The Brechfa forest plots: results after 70 years

by Adam Offler and Chris Reynolds

Summary:
The forest plots at Brechfa in South Wales offer a rare opportunity to observe and measure a range of potential alternative forestry species in maturity. This article revisits these plots, last reviewed by Danby and Mason (1998). Assessment of height and DBH was carried out in March 2024, shortly before Storm Darragh in December, providing us with data following nearly 70 years of growth for 34 species. Growth was generally consistent with the previous review, with fir and spruce the overall best performers, along with western red-cedar and Japanese-cedar. In contrast, of the three pines previously measured, only Macedonian pine remains. In total, nine species show growth comparable to that expected of Sitka spruce in this area. These results are compared with those previously published and are placed in the context of a changing forestry landscape.

Introduction

Our climate suits a wide variety of trees, and around 500 species have been grown, with many being actively evaluated for forestry. Following the formation of the Forestry Commission in 1919, thousands of experiments have been established, many of which aimed to evaluate and identify candidates for plantation forestry. These species trials were an important function undertaken by Forest Research until the late 1960s when, mainly driven by economics, large scale species trials largely ceased.

Consequently, the mix of species within British forests today tends towards a small number of very widely-planted species, especially amongst the conifers (Forestry Commission, 2024). However, in recent decades, a number of these species have been threatened by increased pressure from pests and diseases, leading to restrictions on planting Corsican pine (Reynolds et al., 2021), larch (Forest Research, 2025a), and now spruce in southern England (Blake et al., 2024). A sensible response would be to widen our range of species, both to spread the risk, but also to

Figure 1. Aerial shot of Brechfa Forest Garden. The impressive Abies plots (centre) run across the site above the road. The main broadleaved plots run from the centre to the right.

Table 1. Category definitions for Emerging Species research. After Reynolds et al., 2021.

Principal tree species are defined as species that are currently widely used for timber production and will continue to be dominant species unless affected by a new pest or disease or become adversely affected by climate change.

Secondary tree species have been planted on a much smaller scale than the Principal species because they are restricted to particular climate zones or have been overshadowed by more popular Principal species. The qualities of Secondary species are reasonably well understood, and they have demonstrated their suitability for forestry under current conditions and so have potential for wider use in future.

Plot-stage species are species that have not been planted commercially on any significant scale but have demonstrated positive silvicultural characteristics in trial plots and have qualities suitable for forestry objectives to justify further testing and development.

Specimen-stage species are species that have rarely been trialled for forest potential in experimental plots, but have demonstrated, as specimens in tree collections, positive traits of good form, growth rate and hardiness to warrant further testing in plots on a limited scale.

be more able to closely match tree to site conditions. So, what can we do to increase the range of species available to foresters?

After a gap in species research of nearly 40 years, Forest Research initiated a new round of species and provenance trials. Among these is a series of trials planted in 2012 across England, Scotland and Wales, which are testing 42 species and 116 provenances (Reynolds et al., 2021). Other trials aim to fill gaps in our operational knowledge of existing species being planted more widely to improve silvicultural practices. To help focus our research, Kerr and Jinks (2015) suggested a logical approach to research on species by allocating species into one of four categories (Principal, Secondary, Plot-stage and Specimen-stage) based on available evidence on topics such as use and silvicultural knowledge. Generally referred to under 'Emerging Species', this research looks into those species that exhibit the greatest potential for wider use in forestry, mainly those species within the Secondary and Plot-stage categories (Table 1). Unfortunately, trees take time to grow, and these young trials often provide only a tantalising glimpse of future potential. To fully assess a new species and to be confident in their silviculture takes time, with an estimate of two rotations to do it properly.

Fortunately, we have a legacy of old trials where, in some instances, Emerging Species are still thriving. Of particular interest are those trials where species were planted in plots, colloquially referred to as Forest Gardens (Forestry Commission, 1931). Although these trials are generally unreplicated, the existing established plots can be assessed and the species reviewed as mature trees. Unfortunately, time has not been kind to many sites, and a paucity of resources has seen many of them in a slow decline. The old forest plots (Forest Garden) at Bedgebury Pinetum in Kent were devastated in the great storm of 1987, with now only a few scattered but still intriguing species left. It is therefore important that we review these sites before they deteriorate further. Kilmun Arboretum in Scotland was recently reviewed (Mason et al., 2018), but Brechfa Forest Garden in Wales has not been reviewed since a comprehensive assessment by Danby and Mason (1998) (thereafter referred to simply as 'Danby and Mason'). This article returns to Brechfa, to review the progress of a range of species over the intervening nearly 30 years.

Brechfa – the history

Brechfa Forest Garden, part of Brechfa Forest and now managed by Natural Resources Wales, has had more than 90 species plots established since the mid-1950s. The initiative appears to have been based on local staff enthusiasm with the desire to trial species suited to the locality in a high rainfall area. Species selection was set by plant availability at the time and, although early management records are sparse, details of seed origins and basic establishment do still exist. The Forestry Commission Research Division (now Forest Research) took a close interest in management in 1982, following which basic cleaning and maintenance was undertaken and access improved. When possible, plots were assessed with some selected as 'sample plots' for mensuration purposes. There have been periodic visits over recent years, but input into the site has been limited and often initiated by enthusiastic individuals. Site activities now centre around recreation, and Forest Research has no formal management responsibility, with research activities focused on maintaining a source of data and offering advice on an ad-hoc basis. There is still interest in the potential for the site from local staff and individuals, but no current budget to take forward any initiatives. Recently, many plots suffered significant windblow from Storm Darragh in December 2024.

Table 2. Surviving plots at Brechfa Forest Garden. Those which have been assessed are highlighted in grey.

Plot	Plot status	Planting year	Botanical name[2]	Common name	Natural distribution	Seed ID	IUCN status	'Emerging Species' status
24	Viable	1959	*Abies amabilis* Douglas ex J. Forbes	Pacific silver fir	W North America	55-689[3]	LC	Secondary
18	Viable	1957	*Abies cephalonica* Loudon	Greek fir	Greece	AC-79-51	LC	Plot-stage
8	Viable	1961	*Abies fraseri* (Pursh) Poiret	Fraser fir	E USA	54-257	EN	Specimen
16	Viable	1957	*Abies grandis* (Douglas ex D. Don) Lindley	Grand fir	USA	54-607[3]	LC	Principal
23[1]	Viable	1959	*Abies homolepis* Siebold et Zuccarini	Nikko fir	Japan	55-10[3]	EN	Specimen
19[1]	Viable	1958	*Abies nordmanniana* (Steven) Spach	Caucasian fir	Caucasus	52-338	LC	Plot-stage
17	Viable	1957	*Abies procera* Rehder	Noble fir	USA	53-611[3]	LC	Principal
21[1]	Viable	1958	*Abies veitchii* Lindley	Veitch's fir	Japan	52-3[3]	LC	Specimen
85	Viable	2014	*Acer macrophyllum* Pursh	Oregon maple	North America		LC	Plot-stage
68	Viable	1957	*Acer platanoides* L.	Norway maple	Europe		LC	Secondary
67	Viable	1957	*Acer pseudoplatanus* L.	Sycamore	Europe	55-63C	LC	Principal
64	Viable	1959	*Acer saccharinum* L.	Silver maple	North America	54-630[3]	LC	Plot-stage
89	Viable	1957	*Betula lenta* L.	Cherry birch	North America	55-635[3]	LC	Specimen
91	Viable	2014	*Betula maximowicziana* Reg.	Monarch birch	Japan		LC	Specimen
83	Viable	1959	*Betula pendula* Roth	Silver birch	Europe, Asia		LC	Principal
87	Viable	1959	*Betula pendula* Roth	Silver birch	Europe, Asia	Mildenhall[3]	LC	Principal
92	Viable	2016	*Carya tomentosa*					Specimen
13	Viable	1958	*Cedrus deodara* (Roxb. ex D. Don) G. Don	Indian cedar	Himalaya	55-674	LC	Plot-stage
50	Viable	1957	*Cryptomeria japonica* (Thun. ex L. f.) D. Don	Japanese cedar	Japan	54-649[3]	NT	Secondary
82	Viable	1981	*Cupressus* x *leylandii* (Jacks. Dallim) Dallim.	Leyland cypress		Clone 11		Secondary
38	Viable	1957	*Fagus sylvatica* L.	Common beech	Europe		LC	Principal
71	Viable	1959	*Liriodendron tulipifera* L.	Tulip tree	North America	56-754[3]	LC	Plot-stage
37	Viable	1957	*Nothofagus obliqua* (Mirb.) Bl.	Roble beech	Chile, Argentina	FLEET[3]	LC	Secondary
14	Viable	1957	*Picea abies* (L) Karsten	Norway spruce	Europe	51-312[3]	LC	Principal
75	Viable	1961	*Picea koyamae* Shirasawa	Koyama spruce	Japan	Japan[3]	CR	Specimen
56[1]	Viable	1959	*Picea omorika* (Pančić) Purk.	Serbian spruce	Serbia, Bosnia		EN	Secondary
54	Viable	1957	*Picea orientalis* (L) Peterm.	Oriental spruce	Caucasus, Asia Minor	51-53A	LC	Plot-stage
55	Viable	1963	*Picea rubens* Sargent	Red spruce	North America	56-747[3]	LC	Plot-stage
30	Viable	~	*Picea sitchensis* (Bong.) Carrière	Sitka spruce	W North America		LC	Principal
47	Viable	1957	*Pinus contorta* var. *contorta* Doug. ex Loud.	Shore pine	W North America	55-682[3]	LC	Principal
40[1]	Viable	1959	*Pinus peuce* Grisebach	Macedonian pine	Balkans	55-615[3]	NT	Plot-stage
29[1]	Viable	1959	*Pinus strobus* L.	Weymouth pine	North America	56-693[3]	LC	Plot-stage
73	Viable	2004	*Prunus avium* 'Wildstar'					Plot-stage
1	Viable	1957	*Pseudotsuga menziesii* (Mirbel) Franco	Douglas-fir	W USA, Mexico	55-605[3]	LC	Principal
63[1]	Viable	1959	*Quercus canariensis* Willd.	Algerian oak	Europe, Africa	56-4238	NT	Plot-stage
66	Viable	1958	*Quercus cerris* L.	Turkey oak	Europe, Asia Minor	56-61-13	LC	Plot-stage
65	Viable	1959	*Quercus lusitanica* Lam.	Portuguese oak	Spain, Portugal, Africa	56-104	LC	Specimen

Notes:

1. FR historical mensuration plots.
2. Authorities used - https://www.conifers.org/ - EUCLID Home - Mitchell (1974).
3. Seed source of known origin in a wild population area.

(*continued on page 22*)

Site details

Located about 14 miles to the west of Llandovery in Carmarthenshire (national grid reference SN 5747 3567, W3W long.contour.worldwide), the site occupies a hillside on the western side of the Afon Cothi valley, predominantly on a north-easterly aspect but with a few plots facing south (Figure 1). Elevation ranges between 150 and 250 metres above sea level. The site falls within the 'warm-moist' climatic zone defined by the Ecological Site Classification (Pyatt et al., 2001), receiving mean annual rainfall of 1,300 mm and accumulated day degrees (>5.6 deg C) of 1,471. This mild climate was noted as "very favourable to tree growth" by Danby and Mason, with the only reported problem a frost pocket in the flatter areas. Soils are mostly deep brown earth with a pH between 4.5 and 5.0, although there are some areas of gleying.

A total of 92 plots have been established at Brechfa, the majority between 1955 and 1960. These plots vary in both shape and size according to local topography and number of available plants, but all within the range of 0.05 to 0.15 ha. A complete list of species planted was provided by Danby and Mason, and a revised list of surviving plots is given in Table 2, mapped in Figure 2. Plots were established mainly through semi-pit planting, occasionally turf planting, at spacing of either 1.5 x 1.5 m or 1.8 m x 1.8 m. At planting, each tree was fertilised with 57 g (2 oz) of superphosphate, which has been taken to suggest that the site appeared impoverished at the time, despite the apparent fertility today. First thinnings began in 1983, which Danby and Mason noted as suitable to some species but was late for others, such as western hemlock.

Assessments

In June 2022, an initial assessment allowed for plots to be categorised by condition. Those of general good health with an even distribution of stems across the plot were classed as 'Viable', those with a few trees in varying degrees of health that are now considered as specimens were classed as 'Remnant', and those which no longer contain any original plot trees were classed as 'Vacant'.

To provide a comparison with the previously published assessment, in March 2024, all of the 'Viable' plots were remeasured where sufficient trees remained for a plot of at least 0.01 ha. Top height and mean DBH were calculated, and General Yield Class (GYC) estimated from top height and age using ForestYield (Matthews et al., 2013). Species without their own yield curve were mapped to a similar species, as shown in Tables 3 and 4. At this time, other 'non-timber' values of the collection were evaluated, which are summarised below.

Results

Of the 92 plots, 43 were considered 'Viable', 28 'Remnant', and 20 'Vacant'. Of the 43 'Viable' plots, 35 were assessed, comprising 19 conifer and 16 broadleaved species. The

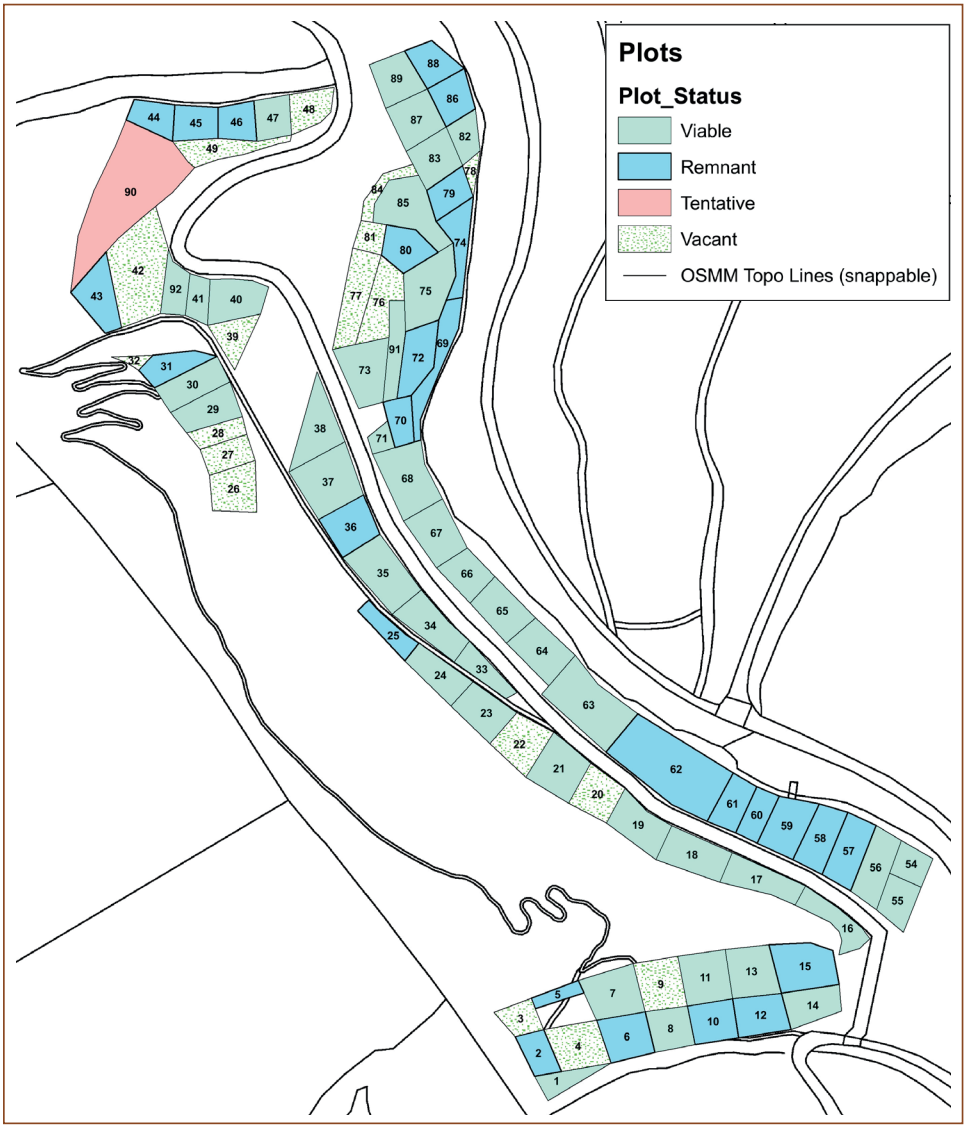

Figure 2. Map of the plots at Brechfa. For species within each plot number, see Table 2.

Table 2 (continued). Surviving plots at Brechfa Forest Garden. Those which have been assessed are highlighted in grey.

Plot	Plot status	Planting year	Botanical name[2]	Common name	Natural distribution	Seed ID	IUCN status	'Emerging Species' status
33	Viable	1957	*Quercus petraea* (Mattuschka) Lieblein	Sessile oak	Europe, Asia Minor	54-61L[3]	LC	Principal
41	Viable	2014	*Quercus pyrenaica* Willd.				LC	Plot-stage
34	Viable	1957	*Quercus robur* L.	Common oak	Europe, N Africa	54-61N[3]	LC	Principal
35	Viable	1957	*Quercus rubra* Michx. F	Red oak	Canada, USA	54-2	LC	Secondary
11[1]	Viable	1958	*Sequoia sempervirens* (D. Don) Endlicher	Coast redwood	USA	58-8[3]	EN	Secondary
7[1]	Viable	1959	*Thuja plicata* Donn ex D. Don in Lambert	Western red-cedar	W North America	54-611[3]	LC	Principal
90	Tentative	~	*Abies* spp.					Specimen
60	Remnant	1960	*Abies balsamea* (Linnaeus) Miller	Balsam fir	North America		LC	Specimen
25	Remnant	1959	*Abies delavayi* (Van Tiegh.) Franchet	Delavay silver fir	China	53-213	LC	Specimen
15	Remnant	1961	*Abies koreana* E.H. Wilson	Korean fir	Korea	57-56	EN	Specimen
59	Remnant	1960	*Abies lasiocarpa* (Hooker) Nuttall	Subalpine fir	USA	56-674[3]	LC	Specimen
61	Remnant	1960	*Acer pensylvanicum* L.	Moosewood	USA	56-4361	LC	Specimen
86	Remnant	1959	*Alnus rubra* Bong.	Red alder	W North America	56-101	LC	Plot-stage
88	Remnant	1957	*Betula maximowicziana* Reg.	Monarch birch	Japan	55-602[3]	LC	Specimen
72	Remnant	1957	*Castanea sativa* Mill.	Sweet chestnut	Europe, Africa	55-608	LC	Principal
6	Remnant	1957	*Chamaecyparis lawsoniana* (A. Murray) Parl.	Lawson cypress	W USA	53-33D	NT	Secondary
12	Remnant	1958	*Eucalyptus pauciflora* subsp. *debeuzevillei* (Maiden) L.A.S.Johnson & Blaxell	Jounama snow gum	Australia	55-670[3]	LC	Secondary
58	Remnant	1959	*Eucalyptus pauciflora* subsp. *pauciflora* Sieber ex Spreng.	Cabbage gum	Australia		LC	Secondary
2	Remnant	1960	*Larix decidua* Miller	European larch	Europe	57-4382[3]	LC	Principal
43	Remnant	1965	*Picea asperata* Masters	Dragon spruce	China	57-49	VU	Specimen
51	Remnant	1957	*Picea glauca* (Moench) Voss	White spruce	North America	53-625	LC	Plot-stage
57[1]	Remnant	1960	*Picea mariana* (Mill.) Britton Sterns, et Pogg.	Black spruce	USA	57-713[3]	LC	Specimen
44	Remnant	1957	*Pinus banksiana* Lambert	Jack pine	North America	46-640	LC	Specimen
45	Remnant	1959	*Pinus mugo* Turra	Mountain pine	Europe	56-116	LC	Specimen
46	Remnant	1957	*Pinus mugo* Terra (syn. var. *pumilio*)	Mountain pine	Europe	52-366[3]	LC	Specimen
31	Remnant	1960	*Pinus uncinata* Ramond ex De Candolle	Mountain pine	Europe	56-4364[3]	LC	Specimen
69	Remnant	1961	*Populus* 'Balsam Spire'	Hybrid poplar				Principal
74	Remnant	1961	*Populus* 'Balsam Spire'	Hybrid poplar				Principal
80	Remnant	1961	*Populus* 'Robusta'	Hybrid poplar				Principal
79	Remnant	1957	*Robinia pseudoacacia* L.	False acacia	USA	55/639 54/921(4) 53/621	LC	Plot-stage
10[1]	Remnant	1959	*Sequoiadendron giganteum* (Lind.) J.Buch.	Wellingtonia	USA	55-7[3]	EN	Secondary
36	Remnant	1959	*Tilia cordata* Mill.	Small-leaved lime	Europe	55-613[3]	LC	Secondary
70	Remnant	1959	*Tilia cordata* Mill.	Small-leaved lime	Europe	55-646[3]	LC	Secondary
5	Remnant	1959	*Tsuga mertensiana* (Bong.) Carrière	Mountain hemlock	W North America		LC	Specimen
62	Remnant	1960	*Ulmus glabra* Huds.	Wych elm	Europe, W Asia	58-1005	DD	Secondary

Notes:

1. FR historical mensuration plots.
2. Authorities used - https://www.conifers.org/ - EUCLID Home - Mitchell (1974).
3. Seed source of known origin in a wild population area.

remaining eight plots were either recent plantings that were too young to offer creditable data for comparison, or plots that were too small in which to place a sample plot.

The top height, mean DBH and estimated GYC of these assessed plots are presented in Tables 3 and 4. For those species originally selected by Danby and Mason, their estimated GYC and the age at time of assessment are given for comparison. Changes since the previous assessment are given as a percentage increase in top height and mean DBH, and an indication of where estimated GYC has risen, fallen or remains the same.

These results are reviewed below, with species mainly grouped into genera for ease of comparison, or into 'Other conifers' and 'Other broadleaves' for outlier species. Within each of the conifer groups, performance is compared to a relevant Principal Species in order to highlight species that offer similar productive potential at maturity.

Conifer species

True firs (Abies spp.*)*

Firs were considered to be the standout genera at Brechfa, with Danby and Mason selecting six of the 14 plots at Brechfa for measurement. Only 12 species plots remain from the original 14, but the original six measured plots were intact and in good health at the time of assessment. From the perspective of the Emerging Species project, the comparison Principal Species are grand and noble fir (*A. grandis* and *A. procera*, Figure 3), which achieved GYC of 24 and 22 respectively at this assessment. Compared to previous assessment, the grand fir has maintained its performance, but the noble fir has dropped 6 classes.

Pacific silver-fir (*A. amabilis*) appeared to be a comparable productive species with a similar GYC of 22. Three other species, Caucasian fir (*Abies nordmanniana*), Nikko fir (*A. homolepsis*) and Veitch's fir (*A. veitchii*) were noticeably smaller in height, DBH and GYC (16, 14 and 18 respectively) but still produced impressive plots in their own right, although some variable form was noted for Caucasian fir. Veitch's fir is worth noting for its improved growth over the last 30 years, moving from a GYC of 12 at the Danby and Mason assessment to 18 in this study.

Greek fir (*A. cephalonica*) had good survival and achieved a GYC of 22, which seems high for this under-researched species and needs further verification. Fraser fir (*A. fraseri*) had varying condition and GYC assessed at 10. The other six species still present are worth mentioning despite comparatively poor performance. Balsam fir (*A. balsamea*), Korean fir (*A. koreana*), sub-alpine fir (*A. lasciocarpa*) and Delavay's fir (*A. delavayi*) were in poor condition and not considered for assessment, while both Colorado fir (*A. concolor*) and Low's fir (*A. lowiana*) had failed completely with only dead stems remaining; thoughts on why will be discussed later.

Figure 3. Noble fir (Abies procera) plot 17, showing good form but variable stem size. Worth noting is the range of fir species regenerating; on a site visit, the authors found three species: noble, grand, and Caucasian, and there may well be others.

Spruce (Picea spp.*)*

Along with fir, Danby and Mason noted spruce species as well suited to the moist climate at Brechfa and selected four plots of interest out of ten species planted. Norway spruce (*Picea abies*) provides a useful Principal Species for comparison, achieving a GYC of 16. In line with other sites (Savill et al., 2017), Serbian spruce (*P. omorika*) was slower growing, with a GYC of 12. At Brechfa, the difference was more pronounced in DBH than height. Both species appear to have slowed growth in the last 30 years. Black spruce (*P. mariana*) deteriorated over the last 30 years, with only 20% of the original stocking left and was not measured. The Koyama's spruce (*P. koyamae*), by contrast, has been a pleasant surprise with excellent survival and a GYC of 20 – increased by 2 since 1998 – putting it 4 classes ahead of the Norway spruce.

Of the other six species, only Oriental spruce (*P. orientalis*) and red spruce (*P. rubens*) were assessed, both with a GYC of 10. Dragon spruce (*P. asperata*) and white spruce (*P. glauca*) appeared generally healthy, but

Table 3. Assessments for conifers in viable plots at Brechfa Forest Garden. Those plots previously assessed by Danby and Mason are highlighted.

	Species	Plot	Age[1]	Top height (m)[2]	Mean DBH (cm)[2]	GYC[3]	Status
Firs	*Abies grandis*	16	67 (39)	38.7 (+36.1%)	45.2	24 (24) –	Principal
	Abies procera	17	67 (39)	35.3 (+17.9%)	45.1	22 (28) ↓	Principal
	Abies amabilis	24	65 (37)	36.0 (+68.2%)	40.8	22 (22) – [b]	Secondary
	Abies homolepsis	23	65 (34)	31.3 (+65.1%)	29.5 (+40.9%)	14 (14) – [b]	Specimen
	Abies veitchii	21	66 (35)	31.3 (+88.3%)	36.9 (+91.0%)	18 (12) ↑ [b]	Specimen
	Abies nordmanniana	19	66 (35)	31.1 (+61.1%)	25.8 (+39.4%)	16 (16) – [b]	Plot stage
	Abies cephalonica	18	67	38.3	43.5	22[b]	Plot stage
	Abies fraseri	8	63	19.9	24.5	10[b]	Specimen
Pine	*Pinus peuce*	40	65 (33)	27.2 (+64.5%)	34.5 (+53.2%)	16 (14) ↑ [d]	Plot stage
Spruce	*Picea abies*	14	67 (39)	27.5 (+27.3%)	34.9	16 (18) ↓	Principal
	Picea omorika	56	65 (34)	24.2 (+61.3%)	24.7 (+31.0%)	12 (16) ↓ [c]	Secondary
	Picea koyamae	75	63 (34)	30.4 (+58.9%)	30.0	20 (18) ↑ [c]	Specimen
	Picea orientalis	54	67	22.2	32.5	10 [c]	Plot stage
	Picea rubens	55	61	21.1	21.5	10 [c]	Plot stage
Other conifer	*Pseudotsuga menziesii*	1	67 (39)	36.5 (+12.8%)	40.0	20 (26) ↓	Principal
	Thuja plicata	7	65 (33)	35.5 (+88.0%)	43.0 (+82.4%)	24 (22) ↑	Principal
	Cryptomeria japonica	50	67 (37)	30.4 (+45.9%)	34.2	22 (20) ↑ [f]	Secondary
	Sequoia sempervirens	11	66 (34)	35.9 (+69.6%)	75.9 (+96.7%)	22 (30) ↓ [a]	Secondary
	Cedrus deodara	13	66	21.0	23.7	8 [e]	Plot stage

Notes:
1. The age when assessed by Danby and Mason is given in brackets.
2. The percentage change since Danby and Mason is given in brackets.
3. The GYC estimate by Danby and Mason is given in brackets. Arrows show where this has increased or decreased, level line shows that it remains unchanged. Those species without yield class curves have been mapped to (a) grand fir, (b) noble fir, (c) Norway spruce, (d) Corsican pine, (e) Scots pine, (f) western red-cedar.

Table 4. Assessments for broadleaves in viable plots at Brechfa Forest Garden. Those plots previously assessed by Danby and Mason are highlighted.

	Species	Plot	Age[1]	Top height (m)[2]	Mean DBH (cm)[2]	GYC[3]	Status
Oaks	*Quercus petraea*	33	67	21.2	26.4	6[a]	Principal
	Quercus robur	34	67	20.2	25.4	6[a]	Principal
	Quercus rubra	35	67	27.7	27.2	8[a]	Secondary
	Quercus canariensis	63	65 (34)	18.5 (+47.8%)	23.3 (+94.5%)	4 (6) ↓ [a]	Plot stage
	Quercus lusitanica	65	65	21.7	26.9	6[a]	Specimen
	Quercus cerris	66	66	23.1	30.5	8[a]	Plot stage
Maples	*Acer pseudoplatanus*	67	67	15.5	14.1	4	Principal
	Acer platanoides	68	67	21.1	17.0	8[b]	Secondary
	Acer saccharinum	64	65	18.6	28.4	6[b]	Plot stage
Birches	*Betula pendula*	87	65	20.9	19.6	8[b]	Principal
	Betula pendula	83	65	22.4	20.6	6[b]	Principal
	Betula lenta	89	67	17.3	19.5	4[b]	Specimen
Other b/leaves	*Fagus sylvatica*	38	67	10.7	22.4	4	Principal
	Nothofagus obliqua	37	67	29.9	42.0	14	Secondary
	Tilia cordata	70	65	22.5	25.2	8[b]	Secondary
	Prunus avium 'Wildstar'	73	20	8.4	11.7	6[a]	Secondary

Notes:
1. The age when assessed by Danby and Mason is given in brackets.
2. The percentage change since Danby and Mason is given in brackets.
3. The GYC estimate by Danby and Mason is given in brackets. Arrows show where this has increased or decreased, level line shows that it remains unchanged. Those species without yield class curves have been mapped to (a) oak, (b) sycamore.

low survival rates meant they were not assessed, while Jezo spruce (*P. jezoensis*) and Engelmann spruce (*P. engelmannii*) had failed completely.

Pines (Pinus spp.*)*
Of 17 species of pine originally planted, trees only survive for seven, and only one species has a plot in any condition to measure. Danby and Mason did note that pines as a genus are more suited to drier climates than Brechfa, a point we will return to later. They selected only three plots of pine, which included both Lodgepole (*Pinus contorta*) and Weymouth pine (*P. strobus*), which have both deteriorated to such a degree that they could not be assessed. This leaves only Macedonian pine (*P. peuce*), a species which has received considerable interest for its climatic tolerance and resistance to pests (Savill and Mason, 2015). The plot at Brechfa has grown steadily at GYC 16, an improvement of two since the last assessment.

Other conifers
Eight other conifer species were highlighted by Danby and Mason, of which only four survived to the most recent assessment. The four plots which did not survive included western hemlock (*Tsuga heterophylla*), felled by local staff in the early 2000s due to concerns over invasiveness, and giant redwood (*Sequoiadendron giganteum*), which slowly deteriorated over time, defoliating until the trees are now in very poor health or dead, and so not considered suited for assessment. Leyland cypress (*Cupressus* x *leylandii*) suffered considerable windblow, while the Lawson cypress (*Chamaecyparis lawsoniana*) plot proved too difficult to assess.

Of the surviving four species, both the western red-cedar (*Thuja plicata*) and Japanese-cedar (*Cryptomeria japonica*) appeared the most productive with a GYC of 24 and 22 respectively, both an improvement of 2 since the last assessment. In contrast, Douglas-fir (*Pseudotsuga menziesii*) fell by 4 to GYC 20, and overall appeared to be deteriorating. Coast redwood (*Sequoia sempervirens*, Figure 4) also saw a fall in GYC, dropping by 8 to GYC 22, although this may be a measurement issue, as assessing height was problematic in this plot.

Broadleaved species

Nineteen of the 35 remaining broadleaved plots contained only a scattering of specimen trees, leaving only 16 of sufficient quality for assessment. Danby and Mason selected only one broadleaved species for inclusion in their review, Algerian oak (*Quercus canariensis*). However, improved growth on many plots and increased interest in broadleaved species means that it is now appropriate to review a wider number of species, although, unlike the conifers, it is not possible to provide a baseline species for comparison.

Figure 4. Coast redwood (Sequoia sempervirens) plot 11. By far the largest trees at the site; this is an active mensuration plot.

Oaks (Quercus spp.*)*
There are seven oak species planted, with only Pyrenean oak (*Quercus pyrenaica*) not assessed as it was planted in 2014 and was too small for comparative measurement. Although the Algerian oak had grown in both height and girth, productivity fell from GYC 6 to 4. This was below the other five oaks measured. Red oak (*Q. rubra*) and Turkey oak (*Q. cerris*) both appeared to be performing at a GYC of 8 (Figure 5), while the two native oak – common (*Q. robur*) and sessile (*Q. petraea*) – along with the Lusitanian oak (*Q. lusitanica*) were all achieving GYC 6.

Figure 5. Turkey oak (Quercus cerris) plot 66, of generally poor form but GYC 8. Adjacent and in the background is plot 65, Lusitanian oak (Q. lusitanica). The steep bank does not provide a true representation of the tree size as much of the tree is hidden from view.

Figure 6. Monarch birch (Betula maximowicziana) plot 91, showing the possible potential of this species at 8 years of age. In the background is Koyama's spruce (Picea koyamae, plot 75), the Critically Endangered conifer from Japan that is demonstrating potential as a productive forest species.

Maples (Acer spp.*)*

Five maple species have been planted at Brechfa; the most recent of these, big-leaf maple (*Acer macrophyllum*), was planted in 2014 and was too small to assess but did appear to have established well. A plot of moosewood (*A. pensylvanicum*) had a few remaining very poor trees and, although not of good form, the site would appear suitable for regeneration as evidenced by a scattering of seedlings and young plants. The three measured plots were sycamore (*A. pseudoplatanus*), silver maple (*A. saccharinum*) and Norway maple (*A. platanoides*), which achieved GYC of 4, 6 and 8 respectively.

Birches (Betula spp.*)*

Plots of all three of the birch species planted remain, but are of varying degrees of quality. There are two plots of Monarch birch (*Betula maximowicziana*), one a remnant original plot with some good individual trees, which appears to have merited a new planting in 2014 (Figure 6). These new trees established very well with good form and vigour, but were too small for this assessment. The measured plots were a cherry birch (*B. lenta*), which achieved a GYC of 4, along with two seed sources of silver birch (*B. pendula*), achieving GYC of 6 and 8, although only the latter is of known origin.

Other broadleaves

Plots containing examples of 14 species remain, but only four are sufficiently stocked for assessment. Three of these are natives. Beech (*Fagus sylvatica*) achieved a GYC of 4, small-leaved lime (*Tilia cordata*) GYC 8 and wild cherry (*Prunus avium*) GYC 6. The cherry was a variety called 'Wildstar', which was planted in 2004, around the time it was introduced as a tree of forestry potential.

Other values of the Brechfa collection

Although the primary objective of the plots was to test new species, they also offer other tangible benefits. As plots containing a relatively large number of trees, often grown from seed of known origin, they can be a conservation resource, providing an accessible living library for study by scientists, foresters, arboriculturists, horticulturists, pharmaceutical researchers and general tree enthusiasts.

Champion trees

The latest version of Champion Trees of Britain and Ireland (The Tree Register, 2025) records trees that are exemplary examples of their species for various categories such as height or girth and contains information on over 89,000 trees of many species. A search reveals 36 records for Brechfa Forest Garden. Of these, 13 are Welsh Champions (seven firs, three spruce, one poplar, one birch, and a

Eucalyptus) and six British Champions (three fir, two pine and one spruce). Of the total list, 15 champions are fir and seven spruce. The Koyamae spruce stands out being a British Champion, and the list supports the evidence that fir and spruce are generally suited to the site conditions. The list and entries in the Tree Register will need to be revised as it is likely many trees were windblown during Storm Darragh in December 2024.

Conservation value

Globally, conifers are one of the most threatened groups of plants. Of the 631 conifer species, 211 (34%) are listed by the IUCN as being of conservation concern – Red Listed (Royal Botanic Garden Edinburgh, 2016). The plots at Brechfa include 11 of these Red Listed species (Table 2). Six of these have seed data showing they were collected from the natural distribution and include the Critically Endangered Koyama's spruce and Endangered coast and giant redwoods. Other species on the list where there are insufficient data to ascertain origin may be worth investigating further, as although seed was sourced from other tree collections, Botanic Gardens' records may show the seed was originally wild sourced.

Broadleaved tree species are also under enormous threats, but only one Red Listed species, Algerian oak (Near Threatened), is planted at Brechfa. Unfortunately, the seed origin cannot be confirmed.

These plots make Brechfa an important resource for *ex situ* conservation of these species. More research is required to fully assess this potential and how it might be recorded and used.

Pest and disease monitoring

With the range of species at Brechfa, the site offers value as a location for monitoring pests and diseases. The international Plant Sentinel Network (Botanic Garden Conservation International, 2025) already includes many UK Arboreta, both private and state owned. Sites such as Brechfa could be a valuable addition.

Identification

The value of the collection hinges on our certainty as to the identity of each species. A single plot of mixed *Abies* spp. remains unverified (Table 2), but a quick review by the authors would suggest that the majority of plots are as recorded. However, the identity of all species needs to be verified systematically, as there is always the potential that the recorded names are based on trust against the original ones supplied with the planting stock, which is not always reliable! In particular, a closer look at some of the potential hybrid species should be a priority.

Discussion

Our thoughts will follow the discussion of Danby and Mason to provide comparisons on how various species have fared in the last 30 years. Additional commentary is provided on those species not previously covered, in light of current needs for additional species for forest diversification.

The relative weaknesses of the collection have not substantially changed. The provenance information for some species is still unknown or, in some cases, unclear, sometimes being sourced from trees in small plots elsewhere in Britain. It has been known for some seed source notes to record the business location of the seed supplier rather than the natural distribution of the species. Verification of the species plots has not been undertaken in an organised manner, and some seed sources may well have hybrid genetics. It was originally noted that some of the Greek fir (*Abies cephalonica*) appeared to have morphological characteristics close to European silver fir (*Abies alba*). There is a recognised hybrid Macedonian or King Boris fir (*Abies* x *borisii-regis*) which might explain the unexpectedly high GYC for the plot (Nikolić et al., 2021; Gymnosperm Database, 2025). Similarly, the Algerian oak was sourced from the Forest of Dean, where it is likely to have grown with both sessile and common oak, species with which it is known to hybridise freely. As the plot trees exhibit varying characteristics, species performance should be considered as indicative rather than conclusive for the time being.

It is also worth noting that planting was limited to the stock available from nurseries at the time. This means that species chosen may not have been selected based on suitable provenance information. Provenance trials carried out and summarised since the establishment of the Forest Garden would provide further guidance (Forest Research, 2025b). This could potentially mean that some species already performing well could do even better, and some of the marginal species improve their productivity.

Despite this, some general trends are apparent after 70 years' growth, although these are still based upon single plots. Conifer species which are adapted to wet, moist climatic conditions (such as various *Abies* spp., some *Picea* spp., western red-cedar, Japanese-cedar and coast redwood) have generally continued to grow well, whereas those which are more characteristic of drier climates (such as most pine species and cedars) have either failed completely or are in poor health. The latter comment is

Figure 7. Felled plot of western hemlock now regenerating with a range of Pacific northwest conifers and European larch (Larix decidua, plot 2) to the left. Western red-cedar (Thuja plicata, plot 7) is to the right and growing strongly.

worth considering for the Colorado fir and Low's fir, which had completely failed. Plot records from 1987 indicated the Colorado fir was mostly dead or failing, but the Low's fir still appeared to be thriving. Both species are more suited to warm, free draining sites so were probably not best suited to Brechfa, and the subsequent failing of the Low's fir is likely just a delayed response. Low's fir has performed reasonably well on other sites in Britain (Kerr et al., 2016; Reynolds et al., 2021).

It was noted that the overall poor performance of pines reflected the general unsuitability of this genus across Wales. The sole healthy plot remaining is Macedonian pine (*Pinus peuce*), which had improved in performance since last reported. This supports the findings that the species is a generalist and able to cope with a range of site conditions (Savill and Mason, 2015), and therefore a useful species to have in the toolbox. The lodgepole pine plots, previously noted as very poor, have subsequently failed completely along with several hectares of plantation lodgepole surrounding the site. This may be due to a combination of poor provenance choice, unsuitable site conditions and the impacts of Dothistroma needle blight (*Dothistroma septosporum*). The latter is a common and enduring problem with pines across Britain (Forest Research, 2025c), which is forcing us to reassess our use of this genus.

Here, it is worth referencing a species trial, established in 2012 at Crychan Forest, roughly 16 miles to the east of Brechfa (Reynolds et al., 2021; Ovenden et al., 2024). Although still young, these trees have to date shown varying degrees of success with most of the 19 species of pine surviving, but not necessarily thriving. However, it is still early in their establishment, and it will be interesting to see if survival follows the trend at Brechfa, or whether climatic conditions changed enough over the last 30 years to allow some to succeed.

If one of our overarching goals is to diversify productive species choice from Sitka spruce, a key result of this review must be comparison. It is unfortunate that no Sitka spruce was included in the early plantings, but to aid comparison, an Ecological Site Classification assessment for this site would suggest a potential Yield Class 20 is achievable (Forest Research, 2025d). This is somewhat higher than the GYC 14-16 estimated by Danby and Mason. The results in Table 2 suggest that of the 19 conifers assessed, seven species show a GYC above 20, two at GYC 20 (Douglas-fir and Koyama's spruce), and another four with GYC 16 to 18. The seven species exceeding 20 are largely those which looked promising in the previous assessment. The exceptions to this are giant sequoia (*Sequoiadendron giganteum*), which failed, and western hemlock (*Tsuga heterophylla*), discussed below. The additions were Japanese-cedar (*Cryptomeria japonica*) and Greek fir (*Abies cephalonica*). Even if the identity of the latter is suspect, the performance is not. The results for four out of these seven fast-growing species (grand fir, noble fir, western red-cedar and Douglas-fir) are in general agreement with a study by Stokes et al. (2022), which found that these four species in general were of similar or better productivity to Sitka spruce on a range of sites across Britain, some of which could be comparable to Brechfa.

There is also clear evidence that a wide range of species can be grown to achieve GYC 16 to 18. At Brechfa, these species included Veitch's fir, Caucasian fir, Macedonian pine and Norway spruce. This demonstrates that, if diversification is a key objective and a marginal loss in productivity accepted, there is potentially a wider range of species which could be planted on sheltered, fertile sites in this part of Wales, provided that species are carefully matched to site.

As mentioned, western hemlock was removed due to concerns over invasiveness. Previous evidence indicated this was the second most productive species on site (after coast redwood) with a GYC of 24. The coast redwood appears to have declined, but wider knowledge on the growth of western hemlock would make it likely this species would still be one of the top performers. It should not be ignored as an alternative productive conifer for these sites.

It is rather ironic that its felling appears to have encouraged regeneration of western hemlock, western red-cedar, Lawson cypress and Douglas-fir, now making a fine mixed species plot of fast-growing Pacific northwest conifers! (Figure 7).

Very little has changed when reviewing the broadleaved species. Their representation is still limited, and performance to date is variable. The majority of the broadleaved species have either failed or declined to a point that they are only classed as remnant plots. In general, the oaks, maples, birches, beech and roble have shown reasonable growth, even if the form of the trees is not great. However, a few species do still demonstrate some potential and are worth further study, including the mockernut (*Carya tomentosa*), Monarch birch (*Betula maximowicziana*), big-leaf maple (*Acer macrophyllum*) and Pyrenean oak (*Quercus pyrenaica*).

It is relatively straightforward to review how species have performed on the site up to this point. We must, however, consider the potential impacts of climate change and pests and diseases. The impacts of climate change are still being understood, but this part of the west of Britain may well get warmer and wetter, so potentially suiting a wider range of tree species. Opposing that is the potential for pests and diseases already present in Britain (or those yet to get a foothold) spreading further, taking advantage of suitable conditions. To this end, diversification with a range of healthy vigorous species is the key.

Acknowledgements

We would like to thank Natural Resources Wales for their continued support and management of the site, and Forest Research Technical Services Unit Talybont for their fieldwork, including assessments of the plots.

References

Blake, M., Straw, N., Kendall, T., Whitham, T., Manea, I. A., Inward, D., Jones, B., Hazlitt, N., Ockenden, A., Deol, A., Brown, A., Ransom, E., Smith, L. & Facey, S. (2024) Recent outbreaks of the spruce bark beetle *Ips typographus* in the UK: Discovery, management, and implications. *Trees, Forests and People,* **16**:100508.

Botanic Gardens Conservation International (2025) International Plant Sentinel Network. https://www.bgci.org/our-work/networks/ipsn.

Danby, N. & Mason, B. (1998) The Brechfa Forest Plots: Results after 40 years. *Quarterly Journal of Forestry,* **92**(2):141-152.

Forestry Commission (1931) *Forest Gardens*. Forestry Commission Bulletin 12. HMSO, London.

Forestry Commission (2024) Forestry Statistics. Forestry Commission. https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2024.

Forest Research (2025a) *Ramorum* disease (*Phytophthora ramorum*). https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources/ramorum-disease-phytophthora-ramorum/. Accessed July 2025.

Forest Research (2025b) Provenance variation of emerging species. https://www.forestresearch.gov.uk/research/provenance-variation-of-emerging-species/. Accessed June 2025.

Forest Research (2025c) Pest and disease resources. https://www.forestresearch.gov.uk/tools-and-resources/fthr/pest-and-disease-resources. Accessed June 2025.

Forest Research (2025d) Ecological Site Classification (ESC) https://www.forestresearch.gov.uk/tools-and-resources/fthr/ecological-site-classification. Accessed June 2025.

Gymnosperm database (2025). *Abies borisii-regis* (Macedonian fir). https://www.conifers.org/pi/Abies_borisii-regis.php. Accessed June 2025.

Kerr, G. & Jinks, R. (2015) A review of Emerging Species research in FC programme 3. Forest Research internal publication.

Kerr, G., Forster, J. & Jinks, R. (2016) Summary of FR Seed Origin Trials on Low's fir (*Abies concolor* var. *lowiana* (Gord.) Lemm.) Forest Research internal publication.

Mason, W.L., MacDonald, F., Parratt, M. & McLean, J.P. (2018) What alternative tree species can we grow in western Britain? 85 years of evidence from the Kilmun Forest Garden. *Scottish Forestry*, **72**:24-33.

Matthews, R.W., Henshall, P.A., Duckworth, R.R., Jenkins, T.A.R., Mackie, E.D. & Dick, E.C. (2016) Forest Yield: a PC-Based yield model for forest management in Britain. Forestry Commission, Edinburgh.

Mitchell, A. (1974) *A field guide to the trees of Britain and northern Europe*. Collins, London.

Nikolić, J.S., Zlatković, B.K., Jovanović, S.C., Stojanović, G.S., Marin, P.D. & Mitić, Z.S. (2021) Needle volatiles as chemophenetic markers in differentiation of natural populations of *Abies alba*, *A. x borisii-regis*, and *A. cephalonica*. *Phytochemistry*, **183**:112612.

Ovenden, T.S., Jinks, R.L., Mason. W.L., Kerr, G. & Reynolds, C. (2024) A comparison of the early growth and survival of lesser-known tree species for climate change adaptation in Britain. *Forest Ecology and Management,* **572**:122340.

Pyatt, G., Ray, D. & Fletcher, J (2001) An ecological site classification for forestry in Great Britain. Forestry Commission Bulletin 124. Forestry Commission, Edinburgh.

Reynolds, C., Jinks, R., Kerr, G., Parratt, M. & Mason, B. (2021) Providing the evidence base to diversify Britain's forests: initial results from a new generation of species trials. *Quarterly Journal of Forestry*, **115**(1):26-37.

Royal Botanic Garden Edinburgh (2016) Threatened Conifers of the World. https://threatenedconifers.rbge.org.uk/. Accessed June 2025.

Savill, P. & Mason, B. (2015) *Pinus peuce* Griseb., Macedonian or Balkan pine. *Quarterly Journal of Forestry,* **109**(4):245-252.

Savill, P., Wilson, S., Mason, B., Jinks, R., Stokes, V. & Christian, T. (2017) Alternatives to Sitka and Norway: Part 1 – Serbian spruce (*Picea omorika*). *Quarterly Journal of Forestry*, **111**(1):32-39.

Stokes, V.J., Jinks, R. & Kerr, G. (2022) An analysis of conifer experiments in Britain to identify productive alternatives to Sitka spruce. *Forestry: An International Journal of Forest Research,* **96**:170-187.

The Tree Register (2025) Champion Trees. https://treeregister.org. Accessed June 2025.

Adam Offler is a Silviculturist in the Centre for Forest Management, Forest Research, Alice Holt.

Email: adam.offler@forestresearch.gov.uk

Chris Reynolds is Project Leader on Emerging Species in the Centre for Forest Management, Forest Research, Alice Holt. His 35 years as a forester and keen interest in all things trees enables him to link sound research with practical applications to provide silvicultural confidence in a range of alternative species.

Email: christopher.reynolds@forestresearch.gov.uk