Non-native alder species (*Alnus* spp.)

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review the record and future potential for British forestry of alder species introduced from Europe and North America.

Much thought is being given by foresters to alternative tree species that might be grown in Britain and Ireland if climatic change proceeds as predicted. There is also increasing awareness of threats from novel tree pests and diseases. Recently the Wessex Silvicultural Group has considered this matter (Bladon and Evans, 2015), as have Forest Research (2018). There is an on-line network promoting novel species thought to have potential in Britain (SilviFuture, 2018), proposing a range of high and medium priority species. Read et al. (2009) previously suggested 49 'emerging' species (24 conifers and 25 hardwoods) with potential for adapting British forests to predicted climate change.

The debate about species diversification initially emphasised alternative conifers. However, increasing incidence of Chalara (*Hymenoscyphus fraxineus*) in ash (*Fraxinus excelsior* L.) since 2012, more recent *Cryphonectria* blight in sweet chestnut (*Castanea sativa* Mill.), acute oak decline (AOD), and the awareness that some existing broadleaved choices such as European beech (*Fagus sylvatica* L.) may prove vulnerable to drought in a warming climate in southern Britain, imply there is also a need to consider and evaluate alternative hardwoods. This article considers selected non-native alders (*Alnus* spp.) from Continental Europe and North America for British forestry, potentially offering fresh options for afforestation on demanding sites, diversification of conifer plantations and short-rotation biomass production (McKay, 2011; Woods, 2009).

Introduction

Alders belong to the Betulaceae (birch) family, which has six genera: birches (*Betula* spp.), alders (*Alnus* spp.), hazels (*Corylus* spp.), hornbeams (*Carpinus* spp.), hazel-hornbeams (*Ostryopsis* spp.) and hop-hornbeams (*Ostrya* spp.), totalling 167 species. They are mostly natives of the temperate Northern Hemisphere, with a few reaching the Southern Hemisphere in the South American Andes. The first four genera include species native to the British Isles.

The alders (*Alnus* spp.) are monoecious (i.e. male flowers and female flowers are in separate structures on the same tree) and occur widely in temperate deciduous and boreal forests across the Northern Hemisphere. Typical male flowers are catkins, often appearing before the leaves, and female catkins ripen into woody cone-like structures. Along with birches, alders are wind-pollinated, light-seeded and mostly light-demanding, filling early successional or 'pioneer' roles in colonisation of open sites. Many are short-lived, often growing rapidly at first, and can reach large final dimensions. Some alders can grow on relatively infertile sites, including less acidic peats. Most do better on richer alluvial sites. Many are adapted to growth on wet, even inundated, sites. Alders can fix atmospheric nitrogen through the action of actinomycete symbionts (*Frankia*) hosted in root nodules (Evans, 1984). In nature alders grow in monospecific stands or in mixtures with conifers (e.g. spruce and pine) or light-demanding / medium-tolerant hardwoods (e.g. ash, birch, rowan, oak). On better sites alders may form pioneer stands before succession to mixed forest. Many alders reproduce readily by coppice regrowth, recovering from browsing or short-rotation harvesting (Weih, 2004).

In the British Isles the alder genus is represented by a single native species: common or black alder (*Alnus glutinosa* (L.) Gaertn.). This is an atypical alder, being a later-successional species of intermediate shade tolerance (Claessens et al., 2010; Edlin, 1964), which did not colonise extensively until the mid-Holocene. It generally does best on fertile riparian and alluvial sites (Peterken and Hughes, 1995), although it is found in 'slope alderwoods' where there is a springline moisture supply (Rodwell, 1991), and can be successfully established, at least initially, as part of afforestation on poorer upland sites, including less acidic peats.

Useful earlier reviews of the role of introduced alders in Britain were provided by Evans (1984), Savill (2013), and White and Gibbs (2000). They have been used to varying extents, mainly for afforestation of demanding sites, including those reclaimed from industrial or extractive use (Evans, 1984; Moffat and Roberts, 1989; Richardson, 1993; Vann et al., 1988), but also locally on upland moorlands. Key species (see Figures 1a and b) are grey alder (*Alnus incana* (L.) Moench), Italian alder (*Alnus cordata* (Loisel.) Duby), red alder (*Alnus rubra* Bong.) and green alder (*Alnus viridis* (Chaix) DC), now including the North American Sitka alder. These species are potentially suitable for short-rotation biomass production (McKay, 2011), or as 'nutritional nurses' in mixtures with productive species (Mason and Connolly, 2014).

Grey alder (*Alnus incana* (L.) Moench)

Taxonomy and distribution

Between four and six sub-species are recognised by various authors, including grey alder (*Alnus incana* ssp. *incana*), native throughout much of Central and Eastern Europe, Scandinavia and western Russia; Manchurian alder (*A. incana* ssp. *hirsuta*) from northeast and central Asia;

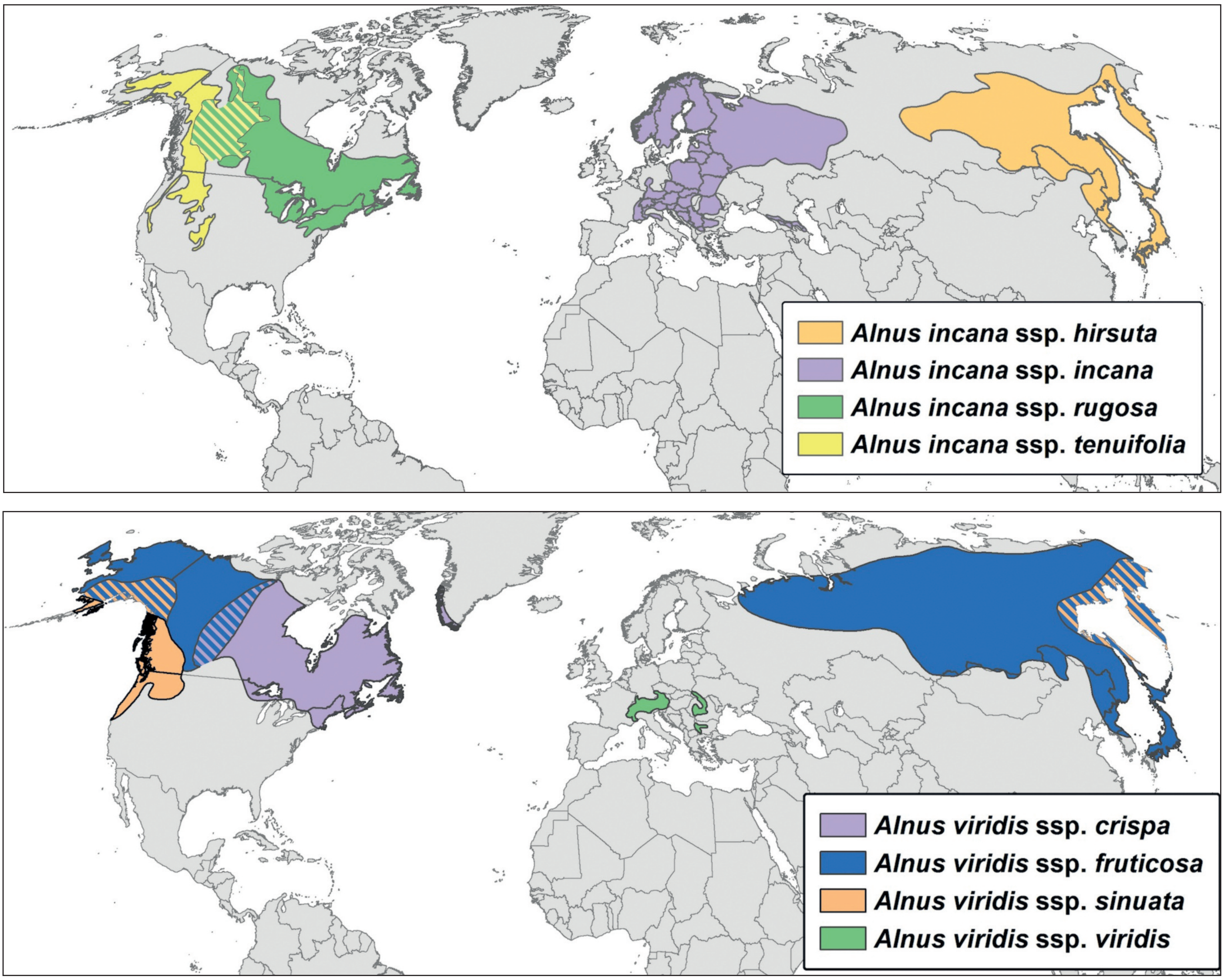

Figure 1a. Distribution maps for non-native alder species. Top: Grey alder (Alnus incana). Bottom: Green alder (Alnus viridis). Source: Caudullo et al (2017).

speckled alder (*A. incana* ssp. *rugosa*) from north-eastern North America; and mountain or thin-leaf alder (*A. incana* ssp. *tenuifolia*) from western North America (see Figure 1a). The ecological association of grey alder in Europe is with riparian woodland, along with willows and poplars. There is an association with mountainous areas in southern parts of Europe, extending to 1500m asl. Further north the species can descend to sea level. In Canadian boreal forests the speckled alder is strongly associated with black spruce, forming the wetland forest association 'black spruce/speckled alder'. Hadfield (1968) indicates that grey alder is also associated with pine-spruce forests within Scandinavia.

Grey alder is considered to have low to moderate shade tolerance. It is known as a pioneer colonist of alluvial soils, screes and abandoned farmland. It was first introduced to Britain in 1780 (Macdonald et al., 1957; Savill, 2013) and has been used fairly frequently in plantations, particularly to nurse oak, ash, beech and the more sensitive conifers (e.g. *Thuja*) in frost-prone areas. It has also been favoured on reclaimed land (e.g. former industrial, mining and quarrying sites), partly due to its greater drought tolerance than native black alder. It is a medium-sized tree, reaching 10-20m in height (Tutin et al., 1964) with a relatively short lifespan (60-100 years). Leaves are more lanceolate/ovoid than in native black alder and typically 4-12cm long by 4-8cm broad (Hora, 1981). The bark is smooth and grey throughout life. The species can hybridise with the native black alder (Hora, 1981) to form *A. x pubescens* (Tausch), common where the parents co-occur (Tutin et al., 1964).

Climate and soil requirements

Savill (2013) indicates no major climatic limitations to growth of grey alder in Britain, but it is slightly less frost hardy than

Figure 1b. Distribution maps for non-native alder species. Left: Italian alder (Alnus cordata). Right: Red alder (Alnus rubra). Sources: Red alder - (US Geological Survey, 1999); Italian alder – Caudullo et al (2017).

Figure 2. Young stand of grey alder.
(Photo: John White, Forestry Commission)

native black alder (Evans, 1984) and will not stand significant exposure. It has fairly wide soil tolerances, as compared with other alders, but will not stand severe drought. In terms of the Forestry Commission Ecological Site Classification (ESC) (Pyatt et al., 2001) it accepts a soil moisture regime of Moderately Dry to Wet and a soil nutrient regime of Poor to Medium. It will not tolerate alkaline soils, very acidic peats or nutritionally very infertile moorland or heathland soils (Forest Research, 2018)

Provenance selection

There has been little provenance research on this species in Britain. Forest Research (2018) recommend that material be obtained from good stands in Britain or western Scandinavia.

Seed production and nursery practice

Grey alder has separate male and female catkins on the same tree, the male catkins being noticeably pendulous and up to 10cm long. Savill (2013) reports that grey alder flowers between February and May and then seeds between September and October. Seeds are very light (averaging ~1,500,000 seeds/kg) but the germination rate is typically only 25-30%. Nursery practice is similar to that for black alder, more widely propagated in Britain for use in native woodland restoration (Aldhous and Mason, 1994; Gordon, 1992; Gordon and Rowe, 1982; Gosling, 2007). This includes cold storage below 4°C, after drying to 8-10% moisture content. Dormancy is shallow, but cool pretreatment at 4°C for four to six weeks may improve germination. As for all alders, inoculation with crushed nodules is effective in ensuring good development of nodules in seedling root systems (for references, see red alder below).

Silviculture and yield

Grey alder is most often grown either as a nurse to final crops of conifers or hardwoods or as a shorter-rotation biomass crop in single-species plantations (see Figure 2). There is a fairly limited silvicultural record with this species in Britain. Results are reported from two sample plots at Drummond Hill in Perthshire (on a fertile loam) and Thetford Forest in Suffolk (on sand over chalk) (see Table 1). Mason et al. (1999) report that trees of the Drummond Hill provenance, when tested at Kilmun Forest Garden in Argyll, reached 10.2m in height after 28 years of growth, with a GYC of 4 (see Table 2). Earlier attempts to use grey alder as a nurse to oak were often only partially successful as these mixtures were planted too close. Suckering of the grey alder was problematic and gave rise to concern over its potential invasiveness, especially if cultivated close to native semi-natural woodlands. Grey alder displays vigorous stump and root suckering from 3-5 years (Evans, 1984). Greater success was achieved with nursing mixtures of grey alder with ash or beech in southern England (e.g. Buriton Forest and Friston Forest, South Downs) (Wood and Nimmo, 1962). Alder was usually established in advance of companion species. Where there was a sufficient clay-with-flints overburden, the alder achieved 5m in height after seven years and 10m after 20 years (Macdonald et al., 1957). On shallow rendzinas grey alder typically failed. Work at Friston Forest suggested that nitrogen fixation by grey alder protected companion ash from nutritional check. Upland trials suggested that grey alder performs quite well on better

Table 1. Summary data from Forest Research sample plots of alder species.

Species	Location	County	Age (years)	Top height (m)	Mean dbh (cm)	Cumulative basal area (m^2 ha^{-1})	Cumulative volume (m^3 ha^{-1})	General (local) yield class (m^3 $ha^{-1}yr^{-1}$)
Alnus glutinosa	Mildenhall	Suffolk	56	20.7	32.1	57.6	476	8 (9)
Alnus cordata	Holt Down	Hampshire	52	19.7	29.9	76.3	559	8 (11)
Alnus incana	Drummond Hill	Perthshire	40	18.8	35.8	-	417	8 (10)
Alnus incana	Croxton Mousehall	Suffolk	40	16.1	25.7	40.1	253	6 (6)

Table 2. Growth and yield of non-native alder species recorded in British trial plots. (n.d. indicates no data for that parameter)

Species	Location	County	Age (years)	Mean height (m)	Mean dbh (cm)	Yield class (m^3 $ha^{-1}yr^{-1}$)	Source authors (see note below)
Alnus incana	Nith Bridge	Dumfries-shire	38	22.6	n.d	n.d.	1
Alnus incana	Kilmun	Argyll	28	10.2*	n.d.	4	4
Alnus cordata	Buriton	Hampshire	22	13.7	13.7	11	1, 2
Alnus cordata	Micheldever	Hampshire	21	17.0*	22.0	12	2
Alnus cordata	Rockingham	Northants.	21	7.3	n.d.	n.d.	1
Alnus cordata	Kilmun	Argyll	63	24.8*	n.d.	12	4
Alnus rubra	Benmore	Argyll	25	8.8	n.d.	n.d	1
Alnus rubra	Buriton	Hampshire	26	14.3	22.6	n.d.	1
Alnus rubra	Rockingham	Northants.	21	9.5	n.d.	n.d.	1
Alnus rubra	Lennox	Dunbarton-shire	17	n.d.	10.4	12	3
Alnus rubra	Glencorse, Bush	Midlothian	5	n.d.	9.6	14	3
Alnus rubra	Shin 112	Sutherland	11	2.5	n.d.	n.d.	5
Alnus rubra	Solway 12	Dumfries-shire	10	4.7	n.d.	n.d.	5
Alnus rubra	Falstone 14	Northumb.	11	6.2	7.2	n.d.	5
Alnus rubra	North York Moors 79	Yorkshire	10	10.0	12.4	n.d.	5
Alnus rubra	York 13	Yorkshire	10	6.8	n.d.	n.d.	5

*indicates that reported measure is of top height rather than mean height in this particular instance.
Published data sources above:- 1. Macdonald et al (1957); 2. Evans (1984); 3. McIver (1991); 4. Mason et al (1999); 5. Mason (2011) in McKay (2011).

Molinia peats and Juncus flushes, but typically fails if used on ericaceous moorland or heathland sites. This limits its potential value as a nurse or companion to conifer species on acidic sites. Greer (1979) reported early success with grey alder in upland woodland creation in Perthshire. Willoughby et al. (2007) indicated that grey alder is suitable for heavy clays in southern England, based on early trial performance. Evans (1984) indicated that grey alder can be expected to achieve GYC 6-8 on poorer sites, over a rotation of 30 years (c.f. sample plot data in Table 1), whereas on better sites, GYC 14 over 20 years may be achievable.

Pests and diseases

Grey alder is susceptible to *Phytophthora alni* (Brasier, 1999; Cech and Hendry, 2003; Webber et al., 2004), but rather less so than native black alder according to Forest Research (2018) and Savill (2013), while White and Gibbs (2000) had earlier reported it as being equally susceptible. Alders generally are susceptible to *Armillaria* and to deer browsing.

Timber properties and utilisation

Evans (1984) indicated that grey alder timber was similar to that of the native black alder. Johanssen (2005) reports comparative volume and wood density information for grey and black alders in Sweden. White and Gibbs (2000) indicated that grey alder wood density at 15% moisture content is 530kg/m^3 – similar to that of birches. Grey alder timber is paler in colour than the conspicuously reddish wood of native black alder, and is normally used for lower-value biomass applications, not having the same domestic record of traditional craft/carpentry applications (e.g. clog manufacturing, musical instruments, submerged dockworks).

Italian alder (*Alnus cordata* (Lois.) Duby)

Taxonomy and distribution

Italian alder is native to sub-montane Mediterranean areas of southern Italy and Corsica, reaching 1400m asl (Rameau et al., 2008) (see Figure 1b). It occurs together with poplars in riparian woodlands. It has been extended into France, Belgium and Spain as a plantation tree, and is used for pioneer afforestation over dry soils and on reclamation sites. Italian alder has been introduced and become naturalised elsewhere, including Chile and New Zealand. It was introduced to Britain in 1820 (Savill, 2013). Several trial plantations have been established in Britain but the species has not been widely deployed in plantations. During the 1960s and 1970s Italian alder was fairly widely planted for reclamation work, such as on colliery spoil, but later declined following drought damage in 1976 (Evans, 1984; White and Gibbs, 2000). Italian alder is a medium-sized tree, growing to 20-25m in height, occasionally 28m, and typically living for 60-100 years. The leaves, which are occasionally confused with poplar, are heart-shaped (cordate) with serrated margins, and 2-11cm long (Hora, 1981; Tutin et al., 1964). Male catkins are reddish and pendulous, reaching 10cm long, while female catkins are smaller and harder, superficially resembling the cones of conifers. The species can hybridise with native black alder (Hora, 1981), and can prove invasive under certain circumstances.

Climate and soil requirements
Italian alder has no significant climatic limitations in Britain, with cold hardiness to -25°C (Forest Research, 2018; Savill, 2013). It is relatively tolerant of exposure and atmospheric pollution. However, optimum growth can probably be expected in warmer lowland districts (Forest Research, 2018). It has broad soil tolerances, including shallow, dry and calcareous site types, performing best on deep chalky soils and least well on acidic and peaty soils. Preference is for a Slightly Dry to Moist soil moisture regime (SMR) and Poor to Medium soil nutrient regime (SNR) in terms of the Forestry Commission Ecological Site Classification (ESC) (Pyatt et al., 2001). It is less strongly associated with riparian and alluvial site conditions than most other alder species. Its site tolerances make it a useful pioneer option in Britain for demanding (including reclamation) sites with compact, anaerobic soils (Willoughby et al., 2007), where its nitrogen fixing capability, due to *Frankia*, is valuable.

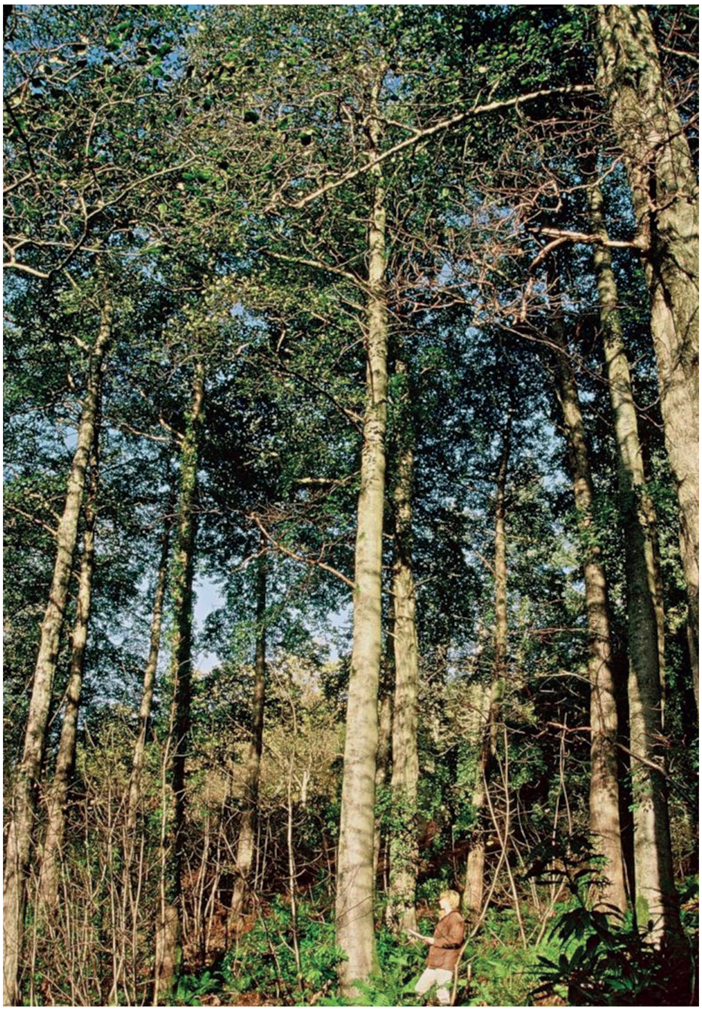

Figure 3. Italian alder at Kilmun Forest Garden, Argyll. Age 63 years/GYC 12. (Photo: Glenn Brearley, Forest Research)

Provenance selection
There is no information available on provenance selection for this species in Britain as no provenance trials have been undertaken. Seed should be sourced from the native range.

Seed production and nursery practice
The species begins to produce seed early in life and seed is light (363,000 seeds/kg) with a germination rate around 50% and seed does not store well (Savill, 2013). Macdonald et al. (1957) estimated 484,000 seeds/kg and a germination rate of 25% from home collections. Nursery practice is believed to be similar to that for native black alder (Aldhous and Mason, 1994; Gordon, 1992; Gordon and Rowe, 1982; Gosling, 2007). This includes cold storage below 4°C, after drying to 8-10% moisture content. Dormancy is shallow, but cool pretreatment at 4°C for four to six weeks may improve germination. 1+1 transplants are usually suitable for planting out (Macdonald et al., 1957). Italian alder coppices variably, and some authors advocate a higher cut than normal, at around 30cm, to improve sprouting success.

Silviculture and yield
Macdonald et al. (1957) and Evans (1984) reported on early British trial plantations of this species, including Benmore (Argyll), Queen Elizabeth Forest (Hampshire), at an elevation of 200m, with ~900mm annual rainfall, on a loamy soil over chalk and at Rockingham Forest (Northants), over a calcareous boulder clay (see Table 2). Italian alder was reported to have failed on the acid silty soils of Bedgebury (Kent), and similarly when planted experimentally onto peats. Mason et al. (1999) reported performance of an Italian alder plot at Kilmun Forest Garden (Argyll) as exceptional for that northerly latitude (see Table 2 and Figure 3). A Forest Research sample plot at Holt Down reached 19.7m in height and 29.9cm dbh after 52 years, with an estimated GYC of 8 and Local Yield Class of 11 (see Table 1). In Britain a GYC of 11-12 over a rotation of 20-30 years can be expected (Evans, 1984). A good plot at John F. Kennedy Arboretum, Co. Wexford, was producing 16m^3/ha/yr after 48 years (see Figure 4).

This is a strongly light-demanding species, likely to prove

Figure 4. Italian alder at John F. Kennedy Arboretum. Co. Wexford. Age 48 years/GYC 16. (Photo: Scott McG. Wilson)

suitable for deployment in single-species stands for afforestation on demanding sites with compact, anaerobic and/or calcareous soils. There is also potential for short-rotation biomass forestry (McKay, 2011), perhaps under coppice, and for use in nursing mixtures, for example over calcareous soils.

Pests and diseases

Italian alder is susceptible to *Phytophthora alni* (Brasier, 1999; Cech and Hendry, 2003; Webber et al., 2004; White and Gibbs, 2000), but possibly less so than for native black alder (Forest Research, 2018). Alders generally are susceptible to *Armillaria* and to deer browsing.

Timber properties and utilisation

The timber is reddish-brown and comparable to that of hybrid poplars, if rather heavier and stronger (Savill, 2013). It is less dense than that of black alder (Evans, 1984), but durable when fully submerged. It has previously been used for a variety of applications including moulding, turning and carving, utility furniture-making, panel and plywood manufacture. In Britain its major potential application is likely to be for woodfuel biomass production.

Red (or Oregon) alder (*Alnus rubra* Bong.)

Taxonomy and distribution

Red alder is native to the mainly coniferous forests of the coastal Pacific Northwest, from Alaska south to southern California / Idaho (see Figure 1b) (Evans, 1984; Phillips, 1978), where it often grows together with Sitka spruce (*Picea sitchensis*), grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), red cedar (*Thuja plicata*) and Douglas fir (*Pseudotsuga menziesii*). It is the common nitrogen-fixing tree in those forests. In riparian stands it occurs with poplar, willow and ash. Its native range is predominantly within 200km of the coast, but does extend considerably further inland in Oregon and northern Montana (Burns and Honkala, 1990). It typically occurs below 750m asl (Burns and Honkala, 1990), being replaced by Sitka alder (*Alnus viridis* ssp. *sinuata*) at higher elevations (see below). Further north it is mainly found nearer to sea level. On drier east-facing slopes it is replaced by thinleaf alder (*A. incana* ssp. *tenuifolia*) (see above). It is a light-demanding pioneer following storm damage, forest fires and clearfelling, aided by *Frankia* nitrogen fixation.

In the native range red alder reaches 30-40m in height with 90cm DBH (Burns and Honkala, 1990) and is one of the largest alders in the world. It was introduced to Britain before 1880 (White and Gibbs, 2000), but has not proven particularly successful here, typically becoming a small to medium-sized tree of around 12-15m height (Phillips, 1978) (see Figures 5 and 6). The bark is silverish-grey in the home range, but often darker in younger plantations. Leaves are similar to those of grey alder, but usually more lanceolate (7-12cm long), and deeply serrated, with an orange down on the underside. Male catkins can reach 10-15cm long in spring. Red alder can be crossed successfully with other alders and there are reports of natural hybridisation with thinleaf alder in the native range (Burns and Honkala, 1990).

Climate and soil requirements

Red alder is best suited to an oceanic climate similar to that of western and upland Britain (Forest Research, 2018). In the native range it does best on cool moist, west-facing slopes with annual rainfall in excess of 630mm (Burns and Honkala, 1990), and in California becomes increasingly associated with riparian sites with good groundwater supplies. It is winter cold hardy when dormant, potentially to around -30°C (Cannell et al., 1987; Mason, 2011) but Evans (1984) and Savill (2013) report greater sensitivity to aseasonal frosts than for other alders, which may explain frequent observations of severe die-back, often occurring after 10-15 years of growth.

Figure 5. Red alder at Crarae Forest Garden, Argyll. Age 54 years. (Photo: Scott McG. Wilson)

Red alder is intolerant of wind exposure. Its soil preferences for optimum growth are not fully resolved, but it appears to perform well on deeper clay soils, where its tap rooting habit allows it to survive summer droughts. In terms of the FC Ecological Site Classification (ESC) (Pyatt et al., 2001), optimum conditions will be a Poor to Medium soil nutrient regime (SNR) and a Fresh to Wet soil moisture regime (SMR). It is unsuited to acid peats or alkaline soils and early growth is slow on droughty or infertile soils. It is unclear whether red alder can combine efficiently with European strains of the *Frankia* bacterium.

Provenance selection

Provenance trials have been undertaken with red alder in Britain (Mason, 2011). A variety of individual provenances have been tried in Scotland (e.g. in the Kilmun Forest Garden, Argyll (Mason et al., 1999)) including some more northerly ones from British Columbia (e.g. Queen Charlotte Islands). Cannell et al. (1987) and Sheppard (1993), reporting systematic provenance trials at Glencorse, indicated that while coastal Washington or British Columbia were probably best matched to British growing conditions, susceptibility to damage by even moderate late spring frosts (-3°C) arose, even with northerly Alaskan origins. Forest Research (2018) recommend use of seed from good British provenances or those from coastal Washington or British Columbia, for any future plantings of red alder in this country. Evans (1984) suggested that use of higher elevation provenances, or putative hybrids with Sitka alder (see below) might confer enhanced frost resistance for use in Britain.

Seed production and nursery practice

This monoecious species is sexually mature by eight years (Burns and Honkala, 1990). Moderate seed crops are produced every year and prolific crops every 3-5 years. Burns and Honkala (1990) state that red alder produces 800,000-3,000,000 seeds/kg within the native range. Macdonald et al. (1957) indicate that it produces ~1,500,000 seeds/kg with a 40% germination rate from home collections in Britain. Nursery practice is believed to be similar to other alder species (Aldhous and Mason, 1994; Gordon, 1992; Gordon and Rowe, 1982; Gosling, 2007). This includes cold storage below 4°C, after drying to 8-10% moisture content. Dormancy is shallow, but a cool pretreatment at 4°C for four to six weeks may improve germination. Seedlings achieve rapid early growth (Burns and Honkala, 1990). The potential benefits of nursery inoculation with *Frankia* to aid nodulation, in this and other alder species considered, were discussed by Aldhous and Mason (1994), Hooker and Wheeler (1987), McNeill et al. (1989) and Wheeler et al. (1991).

Silviculture and yield

In the native range red alder has traditionally been regarded as a 'weed species', with extensive efforts by foresters to eliminate it using herbicides (Burns and Honkala, 1990). It colonises clearfell and/or wildfire sites rapidly by seeding if the mineral soil surface is disturbed. Burns and Honkala (1990) indicate that the species coppices well when young, but that productivity declines with successive coppicing cycles. In the native range early growth is rapid (9m at five years, 16m at ten years, 24m at 20 years). Volume yield is estimated at 21m^3/ha/yr over shorter rotations of 10-12 years and 14m^3/ha/yr over timber rotations of ~30 years. Growth slows markedly after the juvenile stage, especially on poorer sites (site index at 20 years being 10-25m and at 50 years, 18-37m). Burns and Honkala (1990) indicate that red alder will match Douglas fir for height until 45 years of growth. In Britain red alder typically grows rapidly for the first 10-15 years, often reaching 15m in height, before a rapid decline in growth rate, with subsequent die-back. For this reason, its use as an early nurse for hardwoods and sensitive conifers has previously been considered (Lines and Brown, 1982). Trees planted in early trials on peaty soils grew rapidly initially, but often subsequently failed. Macdonald et al. (1957) report results from a trial plantation of red alder at Buriton Forest, Hampshire (clay-with-flints over chalk) and another at Rockingham Forest, Northants (calcareous boulder clay) (see Table 2). McIver (1991) discussed the potential of red alder for initial afforestation of sites in Central Scotland, while Mason (2011) reviewed its wider potential for use in short-rotation biomass forestry. McKay (2011) suggested a biomass rotation of 15 years. Occasional British stands have reportedly continued rapid growth for longer, mainly in coastal and sheltered locations where frost damage was avoided.

Pests and diseases

Red alder's susceptibility to *Phytophthora alni* (Brasier, 1999; Cech and Hendry, 2003; Webber et al., 2004) is considered to be lower than that of native black alder (Forest Research, 2018), but instances of significant damage have previously been reported (White and Gibbs, 2000). A plot of red alder under test in the Brechfa Forest Garden, Wales failed after an attack by a willow scale insect (*Chianaspis salicis*) (Danby and Mason, 1998) as did another near Alice Holt. Alders generally are susceptible to *Armillaria* and to deer browsing.

Timber properties and utilisation

Red alder wood is similar to that of other alders, and used for pulping in America. There is some utility for furniture and musical instrument manufacture (Evans, 1984), and this is reportedly a preferred species for salmon smoking in the Pacific Northwest. There are traditional Native American cultural and craftwork applications. A major use for material produced in Britain would likely be woodfuel biomass (Mason, 2011; Sheppard, 1991), which could arise from use for diversification in upland conifer forests (Deal et al., 2014), or for initial afforestation on demanding lowland sites, where site conditions allowed.

Green alder (*Alnus viridis* (Chaix) DC.) inc. Sitka alder (formerly *Alnus sinuata*)

Taxonomy and distribution

Green alder occurs widely across the northern hemisphere as several distinct sub-species (see Figure 1a). The

Figure 6. Red alder at Glen Oykel, Sutherland. Age 27 years. (Photo: Bill Mason, Forest Research)

Species Profile

European sub-species (*Alnus viridis* ssp. *viridis*) is found in the Alps and Carpathian mountains. Also of significance is the western North American species (*A. viridis* ssp. *sinuata*), also known as Sitka alder (formerly *A. sinuata*), which extends into Kamchatka. The mountain alder (*A. viridis* ssp. *crispa*) is found in eastern Canada and Greenland, while *A. viridis* ssp. *fruticosa* is found widely across Siberia and Alaska in boreal forests. At high latitudes the species functions as a pioneer colonist of fluvioglacial gravels, with willows. At lower latitudes green alder becomes strongly associated with mountain environments, acting as a pioneer colonist of disturbed sites (e.g. after avalanches). It occurs above red alder in the mountains of the Pacific Northwest and above grey alder in the mountains of central and southern Europe. The habit of green alder is described by Mitchell (1974) as "an erect-branched shrubby plant, rarely a small tree", seldom exceeding 3m in height in Europe, but reaching 12-13m in the case of western American Sitka alder (Hora, 1981) (see Figure 7). It has shiny green ovate leaves (3-8cm long; 2-6cm broad). Green alder was introduced into Britain over a century ago (e.g. Sitka alder in 1903 according to White and Gibbs (2000)), and is used to some extent for afforestation of reclaimed sites (e.g. Moffat and Roberts, 1989).

Climate and soil requirements

This species is winter cold hardy in Britain (Forest Research, 2018) and believed more frost resistant than red alder, but is intolerant of wind exposure. It grows best on a free-draining soil of poor to moderate fertility. Droughty, poorly drained and alkaline soils are unsuitable. Its nitrogen-fixing capacity (due to *Frankia* in root nodules) helps to ameliorate infertile sites.

Figure 7. Sitka alder at Crarae Forest Garden, Argyll. Age 42 years. (Photo: Scott McG. Wilson)

Provenance selection

There is currently no information available to guide provenance selection in Britain.

Seed production and nursery practice

As with other alders, green alder seed is light, and is wind and water dispersed. Green alder also reproduces by profuse stump and root suckering and can become invasive in some circumstances. Nursery practice is believed to be similar to that for other alder species (Aldhous and Mason, 1994; Gordon, 1992; Gordon and Rowe, 1982; Gosling, 2007). This includes cold storage below 4°C, after drying to 8-10% moisture content. Dormancy is shallow, but cool pretreatment at 4°C for four to six weeks may improve germination.

Silviculture and yield

Green alder might find a role as a soil improving or diversification species within upland conifer forests on certain site types. It is less likely to become over-competitive than red alder (Evans, 1984). Vann et al. (1988), reviewing the establishment success of alder species on ex-industrial sites in the Pennines, suggested that the European sub-species of green alder had performed as well as native black alder, while red and Sitka alders had performed poorly. The use of hybrids with red alder to enhance frost resistance has been suggested (Evans, 1984). Green alder has become an invasive weed in New Zealand, and this should certainly promote caution as to its potential deployment in Britain, especially near to native woodland sites.

Pests and diseases

Forest Research (2018) indicate that susceptibilities are likely similar to those of Italian alder.

Timber properties and utilisation

There is little record of domestic use of the timber due to its poor stem form – any material harvested from British deployments would be likely to supply woodfuel biomass markets.

Conclusion

The species discussed in this article are currently unlikely to be deployed to replace native black alder (*Alnus glutinosa*), either in existing woodlands or when creating new woodlands for habitat restoration or biodiversity conservation. Significant risks of invasive regeneration and hybridisation render non-native alders unsuitable for deployment close to native alder populations or ancient or semi-natural woodlands. Any future deployment is likely to be for afforestation for timber and woodfuel production, carbon sequestration, soil conservation and flood mitigation, particularly where carried out on difficult sites with infertile or immature/reclaimed soils. The role of alder species in providing additional nitrogen by bacterial fixation is valuable in such situations. These species might be deployed to form pure or mixed hardwood stands for short-rotation forestry, or as nurses to rotational coniferous crops (e.g. Sitka spruce). The former approach could be applied under lowland conditions – for example, on suitable reclamation sites or in some floodplain contexts. Candidate alder species for such situations are likely to be grey and Italian alders. 'Nursing/nutritional mixtures' with conifers are most likely to be applicable to those more upland areas with lower frost risk, in order to enhance the biodiversity value of productive conifer plantations or to improve their long-term sustainability (e.g. on sites where rotational nutrient depletion is a factor). Here red alder or green alders might prove suitable. Further controlled trials of both these silvicultural regimes remain essential before wider deployment. As with all other non-native species covered in this series any future deployment of non-native alder species must abide by legislation/regulations in force at the time, and licensing may be required.

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