by the improved phosphorus status of the soil where it is grown. European larch is also regarded as a good nurse species.

Diseases and pests

The main limiting factor to the growing of European larch in this country is its susceptibility to larch canker disease.

Mature European larch stand at Kilnamanagh property, Glenealy Forest.

Provenance

Registered Irish, British, German (Schlitz) and Austrian (Wienerwald) seed stands are preferred. Seed imports under EU derogation from southern Poland, Czech Republic (Sudetan mountains) and Slovakia (Tatra mountains) are also acceptable.

Plants and planting

European larch flushes early in spring, and to avoid heavy losses planting should be completed before flushing starts. Sturdy, well-balanced plants (average height 30 cm) establish better than large unbalanced plants, which find it difficult to cope with high water requirements directly after flushing. Heavy losses can also occur on very free-draining slopes, and on sites where the soil remains cold after flushing. Mounding provides a warm, well-aerated, weed-free environment, significantly enhancing survival and early growth.

Spacing and stocking

The recommended planting spacing for European larch is 2 x 2 m (2,500 plants/ha).

Fertiliser

Apart from phosphate on marginal sites, nutrition should not be an issue on typical European larch sites.

Vegetation control

European larch is very intolerant of shade and it is therefore important that competing vegetation is kept under control. Bracken, often found growing on larch sites, is best controlled by herbicide application in late summer/early autumn prior to planting.

Pruning

Natural pruning takes place rapidly in well-stocked stands, although pruning may be necessary in poorly stocked plantations and in mixtures where larch has become dominant.

Thinning

Being a strong light demander, thinning should have commenced before the stand top height reaches 10 m. The early thinning should be heavy. Delayed thinning results in a serious reduction in the live crown, which is not easily increased when the stand is opened up. Subsequent thinnings should be carried out at 3-5 year intervals.

Growth and yield

Yield class in Coillte's estate ranges from 4 to 12 (averaging 8) giving a rotation length of 50-60 years.

Wood properties and uses

The wood is stronger and heavier than that from most other conifers. The heartwood is naturally durable, but the sapwood needs preservatives for outdoor use. Its wood is resinous and has a tendency to distort when seasoning. Uses include transmission poles and a wide range of areas where strength and durability are important. Thinnings always find a ready market for fencing stakes and rustic work.

6.2.8 Hybrid larch

Hybrid larch, first identified in 1905 in Scotland, is a natural hybrid between European and Japanese larch. It is superior to either of its parents in terms of vigour, stem form and resistance to disease. In most other respects (climatic and site requirements, stocking, yield and rotation length) hybrid larch is similar to Japanese larch.

Hybrid larch seed is very expensive and not always available. Plant quality varies with the seed orchard and nursery practice must be geared to ensuring that the buyer gets only true hybrids. This has an obvious effect on the production cost of transplants which currently runs at about thirty percent above the cost of the other larch species. Consequently, it makes good economic sense to confine the planting of hybrid larch to sites where timber production is the principal objective. Though more productive than either European or Japanese larch, it is not a high volume producer (maximum $14m^3$/ha/yr.). It therefore compares unfavourably with species such as Douglas fir, western hemlock and many other conifer species whose growth potential is significantly higher. However, as a component of some mixed species plantations, it has the potential to significantly enhance their profitability, by virtue of its rapid early growth and superior form, combined with buoyant markets for even very early thinnings for rustic work and stake production.

Conversely, where it is proposed to use larch as a sacrificial species in self-thinning mixtures and/or solely for landscape enhancement, Japanese larch is the preferred choice.

Provenance

Irish, British, Dutch, Danish, Swedish, Belgian, German, French and Polish seed orchards are all suitable sources.

Hybrid larch at Kilnamanagh property, Glenealy Forest.

6.2.9 Japanese larch

Climatic requirements

Japanese larch will grow under conditions of considerable exposure, although on such sites the trees will have very poor form. It withstands salt spray very well. [illegible] moisture is important, but it is not a limiting factor in this country, except when planted on very dry soils in areas of low rainfall. The species is susceptible to spring and early autumn frosts.

Suitable sites

Japanese larch is an accommodating species, capable of growing on a wide range of sites, but it does best on moist, well-drained, moderately fertile soils, which are not too heavy. On fertile and/or heavy soils it is often very coarse, crooked and unstable. It can be grown on the better-drained peats and infertile podzols.

Unsuitable sites

Sites which lack or have an excess of moisture, frost hollows, very fertile or heavy soils, very exposed sites and unflushed blanket peats are all unsuitable. Sites that become [illegible] by Irish furze also adversely affect the performance of Japanese larch.

Other silvicultural characteristics

Japanese larch is a good pioneer species, a strong light-demander and has high amenity value. Early growth is rapid, making it very useful on scrub areas and sites where weeds (especially bracken) are a problem. It produces a heavy needle fall that quickly kills off surface vegetation, and has soil-improving properties. On nutrient poor Old Red Sandstone soils, where Sitka spruce often suffers from a condition known as 'check', Japanese larch is used extensively as a nurse, enabling the Sitka spruce to grow successfully. The growth of the Japanese larch on these soils is slower than when planted on more fertile soils, but form is improved particularly on the less exposed sites.

Diseases and pests

Japanese larch is resistant to larch canker, but susceptible to butt-rot caused by *Fomes* and is particularly sensitive to honey fungus.

Provenance

Registered Irish, British, and European seed stands are preferred. Seed imports under EU derogation from Hokkaido Island (Japan), material from the Suwa region of Nagano Prefecture (on Honshu Island) between 1,300 and 2,000 m elevation, and stands derived from these sources are also suitable.

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Japanese larch at Ballinagappogue, Aughrim Forest.

Plants and planting

Due to its rapid early growth there is no necessity to use large plants. Sturdy well-balanced plants (20-40 cm) are cheaper to buy and plant, and they establish much better than large unbalanced transplants, which tend to check after planting. Japanese larch flushes early in spring and it is therefore important that all hot-planting is completed by early March.

Planting directly into cold wet conditions results in high plant mortality. Ground preparation involving mounding provides a warmer, better-aerated, weed-free environment, significantly enhancing survival and early growth.

Spacing and stocking

The current recommendation is to plant Japanese larch at 2 x 2 m (2,500 plants/ha).

Fertiliser

Japanese larch is planted on a wide range of site types of varying degrees of fertility. Fertiliser application should be avoided on fertile sites, as it gives rise to poor stem form and crop instability. Nutritionally marginal sites will benefit from an application of 250 kg/ha rock phosphate, while on very infertile soils this could be increased to 350 kg/ha.

Vegetation control

Very little cleaning is usually required, due to its rapid early growth.

Pruning

Natural pruning takes place readily, but in stands with low stocking, or heavily thinned plantations, pruning may be desirable.

Thinning

Japanese larch is a strong light demander and consequently needs to be thinned earlier and heavier than most other conifers. At least one third of the total stem length should be live crown. Thinning should therefore commence when the crop reaches a top height of about 8 m. Where thinning has been delayed, crops often end up with serious reduction of live crowns, which is not easily increased when the stand is opened up.

Growth and yield

Yield class in Coillte's estate ranges from 4 to 14, averaging 10, with a corresponding rotation length of 45-55 years.

Wood properties

Japanese larch has a higher wood density than Sitka spruce and is of superior strength and stiffness. The timber dries fairly rapidly, although there is a tendency to distort, split and crack, and for knots to split and loosen. When dried, the timber saws and machines fairly easily. It takes paints and varnishes well, but has a tendency to split on nailing. It is moderately durable and resists uptake of preservatives. Uses include stakes and transmission poles. Demand for larch fencing material has always been strong, with the result that even early thinnings are profitable.

6.2.10 Austrian pine

Climatic requirements

Austrian pine is best suited to the warmer parts of Ireland (south and southeast). It is resistant to winter and late spring frosts, drought and salt-laden winds.

Suitable sites

Austrian pine is one of the few conifer species that can thrive on exposed limestone sites, even when the soil is dry and shallow. It can be useful as a nurse for beech on such soils.

Unsuitable sites

Infertile, wet and heavy soils should be avoided.

Other silvicultural characteristics

Apart from providing a nurse to beech on calcareous soils, Austrian pine is only worth planting where salt-laden winds, limestone, or pollution rule out other conifers, and then only as a shelterbelt or for amenity (Savill 1992).

Provenance

[illegible] seed stands are preferred.

Wood properties

The timber is intermediate between Scots pine and Corsican pine, but stem form is generally very poor and [illegible] as a result of large branches.

Austrian pine at Glenealy, Co Wicklow.

6.2.11 Corsican Pine

Climatic requirements

As it is a Mediterranean species, Corsican pine is best suited to the warmer and drier south and southeastern regions of Ireland. It declines in health and vigour the closer it is planted to the cooler, moister regions (MacDonald 1957). It is intolerant of salt spray, but away from the coast and where the general climate is favourable, Corsican pine tolerates exposure quite well. It is more susceptible to spring frost than Scots pine, but as it flushes rather late in the season it often escapes damage. Winter cold is not a problem.

Suitable sites

Corsican pine grows well on a wide range of mineral soils, doing best on fertile, well-drained loams, and also on soils with a high sand and gravel content. It is less subject to lime-induced chlorosis on calcareous soils than Scots pine.

Unsuitable sites

High elevations, heavy clays and compacted soils subject to drainage impedance, are not suitable.

Other silvicultural characteristics

Corsican pine is a strong light demander. It has an inherent ability to produce straight stems. However, branches can be heavy and the species does not self-prune well.

Diseases and pests

Corsican pine is prone to dieback when planted at high elevations or in areas of high rainfall. It is less liable to be attacked by rabbits and hares than Scots pine and also shows resistance to damage from the pine shoot moth.

Provenance

Registered Irish, British and Corsican seed stands are preferred.

Plants and planting

Corsican pine transplants are very sensitive to rough handling, and heavy losses can be expected if roots are allowed to dry out. With bare-root stock best results are obtained with small, well-balanced plants. However, to ensure satisfactory survival, containerised stock planted during late spring/early summer is the preferred option.

Corsican pine stand at The Raven, Curracloe, Co Wexford.

Spacing and stocking

The current recommended planting spacing is 2 x 2 m (2,500 plants/ha).

Fertiliser

Depending on site fertility an application of between 250-350 kg/ha rock phosphate should be applied at establishment.

Vegetation control

Height growth of Corsican pine is usually good in the second and subsequent years after planting. Vegetation control is rarely required after the second growing season.

Pruning and thinning

As branches tend to be heavy and natural pruning slow, timber quality can be considerably improved by pruning. Due to the uniformity of the crop and the infrequency of poorly formed stems, purely mechanical methods of first thinning can be carried out without any adverse effect on production.

Growth, yield and rotation length

Yield class in Coillte's estate ranges from 8 to 16, averaging 10. This would indicate a rotation length of 45-60 years.

Wood properties and uses

Its wood is similar to Scots pine but it has a larger proportion of sapwood and is usually coarser. Large knotty whorls are the main source of its weakness. It is not naturally durable, but it takes preservatives easily. Freshly felled logs are very susceptible to blue stain fungi. Overall, it is good general-purpose softwood, suitable for a wide range of end uses.

6.2.12 Lodgepole pine

Climatic requirements

Appropriate provenances of lodgepole pine are resistant to cold, spring frosts, salt-laden winds and air pollution, and will withstand extreme exposure.

Suitable sites

Lodgepole pine is an extremely undemanding species, capable of growing on the poorest of soils, following ground preparation and phosphate application.

Good form of north coastal lodgepole pine.

Unsuitable sites

Avoid good lowland sites, where a broad range of other species are much more productive.

Other silvicultural characteristics

Lodgepole pine is an outstanding pioneer species for difficult sites, quickly suppressing heather if present. It regenerates freely, especially south coastal provenances, presenting opportunities for natural regeneration on poor sites where costly operations at establishment may be prohibitive. However, this may present problems where there is a change of species required for the second rotation. This is especially a problem where mineral soil has been exposed during harvesting operations or following ground preparation for reforestation.

Lodgepole pine can act as a nurse to Sitka spruce, enabling the spruce to grow satisfactorily on soils deficient in available nitrogen. However, to avoid early suppression of spruce by the pine, it is imperative that the correct provenance of pine is used. Vigorous south coastal provenances are very prone to basal sweep, snowbreak and windthrow on wet sites. Rooting depths of up to 1.5 m have been observed in crops growing on nutrient-poor, free-draining soils, suggesting that its reputation as an unstable species may be unwarranted. Instability may simply occur as a result of the trees being planted on soils of poor physical condition, inadequate aeration or drainage, or excessively high nutrient status.

Diseases and pests

A wide range of organisms can damage lodgepole pine. Among the most serious is the pine shoot moth, which [illegible] to severe deformity in young crops. Defoliation of the previous year's needles - without tree mortality occurring - is common [illegible] caused by the European pine sawfly. By contrast, severe defoliation by the pine beauty moth is extremely rare but can be fatal.

In common with many other tree species, lodgepole pine is prone to deer damage. However, a recent survey of bark stripping by deer, in a twenty eight year old lodgepole pine provenance trial at Fermoy forest, Co Cork, has indicated that deer are less likely to damage south coastal provenances, whereas north coastal and inland provenances are more susceptible. Brashing, which allows easier access to stands by deer, exacerbates damage levels in all provenances.

Provenance

There are several provenance options, depending mainly on the plantation objectives, which in turn are influenced by the quality of the sites available. South Coastal material is from the coastal regions of southern Washington state and northern Oregon. These provenances provide rapid growth and volume production (average YC 11) but with typically poor stem form. North Coastal sources are from the coastal regions of Alaska and British Columbia and include Queen Charlotte Island (QCI) and Vancouver Island sources. These provenances provide a better stem form than South Coastal material, but at a slower growth rate (average YC 9). Inter-provenance hybrids provide a compromise between the two, and aim to provide the faster growth rate and volume production of the South Coastal with the better stem form of the North Coastal sources.

Material from Irish and British seed orchards and stands is preferred for all provenances. The choice of provenance will depend on the site and whether planting as a single species or in mixtures (Table 6.2).

Rooting depths of 1.5 m have been observed for lodgepole pine.

Plants and planting

Using survival and early growth as criteria, lodgepole pine is an easy tree to establish. However, when the form and development of the root system are included the situation becomes more complex. It is now generally accepted that the use of plants with badly deformed J-shaped root systems, or poor planting technique, are major contributory factors to instability of lodgepole pine. This in turn leads to the development of basal sweep, resulting in harvesting and conversion difficulties. The vigorous crowned south coastal provenances are more prone to this phenomenon, since they place greater strain on stabilising root systems than the sparsely foliated interior and north coastal types.

Undercutting seedlings, as opposed to lining out in the nursery, and the use of containerised seedlings, have reduced the incidence of basal sweep, but it will not eliminate the problem. Direct seeding is an option, which not only produces plants with natural root systems, but also eliminates the problems caused by poor planting practices.

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TABLE 6.2: Suitable lodgepole pine provenances.

SITE	PURE PINE CROPS	IN MIXTURE WITH SITKA SPRUCE
Exposed, nutrient poor sites, such as peatlands and infertile mineral sites (scrawed)	QCI, west Vancouver Island or Interprovenance hybrids	Not recommended on these sites
Less exposed, nutrient poor sites, such as peatlands and infertile mineral sites (scrawed)	South coastal, Interprovenance hybrids, or North coastal from the lower Skeena river (i.e. Terrace, Kalun Lake, Burns Lake and Hazleton)	Not normally recommended on these sites
Peatlands, nutritionally marginal for pure crops of Sitka spruce	Interprovenance hybrids, or North coastal from the lower Skeena river (i.e. Terrace, Kalun Lake, Burns Lake and Hazleton)	While nutritional nursing on deep peat is unsubstantiated in Ireland, on occasions mixtures with lodgepole pine from Alaskan, QCI, and Vancouver Island sources can be justified on the grounds of providing an improved micro-climate
Mineral soils nutritionally marginal for pure crops of Sitka spruce	Not recommended on these sites	Alaskan, QCI and Vancouver Island sources
Fertile gleys/peaty gleys where conventional thinning practice could induce windblow	Not recommended on these sites	Use South Coastal as the sacrificial species in a self thinning regime

Spacing and stocking

The current recommendation is to plant lodgepole pine at 1.8 x 1.8 m (3,100 plants/ha). This works well with less vigorous north coastal or inter-provenances, planted on sites where it is possible to practise conventional silviculture. However, on many of the less favourable sites, widely spaced (3.5 x 3.5 m - 800 trees/ha) south coastal lodgepole pine coupled with an intensive pruning regime could be considered. Preliminary studies suggest that such a system offers lower establishment costs, greater crop stability, clean, knot-free logs, and the greatest financial return.

Fertiliser

As the planting of lodgepole pine is confined to nutrient-poor sites, most crops will benefit from an application of 250 kg/ha rock phosphate at establishment.

Vegetation control

Competing vegetation is rarely a problem on sites where lodgepole pine is planted.

Thinning and pruning

South coastal lodgepole pine is prone to basal sweep.

In conventionally established crops, thinning should only be attempted in stable crops of adequate vigour and form. First thinning should consist of the removal of one line in seven, or preferably one line in nine as extraction racks with selective thinning between lines. This should take place before the crop reaches a top height of 10 m (to avoid windthrow) and should be followed by the selection of 600 potential final crop trees per ha. These should be selected from the dominants and co-dominants on the basis of vigour, combined with good stem form and light branching. Subsequent thinnings should favour these trees by removing competing stems. To minimise the knotty core, pruning to 6 m should be carried out as soon as possible. This will require at least two lifts, as no more than 40% of live crown can be removed without serious loss of increment. In crops planted at wide spacing (see above) free growth of individual stems is enabled and no thinning would be envisaged, but all trees should be pruned to 6 m in up to three lifts.

Growth, yield and rotation length

Yield class in Coillte's estate of north coastal lodgepole pine ranges from 4 to 14, averaging 9. Yield class of south coastal ranges from 4 to 18, averaging 11. The corresponding rotation lengths indicated are 55-75 years for north coastal and 45-70 years for south coastal lodgepole pine.

Wood properties and uses

The timber has similar properties to Scots pine, and can be used for the same purposes.

6.2.13 Macedonian pine

Climatic requirements

Macedonian pine is very frost-hardy. It will grow under conditions of considerable exposure, while retaining its good form, though with reduced height.

Site requirements

It is an accommodating species, capable of satisfactory growth on a wide range of soil types, including acid brown earths, midland cutover milled peats, and podzols. Contrary to the British experience, Macedonian pine planted on blanket peat sites in this country has not survived.

Other silvicultural characteristics

Macedonian pine is a difficult tree to grow in the nursery, with a tendency for poor and delayed germination. It is a good pioneer species, with a well-developed deep root system. It has a thin bark and is thus vulnerable to bark stripping by deer.

Diseases and pests

Stands of Macedonian pine are typically healthy, and appear to be attacked by fewer

Good form of Macedonian pine.

Thirty-four year old Macedonian pine plantation at JFK Forest Park.

insect and fungi than many other pines. In a mixed plantation of Scots pine and Macedonian pine in Wales, the Scots pine has been badly damaged or killed by grey squirrels, but the Macedonian pine has been unaffected (Carrick 2000).

Plants and planting

Macedonian pine appears to be an easy tree to establish, with no special problems.

Vegetation control

By virtue of its very slow early growth, vegetation control may be required for up to four years after planting.

Spacing and stocking

Up to now, there has been no Forest Service recommendation on spacing for this species but, based on the performance of existing crops, an initial plant spacing of 1.6 x 1.6 m (3,900 plants/ha) seems appropriate.

Growth, yield and rotation length

Early growth is characteristically slow, even on favourable sites. Height growth improves after 6-10 years, making strong vertical growth during the 15-20 year old period, when average annual height increment can exceed 50 cm.

Three experimental plots of Macedonian pine exist in Ireland. These are located at JFK Arboretum (Wexford), Tullamore (Offaly) and Fermoy (Cork). The Tullamore and Fermoy plots are now only 14 years old. Data from the JFK Arboretum plot is most meaningful as the crop is now 36 years old. A number of recent measurements of this plot have attributed impressive grow rates to this species, suggesting a current annual increment (CAI) in excess of 30 m^3/ha. No yield models exist for this species, but using models for similar species [illegible] that the crop will reach YC 20.

Wood properties

Preliminary studies in Britain indicate that an important attribute of the wood from Macedonian pine is its stability compared to other common coniferous timbers, though its strength is low. Its density, at about 12% moisture content, is about 350 kg/m^3, which is considerably lower than for Scots pine.

6.2.14 Monterey pine

Climatic requirements

As this is a species from a warm climate, temperature is the main limiting factor to the success of Monterey pine in this country. Due to the fact that it never becomes completely cold-hardy, the planting of this species should be confined to the warmer areas (south and southwestern coastal regions). It is not limited by rainfall and is tolerant of salt spray and strong winds.

Suitable sites

Monterey pine grows well on a wide range of mineral soils, doing best on light, moist, well-drained soil types. It is not a nutrient-demanding species, and is capable of good growth on nutritionally marginal Old Red Sandstone podzols. It has also shown promise on flushed blanket peats and on cutaway raised bogs.

Unsuitable sites

Wet and/or heavy soils, alkaline soils, unflushed blanket peats, and very exposed or frosty sites should be avoided.

Young stand of improved Monterey pine at Kilnamanagh property, Glenealy Forest.

Other silvicultural characteristics

Monterey pine is a good pioneer species, [illegible] is regarded as a difficult species to transplant in this country. Monterey pine has a prolonged juvenile period, which lasts 4-5 years from seed. During this period it does not form a sealed terminal bud, but has a free growth pattern, which enables it to compete successfully with vegetation.

This free growth pattern in Monterey pine can also be a disadvantage in this country, causing it to grow late into the season and thus being only partially lignified when the lowest temperatures occur. Juvenile instability, associated with a number of factors (including deformed root systems, poor root-shoot ratio, cultivation methods, site fertility and exposure), is a frequent occurrence in young plantations. Some plantations have been completely devastated, with up to 70% of the trees blown over in the first few

Monterey pine growing in mixture with larch. This tree is 16 years old, with a height of 16.2 m and a DBH of 34.3 cm, years. Establishment techniques, aimed at alleviating this problem, are currently under investigation. Its very coarse branching habit requires an intensive silvicultural and management regime to produce quality stems.

Diseases and pests

The most serious disorder, called 'yellows' or 'yellows disease' which causes all needles more than one year old to turn yellow and fall off. It is caused by the fungus *Cyclaneusma minor*. This condition only begins to manifest itself from four years after planting. The condition results in reduced growth, and, in extreme cases, up to 30% of the trees can die before the age of the first thinning. This problem can be overcome through the correct choice of provenance.

Provenances

Seed stands from Guadalupe Island (Mexico), if available and healthy (non-yellowing trees) Irish home-grown stands, are best.

Plants and planting

Traditionally raised, bare-rooted stock is not recommended. However, conditioned seedlings involving an intensive nursery regime of undercutting, side-pruning and wrenching has proved very successful in terms of satisfactory survival and early growth. Excellent survival rates can also be achieved with containerised stock; however, root spiralling can occur, resulting in instability if hard-walled containers are used. The use of larger paper pots may help alleviate this problem, but pots should be removed prior to planting.

Rooted cuttings have also been successful. They are physiologically older than seedlings, and have a set growth pattern and sealed buds. They are generally more robust and have adult foliage, which makes them more resistant to exposure.

For filling-in to be effective it needs to be done as soon as dead trees are identified. If delayed for a full year after initial planting, replacements rarely catch up with the rest of the crop.

Spacing and stocking

The current recommendation (Anon. 2000d) is for an initial plant spacing of 2 x 2 m (2,500 plants/ha). However, it is the authors' view that this could be increased with advantage to 2.5 x 2.5 m (1,600 plants/ha). This is based on its strong light-demanding characteristics and the practice in New Zealand, where initial spacing can be as wide as 4 x 4 m (625 plants/ha).

Fertiliser

Monterey pine does not have a high nutrient requirement. Apart from very impoverished sites, where an application of up to 250 kg/ha of rock phosphate may be applied, fertiliser is not normally recommended. Fertiliser, if required, is best applied 4-5 years after establishment, when root systems are sufficiently developed to cope with rapidly expanding crowns.

Vegetation control

Only bracken, bramble and fireweed are likely to pose a serious threat on a typical Monterey pine site. These are best controlled by a pre-planting chemical application.

Pruning and thinning

If the objective of planting Monterey pine is to produce high quality timber, pruning is essential. This should be carried out on final crop trees sufficiently early in the rotation to ensure that the knotty core is as narrow as practicable. Bearing in mind that no more than 40% of live crown may be removed without loss of increment, an objective of 6 m of knot-free timber will require three lifts, with the final lift being carried out at a top height of 11 m.

There is an insufficient number of stands of reasonable stocking in this country on which to make thinning recommendations but, based on the New Zealand experience, early thinning is recommended.

Growth, yield and rotation length

The average yield class of Monterey pine in Coillte's estate is 17, with a corresponding rotation length of 50 years.

Wood properties and uses

Monterey pine has a higher wood density than either Scots or Corsican pine, with strength properties similar to Scots. It is easy to saw, and when dried is similar to Douglas fir. Knots will present finishing problems. The wood is not durable, the heartwood being moderately resistant to preservative treatment by pressure methods, but the sapwood is readily treated. Monterey pine is suitable for use in the construction and [illegible] industries.

6.2.15 Scots pine

Climatic requirements

Scots pine is very frost-hardy. It does not grow well where exposure is excessive, and it prefers areas with low rainfall.

Suitable sites

It is an adaptable species, but grows best on light, non-alkaline soils, and especially on sands, gravels and other well-drained sites at low to moderate elevations. It has shown promise on the cutover midland bogs.

Recently thinned Scots pine plantation.

Characteristic crown shape of mature Scots pine.

Unsuitable sites

Avoid high elevations (unless there is adequate topographic shelter) and sites exposed to sea winds. Heavy soils, alkaline soils, and poorly drained and infertile peats should also be avoided.

Other silvicultural characteristics

Scots pine is a good pioneer species and a strong light-demander. It is a useful nurse species, often used with broadleaf species, especially beech on frost-prone sites. It grows rapidly when young, often leading to instability, especially on moist sites. Given suitable conditions it will regenerate, but if canopy opening is delayed [illegible] will not survive. It does not self-prune well, and to obtain clean timber without loose, dead knots, pruning is necessary. Due to its low production and long rotation it is likely to play a minor role in the future as a forest crop, though it will have its uses as an amenity tree in many situations.

Diseases and pests

While various diseases and insects can damage Scots pine, none are specific and, where appropriate control measures are in place, they are not limiting factors.

Provenance

Irish and Scottish seed orchards, and registered seed stands, are best.

Plants and planting

Scots pine is an easy tree to establish. Best results are achieved using small (10-20 cm), sturdy, well-balanced plants. Larger plants tend to become top heavy, causing the plant to rock around in the planting hole and become unstable.

Spacing and stocking

The recommended planting spacing for Scots pine is 2 x 2 m (2,500 plants/ha).

Fertiliser

Depending on site conditions, it may be necessary to apply between 250 and 350 kg/ha of rock phosphate at planting time. Also, on midland peats, and an application of potassium is recommended, as for other species, either at planting time or within three years of planting, using muriate of potash at 250 kg/ha.

Vegetation control

By virtue of its rapid early growth, vegetation control is seldom a problem. However, it is a strong light-demander and requires prompt attention from competing vegetation to prevent suffocation.

Thinning and Pruning

In crops with adequate vigour and form, thinning should begin at a top height of about 10 metres. Prior to commencement of thinning, 600 potential final crop trees/ha should be selected from the dominants and co-dominants on the basis of vigour, good stem form and light branching. Apart from the removal of one line in every seven or nine lines as extraction racks, first and subsequent thinnings should concentrate on freeing these potential final crop trees from undue competition. To minimise the knotty core, pruning of the final crop trees to 6 m should be carried out as soon as possible. This will require at least two lifts, as no more than 40% of live crown may be removed without serious loss of increment. When final crop tree numbers are reduced to 400 trees/ha, consideration could be given to underplanting with western hemlock or western red cedar. The understorey species should be managed in the normal manner, until it has reached commercial size, when both species could be harvested simultaneously. Alternatively, beech could be introduced as an understorey, where the growth and form of the beech would benefit from the microclimate created by the Scots pine overstorey.

Growth and yield

Yield class in Coillte's estate ranges from 4 to 14, averaging 10. These data indicate a rotation range of 60-90 years for Scots pine.

Wood properties and uses

The wood of Scots pine (known in the trade as 'red deal') combines relatively high density with good strength and stiffness properties. It is not naturally durable, but it takes up preservatives well. The timber dries rapidly with little degrade. It is susceptible to blue stain; therefore, sawing should take place as soon as possible after felling, followed immediately by kiln drying. Dead knots, which fall out when sawing and planing, can be a problem. The timber machines well, and its wide range of uses include transmission poles, joinery, flooring, decking and decorative panelling.

6.2.16 Coast redwood

Climatic requirements

The susceptibility of young coast redwood plants to frost has been an important factor in limiting the planting of this species in Ireland. It is also intolerant of exposure, especially to cold easterly winds. It is therefore best suited to the warmer and moister southwestern parts of Ireland.

Suitable sites

It grows best on sheltered, frost-free sites, with good deep fertile soil and abundant moisture.

Unsuitable sites

Avoid exposed and frosty sites, and very acid soils and peatlands.

Other silvicultural characteristics

Coast redwood is a good shade-bearer and, due to its very fast growth, it may be used for the conversion of scrub areas [illegible] It is very difficult to grow from seed, with less than a 10% viability rate. The seedlings are also very susceptible to frost. Its ability to produce suckers from the stump is unique among commercially planted conifers. Blown trees, with their roots still attached, can produce straight clean stems from

Coast redwood can produce suckers from freshly cut stumps, a characteristic unique among commercially planted conifers.

Specimen mature coast redwood at Coolattin, Shillelagh, Co Wicklow.

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branches growing along their stem. The species can also be propagated by layering or rooted cuttings. Coast redwood is reasonably wind-firm on suitable sites and it is resistant to salt spray. It is sensitive to atmospheric pollution. Coast redwood has a very thick, soft, fibrous red bark that is resistant to fire.

Provenance

Irish and British stands, and imports from coastal southern Oregon and northern California, are suitable.

Diseases and pests

Coast redwood appears to be a remarkably healthy tree, with no economically important insect or fungal problems.

Spacing and stocking

The current recommended planting spacing is 2 x 2 m (2,500 plants/ha).

Growth, yield and rotation length

In Ireland very few stands of coast redwood exist, but the indications are that on favourable sites this species can be remarkably productive. Data from a 23 year old mixed stand of coast redwood and birch at Curraghbinny, Co Cork (86% of stems are coast redwood) are presented in Table 6.3.

If this had been a pure coast redwood plantation, cumulative volume would probably have been 529 m^3/ha. As there are no published yield tables for coast redwood, grand fir tables, which are the nearest equivalent, were used. These indicate a local yield class well in excess of 30 for the coast redwood at this site, and an estimated corresponding rotation length at this site of 50-60 years.

However, these data need to be treated with caution as they are based on only one site, with close to ideal growing conditions for the species.

TABLE 6.3: Growth performance of coast redwood at Curraghbinny, Co Cork.

AGE (years)	TOP HEIGHT (m)	MEAN DBH (cm)	STOCKING (stems/ha)	STANDING VOLUME (m^3/ha)
23	18	26	1,167	455

Wood properties and uses

The wood turns a maroon colour soon after felling. It is naturally durable with strength properties superior to western red cedar, but inferior to Douglas fir and Sitka spruce. The wood is light, with an average density of about 420 kg/m^3 at 15% moisture content. It is non-resinous and stable in service, but its main drawback in use is its softness. Due to its natural durability it is often used in the production of shingles and cladding in America.

6.2.17 Norway spruce

Climatic requirements

Although Norway spruce is not as susceptible to spring frosts as Sitka spruce, it can still suffer considerable damage. It is very susceptible to exposure and salt-laden winds, and its foliage can turn completely brown following cold, drying winds in late autumn/early winter, but it generally recovers once the buds are not damaged.

Suitable sites

One of its main requirements is an adequate supply of soil moisture. It grows well on old woodland sites, grass-rush sites, as well as on moist, reasonably fertile soils, including heavy clays and the more fertile shallow peats.

Unsuitable sites

Avoid exposed situations, dry sites, heather-covered sites, frost hollows, and alkaline soils. Soils with poor water-holding capacity, such as shallow, coarse-textured, free-draining soils are also unsuitable, as are peaty sites where the water table level can drop quickly and for prolonged periods.

Other silvicultural characteristics

Norway spruce grows slowly for the first few years after planting. Unlike many other species, performance is not greatly enhanced by chemical vegetation control. Its root system is very superficial, rendering it capable of living on very shallow soils, but making it susceptible to unseasonable droughts and to windthrow. It is regarded as a moderate shade-bearer in its earlier years.

Diseases and pests

Norway spruce is susceptible to top dying at pole stage or later, if planted on soils with poor moisture-holding capacity, or where the stand has been heavily thinned or suddenly

Mature Norway spruce at Rathdrum, Co Wicklow.

exposed (e.g. [illegible] or in stands grown from seed from Romania or southern Poland. It is also susceptible to butt rot.

Provenance

Registered seed stands in Ireland, Britain, Denmark, and the low elevations of northern Germany are recommended. Seed imports under EU derogation from Sudetan and Beskid regions of the Czech Republic, Tatra Mountains of Slovakia, northeast and lowlands of South Poland are preferred.

Plants and planting

Apart from its very slow early growth, Norway spruce is generally an easy tree to establish. Sturdy, well-balanced plants (20-40 cm) are recommended.

Spacing and stocking

The recommended planting spacing for Norway spruce is 2 x 2 m (2,500 plants/ha).

Fertiliser

Fertiliser is rarely required on ideal sites, as Norway spruce is normally planted on fertile lowland sites. On more marginal sites an application of 250 kg/ha rock phosphate should be applied. As with other species, on midland peat soils an application of muriate of potash at 250 kg/ha may also be required [illegible]

Young Norway spruce.

Vegetation control

Even on the best sites Norway spruce grows slowly for the first few years. On some sites vegetation control may be required for up to four years after planting. It is more sensitive to herbicide than many other species.

Thinning

Frequent, light thinnings are recommended, particularly on sites where it is anticipated that top dying could be a problem.

CONIFERS

Growth, yield and rotation length

Yield class in Coillte's estate ranges from 4 to 22, averaging 16. These data indicate a rotation length for Norway spruce of 60-80 years.

Wood properties and uses

Norway spruce wood is stable during changing conditions of humidity. It works well and has a clean white colour. It is a good general-purpose timber, known in the trade as white deal. It has a wide range of uses, which include joinery, and the construction and [illegible] industries.

6.2.18 Serbian spruce

Climatic requirements

Serbian spruce has no climatic limitation to its growth in this country. It is frost-hardy and moderately resistant to exposure.

Suitable sites

Though its natural habitat is on limestone soils, it grows well on a wide range of other soil types. For instance, it looks healthy on a flushed blanket peat site at Glenamoy, Co Mayo, even though production is modest for its age (43 years).

Diseases and pests

Serbian spruce appears to be particularly susceptible to honey fungus. It can also suffer from dieback (similar to Norway spruce) if planted on narrow strips on very exposed sites.

Other silvicultural characteristics

Serbian spruce has very straight stems, extremely narrow crowns and a light branching habit. Its lower branches are capable of rooting.

Provenance

Irish and British stands, and seed imports from Serbia, are preferred.

Spacing and stocking

The recommended planting spacing for Serbian spruce is 2 x 2 m (2,500 plants/ha). However, by virtue of its short branches and columnar crowns, much growing space is under- utilized, and vegetation suppression is delayed. Therefore, it seems silviculturally

Serbian spruce.

Mature Sitka spruce stand showing good form.

and economically prudent to increase stocking density to about 3,900 plants/ha (1.6 x 1.6 m).

Growth and yield

There are insufficient stands and records of Serbian spruce in this country to make a definitive statement on its potential growth and yield. However, it seems likely that average yield class would be within the range of 10-20.

6.2.19 Sitka spruce

Climatic requirements

Sitka spruce's natural range is in a [redacted] maritime climate, indicating its high moisture requirement. It is, therefore, suitable to most sites in Ireland except in some very localised free-draining sites in low-rainfall areas. Sitka spruce is also very susceptible to damage by late spring frost when young. [redacted]

Suitable sites

Sitka spruce is a very versatile species and will grow satisfactorily over a wide range of site conditions. It grows best on moist, fertile soils under conditions of high atmospheric humidity.

Unsuitable sites

Avoid frost-prone sites, less fertile and more acid peats, impoverished Old Red Sandstone podzols, heather-dominated sites, and very dry sites in low-rainfall areas.

Other silvicultural characteristics

Sitka spruce is by far the most widely planted and successful exotic tree species grown in Ireland. It has grown successfully here since the early part of the nineteenth century, and has become fully naturalised in that it can maintain and extend its habitat by natural seeding. Sitka spruce withstands exposure better than most other common conifers. It thrives on wet soils, though windthrow is a serious risk and a frequent occurrence. It is very demanding of light and responds well to heavy thinning. Natural pruning is rather slow. In pure Sitka spruce stands needle decay and consequent nutrient cycling is often poor, resulting in nutrient deficiencies. Where conditions permit it should be planted in mixture with species which have quickly decomposing litter and deeper-rooting attributes, to act as stabilisers and to maintain soil fertility. Suitable species include

Japanese larch, hybrid larch, Douglas fir, western hemlock, western red cedar, and suitable provenances of lodgepole pine.

Diseases and pests

Sitka spruce is susceptible to defoliation by the green spruce aphid. In addition, while it can suffer from attacks by bank vole, group dying fungus, honey fungus and butt rot, none of these is a limiting factor to its future planting.

Provenance

Registered seed stands in Ireland and Britain, and material from Danish and British seed orchards, are preferred. Imports from QCI, coastal Washington and Oregon are also acceptable. Rooted cuttings derived from genetically improved Washington or QCI material are becoming more common in this country.

Results from field experiments have shown that more southerly provenances consistently outperform those from QCI. These experiments (the oldest of which date from 1975) were established on a range of sites and soils.

Sitka spruce continues to be the most commonly planted species due to its productivity on a wide range of site types.

Plants and planting

Sitka spruce is one of the easiest species to transplant and, while such practices are not advocated, it can cope with rough handling better than any other species in general use. Although survival is the most common method of measuring establishment performance, early growth is of equal importance. While roughly handled plants may survive, early growth can be adversely affected for a number of years, resulting in a prolonged period of vegetation competition and reduced production. Using a combination of stock types (bare-root hot, bag-stored, cold-stored, and containerised) successful establishment can be carried out almost all year round.

Spacing and stocking

The current recommended planting spacing for Sitka spruce is 2 x 2 m (2,500 plants/ha).

Fertiliser

Unless the planting area is at least moderately fertile, nutrients, particularly phosphate, will have to be added. Although an application of phosphate results in satisfactory establishment and early growth, a condition known as ‘check’ (retarded growth) often develops on nutrient-poor soils after a number of years due to nitrogen deficiency. Even after many years in check Sitka spruce responds well to applications of nitrogen fertiliser. An alternative and preferred option on mineral/peaty mineral soils that are nutritionally marginal for Sitka spruce is to plant it in mixture with a nurse species. This reduces the need for fertiliser and consequently reduces the potential for possible negative environmental impacts.

Vegetation control

Height increment in Sitka spruce, even for carefully handled plants, tends to be modest for the first couple of years. During this period cleaning requirements will therefore need to be monitored and cleaning carried out where necessary.

Thinning

Thinning policy on Sitka spruce in Ireland is based on the British Forestry Commission concept of marginal intensity. Thinning should commence at a top height of 10-12 m. First thinning will generally involve the removal of one line in seven, with a selection of the smaller and poorer quality trees between racks. Second and subsequent thinnings will be on a selection only basis. Thinning cycles vary from 3 to 6 years depending on yield class, with final thinning being carried out 3 to 6 years prior to clearfelling.

Growth, yield and rotation length

Yield class in Coillte’s estate ranges from 4 to 30, averaging 17. More recently planted crops have an average yield class of 20. These data indicate that the silvicultural rotation length of Sitka spruce ranges from 45-70 years.

Wood properties and uses

Sitka spruce wood is non-resinous, lightweight and somewhat coarse-textured. It is non-durable and resistant to preservative uptake. It is a moderately strong, general-purpose timber. It is an excellent pulp species and is favoured in many fibreboard products. Uses include fencing, pallets, general construction and reconstituted timber applications.

6.3 NATIVE TREES AND SHRUBS

This section is based on *Our Trees; A Guide to Growing Ireland's Native Trees in Celebration of a New Millennium* (Anon. 2000e).

6.3.1 Alder (Fearnóg)

One of Ireland's most traditional and widely distributed species, alders may be found in damp areas, beside freshwater loughs and along river banks, where their strong fibrous roots may help to stabilise the bank. Alder woodlands are found in Ross Island, Killarney and the Gearagh, Co Cork, while Grantstown Wood, Co Laois, is a rare example of wet woodland on an alkaline soil.

Like most trees, alder flowers before the leaves are out, with attractive reddish catkins and small cones that contain the seeds. Alder will grow in most soils, and has a preference for wet sites. Given rich damp soil alder will grow and produce timber very rapidly. In ancient Ireland sections of alder trunks were used as round shields. Later, it was used for making clogs, and also in the furniture trade where it was known as 'Irish mahogany'. As it is resistant to decay when submerged in water, alder is used to make sluice gates and other structures along streams, rivers and canals (see section 6.1.1, page 97).

Alder leaves and cones.

6.3.2 Arbutus, the Strawberry tree (Caithne)

The arbutus, or strawberry tree, is a small, evergreen tree, which in Ireland can grow to be a forest tree reaching heights of up to 15 metres. It has an unusual distribution, only being found throughout the Mediterranean and certain parts of Ireland. Unlike many of our other native trees, which reached us via Great Britain, arbutus is thought to have spread here over the ancient land bridge from Brittany.

Called the strawberry tree because of the distinct shape and colour of its fruit, this species is found mainly in Co Kerry, especially in the Killarney district where it forms a large part of the natural forest on the islands and shores of the lakes. It is also found in unshaded parts of Glengariff Wood, Co Cork and around Lough Gill in Co Sligo.

Arbutus produces masses of white flowers in November and December. Since the fruit takes 12 months to ripen, the tree carries both mature fruit and flowers at the same time. The fruit itself is edible, but as the Latin name *unedo* □eat only once □implies, it is not very palatable.

The strawberry tree.

6.3.3 Aspen (Crann creathach)

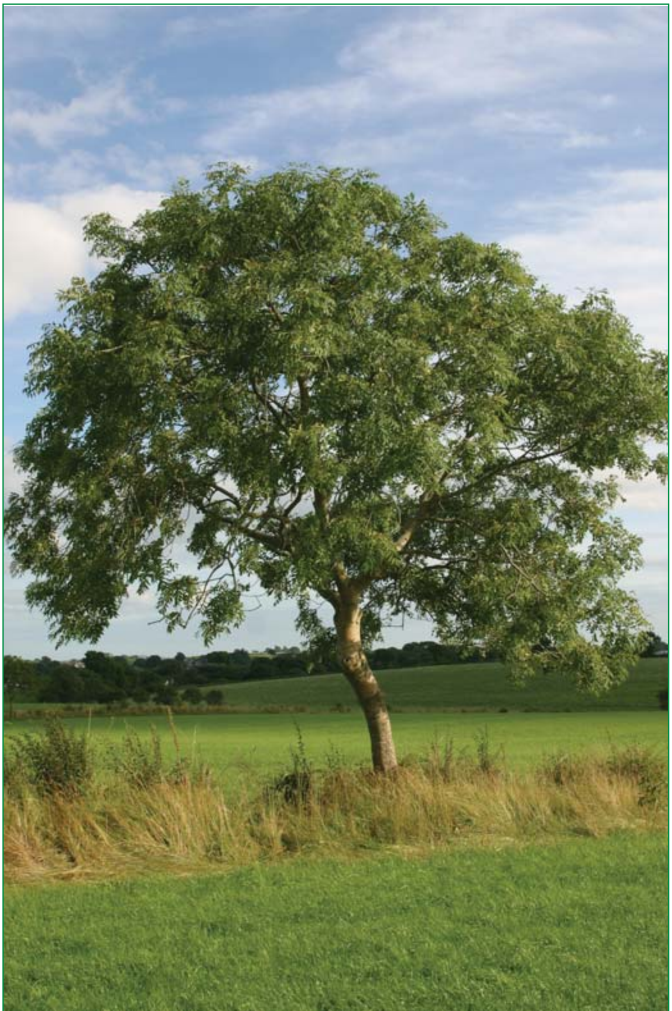
The one definitely native poplar is aspen (all other poplars may be assumed to be introduced, although the Black Poplar is still being argued about). Aspen will grow into a full sized tree. The leaves make a distinctive sound as they rattle gently in the wind, and they have a sweet smell in the spring. Aspen can be found in wet areas and around lake edges, such as in Glenveagh, Co Donegal. Poplars produce seeds on catkins, but also spread vegetatively by suckers (new shoots growing up from the roots). It is easiest to propagate aspen by cutting through roots and transplanting a sucker. A warning should be given about planting aspen in damp sites with good soil. They sucker very readily and may spread too far, taking over too great an area.

If you wish to grow aspen from seed, you must find a mix of aspen trees. Often a 'grove' has arisen by suckers from one tree and will all be of one sex, as aspen is a single sex tree. When both sexes are present, seeds are borne on the female catkins in May. These small seeds must be sown immediately after collection, on damp bare earth, pressed in gently but left uncovered. However, as the seed is only viable for about three days it is more feasible to grow it from suckers. Aspen prefers heavy, damp soil.

Aspen.

6.3.4 Ash (Fuinseog)

Ash is the commonest tree in Irish hedgerows, and is also a traditional woodland species. It will grow in a range of soils, though it grows best in near-neutral, well-drained soils. Ash woods are found in the Burren, Co Clare, and at the Hanging Rock, south Fermanagh. The flowers are very dark, almost black, and may be seen before the leaves develop - ash is one of the last trees to come into leaf and is one of the first to lose its leaves in autumn. The seeds are clumps of winged keys. The pale dense timber makes good firewood and is also used for hurleys, snooker cues and furniture (see section 6.1.4, page 104).



Ash.

6.3.5 Birch

Downy birch (Beith chlúmhach)

Silver birch (Beith gheal)

There are two types of birch in Ireland, downy and silver. The most common is the downy birch, which like silver birch, is a delicate tree with fine branches and small leaves. The springtime flowers are catkins, which stay on the tree and contain the mature seed by autumn.

Birch will grow in poor soils, but it likes a sunny position. Downy birch is tolerant of wet sites, but silver birch needs good drainage. Birch woods occur widely, especially on marginal soils, lake edges such as Lough Ennell in Co Westmeath, fens, and on dried out bogs such as Ardkill Bog, Co Kildare. It makes a good ornamental garden tree, as it does not grow too large. Like alder, its seeds are popular with small seed-eating birds, such as siskin and redpoll. In early times toghers or walkways, usually across bog-land were made from birch. Nowadays, it is more commonly used in making plywood, although it is not used for this purpose in Ireland (see section 6.1.7, page 116).

Birch wood.

6.3.6 Bird Cherry (Donnroisc)

This species is most frequently found in the northwest, for example around Churchill, and Lough Gartan, Co Donegal. It is most easily spotted in the spring, around May, when the flowers are out. The creamy-white flowers are borne in rows along flower stalks about 10 cm long, and are quite obvious above the green foliage.

The dark berries or small cherries ripen in August. Bird cherry is an attractive small tree with true flowers grows vigorously, preferring good soil and a sheltered site. Treat bird cherry fruit as common wild cherry.

Bird cherry.

NATIVE SPECIES

6.3.7 Wild Cherry (Crann silín fiáin)

One of the most attractive trees native to Ireland, with its white or very pale pink flowers in spring, followed by hanging cherries. The bark is also attractive, and the leaves provide autumn colour. Wild Cherry is very common in St. Johns Wood, Co Roscommon.

Cherry is often found in old field hedgerows, where it may have been planted, but it is also found in mixed deciduous woodland. The old farm trees may not be native in the sense of ancient woodland, but they are part of rural history, like crab apple and old varieties of apple, pear, plum and damson, once grown in gardens and small orchards throughout the country. It is often used as a decorative wood in joinery and furniture making (see section 6.1.8, page 120).

Wild cherry.

6.3.8 Crab Apple (Crann Fia-úll)

Like the wild cherry, crab apple has been deliberately grown around old farmsteads, but it is also a true native species found in old woodland. Crab apple is found in hedgerows throughout the country. Unlike modern hybrid apples, crab apples grow true from the apple pips.

It is a small tree, very suitable for gardens. It bears attractive pink/white apple blossom in the spring, while the apples provide an autumn feature in the garden, as well as a useful crop.

Crab apple.

6.3.9 Wych Elm (Leamhán sléibhe)

The wych elm is native, but many varieties of wych elm and smooth-leaved elm have been introduced and planted in Ireland in the past, mostly for timber. Wych elm is chiefly found in mountain glens in the northwest of the country. English elm was mainly planted in demesnes. In recent years many of these trees have died as a result of Dutch elm disease. English elms will re-grow from stumps and will form suckers in woodland or hedgerows, which may be used for propagation.

The Irish wych elm, which is less common, appears more resistant to disease. It does not produce suckers and must be grown from seed. Leaves are rough to the touch, oval, with toothed margins. The flowers, as with many trees, appear before the leaves. They are reddish clusters borne directly on the twigs, and are not obvious until they mature into pale green seeds, which almost look like leaves, except that they ripen and fall soon after the real leaves appear.

Wych elm.

6.3.10 Hazel (Coll)

This native species has many uses and an ancient history. Hazel nuts are one of the foods associated with the very earliest human settlements in Ireland of Mesolithic man, when it was widely used in the construction of hut dwellings, due to the strength and flexibility of its timber. Hazel bushes may be coppiced. The slender timber poles that result from coppicing were used in the construction of wattle and daub, and fences. Hazel is also a traditional material in the construction of eel and lobster traps.

Hazel grows as an understorey in oak and ash woodlands or as pure hazel woods. Hazel scrub woodland covers extensive areas of limestone, particularly on the Burren plateaus of north Clare and soils derived from limestone in the Glens of Antrim. It is often associated with a rich ground flora of woodland flowers. Hazel is well known for its yellow 'lambs tail' catkins in spring, but the nuts grow from small bud-like structures with a tuft of red - the stigma of the female flowers.

Hazel.

6.3.11 Holly (Ciuleann)

The evergreen holly is a native species that forms the shrub layer in some of our oldest woods. It is a visually attractive small tree, very suitable for gardens as a specimen tree or as a hedge, slow growing and very dense. Holly trees are either male or female - only the female can bear berries, so it is always worth planting several holly trees together. Both sexes bear small creamy flowers.

Although they drop their spiny leaves all the year round, especially in the heat of summer, they are green all year and, along with ivy, were traditionally used for mid-winter or Christmas decorations as a sign of green life to come. In some areas it is considered unlucky to cut down holly, and it may be left as standards along a hedgerow. The hard pale wood is valued for woodcarving.

Holly.

6.3.12 Oak (Dair)

Once widespread throughout Ireland, centuries of harvesting, with few trees being replaced, means that truly native oak can be hard to find, though there are small woods in most counties. Very often, semi-natural oak woodlands contain a proportion of birch and ash, with hazel, holly and rowan scattered throughout the understorey. Oak has been harvested for its fine timber for centuries and it is much prized for its visual qualities and durability. It is commonly used in the making of furniture, for veneers, and in the manufacture of casks.

The male flowers of oak are borne on rather inconspicuous catkins, which come out just before the leaves, but the seeds - acorns - are far more obvious. Oak trees do not produce a good crop every year, so it is worth gathering plenty in a good year (see section 6.1.13, page 134).

6.3.12.1 Sessile Oak (Dair ghaelach)

The traditional Irish oak is the sessile oak. It is the main species to be found in Ireland's most familiar woodlands. Sessile oak is found more commonly on poor acid soils, often

Sessile oak.

in hilly regions, such as in the woodlands to be found in Killarney, Co Kerry, the Glen of the Downs, Co Wicklow, and Glenveagh, Co Donegal. They are important ecologically as habitats for hundreds of invertebrate species along with many species of birds and mammals. Sessile means that the acorns have no stalk while those of the pedunculate oak hang from long stalks (see section 6.1.13, page 134).

6.3.12.2 Pedunculate Oak (Dair ghallda)

The pedunculate or English oak is also considered to be a native tree. It is generally associated with heavy lowland soils and can withstand wet soil in winter. Good examples of pedunculate oak woodlands can be found in Charleville, Co Offaly, and Abbeyleix, Co Laois (see section 6.1.13, page 134).

Penduncuate oak.

6.3.13 Rowan (Caorthann)

Rowan (mountain ash) adds colour to woodland throughout Ireland, especially in the hills where it will grow at a high altitude even on rocky ground. Rowan has a lot of folklore and superstition attached to it and is said to deter witches and bring good luck.

The creamy flowers ripen into scarlet berries, which colour early in the season and provide food for thrushes through the winter. A mistle thrush will defend a rowan tree or holly as its territory, not for nesting, but through the winter as its feeding territory. Rowan is an attractive garden tree. It likes well-drained sites, but it will thrive in most soils (see section 6.1.15, page 141).

Rowan.

6.3.14 Scots Pine (Péine Albanach)

Originally Scots pine was a native tree. Pollen found in soil samples from bogs indicates that Scots pine was widespread in Ireland thousands of years ago. Human impact and the gradual change to a warmer, wetter climate led to its decline, and it may even have died out completely. Pine stumps have been found in bogs, standing where they grew, 7,000 years ago, before the formation of the peat. Most of the pines around the countryside now were imported from Scotland and planted over the last 150 years. Efforts have been made to reintroduce this once native species, as in some situations it is fitting that Scots pine be encouraged. It can be grown on marginal land where other species of tree would not survive. Our native red squirrel prefers the seeds of this tree than any other (see section 6.2.15, page 189).

Scots pine.

6.3.15 Whitebeam (Fioncholl gaelach)

These are small trees, quite unusual in the wild, and many imported specimens have been planted in towns and parks, and along roads. If you want the truly native tree you may have to search, but it is most common in the south of the country. Whitebeam leaves have a pale undersurface, which explains its name, while the cream flowers ripen to red berries. The hard pale wood was traditionally used in the construction of small furniture components, such as the legs of stools.

There are several whitebeam species native to Ireland that may be found in wild woods or cliffs, where they have escaped grazing. It can also be found in hedges. The most widespread is *Sorbus aria,* the common European whitebeam, which is most frequent in Co Galway. Also found is *S. rupicola,* especially on cliffs, and *S. devoniensis*, which is restricted to Waterford, Carlow, Kilkenny and Wexford.

The distribution of a further three species is limited to southern parts of the country – *S. latifolia, S. anglica,* which is found only in Co Kerry and the only one unique to Ireland, *S. hibernica*, found on limestone across the midlands and in Glenveagh, Co Donegal.

Whitebeam.

6.3.16 Willow (Saileach)

There are several varieties of willow native to Ireland. All grow in damp soil, have catkins or 'pussy willows' that produce seeds, but are most easily grown from cuttings which root very readily. The most widespread willow species are the goat willow, the rusty or grey willow (both known as 'sallies'), and the eared willow. While these generally grow on damp ground, the goat willow will also colonise rough and disturbed ground in drier areas. The bay leaved willow, with glossy green leaves, is found beside small rivers and ditches.

Osiers, with long fine leaves, do not develop into large trees. They were often grown and managed by cutting right back to the base to encourage long flexible shoots used for baskets. This species may now be grown for biomass to provide a renewable energy source. All willows are rich in insects and so provide a good food source for insect eating birds in summer, notably for the willow warbler.

Willow.

6.3.17 Yew (Iúr)

The yew is native and may be found in old woods, although it is often seen in the surroundings of estates or churchyards. An evergreen conifer (although an unusual one), yew is a dramatic tree with its dark foliage and red berries encasing a single seed. Reenadina Wood on the Muckross Peninsula, Co Kerry, is Ireland's only native yew wood. A sport (unique form) of the Irish yew (*Taxus baccata* 'fastigata'), with very upright growth, was originally found growing on rocky limestone hills in Co Fermanagh. This was cultivated at Florencecourt, and subsequently in many gardens and churchyards.

Many yews are single sex, but most Irish yews are female and so bear fruit. Even if the flesh is removed, these may be slow to germinate. The best seeds are those that have been eaten by birds and have passed through them; such bare seeds may be collected from under yew trees. There are ornamental garden varieties, some with yellow fruit or even golden foliage; these have to be propagated by cuttings.

Irish yew.

Yew trees do not need rich soil, but they do need a well-drained site, preferably not too exposed to wind or frost. The leaves are poisonous to most livestock, and the seeds are also toxic, so care must be taken in planting it where animals and children are not at risk. Yew is a good tree for wildlife and birds.

6.3.18 Blackthorn (Draighean)

A spiny shrub of roadside and hedgerow, blackthorn forms dense scrub cover where it is left untrimmed and ungrazed. It bears dense clusters of small white flowers, which contrast with the dark bark of its twigs very early in the year. Blackthorn hedges can appear to be covered in white. The use of blackthorn wood is mainly decorative, for example in the manufacture of shillelagh walking sticks and tourist souvenirs.

After flowering small oval leaves appear, and then in autumn the harvest of sloes develops. These look like small damsons, but are very sour and are not eaten directly by people, although birds take them. Sloes have traditionally been used for flavouring gin or poteen.

Blackthorn.

6.3.19 Purging Buckthorn (Paide bréan)

An uncommon shrub, which grows at lakesides, often on limestone soil around the shores of Upper Lough Erne, the Shannon, Lough Neagh and Lough Beg. It is not tolerant of heavy shade under trees or very dry sites. There is some resemblance to dogwood (it is sometimes called 'black dogwood'), but the oval leaves have an unusual pattern of almost parallel veins.

The inconspicuous white-green flowers (not unlike spindle flowers) are borne close to the dark branches and are followed by clusters of black berries on the female bushes only. This buckthorn is single sex, with about seven female bushes to each male.

Purging buckthorn.

6.3.20 Alder Buckthorn

Alder buckthorn was once common, coppiced and the wood used for charcoal. It is a bush of wet, though not waterlogged, sites and it is found around the shores of Lough Ree. It has a very long flowering and fruiting season, from July to November.

Alder buckthorn.

6.3.21 Elder (Trom)

Sometimes known as the Bour tree, this is a common shrub around the countryside and often found beside old farmhouses or byres, especially associated with old refuse tips. In the wild, it may be associated with badger setts. The idea of deliberately planting elder trees - which grow again if they are chopped down, and spread rapidly on waste ground - may seem incredible to older country people. However, elder is a very good wildlife species, with its wide heads of creamy flowers, followed by hanging clusters of dark red/black berries.

As with all other species, the truly native variety has the most wildlife value (ornamental varieties are used in landscape planting). Elder seeds germinate profusely, and the tree will grow in most soils. Both elder flowers and berries may be used in cooking and for making wine. The branches have a soft pithy centre that can be removed, and sections can be used to make homemade flutes or whistles. In nature, such hollow branches provide nest chambers for bumblebee larvae, and shelter for hibernating insects.

Elder flowers.

6.3.22 Guelder Rose (Caorchon)

Not a rose at all, but this is certainly one of our most attractive wayside shrubs. Guelder rose is usually found in hedges or at the edge of fields and small woods beside a drain - it needs damp ground.

The flowers are a disc of creamy blossoms, larger at the outer edge. These are followed by translucent bright red berries, which colour early in the autumn, which is when this shrub is most obvious.

Guelder rose flowers.

6.3.23 Hawthorn (Sceach gheal)

Traditionally hawthorn, or whitethorn, was planted in hedges throughout our countryside. Its sweet smelling blossom is a feature in May, and in autumn and winter the deep red haws colour the bare twigs. They are among the berries most favoured by birds. Only untrimmed hawthorn can flower and fruit freely, but hedges have to be cut to keep them stock-proof. Hawthorn hedges may be trimmed regularly, or left for several years and then laid by cutting part way through the main stems and laying these horizontally through the hedge. Even old hawthorn hedges will regenerate if trunks are cut back to base and left to sprout again, but these must be fenced off so that farm livestock cannot reach the tasty young shoots.

Like many other shrubs, hawthorn also grows in woodland where there is enough light - in open glades, along 'rides' through the woodland, or along the edge. A single tree may be left in a field as a 'fairy thorn', especially where there may be an archaeological site.

Hawthorn.

6.3.24 Juniper (Aiteal, Crann fír)

An unusual shrub found in rocky areas, especially on the Burren and in West Donegal, and often at woodland edges. One of our few native evergreens, juniper is generally found on limestone. It will thrive in other soils and could be introduced to areas outside its natural distribution, but this may not be considered desirable. In good conditions it may grow to be small tree size.

Like holly, juniper is an evergreen and bears flowers of different sexes on different plants. The bushes are small and usually low-growing. Its fruit is black, and it can be grown from seed. The berries are used commercially to flavour gin.

Juniper.

6.3.25 Spindle (Feoras)

Another bush more common on limestone soils, though it is tolerant of a range of non-acid soils. It shares its most common areas of distribution with the guelder rose.

It is an inconspicuous shrub, with pale bark, smooth and pointed leaves, and small pale flowers. Young twigs are green and four-sided. It is the fruits that are amazingly colourful, with bright pink cases that split open to reveal hard orange seeds. It will grow from seed, but may also be propagated by cuttings. The hard pale wood was used for making spindles for spinning wheels and looms, hence the name.

Spindle berries.

Glossary

Afforestation	The growing of trees in an area that has lacked forest cover for a very long time or has never been forested.
Age	The number of growing seasons since planting. The age of a crop is calculated to a whole year and 1st July is taken as the operative date for increase in age; e.g. a crop planted over the winter of 1970/1971 is 29 years old if measured on or before 30 June 2000, but is 30 years old if measured on or after 1 July 2000.
Alkaline soil	[illegible] that has pH>7; usually applied to surface layer or root zone.
Apical dominance	Growth concentrated on the leader, which tends to produce a straight stem and conical crown.
Bare-root stock	Plants lifted from the nursery and despatched to the planting site with their roots bare of soil.
Basal area	The cross-sectional area of a tree measured at 1.3 m (breast height) from the ground, or the sum of the basal areas of trees in a specific area, expressed in m^2.
Biodiversity	The variety of all life forms at all levels, including genetic diversity, species diversity, and landscape diversity, within an ecosystem.
Brashing	The removal of lower branches up to a height of about 2 m to facilitate access for inspection, thinning or other purposes.
Broadleaves	Trees with broad, flat leaves, e.g. oak, ash, beech and sycamore. Growth is not in whorls but almost always diffusely branched. Usually deciduous.
Calcareous soil	Soil containing sufficient calcium carbonate to effervesce visibly when treated with 10% hydrochloric acid.
Canker	Dead area of a branch or stem caused by fungal or bacterial attack.

Canopy	The mass of foliage and branches formed collectively by the crowns of trees.
Co-dominant trees	Trees in the upper canopy (which they help to complete) but which are below the crown level of the dominants.
Cold-store plants	Plants which have been placed in cold store (immediately following lifting and when fully dormant) for the purpose of extending the planting season.
Compatible species	Species that grow at about the same rate.
Conifers	Trees and shrubs that have needle-like leaves and bear cones. They are usually, but not always, evergreen.
Coppice	Trees felled close to the ground so as to produce shoots from the resulting stools, giving rise to successive crops of biomass and/or timber over a rotation.
Crown length	The vertical measurement of the crown of a tree measured along the main axis of the stem, from a point halfway between the lowest live branch and lowest live whorl and the tip of the tree.
Crown thinning	The removal of selected trees in the upper canopy to allow growing space for the remaining trees.
Cultivar	A variant of a species that has been selected by gardeners or nurserymen. Cultivars are often loosely termed 'varieties'.
Cultivated	Considerable alteration to physical or chemical properties of the soil or vegetation [illegible]
Current annual increment (CAI)	The basal area or volume increments put on during the current year
Deciduous	[illegible] Most broadleaves are deciduous, whereas only some conifers are deciduous, e.g. larch.
Diameter at breast height (DBH)	The diameter of a tree in cm, measured at 1.3 m above ground level.

Dominant trees	These are the tallest and most vigorous trees in the crop, and usually have a large proportion of their crown free of competition.
Economic rotation	The age at which the financial return is at its maximum.
Epicormic branches	Small branches (shoots) originating from adventitious buds on the stem. They can cause a degrading of the value of the main stem.
Exotic species	Species that occur in a given place as a result of deliberate or accidental actions by man.
Filling-in	The replacement of plant failures, also known as beating up. Usually carried out before the beginning of the second growing season.
Final crop	The trees which remain after successive thinnings and are finally felled at maturity.
Flushing	The commencement of growth of a plant above ground, characterised the swelling and bursting of buds.
Flushed site	considerable enrichment with nutrients from flush water, as indicated by the presence and vigour of tufted hair grass, purple moor grass, soft and bog- rush species.
Forking	Forking describes the occurrence of multiple leaders in a tree. It usually occurs when the leader or terminal bud is damaged. Double or multiple leaders usually replace the leader.
Frost damage	Damage to the soft tissues of trees by cold temperatures (-5°C), which can occur in the nursery and in young plantations. Trees are most vulnerable when freshly flushed in late spring, or early summer, and again in early autumn, prior to hardening off.
Frost hollows	Low-lying concave areas where cold air collects, causing damage to new shoots of trees.
Fungi	A group of microscopic organisms which contain no chlorophyll and are either parasitic or saprophytic on other plants animals.

Habitat	Any place or type of place where an organism or community of organisms normally lives and thrives.
Hot planting	Planting of stock within days of being lifted in the nursery.
Humus	That more or less stable fraction of the soil organic matter remaining after the major portions of added plant (and animal) residues have decomposed (see mull, moder and mor humus).
Indigenous species	[illegible] which arrived and inhabited an area naturally, without deliberate assistance from man.
Indurated soil	[illegible] has strongly compacted material, which is low in organic matter. It normally occurs at depths of 30-75 cm, and extends for 30-50 cm or more.
Iron pan	A hard impervious layer formed largely from iron compounds, having been washed down from the upper soil horizons.
Juvenile instability	The leaning or overturning of young trees (2 to 5 year old) due to the fracture or weakness of the root or base of the stem just below ground level. Affected trees are often not uprooted, but continue to grow, attempting to regain an upright position and resulting in stems with basal sweep.
Leader	The main or leading shoot of a tree.
Lichen	A symbiotic association of fungus and alga.
Light-demanders	Trees which only thrive when allowed unimpeded access to light.
Loamy	The textural class name for soil having a moderate amount of sand, silt and clay.
Lop and top	Woody debris from thinning or felling operations. Also known as slash or brash.
Marginal intensity	An intensity of thinning which in terms of annual rate of volume removal is 70% of the MMAI, i.e. 70% of the yield class.

Maximum mean annual increment (MMAI)	The maximum average annual volume increment volume for the crop.
Mean annual volume increment (MAI)	The total volume production to date, divided by the age, i.e. the average rate of volume production over the life of the crop to date.
Monocultures	in which only one species or cultivar is present or largely dominates.
Moder humus	Intermediate between mor and mull. The current litter layer overlies partly decomposed material which is not matted as in the mor.
Mor humus	Raw humus; type of forest humus layer of unincorporated organic material; usually distinct from the mineral soil. Comprised of current litter layer overlying a matted layer of partly decomposed material.
Mounding	Formation of discrete heaps of soil, usually 20-30 cm in height, at the intended planting spacing.
Mull humus	A humus-rich layer of forested soils consisting of mixed organic and mineral matter.
Natural regeneration	The regeneration of a crop through seeds from mother trees on the ground or in the vicinity.
Needle cast	Defoliation of conifers as a result of disease, or climate.
Nurse species	which enable more delicate or more site-demanding species to grow satisfactorily on what would otherwise be considered unsuitable sites.
pH	A value on a scale of 0-14 that gives a measure of the acidity or alkalinity of a soil. A neutral soil has a pH around 7 (range 6 to 8). Acidic soils have pH values of less than 7 but greater than 3 and alkaline soils have values greater than 7 but less than 9. The lower the pH the more acidic is the soil; the higher the pH the more alkaline.
Pioneer species	The first plant or animal species to colonise a bare or barren area and initiate an ecological cycle.

Provenance	The location of trees from which seed or cuttings are collected.
Pruning	The removal of branches to produce knot-free timber.
Ripping	[redacted] with a long heavy shank mounted on a tool bar to depths of 30-100 cm for the purpose of shattering compacted/indurated layers, including iron pans.
Rotation	The period of years required to establish and grow timber crops to a specific condition of maturity.
Sawlog	Logs, usually of at least 14 cm top diameter, which are intended for conversion in a sawmill.
Scrawing	The removal of the surface layer of organic matter from a soil (such material being normally used as fuel).
Shade-bearers	[redacted] species (not always grown in the understorey) which are adapted to growing with limited access to light.
Shake	A defect in timber, consisting of cracks either radiating from the centre (star shake) or following the annual rings (ring shake).
Shaping	Removal of forks and large branches [redacted] [redacted] with the object of producing straight stems.
Silviculture	The science of forest establishment, maintenance and management.
Soil reaction	The degree of soil acidity or alkalinity, usually expressed as a pH value. Thus, acid soils would be described as having an acid reaction.
Stumping back	The cutting back of plants within a few years of planting to within 5-10 cm of ground level. This stimulates vigorous re-growth of multiple shoots, which can then be reduced to one shoot.
Sub-dominant trees	These trees are not in the upper crown, but their leaders still have free access to light.

Suckers	[illegible] shoots produced from the base or under- ground roots of an established plant.
Suppressed trees	[illegible] whose leaders have no direct access to light and stand beneath the crowns of adjacent dominant, co-dominant and sub-dominant trees.
Terminal height	The height by which it is predicted that 40% of a stand will be [illegible]
Thinning	The removal of a proportion of trees from an immature crop in order to improve the growth and form of the remainder.
Thinning cycle	The interval in years between successive thinnings.
Top height	The average height of the 100 trees of largest diameter per hectare.
Topex	An index of [illegible]
Understorey	Any plants or shrubs growing under a tree canopy.
Windfirm	Descriptive of trees and plantations that, because of species, soil or relative exposure, are unlikely to suffer windthrow.
Windthrow	Uprooting or breakage of trees caused by strong winds.
Wolf trees	Dominant defective trees with large crowns and/or large side branches, which can damage better-formed, adjacent trees if not removed.
Yield class	A classification of rate of growth in terms of the potential maximum mean annual increment per hectare of volume to 7 cm top diameter (m^3/ha/annum), irrespective of age of culmination, or of tree species.

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Appendix I: Common and Botanical Names of Tree Species

BROADLEAVES

Common names		Botanical names
Alders	Common alder	*Alnus glutinosa*
	Grey alder	*Alnus incana*
	Italian alder	*Alnus cordata*
Ash		*Fraxinus excelsior*
Beech	European beech	*Fagus sylvatica*
Southern beech		*Nothofagus obliqua*
		Nothofagus procera
Birch	Silver birch	*Betula pendula*
	Downy (Common) birch	*Betula pubescens*
Cherry	Wild cherry	*Prunus avium*
Chestnut	Spanish chestnut	*Castanea sativa*
Hornbeam		*Carpinus betulus*
Limes	Small-leaved lime	*Tilia cordata*
	Large-leaved lime	*Tilia platyphyllos*
	Common lime	*Tilia vulgaris*
Maple	Norway maple	*Acer platanoides*
Oak	Pedunculate oak	*Quercus robur*
	Red oak	*Quercus borealis*
	Sessile oak	*Quercus petraea*

Common names		Botanical names
Rowan	Mountain ash	*Sorbus aucuparia*
Sycamore		*Acer pseudoplatanus*

CONIFERS

Common names		Botanical names
Cedar	Western red cedar	*Thuja plicata*
Cypress	Lawson cypress	*Chamaecyparis lawsoniana*
	Monterey cypress	*Cupressus macrocarpa*
Fir	Douglas fir	*Pseudotsuga menziesii*
	Grand fir	*Abies grandis*
Hemlock	Western hemlock	*Tsuga heterophylla*
Larches	European larch	*Larix decidua*
	Hybrid larch	*Larix* x *eurolepis*
	Japanese larch	*Larix kaempferi*
Pine	Austrian pine	*Pinus nigra* var. *nigra*
	Corsican pine	*Pinus nigra* var. *maritima*
	Lodgepole pine	*Pinus contorta*
	Macedonian pine	*Pinus peuce*
	Monterey pine	*Pinus radiata*
	Scots pine	*Pinus sylvestris*
Redwood	Coast Redwood	*Sequoia sempervirens*
Spruce	Norway spruce	*Picea abies*
	Serbian spruce	*Picea omorika*
	Sitka spruce	*Picea sitchensis*

NATIVE TREES AND SHRUBS

Common name		Botanical name
Alder		*Alnus glutinosa*
Arbutus		*Arbutus unedo*
Aspen		*Populus tremula*
Ash		*Fraxinus excelsior*
Birch	Downy	*Betula pubescens*
	Silver	*Betula pendula*
Bird cherry		*Prunus padus*
Wild cheery		*Prunus avium*
Crab apple		*Malus sylvestris*
Wych elm		*Ulmus glabra*
Hazel		*Corylus avellana*
Holly		*Ilex aquifolium*
Oak	Sessile	*Quercus petraea*
	Penduncculate	*Quercus robur*
Rowan		*Sorbus aucuparia*
Scots pine		*Pinus sylvestris*
Whitebeam		*Sorbus aria*
Willows		*Salix spp.*
Yew		*Taxus baccata*
Blackthorn		*Prunus spinosa*
Buckthorn	Purging	*Rhamus cathartica*
	Alder	*Frangula alnus*
Elder		*Sambucus nigra*
Guelder rose		*Viburnum opulus*
Hawthorn		*Crataegus monogyna*
Juniper		*Juniperus communis*
Spindle		*Euonymous europaeus*

Appendix II: Common and Botanical Names of Vegetation Species

Common name	*Botanical name*
Bell Heather	*Erica cinerea*
Bent-grass	*Agrostis* spp.
Bilberry or Fraochan	*Vaccinium myrtillus*
Blackthorn	*Prunus spinosa*
Bog asphodel	*Narthecium ossifragum*
Bog bean	*Menyanthes trifoliata*
Bog myrtle	*Myrica gale*
Bog orchid	*Malaxis paludosa*
Bog-rush	*Schoenus nigricans*
Bracken	*Pteridium aquilinum*
Briar or Bramble	*Rubus fruticosus*
Broadleaved dock	*Rumex obtusifolius*
Broadleaved willow-herb	*Epilobium montanum*
Buckthorn	*Rhamnus cathartic*
Bulrush	*Typha latifolia*
Butterwort	*Pinguicula lusitanica*
Cocksfoot	*Dactylis glomerata*
Common comfrey	*Symphytum officinate*
Cotton- grass	*Eriophorum angustifolium*

Common names	***Botanical names***
Cow parsley	*Anthriscus sylvestris*
Cowslip	*Primula veris*
Creeping buttercup	*Ranunculus repens*
Crested dog's tail	*Cynosurus cristatus*
Cross-leaved heather	*Erica tetralix*
Deer-grass	*Trichophorum (Scirpus) caespitosum*
Dog's mercury	*Mercurialis perennis*
European, English, Common, French furze	*Ulex europaeus*
Fen thistle	*Cirsium dissectum*
Fescue	*Festuca* spp.
Fireweed (Rosebay Willow-herb)	*Chamerion angustifolium* syn.
Foxglove	*Digitalis purpurea*
Garlic	*Allium ursinum*
Grasses	*Gramineae*
Great willow-herb	*Epilobium hirsutum*
Guelder rose	*Viburnum opulus*
Hard rush	*Juncus inflexus*
Harts tongue fern	*Asplenium scolopendrium*
Hawthorn	*Crataegus monogyna*
Hazel	*Corylus avellana*
Heath Rush	*Juncus squarrosus*
Herb Robert	*Geranium robertianum*
Holly	*Ilex aquifolium*
Honeysuckle	*Lonicera periclymenum*
Hog-weed	*Heracleum sphondylium*
Irish (dwarf) furze	*Ulex gallii*
Jointed Rush	*Juncus articulatus*
Juniper	*Juniperus communis*

Common names	*Botanical names*
Lady's bed straw	*Galium verum*
Lichen	
Ling Heather	*Calluna vulgaris*
Male fern	*Dryopteris filix-mas*
March marigold	*Caltha palustris*
March thistle	*Cirsium palustre*
Mat-grass	*Nardus stricta*
Meadow sweet	*Filipendula ulmaria*
Milkwort	*Polygala vulgaris*
Moss species	*Sphagnum* spp.
Plantain	*Plantago lanceolata*
Purple moor grass	*Molinia caerulea*
Red clover	*Trifolium pratense*
Red fescue	*Festuca rubra*
Reed	*Phragmites australis*
Rough-stalked meadow grass	*Poa trivialis*
Royal fern	*Schoenoplectus lacustris*
Sedges	*Carex* spp.
Silverweed	*Potentilla anserina*
Soft Rush	*Juncus effusus*
Spindle tree	*Euonymous europaeus*
Stinging nettle	*Urtica dioica*
Sweet vernal grass	*Anthoxanthum odoratum*
Sundew	*Drosera rotundifolia*
Tormentil	*Potentilla erecta*
Tufted hair grass	*Deschampsia caespitosa*
Water lily	*Nuphar lutea*
Wavy hair-grass	*Deschampsia flexuosa*

Common names	Botanical names
Wild parsnip	*Pastinaca sativa*
Willow	*Salix* spp.
Woodrush	*Luzula sylvatica*
Wood sanicle	*Sanicula europaea*
Wood - sorrel	*Oxalis acetosella*
Wood sage	*Teucrium scorodonia*
Yorkshire fog	*Holcus lanatus*

Appendix III: Common and Scientific Names of Disease and Pest Organisms

Common name	***Scientific name***
Ash bud moth	*Prays fraxinella*
Bacterial canker of ash	*Pseudomonas savastanoi*
Bacterial canker of cherry	*Pseudomonas syringae*
Bank vole	*Clethrionomys glareolus*
Beech canker	*Nectria ditissma*
	Ganoderma applanatum
Beech bark disease	*Nectria coccinea*
Beech scale insect	*Cryptococcus fagi*
Beech woolly aphid	*Phyllaphis fagi*
Blister rust	*Cronartium ribicola*
Brown cubical rot	*Polyporus sulphureus*
Cherry blackfly	*Myzus cerasi*
Cooley spruce gall aphid	*Adelges cooleyi*
European pine sawfly	*Neodiprion sertifer*
Fomes heart/butt-rot	*Heterobasidion annosum*
Green spruce aphid	*Elatobium abietinum*
Grey squirrel	*Sciurus carolineusis*
Group dying	*Rhizina undulata*
Honey fungus	*Armillaria mellea*

Common names	*Scientific name*
Ink stain disease	*Phytophthora cinnamomi*
	Phytophthora cambivora
Larch canker	*Lachnellula willkommii*
Leaf rust of alder	*Melampsoridium hiratsukanum*
Leaf rust of birch	*Melampsoridium betulinum*
Oak mildew	*Microsphaera alphitoides*
Pine beauty moth	*Panolis flammea*
Pine shoot moth	*Rhyacionia bouliana*
Pipe rot	*Stereum gausapatum*
Rabbit	*Oryctolagus cuniculus*
Red squirrel	*Sciurus vulgaris*
Shot hole	*Didymascella thujina*
Swiss needle cast	*Phaeocryptopus gaeumannii*
Tar spot	*Rhytisma acerinum*
Witches broom	*Taphrina betulina*
Yellows	*Cyclaneusma minor*

Appendix IV: Guidelines for Soil Sampling

- Samples must be representative of the area proposed for planting.
- Divide the area to be sampled into units (sampling units), which are homogenous in terms of soil, vegetation, and topography.
- Avoid (1) furrows and hummocks, (2) areas where lime, fertilisers/manure were stored or spilled, and (3) sites of uprooted trees and fences.
- Each sampling unit should not exceed about 4 ha (10 acres).
- Sampling points are selected by walking in an "S" shape fashion through the sampling unit.
- From at least 15 points within the sampling unit, take a sub-sample of topsoil and subsoil, taking note of the depths. The parent material should be sampled from at least one of the sampling points. The topsoil, subsoil, and parent material samples are kept separate. [If the topsoil and subsoil layers are not visibly different, then sample as follows: a sample of "topsoil" should be taken within 0-20 cm (8"), or from end of thumb to tip of middle finger of a fully outstretched hand, and a sample of "subsoil" should be taken at a depth of 20-40 cm (8-16"). For peaty soils, it is vital that the depth of peat is recorded at each sampling point and that any mineral subsoil material is also sampled].
- Calcareous layers (material that effervesces in 10% hydrochloric acid) must be sampled separately to topsoils, even if they occur near the ground surface; for example, if the calcareous layer occurs at 10cm depth, then you would have a topsoil sample from 0-10 cm depth and a calcareous layer sample from 10cm to lower depth, which should be noted.
- Pool the 15+ sub-samples of "topsoil" and put into a clean, labelled plastic bag. Repeat for the other layers sampled.
- Label the bag clearly, using an indelible black marker, and attach a label to the outside (do not put label inside). The following information should be marked on

the bag and written on the label: (1) name of sampler, (2) date of sampling, (3) location, (4) sample unit number, (5) soil layer, e.g. topsoil, (6) sampling depths.

- The area sampled should be marked on a map, together with the sampling units and numbers, and sent to the testing laboratory.
- Site details should be supplied on the soil sample record forms to the testing laboratory with details on the following: (1) drainage status, (2) topography (flat, concave, or convex), (3) elevation, (4) aspect, (5) exposure, (6) soil type, (7) frost status, (8) dominant ground vegetation, (9) land use (grazing, tillage, etc.), (10) recent fertiliser history, (11) reclamation history.
- A list of laboratories approved for analysing soil samples is contained in the Forest Service's *Forestry Schemes Manual* (Anon. 2003).