The introduction, evaluation and use of non-native conifer species in Britain

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Introduction

As part of an island grouping separated from mainland Europe, the United Kingdom (UK) has only three conifer species: *Pinus sylvestris* L., *Taxus baccata* L. and *Juniperus communis* L. These species arrived between the end of the last period of glaciation and the disappearance of the land-bridge with mainland Europe. Only *Pinus sylvestris* is of economic importance and it remains naturally distributed in small populations in the Scottish Highlands. The development of techniques of artificial regeneration of managed forests therefore brought an interest in non-native conifer species to exploit the wide range of site conditions present and exotic species now account for the major part of commercial coniferous forestry.

The introduction of exotic conifers to Britain

A summary of the introduction of exotic conifers is given in Table 1. In the table the origin, date of introduction, person who introduced the species, where known, and date when the species was first used as a commercial plantation species is given. More details are given by Macdonald et al. (1957).

Among the European species, *Picea abies* (L.) Karst., which was present before the last glaciation, was probably introduced as early as the 16th century and was grown commercially from that time. *Larix decidua* P. Mill. was introduced in the late 17th century and a number of individual specimens dating from the early 18th century are still standing. It was used as a plantation species from around 1750. *Pinus nigra* Arnold was introduced in 1759 but interest in its cultivation was slower to develop. The other European species were investigated but they have never been the subject of serious commercial exploitation, remaining important only for ornamental use.

Serious exploration of the Pacific north-west of North America began in the late 18th and early 19th centuries and established a major tradition of plant collection from around 1830. The better known collectors include Archibald Menzies, David Douglas, William Lobb, John Matthew, John Jeffrey and William Murray. In Table 1 it can be seen that Douglas can be credited with the introduction of seven of the species listed, two of which, *Picea sitchensis* (Bong.) Carr. and *Pseudotsuga menziesii* (Mirb.) Franco, play a major part on commercial soft-wood production in the UK. Other collectors, notably John Veitch, Charles Maries, Ernest Wilson and George Forrest, brought further species from China and Japan in the late 19th and early 20th centuries.

Past and current importance of exotic conifers

There have been major changes and trends in the use of conifer species during the last 100 years in which commercial forestry became established and expanded in the UK. At the beginning of this period, *Pinus sylvestris* and *Picea abies* were the major plantation species with lower concentration on *Pseudotsuga menziesii* and *Larix* spp. *P. sylvestris* saw a gradual decline but retains an important position on poorer, drier sites. In contrast, *Picea sitchensis* displaced *Picea abies* and rose to be the predominant plantation species during the 40 years following World War II. Other species, such as *Pinus contorta* Dougl. ex Loud., were found to have potential on more demanding sites beyond those suitable for *Picea sitchensis* and became the subject of considerable interest in the period 1960–1980. However, problems with poor growth form and instability in wind and snow, together with policy changes with respect to land use, caused this interest to fall rapidly in later years. Since the early 1990s, planting of conifers in general has given way to a major interest in the use of native broadleaved species with less commercial objectives.

Table 1. The introduction of non-native conifers into Britain†

Species	Origin‡	Date of introduction	Introduced by	Plantation date
Major commercial species				
Abies grandis (Dougl. ex D.Don) Lindl.	NA	1831	Douglas	1900
Abies procera Rehd.	NA	1831	Douglas	1880s
Larix decidua P. Mill	E	17th century	–	1750s
Larix kaempferi (Lam.) Carr.	A	1861	Veitch	1895
Larix x *eurolepis* Henry	HY	1900	Arose in Scotland	1904
Picea abies (L.) Karst.	E	16th century	–	16th C
Picea sitchensis (Bong.) Carr.	NA	1831	Douglas	1852
Pinus contorta Dougl. ex Loud.	NA	1853	Jeffrey	1910
Pinus nigra Arnold	E	1759	–	1840–7
Pseudotsuga menziesii (Mirb.) Franco	NA	1826–7	Douglas	1860s
Thuja plicata D.Don	NA	1853	Lobb	1876
Tsuga heterophylla (Raf.) Sarg.	NA	1851	Jeffrey	1860s
Other species of lower commercial importance				
Abies alba P. Mill.	E	1603	–	1790s
Abies amabilis Douglas	NA	1830	Douglas	1882
Chamaecyparis lawsoniana (A. Murr.) Parl.	NA	1854	Murray	–
Cryptomeria japonica (L. f.) D.Don	A	1842	Home	–
Picea engelmannii Parry ex Engelm.	NA	1864	–	–
Picea glauca (Moench) Voss	NA	1700	–	19th century
Picea omorika (Pani) Purkyne	E	1884	Frobel	1908
Pinus peuce Griseb.	E	1863	–	1950s
Pinus pinaster Soland. non Ait.	E	1596	–	17th–18th century
Pinus ponderosa P.&C. Lawson	NA	1827	Douglas	1940–50
Pinus radiata D.Don	NA	1833	Douglas	1850
Sequoia sempervirens (D.Don) Endl.	NA	1846	Hartweg	1856

† – = information not available
‡ NA = North America; E = Europe; A = Asia; HY = Hybrid

Seed origin and provenance research

Research on within species adaptive variation began in the 1920s and Forest Research (the research agency of the Forestry Commission, the government department responsible for forestry in Great Britain) has established over 400 trials since that time. General recommendations for the UK are given by Lines (1987). These have included all the conifer species listed in Table 1, together with others of very minor interest. Early work depended on availability of seed and on fruitful contact with other researchers or seed suppliers. Samples of seed were used in which there was often no knowledge of the exact location of the source, the population size or the sampling or collection methods. This resulted in trials often comprising a more opportunistic collection of origins rather than one organized on a range-wide basis. This situation improved from the late 1960s when the International Union of Forest Research Organizations (IUFRO) began to sponsor organized representative sampling of the natural range of a number of important commercial conifer species. IUFRO laid down standards in sampling the natural distribution, making seed collections and the design of evaluation trials. In particular, Forest Research played a major part in making collections of a number of North American species and in their evaluation across a major range of site types. Table 2 summarises provenance testing of the most important conifers.

Table 2. Summary of provenance testing in commercial conifers in Britain

Species	Series†	Sites‡	IUFRO§¶
Abies grandis (Dougl. ex D.Don) Lindl.	3	16	11
Abies procera Rehd.	2	11	10
Larix decidua P. Mill.	14	35	–
Larix kaempferi (Lam.) Carr.	7	14	–
Larix x *eurolepis* Henry	6	7	–
Picea abies (L.) Karst.	10	18	3
Picea sitchensis (Bong.) Carr.	13	53	20
Pinus contorta Dougl. ex Loud.	23	79	5
Pinus nigra Arnold	6	14	–
Pseudotsuga menziesii (Mirb.) Franco	8	21	5
Thuja plicata D.Don	1	4	–
Tsuga heterophylla (Raf.) Sarg.	4	17	–

† number of years in which a series of trials was planted
‡ total number of trials planted
§ number of trials using IUFRO collections
¶ – = IUFRO collections not made

Pacific north-west American species

Most of the species from this region which have been evaluated in Britain have extensive natural distributions, covering up to 20 degrees of latitude. In general it has been found that increased rates of growth in the UK are associated with the transfer of material from sources up to ten degrees south of those in which the UK lies. However, this advantage can only be exploited if attention is paid to climatic and site matching. This is illustrated in Figure 1 in which the mean performance of *Picea sitchensis* across two series of sites is compared (Samuel 1995). The British Isles have been drawn next to the Pacific north-west at their equivalent latitude and the performance of each origin is indicated as the percentage of the mean of all origins across the sites included. In Figure 1a, the sites plotted in Great Britain are those which are ecologically well-matched to those in which the species grows in its natural range. In Figure 1b, the site types lie outside those in which the species would occur.

In Figure 1a the sites are located on the western side of the country in which there is an oceanic climate with higher rainfall. Across these sites, the advantage of using more southerly origins from as far south as Oregon is clear. By contrast, in Figure 1b in which colder and drier site types are represented, the clinal relationship with latitude no longer exists; therefore, there are no clear advantages in the use of more southern sources, the best performance being found among origins from the Queen Charlotte Islands, off the coast of British Columbia.

Whilst this pattern has been shown in a number of species, factors other than growth rate need to be taken into account. For example, it has been found in *Pseudotsuga menziesii* that origins from as far south as Oregon, whilst having high growth rates, may have poorer survival with a heavy branching habit which would not produce good quality timber. Therefore, for this species and for *Abies grandis* (Dougl. ex D.Don) Lindl. (grand fir) the use of sources from further south than Washington would not be recommended. In *Pinus contorta*, clinal variation in growth rate with latitude is strongly inversely correlated with basal stem curvature, general stem form and heavy branching, causing serious vulnerability to the high wind profile encountered in Britain and to heavy snow falls. Within a further longitudinal cline across British Columbia in this species, sources with straight stem and fine branching characteristics which occur inland from the coastal distribution would be recommended, although some loss of fast growth potential would have to be accepted. In contrast to the more widely distributed species, there is much less evidence of clinal variation in *Abies procera* Rehd. (noble fir), which has a more limited distribution at higher altitudes in the Cascade Mountains in Washington and Oregon.

European species

A similar general pattern does not emerge from trials of the important European conifers. Sources of *Pinus sylvestris* native to Britain show superiority over continental sources (Worrell 1992) and commercial

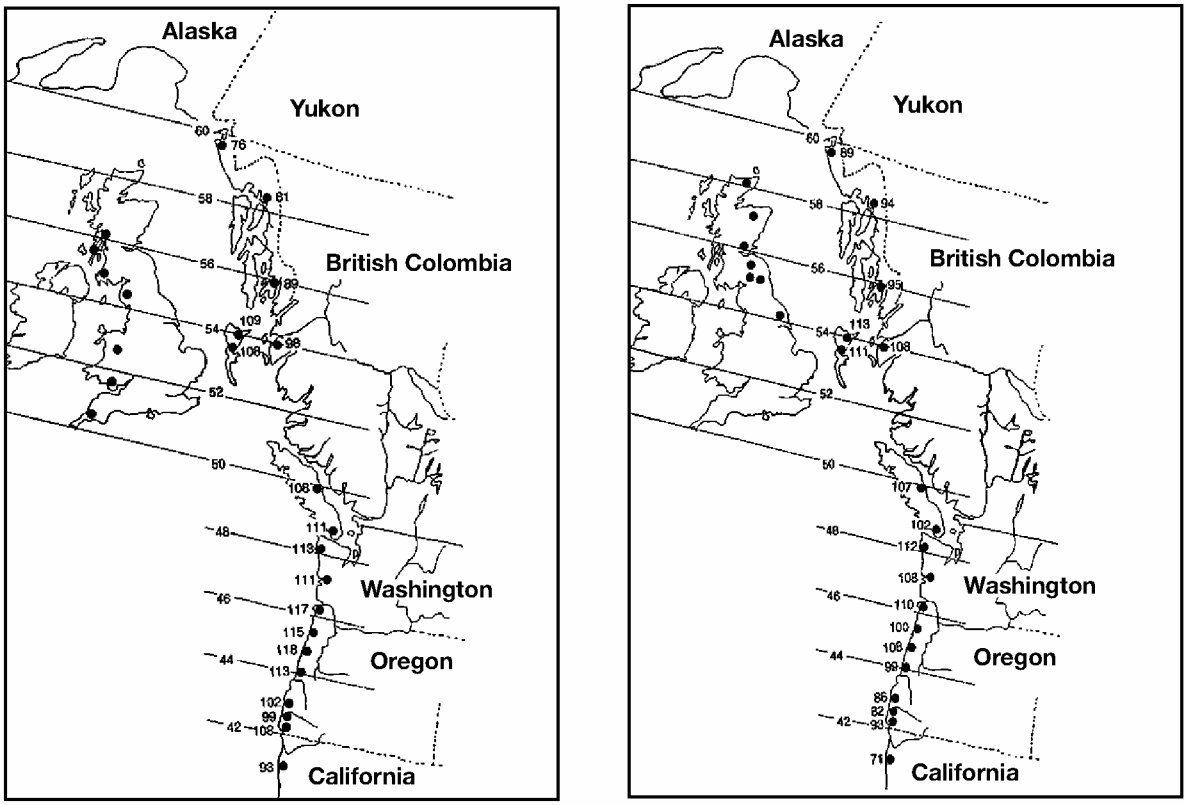

Figure 1. Comparison of mean height (expressed as a percentage of the overall mean of all origins at all sites) at 10 years of Sitka spruce, (*Picea sitchensis*) sources planted at 'on site' (Figure 1a, left) and 'off site' (Figure 1b, right) locations in Great Britain. The British Isles are shown at their equivalent latitude adjacent to the Pacific north-west coast of North America. Points in Great Britain indicate the locations of test sites. Points in N. America indicate the locations of the seed origins and relative height at 10 years is printed next to each origin location point. Figure 1a (left) shows origin performance in 'on site' locations favourable to the growth of Sitka spruce. Figure 1b (right) shows performance in 'off site' locations in which conditions would be less favourable.

plantations derive from selected stands in Britain or from seed orchards. *Pinus nigra* subsp. *laricio* (Poir.) Maire from Corsica has been found to be the best adapted source of this species for dry sites with light soils in Great Britain, whilst some eastern European sources of *Picea abies* (Carpathian mountains in Romania) and *Larix decidua* (Sudetan region of Poland) have proved to have the most superior growth rates.

Further adaptation in first generation transferred from the Pacific north-west to Europe

Seed origin trials of a number of North American species have included some material collected in phenotypically superior first generation stands growing in the Great Britain. For most of these, British sources have grown faster than most of those imported directly from the natural range, indicating that thinning management has favoured the best adapted individuals. For example, results of the IUFRO *Abies grandis* trials, in which diameter at breast height (DBH) was measured 15 years after planting revealed that a UK source of Vancouver Island origin grew 15% faster and a Danish source of Washington origin grew 6% faster than their equivalent IUFRO origins.

References and further reading

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