# Improved Planting Stock for Forestry

## Current guidance on the use of Future Trees Trust broadleaved seed orchard material in the UK

This guidance has been produced by Future Trees Trust (FTT) to help inform practitioners about the types of planting stock that are available for forestry purposes, where it can be obtained and where we consider it suitable for deployment without undue risk of maladaptation. The aim is to highlight the availability of improved material and to promote its use, particularly where timber production is an objective. A series of data sheets have been produced which describe the composition and deployment zones for every FTT seed orchard. This document describes the background to orchard creation and the genetic considerations for each orchard.

## Summary

The use of improved planting stock should be a priority when timber production is a management objective of woodland creation and reforestation. The higher yield and better form of this material makes it the best option for timber production, while its genetic diversity can provide a better chance of adapting to future climate and invasive pests and diseases. It is important to note that improved planting stock can also be used where timber production is not a primary objective: today's woodlands should provide tomorrow's managers with as wide a range of options as possible.

Future Trees Trust (FTT) is working to provide improved material for commercially important broadleaved species in the UK by developing genetically diverse seed orchards. Because improved material of some species may not be suitable for use across the whole of the UK, guidance is needed on where material can be safely deployed given the composition of the orchard and the genetic variation of the particular species. FTT proposes the use of provisional 'Deployment Zones' for each seed orchard to indicate suitability across different areas of the UK. FTT has used published scientific literature, data from research trials, and expert opinion to indicate how material from these programmes is likely to perform in a given location.

## Introduction

The UK is embarking on an ambitious programme of tree planting to meet current Government targets of 30,000 ha of new woodland per year to help mitigate climate change (HMSO 2021 – The England's Tree Action Plan 2021-2024; Scotland's Forestry Strategy 2019-2029). With such ambitious levels of afforestation there is huge potential to develop a large and productive resource of homegrown timber. Now more than ever, it is important to consider what planting material is used, where it comes from, and where it is planted. Future Trees Trust has established clonal seed orchards for seven of the most important broadleaved timber species: sycamore, birch (downy and silver), wild cherry, and, more recently, sweet chestnut and oak (pedunculate and sessile). Seed from these orchards falls into the *Qualified* category of Forest Reproductive Material (FRM; see below).

The overall aim of this report is to outline recommendations on the deployment of *Qualified* seed orchard material. Specifically, the aims of FTT in preparing this report are to:

1. **Promote the use of improved planting stock where timber production is a management objective.**
2. **Outline provisional Deployment Zones for seed from *Qualified* seed orchards to minimise risk of maladaptation.**
3. **Provide clear information on the background of improved planting stock.**

Data sheets for each seed orchard have been produced which should be read in conjunction with this report, and these detail where FTT considers it suitable to plant *Qualified* material from each orchard.

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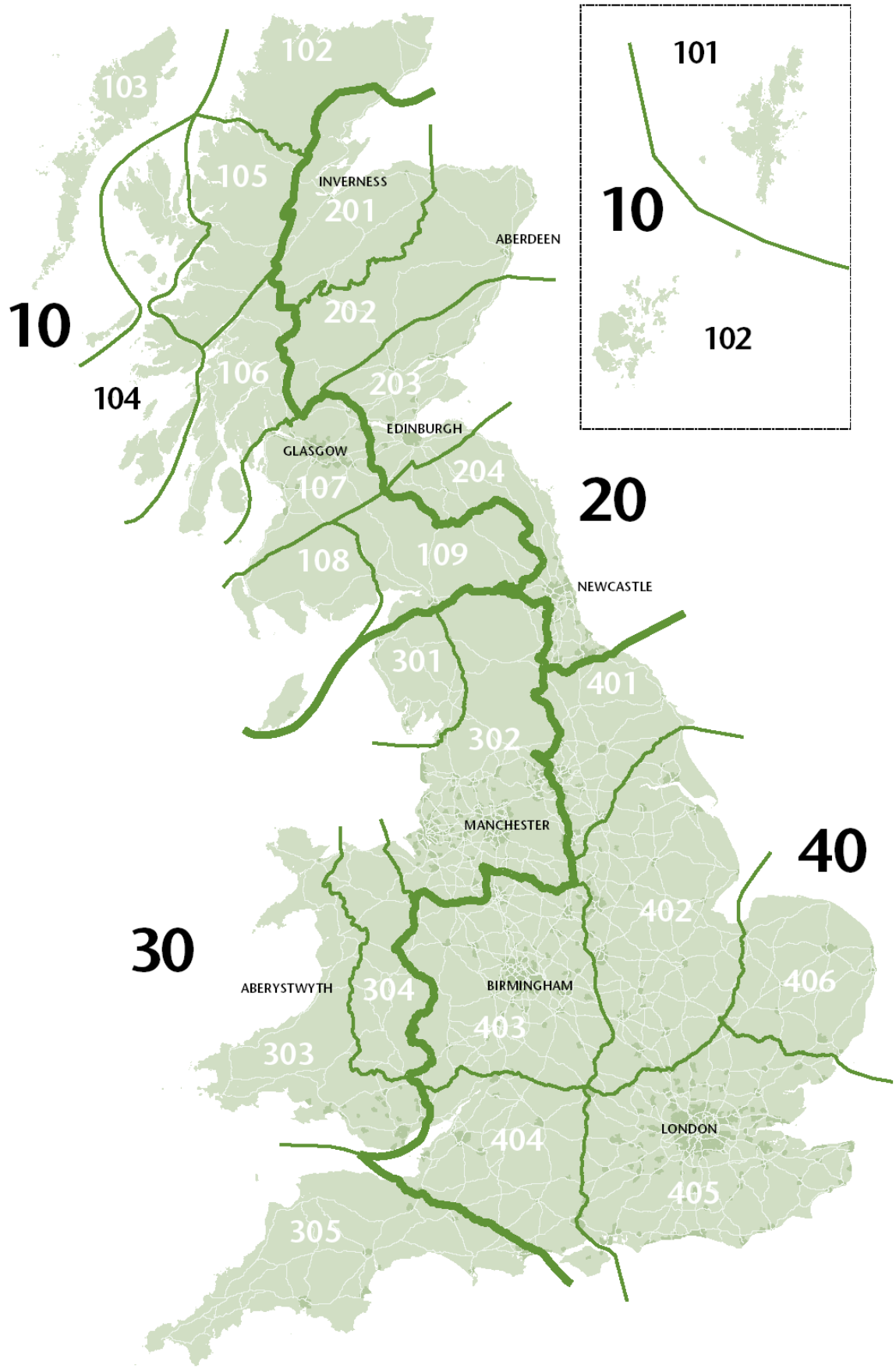
## Regions of Provenance

Map of Regions of Provenance and Native Seed Zones. Reproduced from Forestry Commission Practice Note 8. Using Local Stock for Planting Native Trees and Shrubs (Herbert et al. 1999).



## What are tree improvement and improved material?

A tree improvement programme seeks to utilise the natural genetic variation found within populations to produce trees that are superior to base planting stock for selected traits. By selecting the most desirable trees for traits of interest, rotation times can be shortened through increased growth rates, while the volume of recoverable timber can be increased through superior stem form. When trees arising from an improvement programme are combined with good silviculture, the resulting stands are likely to be healthy, high-yielding, and genetically diverse which will help ensure resilience.

The first step in tree improvement is the selection of individual desirable trees and the bringing together of this selection into a breeding population. Outstanding trees are selected by FTT for commercially important traits such as growth rate, stem form, and tolerance to particular pests or pathogens (e.g., bacterial canker in wild cherry or ash dieback). These selected trees are referred to as 'plus trees' and form the basis of tree breeding programmes from which subsequent improvements are made.

'Improved material' describes the product(s) of the tree improvement programme (seed, scions, propagated cuttings, or transplants) which show enhanced target trait(s).

## How is the use of improved material regulated?

All trees planted for forestry purposes are subject to Forest Reproductive Material (FRM) regulations which are administered in the UK by the Forestry Commission under post-Brexit legacy legislation based on EU Directive 1999/105/EC. They place material in to one of four categories for marketing purposes. These are:

***Source identified:*** from general or specific locations within a single region of provenance or native seed zone with an altitude band, but with no superior qualities.

***Selected:*** from stands showing superior characteristics such as better form, growth rate, or health.

***Qualified:*** from selected superior individual trees which have not yet undergone any form of testing.

***Tested:*** from the selected individual trees or stands which have been evaluated for genetic quality or, in comparison to accepted standards, have been shown to be superior.

## Background of Future Trees Trust improved planting material

Since the 1990s, FTT has selected more than 1,200 plus trees throughout Britain and Ireland for seven of the most important broadleaved species planted for timber. These species are oak (*Quercus petraea* and *Q. robur*), sycamore (*Acer pseudoplatanus*), sweet chestnut (*Castanea sativa*), wild cherry (*Prunus avium*), and birch (*Betula pendula* and *B. pubescens*).

The aim of these breeding programmes is to provide industry with planting material that falls into the two highest categories of FRM: *Qualified* and *Tested*. Table 1 lists species for which *Qualified* seed is already available and suggests a timeframe towards achieving the status of *Tested* material.

**Table 1. Availability of *Qualified* and *Tested* seed and seedlings**

| Species | *Qualified* seed available in: | *Tested* seed available in: |
|---|---|---|
| *Acer pseudoplatanus* – sycamore | Available | 20 years |
| *Betula pendula* – silver birch | Available | 20 years |
| *Betula pubescens* – downy birch | 3 – 5 years | † |
| *Castanea sativa* – sweet chestnut | 5 years | † |
| *Prunus avium* – wild cherry | Available | † |
| *Quercus petraea* – sessile oak | 15 years | 10 years |
| *Quercus robur* – pedunculate oak | 15 years | 10 years |

*† There are currently no plans to establish progeny trials, which are needed to evaluate these species and produce* Tested *material, therefore a timeframe cannot be reliably provided.*

A number of seed orchards are in private ownership or on the public forest estate, and seed can be obtained directly from these. All orchards and their individual datasheets are displayed on the UK Forest Genetic Resources Research Trials map found at www.ukfgr.org.

## Where is the use of improved material recommended?

Improved material is expected to outperform local provenance (*Source identified*) material at the majority of sites across the UK. As with any tree planting, it is important that improved material is planted:

1. In regions of the country where it is well-adapted to climatic and photoperiod conditions where it is likely to thrive.
2. Where it is well-matched to local site conditions, including soil, local climate, and elevation.

This paper addresses the first point above, by considering provenance and seed zoning so as to avoid planting stock being transferred to environments which may lead to poor growth by maladaptation. Maladaptation manifests itself as:

- Physiological (tissue) damage as a result of unseasonal frost, low winter temperatures, drought, or excess moisture.
- Stresses caused by unfavourable climatic or soil conditions, which render plants more susceptible to disease or damage by insects.

Adaptation in trees can be investigated by growing geographically distributed tree populations together in common environments (e.g., provenance trials) to identify differences in performance. Outcomes of research from provenance trials can be used by forestry regulators to develop seed source guidance and predict adaptive responses to climate change.

Seed source guidance sets out rules that help practitioners choose the most appropriate seed sources, both to avoid maladaptation and optimise performance (for traits such as survival, growth, and timber quality), and, in the case of native species, to avoid compromising patterns of genetic variation in semi-natural woodland. UK guidance is based on four broad Regions of Provenance and 24 Native Seed Zones (Herbert *et al.* 1999), which identify areas of climatic similarity and do not take account of soil variability. However, to date, guidance has focussed on genetic conservation of native species in new native woodlands and has, therefore, been quite conservative and restrictive. The use of local seed sources has been promoted, thereby increasing the use of *Source identified* material, much of which is poorly suited for timber production.

The UK Forestry Standard (UKFS, Forestry Commission 2017) sets out the legal requirements

and good practice guidelines for tree planting and restocking. It encourages the use of material from a wide genetic base and discriminates between semi-natural woodlands and woodland for timber production. For semi-natural woodlands, it recommends using local provenance seed, but for woodland creation it recommends using a proportion of non-local provenances with conditions that are well matched to the predicted future climate of the planting site to better exploit growing seasons which are, on average, lengthening. This means sourcing a proportion of material from 2 – 3 degrees south of planting sites, and from a maritime climate similar to the UK (Broadmeadow *et al*. 2005; Hubert 2005; Hubert and Cottrell 2007). It should be noted that the UKFS is currently under review, with a new standard due for publication by the end of 2022.

There is now a need for clear guidance specifically focussed on woodland creation for timber production, in which seed of the best available genetic quality should be used while at the same time taking care to retain high levels of genetic diversity. This paper outlines an approach to this issue by considering the *Qualified* seed being produced now, and in the medium-term, from FTT seed orchards. In the longer term, this approach could be extended to *Tested* material, and the testing process will give us further useful information about the performance of improved material on different sites.

## Use of *Qualified* orchard material and Deployment Zones

Future Trees Trust has compiled information on each seed orchard which details its composition and provides a large-scale map illustrating in which Native Seed Zones (Herbert *et al* 1999) FTT considers it appropriate to plant material from that seed orchard while reducing risk of maladaptation. The Deployment Zoning also incorporates advice and experimental evidence on the use of material further north to provide resilience to current and future climate change. Although areas within the map boundaries are suitable for planting from a genetic perspective, it is still essential for the forester to match species to local site conditions. Guidance on the site types that are suitable / unsuitable for a particular species is available by using the Forestry Commission Ecological Site Classification decision support system (Pyatt *et al*. 2001).

Deployment Zones for each of the seed orchards are described based on FTT's confidence in the performance of *Qualified* orchard material compared to local *Source identified* seed stand material. These are shown on maps in the accompanying orchard data sheets and are classified as:

- **Highly Suitable:** areas where FTT is highly confident seed orchard material will outperform local provenance *Source identified* material in terms of growth rate and form.
- **Suitable:** areas where FTT is confident seed orchard material will outperform local provenance *Source identified* material.
- **Equivalent:** areas where FTT considers that seed orchard material may perform better than local provenance *Source identified* material. This may present as poorer growth rate with improved form or vice versa.

The judgments of FTT are based on:

1. **Interpreting literature** on patterns of genetic variation, provenance choice and effects of transfer for each species (Table 2).
2. **Results from research trials** where this sheds light on the likely effects of deployment of improved material across the UK in relation to the locations of the plus trees in each orchard.
3. **Expert opinion** on how well material from these programmes will perform across the UK.

For some species (e.g., sycamore and sweet chestnut), orchards are comprised of plus trees from the UK and Ireland. Ireland is included in the maps for reference, but we make no recommendations for deployment in the island of Ireland, even though we expect the improved material to perform well when correctly matched to site type. Instead, we recommend consulting country-specific advice.

## Knowledge of patterns of genetic variation: the evidence

It is important to note that different tree species display varying patterns of genetic variation, and therefore react differently to their seed being moved from region to region within the UK. In the absence of specific information on different species, rules on the use of different seed sources (provenances) developed by forestry regulators in the UK have been applied across all broadleaved species. FTT considers this an oversimplification.

A distinction must also be made between native and non-native species which form part of FTT's research programme. For native species, including oak, silver birch, and wild cherry, some degree of geographic adaptation is known to occur among different seed sources. For introduced species, including sycamore and sweet chestnut, the patterns of adaptation are less likely to be geographically based. In common with the general state-of-art knowledge about geographic patterns of adaptive variation, and therefore the likely responses of genetic material to being translocated, FTT's knowledge is limited (Table 2, see next page). The significance of geographic patterns of variation by species has been roughly categorised as follows.

**Significant.** There are significant differences in performance, phenology, and morphology among UK seed sources, with logical geographic patterns. Some degree of maladaptation or poor performance occurs, or is conceivable, as a result of long-distance movement of seed within the UK. Severe maladaptation can occur for some continental seed sources used in some parts of the UK. Example species: silver birch.

**Moderate.** There are some differences in performance and phenology among UK seed sources, with logical geographic patterns; but material transferred quite long distances within the UK (e.g., southern England to central Scotland) often seems to perform adequately. Long distance transfer from eastern Europe to the UK causes maladaptation. Example species: wild cherry, pedunculate and sessile oak.

**Low.** There is evidence of small differences among UK seed sources, but these are not large enough to suggest maladaptation when seed sources are transferred within the UK or from the near continent to the UK. Example species: sycamore and sweet chestnut.

## Other genetic considerations

Conservation interests have sometimes expressed concerns that planting stock specifically bred for production purposes might have a narrowed or skewed genepool, leading to reduced genetic diversity in the future, with the potential to undermine genetic conservation objectives. In reality, seed orchard material will tend to have higher levels of genetic diversity compared with conventional seed collections made from individual stands. This is because seed orchards contain parents from many unrelated populations across a wide geographic range, and their design and management encourage random mating.

Improvement programmes aim to improve the growth and form of trees and the quantity of marketable timber, and this is expressed as 'genetic gain'. Genetic gain varies from trait to trait and is greater if the selection is very intensive, the trait is under strong genetic control (i.e., it is highly heritable), and when it displays high levels of genetic variation. Some very rare alleles present in the base population can be lost in the selected population, giving rise to fears that a selected population is less genetically diverse than the base population. However, when sufficient individuals are included in the selected population, loss of alleles or large random changes in allele frequencies are extremely rare. Such issues are considered by FTT when sampling populations and conducting tree improvement work.

**Table 2. Published evidence on adaptive variation of broadleaved tree species in Britain.**

| | Quality of evidence from UK trials (Good, Adequate, Poor) | Assessed variables | Geographic variation | Effects of transfer | Current suggested transfer rules for timber production in scientific literature |
|---|---|---|---|---|---|
| **Silver Birch** | Adequate. Ref: Lee *et al*. 2015 | Early growth rate and survival, plus some phenological measures | Significant | Within UK seed source trials show seed sources transferred northwards grow fastest. Seed transferred from many parts of Scandinavia or Eastern Europe to northern UK were maladapted. Local sources showed average growth rates. Limited genotype x environment interactions and considerable plasticity among better performing sources. | Transfer allowable up to at least 2 degrees or 200 km north of seed source. |
| **Oak** | Adequate. Ref: Hubert 2005; | Early growth rate and survival; phenology | Moderate | Material from UK registered stands grows well throughout most of GB. Northern material transferred south grows more slowly but has good survival on more testing sites. Some southern material is prone to frost damage on some northern sites. | Transfer allowable up to at least 2 degrees or 200 km north of seed source. |
| **Wild Cherry** | Poor. Ref: Vaughn *et al*. 2007 | Early growth rate and survival; phenology | Moderate | Very little literature on wild cherry in the UK. Evidence from continental Europe suggests clonal clustering resulting from vegetative contributes significantly to lowering the genetic variability within natural populations, with limited gene flow. | Seed orchard material that comprises many geographically distinct individuals will be much more genetically diverse than material originating from single stand collections. Use material from the Region of Provenance 30 or 40 seed orchards. |
| **Sycamore** | Adequate. Ref: Cundall *et al*. 1998; Whittet *et al*. 2021; Neophytou *et al*. 2019; Bittkau 2003 | Early and mid-rotation growth rate and form; limited phenology | Low | Sycamore in the UK likely arises from glacial refugia in the southwest Alps. Little variation even after 27 years in growth and form of UK provenances on three sites in lowland England. Variation in budburst mostly attributable to continental seed sources coming in to leaf earlier than UK provenances. | Deployment of FTT seed orchard material to ecologically suitable sites is likely to be appropriate for all of the UK. |
| **Sweet Chestnut** | Poor. Ref: Jarmen *et al*. 2019 Mattioni *et al*. 2017 | No existing provenance trials for sweet chestnut | Low | Sweet chestnut in the UK arises from western Iberian refugia and forms a single genepool with broad genetic base. Effects of transfer within the UK have not been investigated. | Use GB registered stands from the same or neighbouring Region of Provenance. Seed orchards contain many plus trees and seeds arising are representative of the overall British genepool, despite most of the plus trees being located in southern England. |

## Moving to *Tested* status

At the time of plus tree selection, it is impossible to determine whether an individual's superiority is associated with its genotype or is due to environmental factors, such as favourable local conditions, competitive relationships with neighbouring trees, or good management. Once plus tree selection has been completed, the plus trees are typically replicated through grafting, and placed in clonal seed orchards (for seed production) and clone banks (to ensure long term security). At this stage of improvement, a seed orchard would be described as having *Qualified* status under FRM regulations.

Discerning whether the plus trees are truly genetically superior requires evaluation of their offspring in progeny trials. Progeny trials compare the seedling offspring of different parent plus trees and aim to identify whether superior characteristics of the plus trees have a genetic basis and determine the scope for improvement through further selection. Once progeny trials have reached a satisfactory age (15 years for ash, sycamore, silver birch, and wild cherry, and up to 25 years for oak and sweet chestnut) and have been evaluated, reselection of parents in the breeding programme can take place to specify new seed orchards. These orchards would be described as having *Tested* status under FRM regulations, since they would be composed of parents with demonstrated genetic gain over unimproved seedlots.

The majority of breeding programmes around the world focus on conifer species. For Douglas fir in Canada, gains between 10 – 16% have been realised for height and diameter, which equates to 28 – 49% gain in volume (Stoehr *et al*. 2010). The Sitka spruce breeding programme in the UK has predicted gains of 9 – 13% for diameter growth and 15 – 21% for stem form which brings about predicted volume gains of 25% (Conifer Breeding Co-op pers. comms). Broadleaved examples include the Finnish silver birch programme which reports gains of 29% increase in volume (Gailis *et al*. 2020), and a relatively young oak improvement programme in Croatia which predicts gains of 12% for growth traits (Vidakovic *et al*. 2000).

Future Trees Trust are committed to establishing progeny trials to bring a range of broadleaved species to *Tested* status (Table 1). To date, FTT has established small progeny trials for oak, ash, and sycamore, and is in the process of establishing extensive trials for silver birch and sycamore. Longer-term goals include the establishment of the first progeny trials for wild cherry and more extensive oak trials. This is a long-term process which, once complete, will provide a wealth of information on the variation in performance and adaptability within each species and enable genetic thinning of existing *Qualified* orchards to boost genetic gain and form *Tested* orchards.

In the interim, there are opportunities to deploy material from *Qualified* orchards containing grafted copies of plus trees selected in British and Irish woodlands. The seed produced from these orchards contains high genetic variability as the orchards bring together trees from a wide geographical area. FTT expects that *Qualified* seed will outperform material from *Source identified* or *Selected* seed stands in appropriate regions and recommend using improved material wherever timber production is an objective of woodland creation.

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## It is endorsed by

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## References


Broadmeadow M and Ray D. 2005. Climate Change and British Woodlands. FCIN069. Forestry Commission, Edinburgh.

Bittkau C 2003. (2003) PhD thesis: Chloroplast DNA characterization of genetic variation of European populations of Acer spp. and *Populus tremula*. University of Munich.

Cottrell J. 2019. Fundamental knowledge of genetics and implications for health of oak trees. In: Action Oak Knowledge Review: as assessment of the current evidence on oak health in the UK, identification of evidence gaps and prioritisation of research on needs. Action Oak, Haslemere, UK. ISBN 978-1-527204193-0.

Cundall EP, Cahalan CM and Plowman MR. 1998. Early results of sycamore (Acer pseudoplatanus) provenance trials at farm-forestry sites in England and Wales. *Forestry* **71**: 237–245.

Forestry Commission 2017. The UK Forestry Standard 4th edition. Forestry Commission, Edinburgh.

Gailis A, Zeltins P, Augustovs J, *et al*.. 2020. Genetic parameters of growth and quality traits in open-pollinated silver birch progeny tests. *Silva Fennica* **54 (2)** doi.org/10.14214/sf.10220.

Herbert R, Samuel S and Patterson G. 1999. Using local stock for planting native trees and shrubs. Forestry Commission Practice Note 8. Forestry Commission, Edinburgh.

HMSO 2021. The England's Tree Action Plan 2021-2024. Available online England Trees Action Plan 2021 to 2024 - GOV.UK (www.gov.uk)

Hubert J. 2005. Selecting the right provenance of oak for planting in Britain. FCIN 77. Forestry Commission, Edinburgh.

Hubert J and Cottrell J. 2007. The role forest genetic resources in helping British forests respond to climate change. FCIN 086. Forestry Commission, Edinburgh.

Jarmen R, Mattioni C, Russell K, *et al*. 2019. DNA analysis of *Castanea sativa* (sweet chestnut) in Britain and Ireland: Elucidating European origins and genepool diversity. *PLoSONE* **14 (9)**: e02222936.

Lee SJ, Connolly T, Wilson SMcG, *et al*. 2015. Early height growth of silver birch (Betula pendula Roth) provenances and implications for choice of planting stock in Britain. Forestry 88: 484-499.

Mattioni C, Martin MA, Chiocchini F. *et al*. 2017. Landscape genetics structure of European sweet chestnut (Castanea sativa Mill): indications for conservation priorities. *Tree Genetics and Genomes* **13**, 39.doi.org/10.1007/s11295-017-1123-2.

Neophytou C, Konnert M and Fussi B. 2019. Western and eastern post-glacial migration pathways shape the genetic structure of sycamore maple (*Acer pseudoplatanus* L.) in Germany. *Forest Ecology and Management* **432**: 83-93.

Pyatt, D.G., Ray, D. and Fletcher, J. 2001 An ecological site classification for forestry in Great Britain. *Forestry Commission Bulletin No. 124*. Forestry Commission, Edinburgh, UK.

Stoehr M, Bird K, Nigh G, *et al*. 2010. Realized Genetic Gains in Coastal Douglas-fir in British Columbia: Implications for Growth and Yield Projections. *Silvae Genetica* **59 (5)**: 223-233.

The Scottish Government 2019. Scotland's Forestry Strategy 2019-2029.

Vidakovic M, Kajba M, Bogdan D *et al*. 2000. Estimation of genetic gain in a progeny trial of pedunculate oak (*Quercus robur* L.). *Annales Experimentis Silvarum Culturae Provenhendis* **37**: 375-381.

Vaughn SP, Cottrell JE, Moodley *et al*. 2007. Distribution and fine-scale spatial-genetic structure in British wild cherry (*Prunus avium* L.). *Heredity* **98**: 274-83.

Whittet R, Lopez G and Rosique-Esplugas C. 2021. Mid-rotation variation in growth, form and phenology of sycamore (*Acer pseudoplatanus* L.) provenances in field trials in England. *Forestry* **94**: 704-713. doi:10.1093/forestry/cpab012.

## Glossary

**Genetic Gain:** The amount of improvement (expressed as a percentage) of a measured trait in the improved population over the base population.

**Native Seed Zone:** A subdivision of the UK Regions of Provenance. There are 24 of these.

**Progeny:** The offspring from a single plus tree from open or controlled pollination.

**Progeny Trial:** A trial in which offspring from different parent trees are *tested*. A trial of the superiority of parents in a breeding programme, by which their seedlings are planted in replicated field trials.

**Provenance:** The place in which any stand of trees is growing. There are four Regions of Provenance in the UK.