Alternative Spruces to Sitka and Norway

Part 2 - Oriental or Caucasian spruce (*Picea orientalis*), and the American and Asian spruces

Peter Savill, **Scott Wilson**, **Bill Mason**, **Richard Jinks**, **Victoria Stokes** and **Tom Christian** conclude their exploration of the genus Picea.

In the first part of this article looking at possible alternative species of spruce to the commonly grown *Picea sitchensis* (Sitka spruce) and *P. abies* (Norway spruce) we considered Serbian spruce (*Picea omorika*). (Part 1 appeared in the January 2017 *QJF*.)

Now we turn our attention to *Picea orientalis*, the Oriental or Caucasian spruce. In addition, we will also look at a range of other spruces that have previously been trialled in experimental plots in Britain. (For ease of reference we have repeated the tables published in Part 1.)

Distribution and ecology of Oriental or Caucasian spruce *Picea orientalis* (L.) Peterm.

Oriental spruce (*Picea orientalis*) is effectively the eastern equivalent of the European or Norway spruce, found in central Eurasia. The species is considered native to the mountains around the eastern end of the Black Sea, including the Central Greater Caucasus and the eastern ends of the Trialeti ridge on the Lesser Caucasus. These areas lie within Abkhazia, Georgia and north eastern Turkey (Farjon,

Table 1. Growth of selected sample plots of Serbian, Oriental and other spruces in different parts of Britain.

Species	Location	Age	Top height (m)	Cumulative basal area production (m^2ha^{-1})	Yield class (Local yield class) ($m^3ha^{-1}yr^{-1}$)
Serbian spruce	Bedgebury, Kent (plot 1170)	49	22.6	81.6	16
	Bedgebury, Kent (plot 1175)	49	23.1	92.1	16
	Thetford, East Anglia	49	18.5	75.7	14
	Brechfa, Carmarthenshire	45	22.0	70.8	16 (14)
	Forest of Deer, Aberdeenshire	48	14.3	103.0	8 (10)
	Newcastleton, Borders	57	18.0	87.8	10 (11)
	Glen Urquhart, Inverness	64	18.8	103.9	8 (12)
	Bennan, Galloway	73	27.0	118.3	12 (15)
Oriental spruce	Bedgebury, Kent	35	17.2	67.2	16 (19)
	Dawyck, Borders	53	19.7	93.8	10 (12)
Black spruce	Bedgebury, Kent	31	10.3	-	12
	Brechfa, Carmarthenshire	33	13.5	37.5	10 (9)
Red spruce	Bedgebury, Kent	39	16.7	48.6	16(17)
Englemann spruce	Bedgebury, Kent	32	16.7	37.2	18 (14)
Hondo spruce	Bedgebury, Kent	49	12.6	28.2	4

Figure 1. Natural distribution of Picea orientalis (Map: Vanezza Morales/RBGE)

1990; Kayacik, 1955). Oriental spruce can also be found in northern Iran, though its numbers there have decreased due to deforestation. The species does not exist in the south of Asia Minor, nor further west than the Melet River, and records from other areas are believed to be erroneous (Kayacik, 1955) (Figure 1).

Farjon (2013) states that it occurs in dark coniferous and mixed forests, primarily from 600 to 2100m a.s.l. and reaches its optimum development above 1200m. Its scarcity below 600m a.s.l. may be more connected with the influence of biotic factors (human interference, competition) than climatic and edaphic factors. The species' overall distribution, however, is determined mainly by climatic factors, e.g. restriction due to deficient rainfall and low atmospheric humidity. Kayacik (1955) includes some data on temperature, rainfall and humidity, and a sketch map. Westwards, oriental spruce also becomes limited by dense competitive forest dominated by *Fagus sylvatica* and *Abies nordmanniana*. It is hardy to Zone 5 (cold hardiness limit is between -28.8°C and -23.3°C) (Bannister and Neuner, 2001).

Oriental spruce usually grows on brown forest soils but it can also often be found on stony and rocky slopes and is generally considered undemanding of soils. It forms pure stands or is associated in mixed montane forests with *Abies nordmanniana*, *Pinus sylvestris*, and *Fagus sylvatica*. Oriental spruce-dominated forests may have various types of understorey, of which the Colchic type made up of evergreen shrubs and dwarf trees such as *Laurocerasus officinalis* (*Prunus laurocerasus*), *Ilex colchica*, *Buxus sempervirens*, *Taxus baccata* and *Rhododendron spp*. is particularly notable.

Figure 2. Oriental spruce at Bedgebury Pinetum, Kent. (Photo: Dr Scott Wilson)

Description and growth

Oriental spruce is a large coniferous evergreen tree growing to 30-45m tall (exceptionally to 57m), and with a typical breast height diameter of up to 1.5m (exceptionally up to 4m) (Figure 2).

The shoots are buff-brown, and moderately pubescent (hairy). The leaves are needle-like, 6-8mm long, rhombic in cross-section, dark green with inconspicuous stomatal lines. The cones are slender cylindric-conic, 5-9cm long and 1.5cm broad, red to purple when young, maturing dark brown 5-7 months after pollination, and have stiff, smoothly rounded scales. The comparative performance of oriental spruce with some other spruces at Kilmun Forest Garden in Argyll is given in Table 2 (see next page).

Table 2. Comparative performance of five different spruce species after 50-65 years at Kilmun Forest Garden Argyll.

Species	Age (years)	Top height (m)	Basal area (% of Norway spruce)	Yield class ($m^3ha^{-1}yr^{-1}$)
Norway spruce	62	28.1	100	18
Serbian spruce	62	29.0	112	18
Oriental spruce	62	28.1	143	18
Red spruce (*Picea rubens*)	61	25.8	103	16
Sakhalin spruce (*Picea glehnii*)	52	14.5	80	10

Silviculture

Much has been published on this species; most in the Turkish language. Urgenc (1960) presents tabular and graphical data on maturity of cones and seeds, after-ripening, seed production and collection, morphology of cones and seeds, conditions for germination, and seed quality. All the salient points are given in a six page English summary.

In a discussion on its silviculture Oksbjerg (1957) described the range and site requirements of oriental spruce and its growth in stands in Jutland and Germany, concluding that, while its increment pattern in general resembles that of Norway spruce, its height increment is less affected by good and bad seasons, and it is better suited to growth in shade.

Selective logging, agricultural land development and insect damage are the major threats to the species although they are not thought to be causing an overall decline. Oriental spruce occurs in a number of protected areas throughout its range, e.g. Meryemana Forest (Pontic Mts., Turkey), Kintrishi, Ritsa and Algeti Protected Areas (Georgia) and Teberda Nature Reserve (Russian Caucasus). Population monitoring including species based actions such as selective logging and trade management are needed.

Record and potential in Britain

As noted by Macdonald et al. (1957), although oriental spruce was introduced to Britain in the nineteenth century, there have been surprisingly few trials with this species. Forest Research records suggest that there have only been 18 experiments that include it and most of these have been established in the last few years. Records indicate that from 1920 to 1991 there were no imports of seed from the native range so that all mature stands found in British forests are almost certainly derived from home collections, from small Victorian and Edwardian ornamental plantings of potentially limited genetic diversity.

Although Macdonald et al. (1957) suggested that early growth in one trial plantation at Dawyck, at 200m a.s.l. in the Scottish Borders, was comparable with what would be expected from Norway spruce, there have been few other measurements of the long-term potential of this species. Subsequent data from this plot (Table 1) plus other data from a short-lived plot at Bedgebury show that growth rates are quite similar to that of Serbian spruce. A large plot established in 1940 in the Crarae Forest Garden, Argyll (Figure 3) is one of the best performing in that collection. More recent data from comparative plots of a range of species at Kilmun (Table 2) indicate that at Yield Class 18, oriental spruce had the highest production of a range of alternative spruce species. However, the comparative performance of Sitka spruce on this climatically moist site was equivalent to Yield Class 24.

Provenance

No provenance testing has been carried out in Britain and

there are few forest plots; seed should be sourced from the natural range (Forest Research, 2016). Seed collections from small British stands should be used with considerable caution due to the risk of an inherently narrow original genetic base.

Uses and trade

Oriental spruce is an important timber tree in the Caucasus, where it forms extensive pure stands, many of which are managed for production (Farjon, 2016). It has also been introduced as a plantation tree in countries in the eastern Mediterranean. The species is commonly grown as an amenity tree in parks and large gardens in many European countries and in the USA, favoured for its attractive foliage and ability to grow on a wide range of soils. A number of cultivars exist in the trade, among which are dwarf forms, forms with yellowish flushing leaves and those with 'mounding' habits.

Elsewhere it is grown to a small extent for Christmas trees, timber and paper production, though its slower growth compared to Norway spruce reduces its importance outside the native range.

Timber

Ramsay and Macdonald (2013) give some limited data on the performance of small clear samples from mature wood of four old trees in Turkey. The specific gravity is quoted as 0.52. This is much higher than Norway spruce at 0.35 but may be an artefact of the sampling method used. The wood is most likely to be comparable to that of Norway spruce, and is used for similar purposes. Among these are construction, flooring, carpentry, furniture manufacture and parts of musical instruments.

Figure 3. Oriental spruce at Crarae Forest Garden, Argyll [age 73 years; P40]. (Photo: Dr Scott Wilson)

Threats

There have been several outbreaks of the great spruce bark beetle, *Dendroctonus micans*, which have killed millions of trees in the Black Sea Region of Turkey since its discovery in 1966. Besides wounded and overthrown trees, apparently healthy trees are also attacked by the beetle, usually indicated by resin bleeding (see Figure 4). In infested stands repeatedly attacked trees and unattacked trees or trees with aborted attacks have been reported. Alkan-Aknc and Ersen-Bak (2016) investigated the role of some tree vigour parameters in the beetle's successful establishment on its host. They found that *D. micans* females became established more often on trees with thicker phloems and on vigorously-growing trees. Stressed or destroyed vigorous trees may produce epidemic populations in stands.

Trees are sometimes defoliated by *Rhizosphaera kalkhoffii* (Wilson and Waldie, 1926), in common with most other spruces and many species of pine. The disease is transmitted by splash-borne conidia (Diamandis and Minter, 1980).

Figure 4. Resin bleeds from Dendroctonus micans damage on oriental spruce at Alice Holt. (Photo: Dr Richard Jinks)

With the increase in global warming oriental spruce forests started to experience serious bark beetle problems. More than 200,000 trees died in the native range recently due to bark beetle attack. Tufekcioglu et al. (2008) reviewed existing literature to assess the current status of the spruce stands and concluded that climate change could significantly influence distribution, diversity, structure and stability of oriental spruce ecosystems.

Place in British forestry

Given the likelihood of increased occurrence of drought in parts of eastern Britain, it is possible that this species could be used as an alternative spruce on sites where projections using ESC (Pyatt et al., 2000) suggest that Sitka spruce may become 'marginal' or 'unsuitable'. Limited evidence also suggests that oriental spruce may also be better suited to such sites than Norway spruce. Its reported ability to tolerate shade suggests that it may also have a role where conversion to continuous cover forestry is being considered. However, the limited experience to date suggests that, for the immediate future, any further planting should be on an operational trial basis, with considerable attention being paid to obtaining material from provenances from the native range of the species. There is a need for further research comparing the yield performance of oriental and Norway spruces on equivalent site types.

Other minor spruces

According to Macdonald et al. (1957), a variety of other spruce species have been trialled in Britain at one time or another. Most have been deployed only on a small scale, including the following:

North American spruces

White spruce (*Picea glauca*) is widely distributed across North America (Figure 5b) and has been planted in Britain since around 1700. Its tolerance of exposed conditions meant that it was sometimes planted in exposed sites partly to provide shelter (Macdonald et al., 1957). There have been 37 experiments that have included this species, most of which date from the 1950s (Forest Research, unpublished data). The much superior growth of Sitka spruce on most of these sites has meant that white spruce has been little planted in recent decades. However, natural hybrids between Sitka and white spruces (*Picea* x *lutzii*) are found where the natural ranges of these species overlap in Alaska, and these hybrids are reported to show greater hardiness and resistance to pests. Therefore, there has been interest in crossing these two species to create artificial F1 hybrids that could be planted on sites that are at risk from frost or drought.

Three experiments established by Forest Research in northern England and Scotland in 1987 compared 63 *Picea* x *lutzii* hybrids with Sitka spruce (QCI), white spruce and Engelmann spruce. At all three sites the mean survival and growth of *Picea* x *lutzii* hybrids was comparable with that of

the Sitka spruce control 29 years after planting. At Speyside, the driest of the three sites (mean annual rainfall of 800mm), mean survival of the hybrids was marginally higher than that of the Sitka spruce control (97.2% compared to 95.8%). Mean DBH of all trees and height of the largest DBH tree per plot were 11.4cm and 12.1m, compared to 14.5cm and 12.8m for the QCI Sitka spruce control. At Shin and Spadeadam, the wetter and more exposed sites in northern Scotland and northern England respectively, *Picea* x *lutzii* had lower mean DBH of 9.3 and 16.4cm respectively, compared to 10.9 and 19.8cm for Sitka spruce at Shin and Spadeadam respectively. However, at Shin *Picea* x *lutzii* achieved a greater height than Sitka spruce.

At all sites there were differences in performance between the 63 hybrids and the best hybrids performed as well as Sitka spruce on each site; statistical analysis is ongoing and a full report will be available shortly. The performance of white spruce and Engelmann spruce at all three sites was very poor by comparison.

Englemann spruce (*Picea engelmannii*) is native to western North America (see Figure 5a), where it can be found in higher elevation forests ranging from British Columbia to California and as far south as Arizona. In the northern part of the range it appears to hybridize with white spruce. There have been about 30 Forest Research trials with the species in Britain including a series of provenance trials and comparative species experiments both established in the 1980s. These give little suggestion of much promise under British conditions or to change previous conclusions that it is "slow growing […] and liable to be damaged by frost" (Macdonald et al., 1957). Thus, in five experiments in northern England and Scotland its growth after 15-25 years was about 40-80% of that achieved by Sitka spruce on the same site.

Black spruce (*Picea mariana*) is widespread across boreal Canada, Alaska and parts of the north-eastern USA (see Figure 5c). It grows naturally on a range of site types

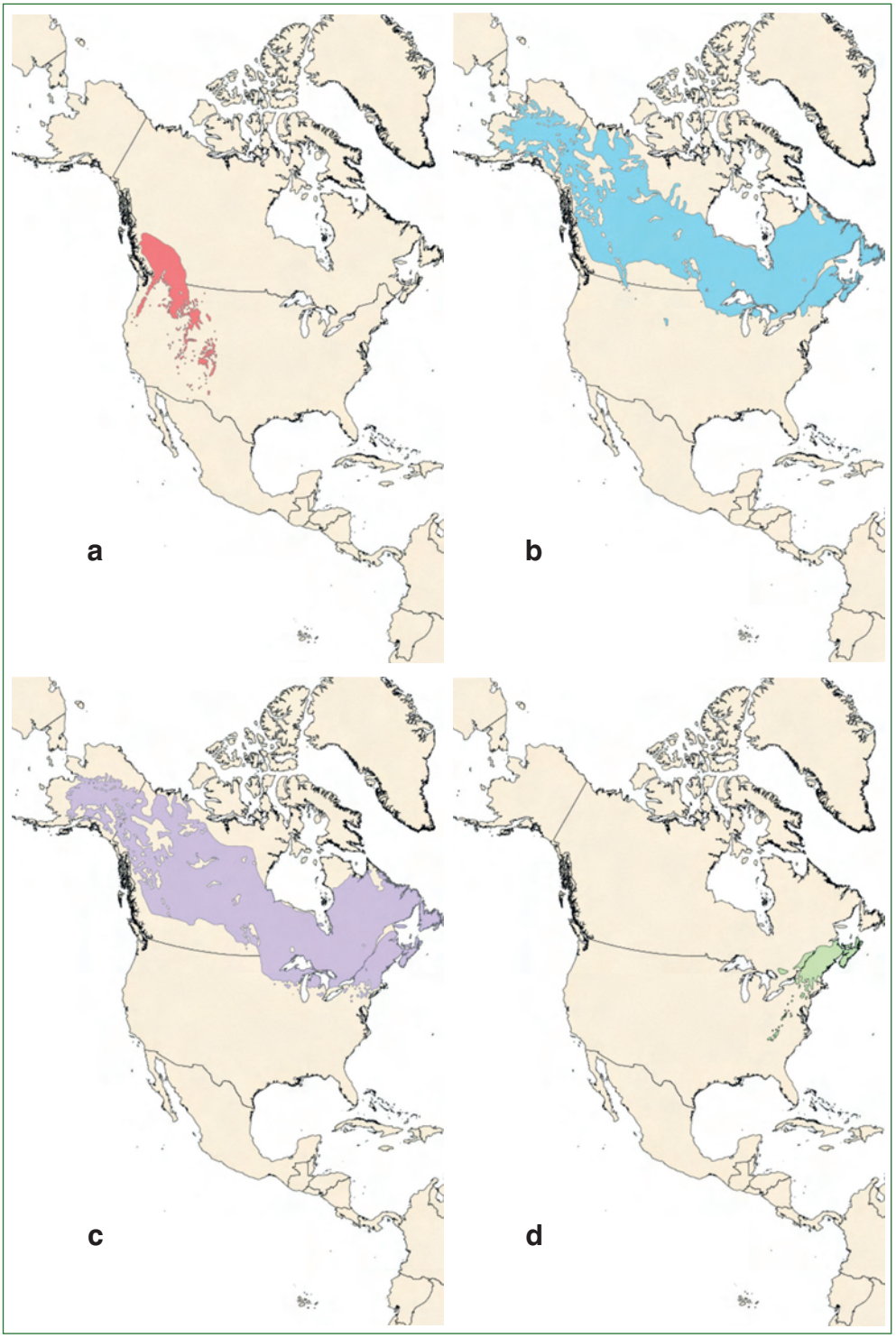

Figure 5. Range maps for a) Picea engelmannii, b) P. glauca, c) P. mariana, and d) P. rubens. (Source: U.S. Geological Survey, 1999)

Figure 6. Red spruce (Picea rubens) age 75 years, P38 at Crarae Forest Garden, Argyll. (Photo: Dr Scott Wilson)

including wet peaty bogs and is a major timber species in parts of eastern Canada. The species has also been planted on a limited scale in Sweden and other Nordic countries, particularly on low lying wet soils where the late flushing habit can make it a viable alternative to Norway spruce. There have been very few research trials with this species in Britain with only four experiments recorded in the Forest Research records – the plot in Kilmun was in poor health at the last assessment in 2015. The general impression (see Table 1) is of a relatively slow growing species that appears to have little advantage over other spruce species for British conditions.

Red spruce (*Picea rubens*) occurs in the north-eastern parts of North America from the maritime provinces of Canada as far south as the Applachian Mountains (see Figure 5d), where it is said to be adapted to a cool, moist climate. Although it was introduced to Britain over 200 years ago, it appears to have been little planted in British forests (Macdonald et al., 1957) and Forest Research records suggest that it has only been planted in 11 experiments. A trial plot in the Crarae Forest Garden, Argyll, established in 1938, grew rather well but has been extensively windblown in recent years (see Figure 6). Such growth data as are available (Tables 1, 2) suggest that its performance might be similar to that of Serbian or oriental spruce, but further long-term trials would be desirable to confirm this.

Asian spruces

Sakhalin spruce (*Picea glehnii*) is found in northern Japan (see Figure 7) and parts of the Russian far-east. The species grows naturally in cold, moist maritime environments and is reported to withstand exposure well. There has been very little experimental work with this species in Britain with only one trial recorded on the Forest Research database. A plot in the Crarae Forest Garden, Argyll, established in 1937, showed straight stem form but relatively slow growth rates (see Figure 8). The plot at Kilmun (Table 2) is healthy but the growth rate and productivity is not striking. Of 20 spruce species studied in Britain *P. glehnii* is reported by Nichols (1987) to be the least favoured by the aphid *Elatobium abietinum*. Asian spruces in general were attacked far less than North American species.

Jezo spruce (*Picea jezoensis*) is native to Japan, north eastern China and the far-east of Russia (see Figure 7) where it is found in cool, moist temperate forests. Two races are often distinguished with the 'Hondo' spruce variety that is native to central Japan seemingly being less frost sensitive than the type variety (Macdonald et al., 1957). However, growth of this variety appears to be quite slow, at least in the south-east of England (Table 1). There have been only four experiments with this species recorded by Forest Research and none since the 1930s. Two surviving plots at Kilmun and

Brechfa are healthy but do not give any evidence of high growth rates or of good productivity (see Figure 9).

Likiang spruce (*Picea likiangensis*) is native to Bhutan and China (Figure 7). Although widely planted in arboreta and tree collections, it appears to suffer from frost in the early years and subsequent growth has not been striking (Macdonald et al., 1957). There have only been two experiments including this species, while growth in the one plot at Kilmun is not impressive after 50 years although the trees are healthy. A small group of surviving trees in the Crarae Forest Garden, Argyll, planted in 1936, show poor vigour (Figure 10).

Conclusions

A considerable number of spruce species have been tested in Britain over the last 100 years and there is little evidence that any are likely to outperform Sitka spruce in the oceanic climate of western and northern Britain. The areas of uncertainty are probably in the more eastern parts of Britain and/or on those soils where moisture stress and drought may become more serious with the impact of climate change. On such sites Sitka spruce may be increasingly at risk of die-back, death or timber degrade, and there could be interest in testing other spruces that are more suited to such environments. On present evidence,

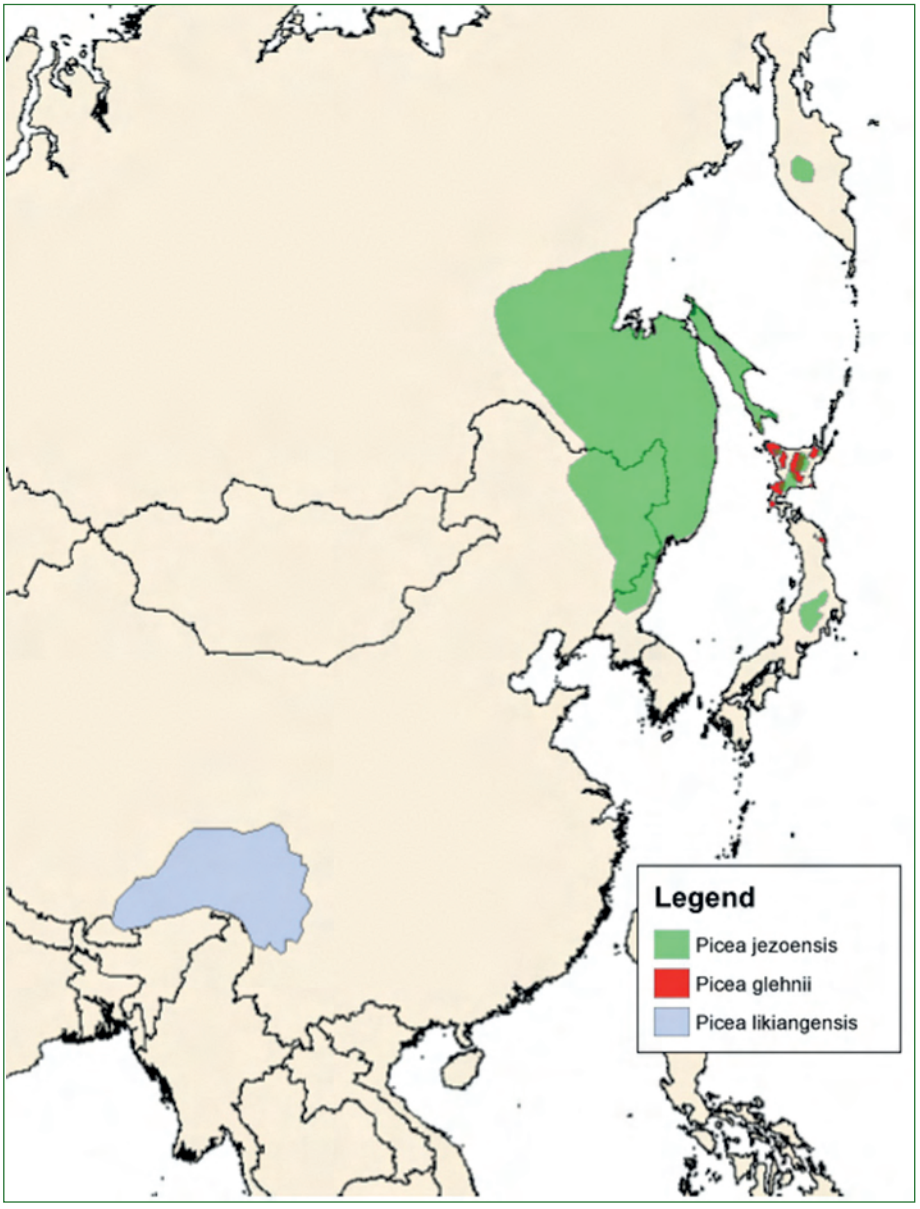

Figure 7. Range map for Picea jezoensis, P. glehnii and P. likiangensis. (Redrawn from Debreczy and Rácz, 2011)

Figure 8. Sakhalin spruce (Picea glehnii) at Crarae Forest Garden, Argyll [age 76 years; P37]. (Photo: Dr Scott Wilson)

Figure 9. Jezo (Picea jezoensis) spruce at Bedgebury Arboretum, Kent (age believed to be c.49 years). (Photo: Dr Scott Wilson)

Norway, Serbian and oriental spruces appear to be the species most likely to be suited for this role, although their deployment is likely to result in some decline in productivity. An alternative approach could be to attempt to create hybrids between Sitka spruce and some of the more drought tolerant spruces with a view to vegetative propagation of any hybrid lines with superior water-use efficiencies and to deploy these on more demanding, drought sensitive sites.

Acknowledgements

We are grateful to Ian Craig of Forest Research, Alice Holt for providing data from the various sample plots that had been established with spruce species in Britain. Stephen Bathgate kindly provided recent information on the area of Serbian spruce found in public forests and Steve Lee clarified an obscure point of genetics for us. The assessment of experiments with *Picea* x *lutzii* hybrids was supported by Forest Enterprise England. Photographic records from the Crarae Forest Garden, Argyll were obtained during a survey by Dr Scott McG. Wilson, funded by the National Tree Collections of Scotland in 2013.

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Figure 10. Likiang spruce (Picea likiangensis) at Crarae Forest Garden, Argyll (age 77 years; P36). (Photo: Dr Scott Wilson)

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Dr Peter Savill, since retiring from Oxford University in 2006, has been working as a trustee of three charities: Woodland Heritage, the Future Trees Trust and the Sylva Foundation. He has also written *The Silviculture of Trees used in British Forestry* (CABI, 2013) and edited *Wytham Woods - Oxford's Ecological Laboratory* (OUP, 2010).

Dr Scott McG. Wilson is an independent Chartered Forester and Chartered Surveyor based in Aberdeen, Scotland whose applied research interests include selection of optimum species and silvicultural systems to realize multiple benefits from British forests.

Dr Bill Mason was a silvicultural researcher at the Northern Research Station near Edinburgh for three decades before retiring in 2012. He is now a Research Fellow of Forest Research, is involved in EU COS Actions on 'Mixed Forests' and 'Non-Native Species' and is the current Chair of the Continuous Cover Forestry Group (CCFG).

Dr Richard Jinks is a project leader in the Centre for Sustainable Forestry and Climate Change, Forest Research, and is based at the Alice Holt Research Station in Surrey. He works on several research projects, including investigating potential species and provenances that might be useful for helping forests adapt to climate change.

Dr Victoria Stokes is a silvicultural researcher in the Forest Management Science Group at Forest Research. She is based at the Northern Research Station, near Edinburgh. Her main areas of research are upland silviculture, management of resilient forests and long-term experiments.

Tom Christian coordinates the National Tree Collections of Scotland initiative and is based at the Royal Botanic Garden Edinburgh. Since graduating in 2008 he has worked closely with the International Conifer Conservation Programme, travelling extensively on collaborative fieldwork overseas and throughout Great Britain and Ireland. In 2015 he became a Trustee of Woodland Heritage.