Silver Firs (*Abies* spp) of Europe and the Near East

Species, silviculture and utilisation potential

Peter Savill, **Scott McG. Wilson**, **Bill Mason** and **Richard Jinks** review the characteristics and potential of silver firs.

Much thought is being given by foresters to alternative tree species that might be used in Britain if climate change proceeds as predicted, and in the light of the threats posed by tree pests and diseases which have become so numerous since the turn of the century. Recently, the Wessex Silvicultural Group has considered the matter (Bladon and Evans, 2015), as has Wilson (2010, 2011). There is an on-line network that promotes novel species known to have potential to grow well in the UK (SilviFuture, 2015) including nine high priority species, and 20 medium priority species. Also Read et al. (2009) suggested a number of emerging species as a means of adapting British forests to climate change, including 15 broadleaves and 10 conifers. Prominent amongst the potential candidates are a number of silver fir species (*Abies* spp.).

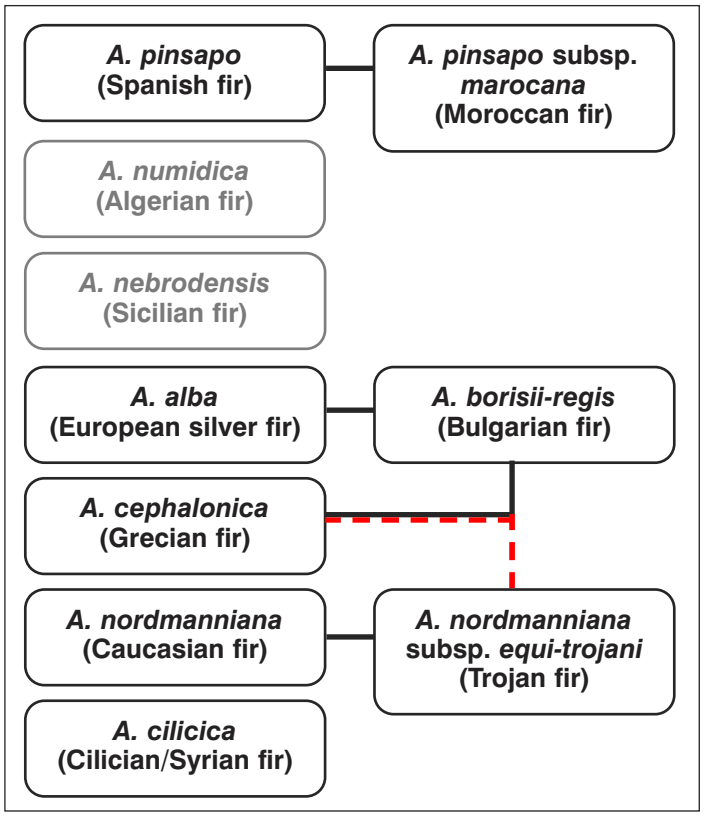

Figure 1. Suggested taxonomic inter-relationships between the Abies species of Europe and the Near East. Solid lines between species indicate firm relationships. The red dashed line between A. cephalonica and A. nordmanniana subsp. equi-trojani indicates uncertainty. Interpreted by the present authors from Knees (2011), Liu (1971) and other references.

According to Farjon (2010), there are 49 species of *Abies* that occur in temperate and boreal parts of the northern hemisphere, chiefly in mountainous regions. The main areas of occurrence are western North America (including the Pacific Northwest), eastern North America (e.g. the Appalachians), Central America, western Eurasia (including the Mediterranean basin), the Himalaya and allied montane regions and the Pacific Northeast of Asia. Common features of many, but not all *Abies* species, are that:

1. They are strong shade bearers and so have a potential role in continuous cover silviculture.
2. Most grow naturally in mixed-species stands.
3. Most are remarkably winter cold hardy.
4. Several species grow well on calcareous soils; an unusual attribute among conifers.

The form of *Abies* trees differs from most genera of *Pinaceae* in its exceptional uniformity. The trees typically possess a single straight stem with regularly spaced branch whorls produced at the rate of one whorl per year. The bark

is generally smooth and thin on young trees, frequently bearing resin blisters. In older trees it is often thicker and furrowed or flaking in plates. In most *Abies* species the bark provides little protection against fire, although a few species are partially fire-tolerant. Cones are borne on one-year-old twigs, and mature in one season. They are erect, ovoid to cylindrical, generally resinous, dehiscent (i.e. they fall apart on maturity); the cone axis persists as an erect 'spike' on the branch. The wood lacks resin ducts. Because of their shade tolerance many silver fir species feature prominently in the later stages of ecological succession in their natural habitats.

There seems to have been a certain amount of 'botanical nationalism' (Farjon, 1998) with some of the *Abies* species, in that many phenotypic varieties, subspecies and sometimes even species have been described relating to particular geographical regions (notably within *Abies nordmanniana*) (see Coode and Cullen, 1965; Liu, 1971). A more recent genetic investigation by Knees (2011) has indicated that while there are identifiable phenotypic and morphological differences between the western Eurasian *Abies* populations, perhaps responding to climatic and edaphic conditions, these are less readily attributable to observed genotypic differences. The main driver of speciation in the Mediterranean basin is believed to be geographical isolation (Alizoti, 2011).

At least eight, and arguably up to twelve, *Abies* spp are found west of the Urals, including the far north-west of Africa (Knees, 2011; Liu, 1971). Two occur in inland montane regions of Central Europe (*Abies alba*) and the Caucasus (*A. nordmanniana*) that enjoy a more temperate or alpine climate. All of the other species are restricted to montane areas surrounding the Mediterranean basin, with a warm, dry regional climate tempered by altitude. The coniferous forests of the Mediterranean basin in particular have been subjected to severe over-exploitation by human societies since ancient times (Andersson (ed.), 2005; Meiggs, 1982; Thirgood, 1981). Some species have survived only in inaccessible montane refugia, but the ranges of most species have been greatly reduced by the effects of clearance for agriculture, livestock pasturage, unrestricted felling and, in some cases,

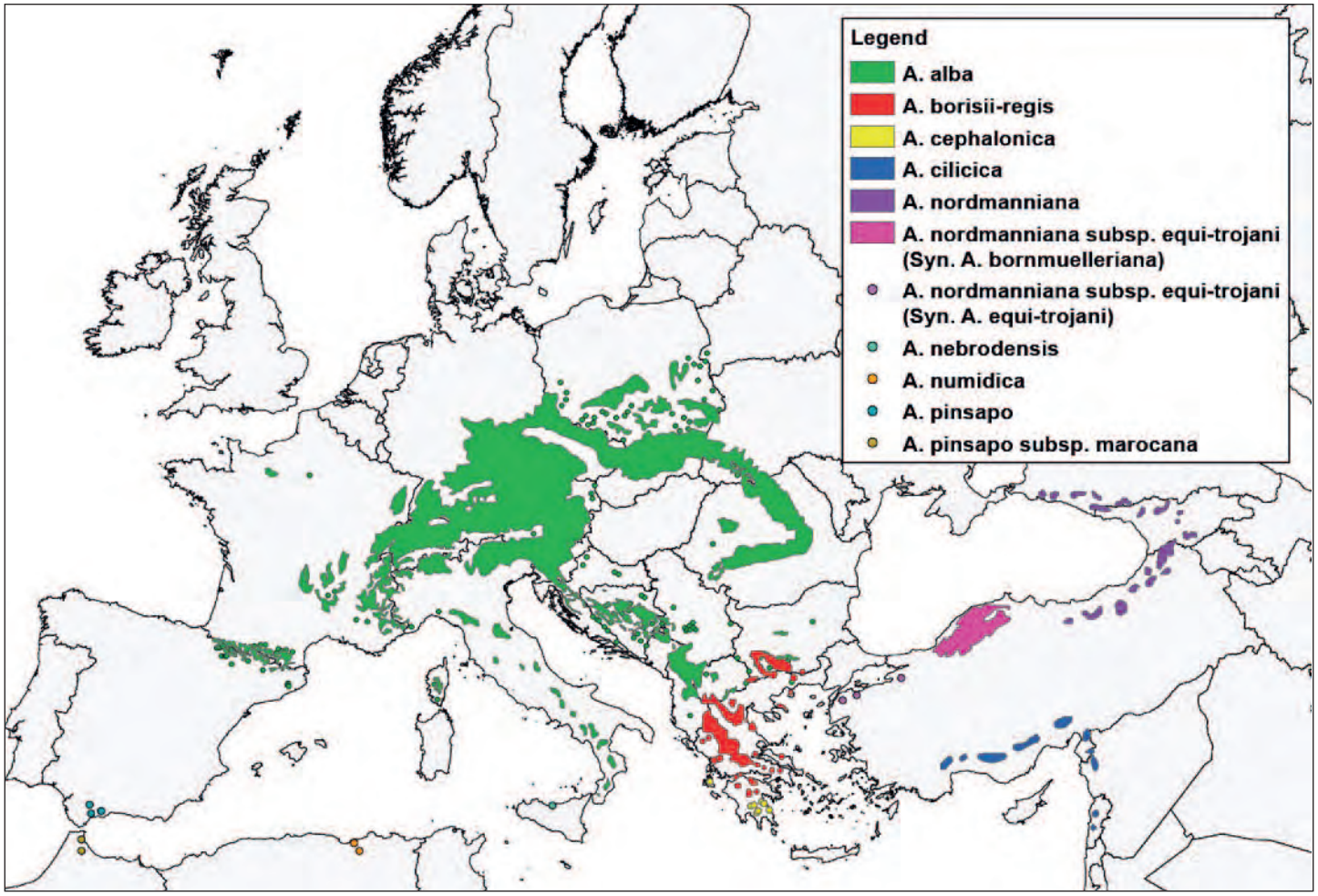

Figure 2. Distribution of the Abies species dealt with in this paper (from Alizoti et al., 2011).

wildfire damage. The *Abies* firs are no exception and some now exist only as relict species – two extreme cases being Sicilian fir (*Abies nebrodensis*) represented by only 29 individuals in the Madonie Regional Park in Sicily (Alizoti, 2011), and Algerian fir (*Abies numidica*).

This article deals with six of the silver firs (*Abies* spp) mentioned by Read et al. (2009), these being *Abies alba* (European silver fir), *A. borisii-regis* (Bulgarian fir), *A. cephalonica* (Grecian fir), *A. cilicica* (Cilician fir, Syrian fir), *A. nordmanniana* (Caucasian fir) and *A. pinsapo* (Spanish fir). *A. equi-trojani* (Trojan fir) is included here as subspecies of *A. nordmanniana* (Caucasian fir). The latter also incorporates *A. bornmuelleriana* (Turkish fir – Fig. 4b) which is no longer regarded as a separate species.

Wilson (2014) reviewed the potential relevance of certain of the Mediterranean *Abies* species for forestry in the drier British lowland areas. The putative phylogenetic relationships between them are shown in Figure 1.

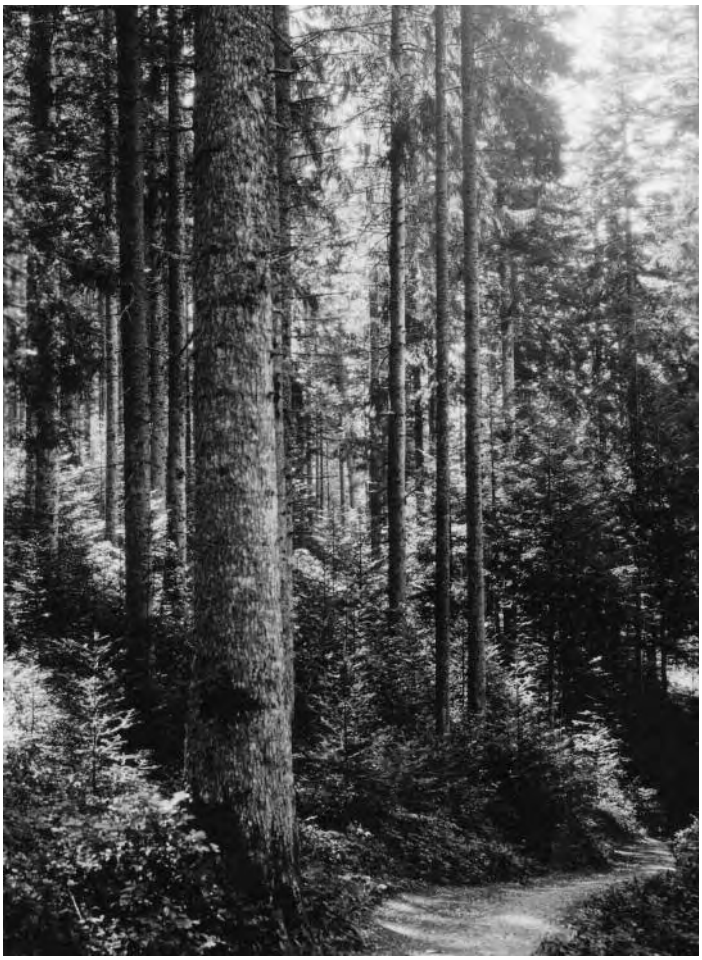

Figure 3a. Single tree selection in the mountainous Couvet Forest in Switzerland in 1913. The main species are Norway spruce (Picea abies) and European silver fir (Abies alba). (Photo: Prof. R.S. Troup).

There is, in addition, a record of successful use of grand fir as a component of mixed woodlands on some lowland estates across southern England (Longleat, Windsor, Highclere, and Weasenham) where skilled silviculture is applied and significant risks from drought cracking can be reduced as a consequence.

Abies alba Mill. – European silver fir

Many details of this species, which is by far the best recorded and extensively distributed of those considered here, are provided by Savill (2013). The tree is native to the mountains of central, southern and eastern Europe (see Fig. 3a), from the Pyrenees, through the Alps and Apennines to the Carpathians and Balkans, with outlying lowland stands in France (Normandy) and eastern Poland (see Fig. 2).

Climate and site requirements

This species is said to be winter cold hardy to around -30°C (Gymnosperm Database, 2015). High humidity and not too high a maximum summer temperature are required for successful growth. European silver fir is sensitive to late spring frosts and, like most shade-bearers, ideally needs overhead cover when young. Frost-prone flat areas and hollows should be avoided. It does not tolerate exposure well, or atmospheric pollution. The species grows well on most soils that do not dry out, including heavy clays, but waterlogged soils (including peats), infertile sands and gravels are best avoided. It does particularly well on fertile mesotrophic and calcareous soils at moderate elevations, on cooler northerly aspects.

Figure 3b. A plot of Abies alba at Kilmun Forest Garden, Argyll. (Photo: Dr S. McG. Wilson).

Other silvicultural characteristics

On good sites advance regeneration can be both prolific and persistent. Large 'seedling banks' are formed, awaiting an overhead gap in the canopy before growing. Young seedlings are very palatable to deer. Early growth is slow, like that of many silver firs, but the species is a considerable volume producer once established, after 8-10 years. It is said to be a much deeper-rooting tree than Norway spruce and therefore more stable, especially on heavy soils. Evidence of this was recently seen by the Wessex Silvicultural Group on a visit to mixed estate woodlands in Wiltshire where individual fir stems had withstood the early 2014 gales and the surrounding Norway spruce had been significantly damaged. European silver fir self-prunes slowly and is inclined to produce heavy branches unless these are discouraged by pruning or maintaining dense stocking. The species is a very important constituent of many continental European selection forests (see Fig. 3a), where Norway spruce regeneration tends to occur under the European silver fir and vice versa.

Nursery conditions

If seed is required for sowing in a nursery it should be collected as soon as it is ripe, before the cones disintegrate on the tree. For the production of bare rooted seedlings it is normal to stratify (or pre-chill) the seed for 6-12 weeks, prior to sowing in March. Unstratified seed should be sown in January or February (Aldhous, 1972). Gosling (2007) stated that *Abies* seeds exhibit shallow or intermediate dormancy. They can be stored at 9-12% moisture content at <5°C. On current evidence *Abies* seeds are considered to have 'intermediate' storage characteristics where seeds can only be partially dried or need very slow, careful drying (Gosling, 2007). They deteriorate more quickly than 'orthodox' seeds but more slowly than 'recalcitrant' seeds. A difficult problem for nurseries is that the seeds are quite often mixed with scales and other material, because of the way the cones break up on the trees. The seeds exhibit the usual features of shallow dormancy in that some untreated seeds will germinate, but pre-treatment will usually stimulate quicker germination of more seeds, over a wider range of conditions. When grown in bare-root nurseries, European silver fir can be slow to develop in the seedbed, requiring one to two years before 'taking off'. A longer nursery residence will therefore be required than in more familiar pines and spruces. It is possible that usable two year old seedlings could be obtained from containerised production.

Internet searches reveal that there is quite a lot of information about nursery practices for other species of *Abies*, but they do not differ much in essentials from those outlined above.

Pests and diseases

European silver fir can suffer badly from attacks by a woolly aphid (*Adelges nordmanniana*), which can cause defoliation, dieback and ultimately death. The relationship between site, silviculture and severity of attack by *A. nordmanniana* is not fully understood, but stands on suitable soils in cool, moist

Table 1. Heights, diameters and locations of the 'champion trees' (the tallest of the Abies species) covered in this paper in Great Britain and Ireland (from Johnson, 2003).

Species	English name	Max recorded height (m)	Dbh(cm)	Place
Abies alba	European silver fir	50	47	Thirlmere, Cumbria
		50	52	Armadale Castle, Highland
Abies nordmanniana	Caucasian fir	32	52	Endsleigh, Devon
		48	36	Cragside, Northumberland
Abies nordmanniana subsp. *equi-trojani* (*bornmuelleriana*)	Turkish fir	37	42	Fulmodeston Severals, Norfolk
Abies cephalonica	Grecian fir	35	73	Culcreuch Castle Hotel, Stirling
		41	41	Bicton Park, Devon
		41	39	Tendring Hall, Suffolk (Macdonald et al.,1957)
Abies borisii-regis	Bulgarian fir	36	49.3	Stonefield House, Argyll
Abies cilicica	Cilician fir	33	24	Glenapp, Ayr
		26	31	Speech House, Glos
Abies pinsapo	Spanish fir	33	-	Balmacaan, Highland
		19	45	Harestanes, Borders

climates recover better from attack than do those on poorer soils and in warm, dry areas (Varty, 1956). The severity of outbreaks in mixed forestry is known to be much less severe than in extensive monospecific plantations (Kerr, 1999). European silver fir is less susceptible to attack by Fomes (*Heterobasidion annosum*) than many other conifers.

Silvicultural record

European silver fir will grow up to 50-60m tall and up to 300cm circumference (95cm diameter) at breast height as shown in Table 1 and Fig. 3b). The species is recorded by Mabberley (2008) as being the tallest-grown European tree. It was introduced to Britain around 1600 and over the following three centuries was deployed as a component of mixed woodlands on private estates across the country. Objectives of establishment and silviculture combined botanical curiosity, landscape amenity and estate timber production. During the period 1880-1910 some timber plantations were established, for example in Argyll. However increasing incidence of the woolly aphid, *Adelges nordmanniana*, led to its progressive abandonment, such that by the mid-1950s it was no longer recommended for planting (Varty, 1956; Macdonald et al., 1957). Much of the existing stock is in Scotland, but large individual specimens can be found almost everywhere dating from the period prior to 1910, where they escaped subsequent fellings during the First and Second World Wars. The current growing stock of younger material is very limited, largely comprising trial plots from the period 1930-1970 in Wales and western Scotland. Recent years have seen renewed interest. There are no modern British yield class (YC) tables specifically for *Abies alba* due to a lack of suitable mensuration plots, but based on recommendations by Hamilton and Christie (1971) that the tables for *Abies procera* be used, the potential productivity ranges from 12 to 22$m^3ha^{-1}year^{-1}$. Ages of maximum mean annual increment would occur between 64 years (YC22) and 73 years (YC12), and mean diameters at these ages are between 28 and 40cm. Kerr et al. (2015) reported productivity varying between 10 and 22$m^3ha^{-1}year^{-1}$ after 46 years for a range of provenances planted in experiments at Thetford, Radnor and Benmore.

Provenance

According to Lines (1978), the tallest sources after 10 years' growth in a comprehensive series of provenance trials came from such divergent places as Calabria (Italy), Czechoslovakia and the Swiss Jura. The current Forest Research (2015) website says much the same: seed sources from the Czech republic and nearby areas in central Europe should be favoured. More recent analysis of the same series of provenance trials, suggests that Calabrian provenances from above 1100m in southern Italy perform best in British conditions (Kerr et al., 2015). However, these authors note that there was relatively moderate provenance variation, with origins grouping within 80-120% of trial mean volume productivity, so that good seed sources within the natural range should be an acceptable alternative. George et al. (2015) comment on the relative drought resistance and resilience of a range of *Abies alba* provenances growing in Austria.

Timber utilisation

Abies alba is grown for timber in Central and Western Europe. The white timber is similar to that of Norway spruce though less resinous and, in Continental Europe, is used for the same purposes (general construction or pulp and paper). It is grouped with Norway spruce by the timber trade, within the 'European whitewood' category. It often forms a minor component of mixed imported timber packs otherwise comprising Norway spruce. The average density at 15% moisture content is about 400kg/m^3 (Ramsay and Macdonald, 2013) though it can be up to 480 kg/m^3. It is not very durable outdoors. Traditionally, large section European silver fir (e.g. 30cm x 30cm baulks) was used for heavy construction framing in Alpine districts of Germany, Austria and Switzerland. In classical Greece and Italy (Rome and later, the Genoese and Venetian maritime territories) montane fir supplies from the Apennines, Alps and from Macedonia were sought for naval construction due to a high strength-to-weight ratio (Meiggs, 1982; Thirgood, 1981). This mirrors the modern values attributed to Sitka spruce (e.g. for aircraft framing). More recently, silver fir timber has been used as an internal component of the massive and cross-laminated timber elements found in novel engineered-timber construction systems, notably in Austria (Wilson, 2011).

There is a limited record of processing European silver fir timber in Britain, although large-section material from the Victorian and Edwardian plantations of Argyll was used by shipbuilders on Clydeside as keel blocks (Elwes and Henry, 1906), with similar applications occasionally arising in the North Sea oil sector today. Traditionally home-grown fir timber was treated and sawn for non-market 'estate uses' and was preferred to grand and noble firs for these applications. The European silver fir makes a good

Christmas tree, though it has now largely been superseded for this purpose by other species of silver fir, especially *Abies nordmanniana* (see below). Its resin is the source of Strasburg turpentine that is used in many bath products, to give them a 'pine' scent.

Abies nordmanniana (Steven) Spach – Caucasian fir

This includes *A. nordmanniana* subsp. *equi-trojani*. (Asch. & Sint. ex Boiss.) Coode & Cullen – Trojan fir. *A. nordmanniana* subsp. *bornmuelleriana* Mattfeld – Turkish fir is now regarded as the same as *A. nordmanniana* subsp. *equi-trojani*.

Abies nordmanniana is described in the Gymnosperm Database (2015) as an evergreen tree reaching 61m tall, densely branched from the ground up, with branches regularly arranged. It was first botanically described in 1836 and introduced to Britain about 10 years later (Bean, 1929).

According to the Gymnosperm Database (2015), the typical subspecies *A. nordmanniana* subsp. *nordmanniana* occurs in the western Caucasus (Abkhazia and Georgia) and in the Pontic mountains of north-eastern Turkey (e.g. Paphlagonia). It typically occurs in natural montane and sub-alpine forests, locally in pure stands, but more often in mixture with *Picea orientalis*, *Pinus sylvestris*, *Fagus orientalis*, *Acer trautvetteri*, *Carpinus caucasica*, *Ulmus elliptica*, *Acer pseudoplatanus*, *Tilia caucasica*, *Taxus baccata* and *Rhododendron ponticum*. These rich forests contain a number of tree species of potential relevance to silviculture in Britain under a warmer climate and their silvicultural dynamics are also of notable interest.

Geographically separated and phenotypically distinct populations in western and northern Turkey have given rise to taxonomic disputes about this species (Gymnosperm Database, 2015). In central northern Turkey a clinal type, or subspecies, referred to as *Abies nordmanniana* subsp. *bornmuelleriana* (see Fig. 4b), has been described, although not officially recognized as a distinct subspecies. It possibly exhibits greater drought tolerance at lower elevations. At the far western end of the range, in north western Turkey, a second subspecies *Abies nordmanniana* subsp. *equi-trojani* (Fig. 1) has been described in the Gymnosperm Database (2015) as a narrowly conical tree, 20-30m tall, 1.8-4m in girth (57-127cm dbh), with a somewhat rounded crown, occurring at 700-2000m asl on the northern slopes of high mountains (e.g. behind Troy) and on Ulu-Dagh in Bithynia. Subsp. *equi-trojani* grows in pure stands as isolated relict populations and

Figure 4a. A plot of Abies nordmanniana at Kilmun Forest Garden, Argyll. (Photo: Dr S. McG. Wilson)

Figure 4b. A. nordmanniana subsp. bornmuelleriana Turkish fir (now regarded as the same as A. nordmanniana subsp. equi-trojani) with Pinus sylvestris in Ilgaz forest in the North Anatolian mountains, Turkey (Photo: Dr Bill Mason)

is also reported to grow well in silviculturally-valuable natural mixtures with *Pinus nigra*. It is said to do best on calcareous soils (Farjon, 1990). Sometimes *Abies nordmanniana* subsp. *equi-trojani* has been treated as a distinct species, especially by Turkish authors (e.g. Ata, 1989). There is some evidence that it represents a stable hybrid, resulting from ancient introgression with *Abies cephalonica*, and hence it may be an eastern analogue of *Abies borisii-regis* (*Abies alba* x *Abies cephalonica*) (Liu, 1971). Hybrid vigour has been reported, producing faster growth and better timber properties, leading to silvicultural interest in this species in Turkey (Ata, 1989).

Climate and site requirements

Abies nordmanniana is native to high mountains around the Black Sea at 900-2100m asl, typically on cool, steep, north-facing slopes. The climate is temperate and moist, with annual precipitation of 1000-3000mm. The species has a cold hardiness limit between -28.9°C and -34.3°C (Gymnosperm Database, 2015). *Abies nordmanniana* subsp. *equi-trojani* is regarded as potentially more drought tolerant than the type species, growing to appreciably lower elevations (Aussenac, 2002). The species grows on a great variety of soils and situations, although does best on strong, deep siliceous loams rich in organic matter and unlikely to dry out in summer, nor retain too much moisture in winter. Cold, stiff clays should be avoided. *Abies nordmanniana* subsp. *equi-trojani* is said to grow better on calcareous soils, possibly reflecting the genetic influence of *Abies cephalonica*. In Scotland there was a belief that *Abies nordmanniana* could potentially tolerate dry, infertile heathland sites in the east of the country to a greater extent than could *Abies alba* (Elwes and Henry, 1906). Interestingly George et al. (2015) comment that this species showed greater resistance to drought than other Eurasian *Abies* spp, due to later flushing, which might also confer enhanced frost resistance.

Figure 5. A plot of Abies cephalonica at Kilmun Forest Garden, Argyll. (Photo: Dr S. McG. Wilson).

Silvicultural record

The timber of *Abies nordmanniana* is considered similar to that of *Abies alba* and has been used for comparable applications in naval and building construction from classical times until the present day. Tutin et al. (1964) reported that it was planted for timber in central Europe, and occasionally elsewhere. In Britain, Kent (1900) states that: "as an ornamental tree for landscape gardening, few can compare with it for beauty of outline, symmetry and the rich contrast produced in summer by the dark glossy green of the old and the light lively tints of the young foliage". This is its main attribute in Britain, where it has become a much sought-after Christmas tree. Some Victorian and Edwardian trial plantings on Scottish estates have given rise to large specimen trees today, and there is a plot of trees dating from the 1950s at the Kilmun forest garden (Fig. 4a).

Abies nordmanniana subsp. *equi-trojani* is regarded as a valuable timber tree within its native range, and is preferred to admixed species such as *Pinus nigra* and *Picea orientalis*. Timber from *Abies nordmanniana* subsp. *equi-trojani* was reputedly used to construct the Trojan horse in 1178 B.C. A stand of *Abies nordmanniana* subsp. *equi-trojani* (*bornmuelleriana*) at the Bedgebury Pinetum in Kent has performed well, showing potential promise for the drier lowland areas of eastern Britain. Susceptibility to *Adelges nordmanniana* is comparable to that of *Abies alba*.

Abies cephalonica Loudon – Grecian fir

Abies cephalonica is native to Greece, mainly Cephalonia, Euboea, Sterea Hellas and the Peloponnese, at 600-2100m elevation, primarily over calcareous soils. The climate experienced is montane Mediterranean, with 750-1500mm annual precipitation. The cold hardiness limit is between -23.3 and -28.8°C (Gymnosperm Database, 2015). In its natural habitat it grows best on moist, but not waterlogged soils in the cooler and moister parts of the country. It can form pure stands at higher elevations, but at lower elevations occurs together with *Fagus orientalis*, *Quercus* spp, *Castanea sativa* and *Pinus nigra*. Northern portions of its range show evidence of past (and perhaps ongoing) natural hybridization with *A. alba* (hybrids are known as *A. borisii-regis* – see Fig. 1 and below), which complicates the genetic conservation of this species (Farjon, 2010). It is described in its natural habitat as a broadly pyramidal tree reaching 30m tall, 2.7-4.5m in girth (86-143cm dbh), with long horizontal branches (see Fig. 5). The species was exploited for timber (especially naval construction) in Greece in classical antiquity, but was always regarded as inferior to *A. alba* of Macedonian origins due to its slower growth and heavier branching. Natural populations in Greece have been very heavily depleted by historical felling, clearance for agriculture, pastoral grazing pressure and many recent incidences of wildfires. Dallimore and Jackson (1948) state that on Mount Enos in Cephalonia, there was once a forest of this fir 19-24km in length and 58km round but its area has since been much reduced by fires. It is extremely sensitive to damage by fires and regenerates very slowly, if at all, after one (Ganatsas et al., 2012).

Outside its native range *Abies cephalonica* has found a place as a Mediterranean plantation tree, for example in southern France and Italy, but early budburst when young can cause frost damage and problems with establishment in more frost-prone regions (Aussenac, 2002; Carey, 2004). It was introduced to Britain as seed in 1824 by General Napier. There are a few trial plantations in Britain dating from the period 1930 to 1960, e.g. at Crarae and Kilmun (Argyll) and at Weston Common, near Alice Holt (Surrey). It has also been tried in mixed species forestry on private estates, for example at Weasenham Woods in Norfolk. It is considered winter hardy over most of Britain but starts annual growth early, so is liable to late spring frost damage (Kent, 1900; McDonald et al., 1957). In milder British climates, such as the west coast of Scotland, the tree becomes established quickly and grows reasonably vigorously. It is said to thrive in the driest regions of Britain (Johnson, 2003), although the biggest trees are mainly in the west. George et al. (2015) indicate that this species shows better recovery from drought than other Eurasian *Abies* spp. The timber form of the tree is usually significantly inferior to the more familiar *Abies* spp in Britain, according to Macdonald et al. (1957). The species has a reputation for a coarse branching habit.

Abies borisii-regis Mattf. – Bulgarian fir

Abies borisii-regis is native to Bulgaria, northern Greece, Albania, and the former Yugoslavia. It was named in honour of Tsar Boris III of Bulgaria (1894-1943, king and later dictator of Bulgaria 1918-1943). This species is generally regarded as of stable hybrid origin, originating from ancient introgression between *A. alba* and *A. cephalonica* (Fig. 1) (Delcheva, 2010; Bella et al., 2015). It is found at elevations of 700-1700m in the Pirin Mountains of S.W. Bulgaria and to 1800m in Greece, areas with typical rainfall exceeding 1000mm. It is cold hardy to between -17.8°C and -23.2°C. (Gymnosperm Database, 2015), hence rather less so than *A. alba* or *A. nordmanniana*. In most other respects it appears to be very similar to *A. alba*.

Konstadinos (1988) has produced a volume table for this species based on measurements from 3011 trees in Pertouli Forest in Greece. Within its native range it is generally regarded as superior to *A. cephalonica* as a timber tree, more similar to the valued Macedonian provenances of *A. alba*. It is not common in Britain and the few existing forest plots have only been planted since 2010 (for example at Kilmun, Argyll). In southwest Bulgaria it grows mainly in mixture with *Picea abies* and Macedonian pine (*Pinus peuce*) whereas in northern Greece it can be found in mixture with Scots pine and beech.

Abies cilicica (Antoine & Kotschy) Carrière – Cilician fir, Syrian fir

Abies cilicica is a tree native to montane areas of southern Turkey (Antitaurus), western Syria and northern Lebanon at 1000-2100m elevation. It is winter cold hardy to between -23.3°C and -28.8°C (Gymnosperm Database, 2015), but because bud burst occurs early, as in *A. cephalonica*, it is liable to late spring frost damage. It is generally a narrowly pyramidal, small to medium-sized tree reaching 25-35m in height (Fig. 6), to 75cm dbh, with ascending branches. In natural conditions, it grows in mixed montane forests in association with the cedar of Lebanon (*Cedrus libani*) and Italian cypress (*Cupressus sempervirens*). These forests generally experience a rather hotter, drier climate than those of northern Turkey, the Caucasus and the Balkans. According to Dallimore and Jackson (1948), *A. cilicica* has timber similar to that of *A. nordmanniana* and grows under similar conditions, though it is said not to be so susceptible to insect attacks, for example by *Adelges nordmanniana*. The timber was extensively harvested in antiquity for building construction and naval purposes where its long straight lengths gave it a distinct role as compared to the true cedars. This ancient exploitation, together with later heavy pastoral grazing pressure and harvesting (e.g. for railway construction during the Ottoman period), led to severe depletion of the natural stands. Botanically described in 1853, according to Streets (1962), *Abies cilicica* has been planted successfully in the Troodos mountains of Cyprus on north-facing aspects between 1050 and 1675m, starting growth slowly, but accelerating to 30 cm/year on better sites.

Figure 6. A very large Abies cilicica in the Forest of Dean recorded as a 'Champion Tree' by Johnson (2003). (Photo: Dr S. McG. Wilson).

Abies pinsapo Boiss. – Spanish fir

As stated above, the conifer forests of the Mediterranean basin have been subjected to overuse by humans since ancient times. Some species now survive only as relict populations. *Abies pinsapo* is perhaps an extreme example, with the species surviving in only three enclaves in southern Spain (Fig. 7) and two in northern Morocco. Until the mid 20th century *A. pinsapo* forests were subject to major anthropogenic pressures, and in Spain they were under constant threat from fire, grazing, and overcutting until they were acquired by the State. Conservation efforts have now, however, been undertaken in both Spain and Morocco, and the fact that all the *A. pinsapo* forests are covered by some form of protection preserves them from further inappropriate use or exploitation. These forests are now recovering after years of intensive grazing and use of their timber for construction, firewood and charcoal making. However, these relict forests face new threats from climate change, wildfire and pests. The limited area occupied by the forests makes them highly vulnerable to disturbance (Esteban et al., 2010).

Two varieties of *A. pinsapo* are recognized (Fig. 1) that

have disjunct (i.e. geographically separated) ranges. According to Farjon (1990):

1. Var. *pinsapo* occurs in Spain: in the provinces of Malaga and Granada, in the Sierrania de Ronda (Sierra de las Nieves, S. de Bermeja and S. de Yunquera). It grows at 1,000-2,000m elevation.

2. Subsp. *marocana* (Trab.) Emb. & Maire occurs in Morocco: in the western Rif Mountains (Mts. Tissouka, Mago, Kraa, Mt. Tazaot, and Bab Rouida), at elevations of 1,400-2,100m.

In its native habitat the climate is montane Mediterranean, at between 1000 and 2000m elevation; dry, warm summers alternate with cool, moist winters, and annual precipitation around 1,000mm. Both varieties occupy similar habitats: north-facing slopes on rocky soils derived from dolomitic limestone or serpentine, with deep drainage (Tutin et al., 1964).

Abies pinsapo was introduced to Britain in 1839. It is not a fast-growing tree and never achieves very large dimensions – 27m is about its limit. A species plot at Crarae, Argyll averaged just under 4m at age 20 (Macdonald et al., 1957) and has subsequently lacked vigour and been subject to windthrow, while the plot at Kilmun (Mason et al., 1999) has also been severely damaged by windthrow. Like *A. cephalonica* it is probably better suited to the drier and warmer parts, particularly in the south of England, including the chalk (Johnson, 2003), although the existing trees are mainly in the west.

Dallimore and Jackson (1948) stated that: "the wood does not appear to possess any commercial value outside its native country". The tree frequently displays coarse stem form, often with multiple leaders and forks (Macdonald et al., 1957) as at Crarae. It is however quite frequently planted for timber outside its present natural range (Tutin et al., 1964), notably in southern France. Like *Cedrus atlantica*, which grows in the same areas (sometimes in intimate mixture, as at Mt. Ventoux), it is one of a small group of conifers adapted to calcareous soils.

Figure 7. Abies pinsapo var. pinsapo – Ronda (Malaga), Spain. (Photo: Dr S. McG. Wilson)

Likely silvicultural and utilisation potential in Britain

The limited growth information that is available from forest plots in Britain (Table 2) suggests that, in the more oceanic parts of Britain, none of these southern European and Asian species is likely to be as productive as *Abies* species from north-west America such as noble fir, grand fir, and Pacific silver fir. British forests already contain some 8,000ha of

Table 2. Growth of Abies species from southern Europe and the Near East in trial plots in forest gardens in Britain.

Species	Location	Age	Top height (m)	Cumulative basal area (m^2ha^{-1})	Estimated yield class
Abies alba	Kilmun, Argyll	47	22.5	75.6	18
Abies cephalonica	Bedgebury, Kent	50	19.7	47.0	8
Abies cephalonica	Kilmun, Argyll	48	21.5	79.2	16
Abies cilicica	Kilmun, Argyll	40	16.8	N/A	12
Abies nordmanniana	Brechfa, Wales	41	22.7	61.4	16
Abies nordmanniana ssp *equi-trojani*	Bedgebury, Kent	53	22.4	74.4	14
Abies nordmanniana	Kilmun, Argyll	50	19.8	84.4	14
Abies pinsapo	Kilmun, Argyll	41	18.0	49.4	14

Notes: 1. For details of Brechfa and Kilmun, see Danby and Mason (1998) and Mason et al. (1999). Information on Bedgebury kindly provided by Ian Craig, Forest Research, Alice Holt.
2.Top heights converted to Yield Class using tables for noble fir as advised by Hamilton and Christie (1971). No basal areas provided for the *A. cilicica* plot at Kilmun because its small size meant that such a measure would be unreliable.

stands comprising *Abies* species, but these are dominated by the North American grand fir (*Abies grandis*) and noble fir (*Abies procera*), in a roughly 2:1 ratio (Mason, 2012). Most existing plantations of these species were established during the period 1920-1980, with very limited deployment in woodland creation or restocking since 1980. Noble fir is primarily used in upland areas of Scotland and Wales where the dominant plantation crop is currently either Sitka spruce (*Picea sitchensis*) or Scots pine (*Pinus sylvestris*). Grand fir is used in a wider range of situations across Great Britain, weighted towards somewhat better sites at lower elevations, where a number of productive conifer and hardwood species are potentially suitable.

Areas of all other *Abies* species are very much smaller and are dominated by older material in mixed woodlands established prior to 1920. Few stands of other *Abies* species can be found outside arboreta and forest gardens. Perceptions of *Abies* (including the NW American species) among foresters and timber processors in Great Britain are currently adverse, due to the established risk of drought crack (Day, 1954) and the lower density and market prices for the timber (Wilson, 2010, 2011). Markets are typically for lower grade, non load-bearing applications such as fencing and pallet wood. However, in the USA noble fir (*A. procera*) is regarded as suitable for general structural purposes and joinery. Its wood is valued by many over that of other true firs because of its greater strength. It has been used in the US for specialty products, such as stock for ladder rails and construction of aircraft (Burns and Honkala, 1990). *A. grandis* is used as a general construction timber, and is commercially valuable even though it is weaker and more prone to decay than many other species. *A. alba* is highly regarded in continental Europe as a general construction timber.

Commentary in recent years has suggested an expanded role for European silver fir (*Abies alba*) and Pacific silver fir (*Abies amabilis*) in forests managed under selection systems in Britain (Kerr, 1999; Kerr et al., 2015; Mason, 2012; Savill, 2013; Wilson, 2010, 2011, 2014). Such applications would take advantage of the advance regeneration and shade tolerance of these species, while use in mixed-species stands would be expected to significantly mitigate the risks from *Adelges nordmanniana*. Pacific silver fir would primarily be a species for the wetter western upland areas on freely draining soils, potentially operated in mixture with Sitka spruce and western hemlock. European silver fir would be expected to grow best on better, mid-slope sites across the country, in mixture with a wide range of other conifers (e.g. Douglas fir, Norway spruce) and hardwoods (oak, beech, sycamore). Field reports also suggest that the timber quality of European silver fir, in particular, exceeds that of the North American *Abies* species, as used in British forestry, although we have little direct evidence to date.

This leaves the question as to whether there is a class of sites in eastern Britain that are too dry for European silver fir but are capable of carrying productive crops of the more drought tolerant *Abies* species. Kerr et al. (2015) have reported that suitable provenances of *Abies alba* performed satisfactorily within a provenance trial at Thetford. There have also been promising trial plantings of Turkish fir (*Abies nordmanniana* subsp. *equi-trojani* (*bornmuelleriana*) at Bedgebury Pinetum in Kent and of Grecian fir (*Abies cephalonica*) at a number of southern localities. However, as Mason (2012) identified, we do not yet have a sufficient number of trial plots to evaluate reliably and compare the performance of these lesser known species under dry lowland climates. However, George et al. (2015) have

reported relevant findings from Austria. Wilson (2014) suggested that there may well be a role for Mediterranean *Abies* species for use in mixture with Scots or Corsican pine (*Pinus nigra* subsp. *laricio*) and/or with Atlas cedar (*Cedrus atlantica*) in developing more resilient planted forests on the lowland heaths (Thetford, Wareham, etc.). This was based on observations from parts of southern France where such mixtures are employed. The severity of *Dothistroma* might be reduced in such mixed-species stands, potentially allowing the current moratorium on use of Corsican pine to be selectively relaxed. The information presented in this paper suggests that the prime candidates for such comparative trials are *Abies nordmanniana* (all variants), *A. borisii-regis*, *A. cephalonica* and *A. cilicica*. By contrast, *A. pinsapo* does not appear to be as drought tolerant as some of the other species considered (Aussenac, 2002) and is probably not a prime candidate for further trials.

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