Forest Research

New Breeding Plans

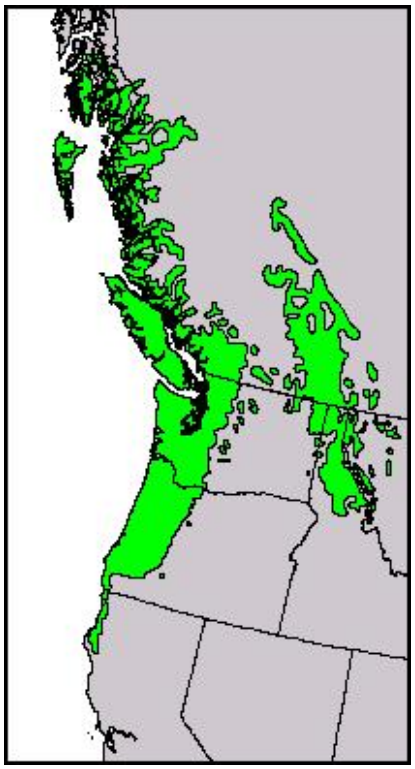
Western Red Cedar	*Thuja plicata*
Western Hemlock	*Tsuga heterophylla*
European Silver Fir	*Abies alba*
Japanese Red Cedar	*Cryptomeria japonica*
Coast Redwood	*Sequoia sempervirens*
Noble Fir	*Abies procera*
Serbian spruce	*Picea omorika*
Macedonian pine	*Pinus peuce*
Oriental spruce	*Picea orientalis*
Norway spruce	*Picea abies*

Steve Lee, FR

The Research Agency of the
Forestry Commission

Thuja plicata

General Introduction



Native to the Pacific north-west of America with a wide range from Alaska to California and also inland to the Cascade Mountains. A shade tolerant species with good vigour and volume production, although early growth can be slow. Best suited to more humid regions with an annual rainfall of > 800 mm. Cold hardy throughout Britain, moderately frost tolerant, does not withstand exposure, but is moderately drought tolerant. Vulnerable to fungal attack in nurseries (Keithia blight; *Didymascella thujina)* which historically has restricted planting stock availability. Grows best on medium to very rich soils with fresh to moist soil moisture but will tolerate calcareous soils if grown under light shelter. Not suited to very poor or very dry soils; will grow on gleys and occurs on some peat soils in its natural range. Can be grown in mixture with a range of conifer and broadleaved species

Markedly susceptible to *Armillaria* (honey fungus) as a cause of decay and death, and to *Heterobasidion* (Fomes root and butt rot). Cypress aphid (*Cinara cupressivora*) is a not uncommon cause of foliage browning on western red cedar.

Currently a minor species in Britain, but may find an expanded role as a means of diversifying upland conifer forests as an adaptation to projected climate change.

Provenance choice

There are limited provenance trials for WRC in Britain. The most optimal origin for most of Britain is thought to be the Olympic Mountains of Washington (US Zone 221) below

150m in elevation; next best is seed sources from Vancouver Island such as Ladysmith (BC Zone 1020). There is an advanced breeding programme for WRC in British Columbia where we have good tree breeding contacts. There is the opportunity for research co-operation including exchange of material, and purchase of seed from their seed orchards.

Five registered seed stands in Britain: (i) Balgownie (NS984881) (ii) Barhill (NS713764), (iii) Darnaway Estate (NH993506), (iv) Burwarton Estate (SO609864) and (v) Bridgenorth Burwarton Estate (SO609864) amounting to nearly 6 hectares.

There are 76 stands identified in the 'Silvifuture' database; 33 identified in Scotland amounting to 38 hectares. Balance of stands are in Wales – nothing from SE England.

Forest Research has 49 plus trees selected from the 19050s still growing in a clonal archive at Alice Holt. These trees along with other selections made in a few other key stands could be used to create a landrace. Representatives could be established in a clonal or even seedling orchard. Harvested seed could be tested against material imported from Vancouver Island.

WRC is one of the few species which is easy to propagate using cuttings. Clonal trials are used extensively in BC, Canada. There is the possibility of establishing clonal breeding orchards using rooted cuttings whilst running clonal trials in parallel. The poorer cuttings could be thinned out in time leaving a tested clonal seed orchard.

Further Reading

http://www.forestry.gov.uk/fr/infd-8cyk64

http://www.silvifuture.org.uk/database.php?species=57 : 76 records listed.

Forest Research

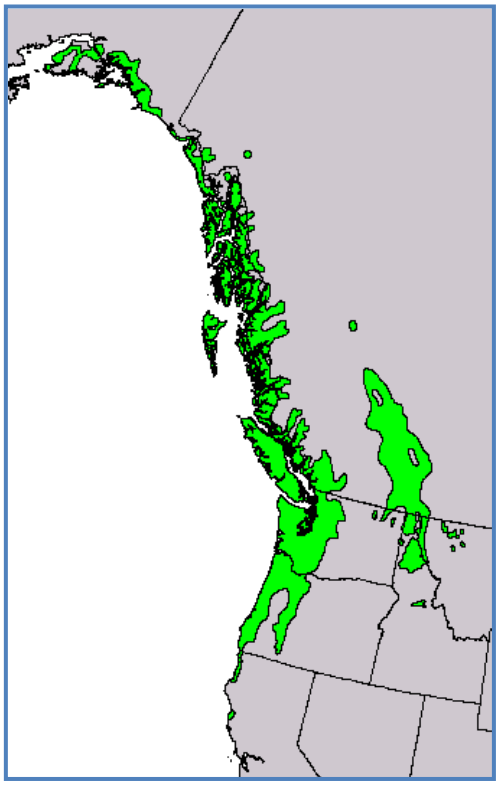
Western Red Cedar (WRC)

Summary:

We do not know the best origins	
We do know where to source the best origins Slim evidence	√
Other organisations are breeding this species & origin Breeding of same origins by Canada	√
We could create a UK land-race We could select superior individuals in stands around the country	√
We already have some seed stands There are some seed stands	√
We already have some plus trees 49 plus trees select already	√
We could create seed orchards Possible using the available plus trees + other selections	√
Further field testing possible but not worthwhile?	
Further field testing may be worthwhile Expensive; 10 years to get results. Roots easily; clonal forestry possible	√

Tsuga heterophylla

General Introduction



Native to the Pacific north-west of America with a wide range from Alaska to California. A shade tolerant species best suited to moister climates in Britain with >1000 mm rainfall. It has rapid growth and high volume production on suitable sites and regenerates freely in a wide range of upland forests. It is cold hardy throughout Britain, but is very sensitive to late frosts, does not tolerate exposure and is drought sensitive. As a consequence trees are often of poor form (e.g. multi-stemmed). These factors mean that it should not be used for afforestation of open ground, but it can be planted under light shade. Although it suffers from heather competition, it will grow on soils of very poor to medium nutrient status and of slightly dry to moist soil moisture. Not suited to peats or very dry soils. Best growth will be found on acid brown earths on lower valley sides in upland forests. Can grow in mixture with other conifers such as Sitka spruce and Douglas fir.

Largely free of major pathogens, western hemlock is nonetheless considered highly susceptible to *Heterobasidion* (Fomes root and butt rot).

Problems with fluting in the bole of the tree. Also favored for grazing and bark stripping by deer.

Provenance choice

Provenances from Vancouver Island are recommended, although more southerly origins could be used on sheltered sites with low frost risk.

We do have 3 provenance trails in GB, and an idea of the best provenances for most of Britain which is Courtenay (BC Region 1020) on Vancouver Island, BC, Canada. Dry sheltered sites in south and east of England benefit from Camano Island (Washington, USA; Region 212).

Western Hemlock is widely planted in GB. There are currently 2 seed stands (5.4 ha) located at Galloway and Nairn. There is scope for finding more seed stands within the RoP that intend to plant more of the species in the future.

There are just 14 entries in the Silvifuture database, all in Scotland.

Interrogation of the NFE in Scotland finds 160 stands greater than 1 hectare amounting to a total of 311 hectares.

Large stand (50 – 80 hectares) at Novar; need to find others further south. There must be decent stands in England and Wales.

38 plus trees were selected by Forest Research in the 1960s, but never grafted. These must now be assumed lost although we do know there original locations (mainly in Scotland).

New plus trees could be selected in stands across the country and placed in untested clonal seed orchards. Selection criteria would be growth rate, stem form, and lack of fluting.

Scope for contacting tree breeders in Vancouver Island and Washington State for exchange and testing of material; they have been alerted. There are orchards in Canada we may be able to get access to.

Juvenile Western Hemlock cuttings root very easily; there could be scope for using this property to deploy cuttings material (supply of plants in years with poor flowering) or test selections (clonal trials). Both these options involve additional expense and will depend on demand.

Seed orchards flower early and heavy seed production is common.

Data from PNW suggest low heritability for most traits. Genetic gains are hard to achieve.

Further Reading:

http://www.forestry.gov.uk/website/forestresearch.nsf/byunique/INFD-8CYK4Xhttp://www.silvifuture.org.uk/species.php?species=79

Summary:

We do not know the best origins	
We do know where to source the best origins Some evidence.	√
Other organisations are breeding this species +origin Breeding of same origins by Canada	√
We could create a UK land-race We could select superior individuals in stands around the country	√
We already have some seed stands These could be added to	√
We already have some plus trees 38 Plus trees select in 1960/70s; none grafted. More could be selected	√
We could create seed orchards Possible using the new selected plus trees	√
Further field testing possible but not worthwhile? Very expensive; 20 years to get results	√
Further field testing may be worthwhile Doubt it. Depends on demand.	

Abies alba Mill.

General Introduction

Native to the mountains of central and southern Europe. A shade tolerant species which grows slowly for a number of years. Suited to the uplands and other cooler areas of Britain receiving over 1,000 mm rainfall evenly distributed across the year. Cold hardy throughout Britain, but vulnerable to frost unless planted under shelter, is sensitive to exposure and drought. Suited to soils of poor to medium nutrient status with fresh to moist soil moisture. Can grow on deep soils over limestone and other calcareous substrates. Does not tolerate very poor soils or heather competition and should not be planted on peats or very dry soils.

European Silver fir tends to be infected by a wide variety of rust fungi in its native range, although few of them are of any practical importance. Recent studies suggest it is resistant to *Heterobasidion* (Fomes root and butt rot) and risks of damage caused by the woolly aphid may have been overstated. Occasionally Phytophthora root infections are reported, particularly in nursery trees. Could find an increasing role as a shade tolerant component of Continuous Cover Forestry stand with an over-storey to protect from frost. Suffers from aphid infestations such as *Dreyfus*i (*Adelges*) *nusslini*, which causes shoot distortion, and balsam wooly aphid, which can cause dieback with severe infestations.

Favoured by deer.

Provenance choice

Recent paper by Kerr *et al* (2015) following analysis of 46-year data in provenance trials replicated across a range of sites in Britain found the best provenances (in priority order): (1) from Calabria (the 'toe' of Italy) at 1,100 m or more above sea level; (2) Austria and Czech republic at a similar altitude; (3) from any areas within the natural range of *A. alba* in Europe where improved seed is available from seed orchards. There was no evidence to select different provenances according to the site in Britain.

There is no breeding programme in Italy and no plus trees or seed orchards, but they do have seed stands scattered around the country. Contact has been made with Italian tree breeders who are keen to cooperate in some manner.

There are 23 records in the 'Silvifuture' database. Evidence from Kerr *et al* would tend to suggest that a British landrace would perform well compared to imported material.

It is suggested a group of better quality trees (50 – 100) are selected in established stands around the country and brought together to create an untested seed orchard. As a precaution, micro-satellites can be used to avoid co-ancestry of selected trees in an orchard.

Further Reading:

http://www.forestry.gov.uk/fr/beeh-9tkpet paper by Kerr, Stokes, Peace and Jinks (2015)

http://www.euforgen.org/fileadmin/bioversity/publications/pdfs/EUFORGEN/925_Technical_guidelines_for_genetic_conservation_and_use_for_for_silver_fir__Abies_alba_.pdf

http://www.silvifuture.org.uk/species.php?species=22

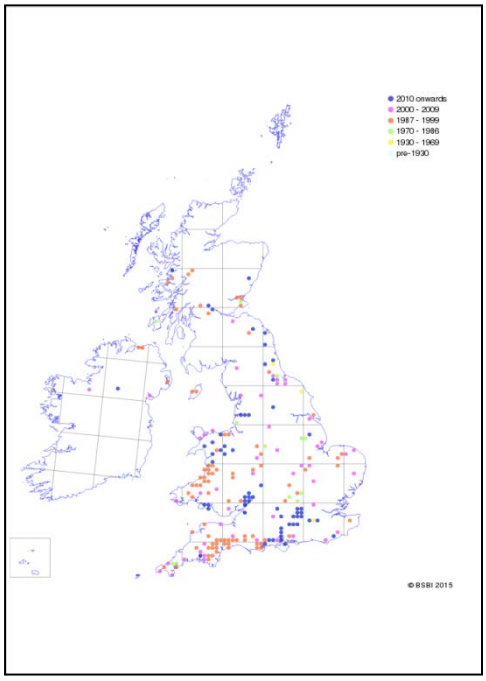
http://www.forestry.gov.uk/website/forestresearch.nsf/byunique/INFD-8CYJZF

Summary:

We do not know the best origins **There are NO provenance trails for the species**	
We do know where to source the best origins	√
Other organisations are breeding this species +origin **Not thought to be breeding in Italy. Seed stands available.**	√
We could create a UK land-race **YES. Select superior individuals in stands around the country**	√
We already have some seed stands	
We already have some plus trees	
We could create seed orchards **Possible using new selections**	√
Further field testing possible but not worthwhile?	
Further field testing may be worthwhile	

Cryptomeria japonica

General Introduction



Japanese Red Cedar a.k. *Sugi* (meaning straight tree) is native to the central and southern islands of Japan where it is a major timber species, as well as parts of China.

Adapted to a warm maritime climate, best growth in Britain is to be found in areas with >1200 mm annual rainfall. The need for warm growing conditions means that the best stands are to be found in Wales or south-western England where the species can be a very high volume producer. Best growth is on soils of poor to rich soil nutrient status and slightly dry to moist. It is not suited to very poor or dry soils, to peats or to alkaline soils. This is a high quality timber species which can be highly productive on the right sites. Pruning is an important component of management regimes in Japan. A very shade tolerant species which is moderately resistant to exposure although the crowns can be liable to snow break

It is susceptible to *Phytophthora* root disease, including *P. cinnamomi*. It is also considered to be susceptible to *Armillaria* root rot (honey fungus). Elsewhere, it has been reported to be affected by Juniper blight (*Phomopsis juniperovora*) which is present in Britain and already widespread on juniper.

Climate warming should increase the range of sites where the species will grow well such as in western Scotland.

(NB: Couldn't find a native distribution map on-line. Map of individual trees in Britain located at On-line Atlas of the British and Irish Flora)

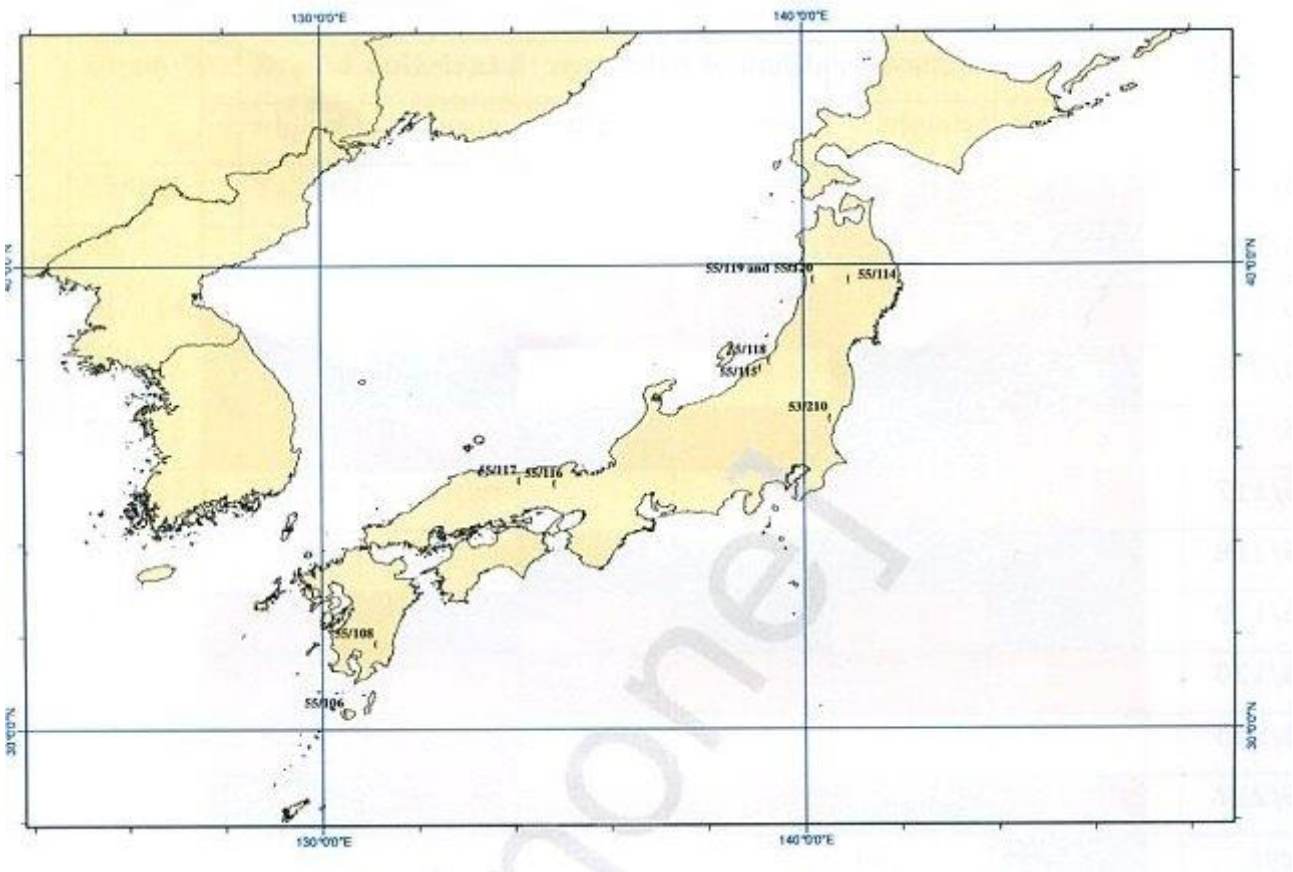
Provenance choice

Japanese Red Cedar has been imported to Britain since mid-1800s. Specimen trees are often large in private gardens and estates. Known to root easily which may be an advantage for clonal trails and establishment of clonal seed orchards. Seed from nine origins in Japan were Included in a trial at Gylnn (Cornwall). There have also been a few plantings in species trials e.g. Plym (Exeter) and Kilmun (Western Scotland) where it looks impressive. A review of the Glynn trial and Kilmun performance was recently reported by Kerr & Jinks of Forest Research as commissioned by FC(E).

Their report is attached here:

Seed origins of JCR and RSQ 24Mar16 FIF

Figure 1 from the Kerr & Jinks report of map indicating location of provenances under test:



The Kerr & Jinks conclusion was that YC20 was quite possible and that seed origins from mid-latitudes of Honshu (34–38°N) are probably best suited to Britain based on the limited information available.

The species tends not to be planted as stands, but individual trees. If stands could be found individual trees might be selected to form a landrace and a seed orchard, or cuttings hedge. The 'Silvifuture' database suggests 26 stands recorded – varying in size from 0.2ha to 2.5 hectares.

Selection of 50 trees across these stands would allow a seed orchard to be created; more would be better. We would check for diversity between trees and the risk of selecting related trees using micro-satellites.

1. There has been a *Sugi* tree breeding programme in Japan since the late 1950s. Over 3,000 plus trees have been selected and tested. Most of the clonal forestry is practised in the sub-tropical south of Japan.

2. I have made contact with tree breeders in northern Japan (Aomori Prefecture; 41°N) and they have agreed to send seed from their seed orchard for research testing in Britain. Christie-Elite have also obtained (improved) forestry material from Northern Japan. I am checking to find out if it's the same material now being offered to me.

There are currently no British seed stands or plus trees.

INRA (France) are also interested in developing this species and I have spoken with J-C Bastien (Orleans) about combining efforts but they are likely to be interested in more southerly origins.

Further reading:

http://www.forestry.gov.uk/fr/infd-8cyk78

http://www.silvifuture.org.uk/species.php?species=56

26 records listed; mainly in oceanic areas.

7 compartments listed in FC(S); largest is 2.4 hectares in Inverawe

Comments on 'Silvifuture' suggest great interest in this species.

Summary:

We do not know the best origins **There is just 1 provenance trails for the species**	√
We do know where to source the best origins **Maybe**	
Other organisations are breeding this species +origin **Yes, in Japan. We could source material for testing in GB**	√
We could create a UK land-race **Outside possibility if a few stands could be found around the country**	√
We already have some seed stands	
We already have some plus trees	
We could create seed orchards **Or indeed, cuttings orchards using best trees from landrace**	√
Further field testing possible but not worthwhile? **Too expensive for the small planting taking place**	
Further field testing may be worthwhile	

Sequoia sempervirens

General Introduction

Native to the coastal zones of central and northern California. A shade tolerant species with rapid early growth and high volume production on suitable sites. Naturally occurs in a mild climate with frequent summer fogs; currently probably best suited to Wales and south-west England in areas with more than 1,250 mm rainfall although it will grow in eastern Britain on suitable soils.

May not be fully cold hardy in Britain; is sensitive to late frosts; does not withstand exposure and is not drought tolerant. Best growth is on poor to medium soils of fresh or moist soil moisture status. Is not suited to heavier gleys, peats or very poor dry soils. Regenerates from seed or sprouts from cut stumps.

This is a species that could be grown more widely in Britain with climate warming, not least because it produces a high quality timber

No insect pests or diseases of major concern are noted for the coast redwood. In its native range it is commonly reported to have fewer foliar pathogens than any other major tree species. *Phytophthora ramorum* has been reported to infect foliage of coast redwood

Provenance choice

Very limited provenance testing has been carried out in Britain. Replicated trials of 11 seed origins were planted in Devon (Experiment: Plym 3). Demonstrations exist at Alice

Holt 147 and Alton 24. A review of provenances was carried out recently by Kerr & Jinks of Forest Research on behalf of FC (E). Link to report presented here:

Seed origins of JCR and RSQ 24Mar16 FI

They concluded southerly origins (south of San Francisco Bay) should be avoided. Others suggest more northerly provenances are likely to be more cold-hardy.

Large seed stand (7.3 hectares) are located at Welshpool, Dartington (SE England) and Longleat. There are just 21 records in the 'SiviFuture' database and 4 stands in Scotland all less than 1 hectare in size.

Forest Research received rooted cuttings from 10 plus trees located towards the northern end of the distribution range in California. It is thought that between 120 and 180 plus trees were selected over the entire range by highly respected US tree breeder Bill Libby as part of the '*International Redwood Provenance Test'*. The 10-trees donated to Britain are growing well at Bedgebury and Westonbirt. Larger sample at Limoges, France (AFOCEL a.k.a. FCBA) and perhaps New Zealand. Contact made with France who is willing to cooperate with further testing. Early results written up as JE Keuser report with limited data.

Contact has been made with new tree breeder Dr. Colleen Spurlock at University of California, Davis regarding future co-operation and further testing of representatives from a larger number of plus trees.

Best zone for Europe is thought to be Northern California around Humbolt County. Epicormic roots can be induced by making cuts into the stem, which lends the species to a clonal testing programme.

Trees sourced by Colin McLean (deceased), imported by Forestart and raised by Alba; were recently planted under the *iConic* initiative in Perthshire.

There are also trees in the 'Reinfforce' trials on unknown origin.

There does seem to be localised interest in coast redwood and there are two options of taking this forward for modest cost, which could be combined at a later date:

i. Look for good phenotypes in existing stands and form a landrace. Test for diversity and co-linearity.
ii. Re-source and propagate as many of the Bill Libby clones as possible; particularly those which came from the Humbolt County area.

Trees could be brought together as a hedging orchard.

Further reading

http://www.redwoodworld.co.uk/locations.htm

http://www.forestry.gov.uk/fr/infd-8cyke9

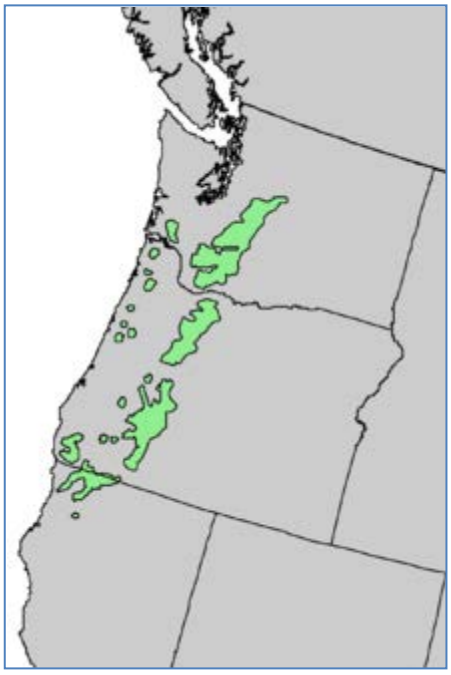
http://www.silvifuture.org.uk/species.php?species=58 - 21 records in the database

Summary:

We do not know the best origins There is just 1 provenance trail for the species	
We do know where to source the best origins Slim evidence of where to source material	√
Other organisations are breeding this species +origin Not really; surprisingly limited in US	
We could create a UK land-race Yes. Select superior individuals in stands around the country	√
We already have some seed stands There is 1 seed stand; we need more	√
We already have some plus trees Copies of Bill Libby plus	√
We could create seed orchards Yes. Could also explore cuttings orchards	√
Further field testing possible but not worthwhile? Very expensive; 20 years to get results	
Further field testing may be worthwhile Doubt it	

Abies procera

General Introduction



Native to the mountain ranges of the Pacific coast of North America. Prefers a cool and moist (i.e. >1000 mm rainfall) climate; can cope with exposure and is more frost resistant than other firs, therefore most suited to upland Britain including higher elevations.

A species of intermediate shade tolerance which is reported to have stronger timber than most other silver firs. Grows best on fresh to moist mineral soils of poor nutrient status, but suffers severely from heather competition. It is a high volume producer under the right conditions, but suffers from drought crack on drier soils

Largely free of major pathogens although reported to be susceptible to the root and butt rot pathogen *Phaeolus schweinitzii*. It is subject to numerous foliage diseases (needle cast and rusts fungi) in its native range, but none are considered significant except on Christmas trees. Occasional reports of infestation by balsam woolly aphid, and some trees may become severely infested and suffer dieback. Stem crack is reported as a major problem in some areas.

A popular species with Christmas tree producers.

Provenance choice

Provenances from the Washington or north Oregon Cascade Mountains (over 975m) are preferred. First choice would be good quality British stands. Limited breeding has taken place in Oregon where mature orchards exist owned by USFS (now neglected) and Bureau of Land Management (more active management). Weyerhaeuser also have some old orchards managed mainly for Christmas tree production.

This is not such a rare species in Britain with over 100 stands listed in Silvifuture database. There are over 20 ha of seed stands in Britain – we should be collecting from those, and also looking for more good quality stands to collect seed from. There are 40 stands over 1hectare amounting to 80 hectares in total in Scotland alone.

Although Genetics Branch selected 97 plus trees in forests we can only locate 11 in current archives. There is scope to select many more plus trees in stands around the country and bring them together in untested clonal seed orchards. The species grafts easily but grafted ramets grow slowly. PNW experience suggests 15 years before a reasonable harvest.

This may be a species worthy of more tree breeding investment using domestic sourced material. Comparison with improved imported material from the PNW would be beneficial.

Testing for co-ancestry using micro-satellites is again possible using generic *Abies* markers.

Further Reading

http://www.na.fs.fed.us/pubs/silvics_manual/Volume_1/abies/procera.htm

http://www.forestry.gov.uk/fr/infd-8cyjxk

http://www.silvifuture.org.uk/species.php?species=24

Fletcher A.M., Samuel C.J.A., 1990. Early height growth in the seed origins of noble fir in Britain. In: 1990 joint meeting of Western Forest Genetics Association and IUFRO Working Parties S2.02-05, 06, 12, and 14 on Douglas-fir, contorta pine, Sitka spruce, and Abies breeding and genetic resources. 20 to 24 August 1990, Olympia, WA. Weyerhaeuser, Tacoma, WA 2.98-2.113. (still looking for link)

Summary:

We do not know the best origins	
We do know where to source the best origins **Southern Washington + northern Oregon above 750m**	√
Other organisations are breeding this species +origin **Breeding of same origins: Canada + USA**	√
We could create a UK land-race **We could select superior individuals in stands around the country**	√
We already have some seed stands **There are over 20 ha of seed stands**	√
We already have some plus trees **97 selected originally, only 11 grafted for archive in 1960/70s**	√
We could create seed orchards **Use original 11 plus new plus tree selections. Could also look for the old ones.**	√
Further field testing possible but not worthwhile? **Depends on areas to be planted.**	
Further field testing may be worthwhile **Needs an assessment of possible annual planting areas. More than 500 ha?**	√

Picea omorika

General Introduction

Limited to small areas of the Balkans, along the Drina valley in Serbia and Bosnia where it grows on soils overlying limestone rocks. Grows on a wide range of sites from slightly dry to wet soil and from poor to rich nutrient regime, including more alkaline soils. It will grow on flushed peats. Is cold hardy throughout Britain and is less sensitive to frost than either Norway or Sitka spruce, but requires sites with over 650 mm rainfall. It is quite tolerant of exposure and can grow in areas subject to air pollution. Little is known about the species' shade tolerance but it grows naturally in mixture with Norway spruce and beech. The typical narrow crown means it sheds sow well and is capable of high stocking densities.

Few diseases are reported in its native range. Aphids, mites and scale cause low level insect problems, but are not significant. The notable exception is white pine weevil (*Pissodes strobi*) which is a serious and economically important native insect pest in North America but is absent from Europe.

Provenance choice

There is little evidence of provenance variation; seed from good British stands or from the natural range should be preferred. There would be great difficulty in sourcing seed from the natural range for new trails.

There are 70 listings of Serbian spruce stands on the 'SilviCulture; website. There are 60 stands in Scotland amounting to 58 hectares; more are likely to exist in England & Wales.

There is currently one seed stand of 1.4 hectares located at Pitlochry.

Forest Research has historically selected 75 plus trees of which we have located 33 in existing archives.

The suggested way forward, as with most of the other species, is to select a number (50 to 100) of good quality

There is currently private sector interest in this species as a source of pollen for hybridisation with Sitka spruce on the premise that the hybrid will grow well on drier sites in the eastern part of the country.

Generic *Picea* micro-satellites could be used to check for co-ancestry.

Further reading:

http://www.forestry.gov.uk/fr/infd-8cyjp8

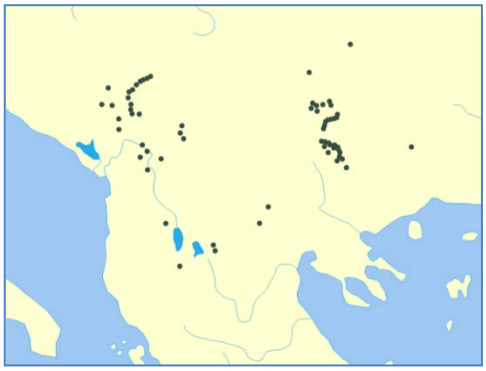
http://www.silvifuture.org.uk/species.php?species=66 – 70 records of this species.

Summary:

We do not know the best origins Natural distribution very small. Not likely to be any little provenance variation	√
We do know where to source the best origins	
Other organisations are breeding this species +origin	
We could create a UK land-race We could select superior individuals in stands around the country	√
We already have some seed stands There is 1 seed stands; in Scotland	√
We already have some plus trees 33 plus trees select in 1960/70s. We could find more	√
We could create seed orchards Possible using the available plus trees	√
Further field testing possible but not worthwhile?	
Further field testing may be worthwhile Interest does not justify this	

Pinus peuce Griseb.

General Introduction



A five-needled pine native to the mountains of the southern Balkans in northern Greece, Albania, Bulgaria and Macedonia. A species with slow early growth and intermediate shade tolerance, but which is capable of sustained growth over many years. Cold hardy and frost tolerant and withstands moderate exposure. Not known to be particularly drought sensitive. Trials have shown good growth on a wide range of soil moisture from flushed peats through to podsols and sand dunes and from poor to medium soil nutrient regimes.

Appears to be resilient to a number of pests and pathogens including pine beauty moth, red band needle blight and, most significantly, white pine blister rust (*Cronartium rubicola*) which affects North American 5-needle pines. Like other pine species, Macedonian pine is likely to be affected by *Heterobasidion* root and butt rot, especially on dryer sites with mineral soils.

Provenance choice

Just one replicated provenance trail planted in Clocaenog planted in 1961 involving 4 treatments – 2 from the native distribution, one from Bedgebury (now felled) and one from Ireland. Savill and Mason reported 50-year data suggesting little differences between the provenances but a slight superiority of the Irish stock. The material from Bedgebury was disappointing (eastern drier site?). One option is to return to the Balkans for new trials but it would be 20-30 years before they give meaningful results and as the species is listed as 'near-threatened' access and collection may not be easy.

Best option is to create a landrace by selecting from what is already available; but that seems to be limited. Silvifuture lists 27 known locations mainly in the north and west of

GB. Ideally, at least 50 superior phenotypes should be selected from a number of stands around the country and forming a seed orchard. Better stands should be used for seed collection.

Selected trees should be checked for relatedness using generic pine microsatellites.

Further reading:

http://www.forestry.gov.uk/website/forestresearch.nsf/byunique/INFD-8CYJEC

http://www.silvifuture.org.uk/species.php?species=44

http://www.euforgen.org/fileadmin/bioversity/publications/pdfs/EUFORGEN/1508_Macedonian_pine_Pinus_peuce.pdf

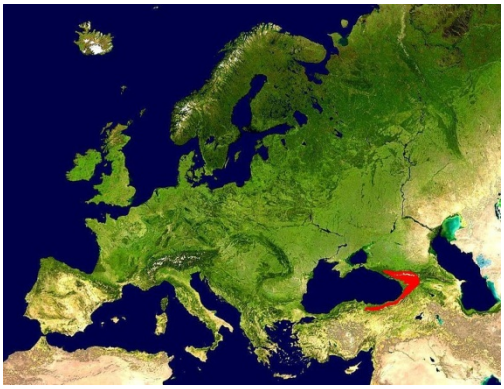
http://www.iucnredlist.org/details/34193/0

Summary:

We do not know the best origins	√
We do know where to source the best origins **1 very small trial of 4 sources; results inconclusive**	
Other organisations are breeding this species +origin **Some material from Ireland possible**	
We could create a UK land-race **We could select superior individuals in stands around the country**	√
We already have some seed stands	
We already have some plus trees	
We could create seed orchards **Possible using new selections**	√
Further field testing possible but not worthwhile?	
Further field testing may be worthwhile	

Picea orientalis

General Introduction



Native to the Caucasus mountains and mountains of NE Asia Minor. Adapted to warm summers and cold winters and seems to tolerate dry conditions better than Norway or Sitka spruce. Best suited to soils of poor to rich nutrient status and slightly dry to moist soil moisture. Does not tolerate peats but will grow on alkaline soils though less suited to the latter than Serbian spruce. Should be cold hardy throughout Britain but only moderately tolerant of exposure; a very late flushing species and therefore can be used on sites prone to late spring frosts. Growth rates are generally comparable with Norway spruce.

A species which could be considered on sites predicted to become marginal for Sitka or Norway spruce in eastern parts of Britain

Generally considered to be largely disease free when growing in its native range, occasionally affected by some needle cast and rust diseases. However, it has been found to be highly susceptible to *Dendroctonus micans* (great spruce bark beetle).

Provenance choice

No provenance testing has been carried out in Britain and there are few forest plots.

Seed should be sourced from the natural range.

There is a stand at Kilmun (Argyll, Scotland) where it looks good, and another small one at Dawyck Gardens, Scottish Borders. There is the possibility of some other stands elsewhere. Individual trees seem to grow well in private estates and arboreta on eastern sites in England and Scotland but this is poorly documented.

Historic tree breeding records state FR selected 5 plus trees in the 1950s/1960s. This needs to be confirmed; we cannot find them in our archives. It is unlikely the original trees are still standing but this could be investigated.

FC(E) recently sourced forest quality seed from two areas. The first seed source is from the north-eastern corner of Turkey close to the border with Georgia. Thought to be from a higher rainfall zone – perhaps 2000 mm - than the second one which looks to be closer to 1000-1500 mm. The second seed source is more western, slightly more inland and appears to come from the southern side of the Pontic Mountains. If correct this should be more capable of withstanding dry conditions. It is important to make sure seed purchased is for forestry, not cultivars.

Little scope for doing much here apart from looking for trees already growing in Britain – testing them for co-ancestry and placing together in a seed orchard – and importing from Turkey when possible.

This species is low priority for breeding resources.

Further reading:

http://www.forestry.gov.uk/fr/infd-8cyjrd

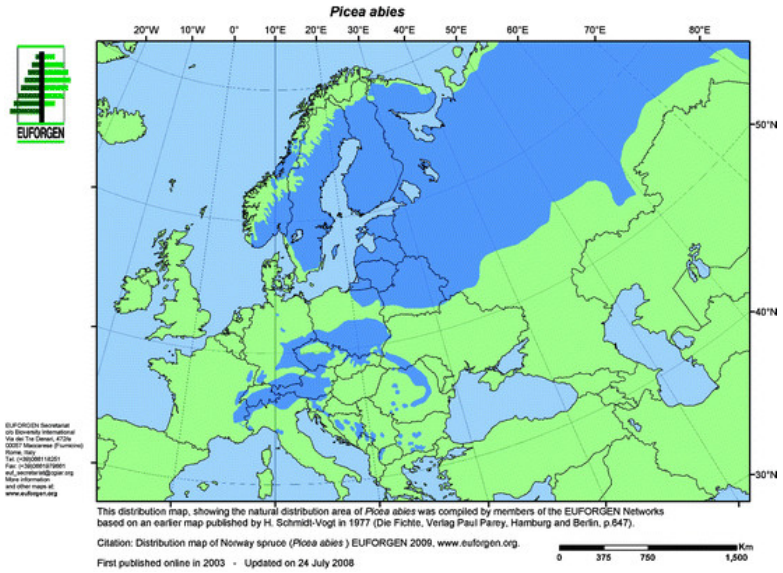
http://www.silvifuture.org.uk/species.php?species=65 – only Kilmun forest garden listed.

Summary:

We do not know the best origins **There are NO provenance trails for the species**	√
We do know where to source the best origins	
Other organisations are breeding this species +origin **Maybe in Turkey**	√
We could create a UK land-race **Outside possibility if a few stands could be found around the country**	???
We already have some seed stands	
We already have some plus trees	
We could create seed orchards	
Further field testing possible but not worthwhile?	
Further field testing may be worthwhile	

Picea abies

General Introduction



Norway spruce (*Picea abies*) is one of the most important tree species in Europe. It produces high-quality timber and its long fibers make it important for the pulp and paper industry. The species also has high ecological importance, being a key species in northern Europe. It is moderately tolerant to shade and is able to grow on a variety of site types, and in both dry and wet habitats. With its straight and regular trunk, it can reach a height of 50-60 m.

In Britain the species is accommodating with regard to climatic conditions as long as annual rainfall exceeds 850 mm although can grow well on moist soils in drier regions. It is cold hardy but suffers from exposure, air pollution, and is vulnerable to late spring frosts at a young age (although less than Sitka spruce). Best growth on moist, sufficiently aerated soils of poor to medium fertility such as sandy loams. Suffers from heather check and nitrogen deficiency on very nutrient poor soils.

Green spruce aphid (*Elatobium*) damage on Norway spruce is less common than on Sitka spruce and usually less severe. However, Norway spruce suffers from a disorder known as top-dying which is of unknown cause. It is relatively common and can be a significant cause of decline and death, especially on the eastern side of Britain. Elsewhere in Europe, the larger European spruce bark beetle (*Ips typographus*) is a significant pest on Norway spruce, killing trees as a result of mass beetle attack.

Apart from being affected by *Heterobasidion* (Fomes root and butt rot), Norway spruce is also highly susceptible to other decay fungi such as *Stereum*, which enter via wounds such as those made during thinning and extraction, and can cause serious levels of degradation.

Provenance choice

Provenances from South-Eastern Europe e.g. Romania, southern Poland; Czech Republic, are generally preferable combining fast growth rate with late flushing times. Some southern Austrian sources have these same characteristics. Next choice would be from northern Germany and the Alps. Scandinavia sources are not recommended due mainly to early flushing dates leading to frost damage.

Plus Tree & Seed stands

89 NS plus trees were selected in the 1960s, and only 9 were grafted. We can assume these trees are now felled since they date mainly from around 1880.

There are approx. 20 hectares of recently selected NS seed stands which would be a good place to start when selecting new plus trees. There seems to be a perception in UK that collection of NS seed is difficult due to heavy squirrel predation, and is only worthwhile in very heavy seed years. As a rule, the feeling seems to be, better to buy the seed in from abroad.

Importing seed orchard material from abroad

Forestry Commission imports seed from a Danish seed orchard FP240 which contains grafted copies of originally 100 plus trees selected in 20 Danish and 4 south-Swedish Norway spruce stands of presumed west-continental origin. Trees were selected for stem straightness, production, wood density, branch quality and health. Forest managers report satisfaction with this material in terms of survival and growth rate. The orchard has been thinned based on progeny test results to 46 clones.

http://www.hdseed.dk/media/Produktblad_Norway_spruce_FP240.pdf

This seed orchard does not represent the best origin for Britain according to Lines (1980). In fact Norway spruce is not native to Denmark but is reported to have been planted there for centuries. Elsewhere, some parts of the private sector are expressing interest in material from tested seed orchards in southern-Sweden, which again is not part of the optimum area.

Private nursery industry is importing material from seed orchards located in (i) Czech Republic (CR) and (ii) South Sweden (SS). Existing wisdom would tend to favour Czech Republic over South Sweden. Other factors to consider would be the relative success of the breeding programmes in each of these locations, the characteristics under selection e.g. growth rate, stem form, flushing times, and whether despite the orchard being located in one place, over what area have the component parent trees been selected?

This latter point may be important for South Sweden seed orchard since trees from the north will flush early in Britain leading to frost damage.

Ideally new comparative trials should take place to compare survival and growth rate of Danish, Swedish and Czech Republic seed orchard material; improved or best available from southern Poland and Romania; and NS British seed stand.

Another Option:

Selection of 'Plus Tree' quality Norway spruce trees in British plantations is the first step towards forming our own British landrace of Norway spruce. Selections would be grafted and placed in breeding archives and could be made available to organisations to create untested clonal seed orchards.

200 Plus Trees might be a good working figure.

Further reading:

https://www.forestry.gov.uk/fr/infd-8cyjmx

http://www.silvifuture.org.uk/species.php?species=64

Lines, R. (1987). Choice of Seed Origins for eh Main Forest Species in Britain. *Forestry Commission Bulletin 66, pp 61*

Summary:

We do not know the best origins	√
We do know where to source the best origins **Southern Poland and Romania**	√
Other organisations are breeding this species +origin **Seed orchards exist in S. Poland + Romania; Seed merchants prefer Danish**	√
We could create a UK land-race **Yes**	√
We already have some seed stands **Three seed stands recently placed on FRM Register**	√
We already have some plus trees **89 were selected. Only 9 remain in clonebanks**	
We could create seed orchards **Yes following selection of plus trees**	√
Further field testing possible but not worthwhile?	
Further field testing may be worthwhile **Could compare seed orchard choices if demand increases**	√

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