
Figure 1. Distribution of black walnut provenances sampled across Europe.

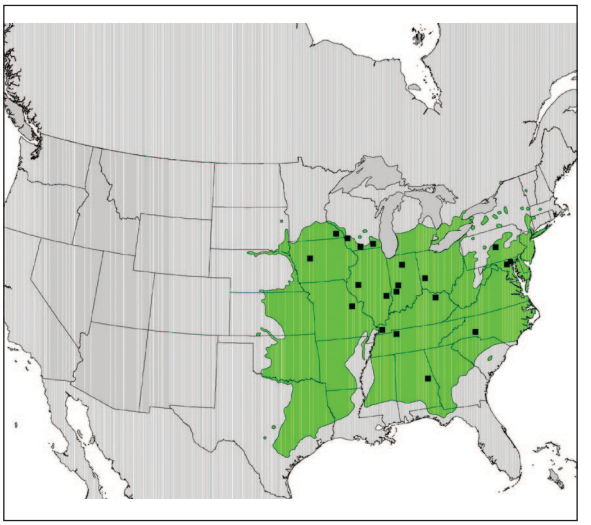

Figure 2. Distribution of black walnut provenances sampled across the USA.

**Table 1. Summary of provenances and progeny included in both phases of the provenance and progeny trials.**

| Collections | Planting year | Provenances n | Progeny n | Populations n |
|---|---|---|---|---|
| **European** | | | | |
| Austria | 2003 | 2 | 15 | |
| Czech Republic | 2003 | 1 | 15 | |
| France | 2004 | 1 | * | |
| Great Britain | 2003 + 2004 | * | 8 | 1 |
| Italy | 2004 | * | 1 | |
| Serbia & Montenegro | 2004 | * | 1 | |
| Slovak Republic | 2003 | 1 | 3 | |
| | | **5** | **43** | **1** |
| **US** | | | | |
| Alabama | 2004 | 1 | * | |
| Illinois | 2004 | 2 | * | |
| Indiana | 2004 | 3 | * | |
| Iowa | 2004 | 1 | * | |
| Kentucky | 2004 | 2 | * | |
| Maryland | 2004 | 2 | * | |
| Minnesota | 2004 | 1 | * | |
| Missouri | 2004 | 1 | * | |
| North Carolina | 2004 | 1 | * | |
| Ohio | 2004 | 1 | * | |
| Pennsylvania | 2004 | 1 | * | |
| Tennessee | 2004 | 1 | * | |
| Wisconsin | 2004 | 3 | * | |
| | | **20** | **0** | |

## Experimental design

The main purpose of the field trials is to assess the suitability of provenances for timber production under British conditions, with particular emphasis on selection for good form, vigour and late flushing. The trials will also provide a resource for genetic diversity studies. The trees were planted out in combined provenance/progeny experiments at two sites in central and southern England (Table 2) during 2003 and 2004 in collaboration with the National Forest Company and the Forestry Commission. Trees

**Table 2. Site details for the black walnut provenance/progeny trials.**

| | Lat/long | Soil (pH) | Soil Type | Altitude (m asl) | Rainfall (mm) |
|---|---|---|---|---|---|
| Lount Wood, The National Forest, Derbyshire | 52° 36' N/1° 25 W | 7.0 | Heavy clay loam | 120 | 600 |
| Paradise Wood, Northmoor Trust, Oxfordshire | 51° 38' N/1° 12' W | 6.2 to 7.7 | Sandy clay loam | 50 | 570 |

were spaced at 2 x 2m (2500 trees $ha^{-1}$) and protected by 0.75m treeshelters. The use of two sites will permit the assessment of genotype x site interaction.

*Phase I*

The experimental design combines both provenance and progeny assessments in a single experiment. Progenies are distributed as single-tree plots (only one tree per replicate) within a randomised complete block design. Where possible the identity of seedlots with individual mother trees has been maintained, thereby allowing progeny testing. Where this was not possible, or where there were insufficient seeds from individual trees, these progeny contribute towards provenance assessment only. Where the number of trees within a progeny is less than six, these are excluded from any analysis and contribute only at the provenance level. There are 45 progeny included in the trials (Table 1).

Provenances were distributed in non-contiguous, multiple-tree plots within 10 replicates across two sites. The number of trees representing a provenance differed for each of the five provenances. Tree positions were assigned randomly at planting time and recorded. Each replicate contains 49 trees, one of which is a British control, planted in spring 2005 at the same time as the Phase II material in a neighbouring trial.

*Phase II*

This phase contained only provenance data. Provenances were distributed in non-contiguous multiple-tree plots within 12 replicates at Paradise Wood and 16 replicates at Lount Wood. Twenty provenances from the States, one French provenance, one British population (the control), and two progenies, one from Italy and the other from Serbia and Montenegro were incorporated. Tree positions were assigned randomly at planting time and recorded. Table 3 summarises the planting details of both phases.

Given the high value of this untested genetic material, all spare trees were planted within the two guard rows surrounding each trial, and their positions mapped.

During winter 2004, height and survival were recorded for Phase I and height baseline data for Phase II at both sites.

Data were analysed with Genstat using plot

**Table 3. Material planted at each site in number of replicates.**

| | No. of Reps | Trees per Rep | Provenances per Rep | Families per Rep | Total no. of trees in trial |
|---|---|---|---|---|---|
| Lount Wood Phase I | 10 | 49 | 5 | 49 | 490 |
| Paradise Wood Phase I | 10 | 49 | 5 | 49 | 490 |
| Lount Wood Phase II | 16 | 80 | 21 | - | 1280 |
| Paradise Wood Phase II | 12 | 80 | 21 | - | 960 |

**Table 4. Summary results for tree growth and survival for Phase 1 (P03).**

| | Lount Wood | Paradise Wood | Both sites |
|---|---|---|---|
| **Tree height (2003)** | | | |
| mean (cm) | 50.3 | 49.8 | 50.1 |
| *s.e.* | *1.3* | *1.5* | *1.0* |
| **Tree height (2004)** | | | |
| mean (cm) | 56.5 | 55.3 | 55.9 |
| *s.e.* | *0.9* | *0.9* | *0.7* |
| **Height increment (2003-04)** | | | |
| mean (cm) | 6.1 | 5.6 | 5.8 |
| *s.e.* | *0.5* | *0.7* | *0.4* |
| **Survival** | | | |
| (%) | 99.5 | 99.7 | 99.6 |
| no. dead | 2 | 1 | 3 |

means. The model of the variance of analysis used was:
*site* + *replicate within site* + *site* x *provenance.*

## Results

Germination of seed lots varied considerably from zero to 60%. Seedlots that germinated poorly were resown winter 2004 with the intention of establishing a further combined progeny/provenance trial if sufficient seedlings are obtained.

*Phase 1*

Tree survival one year after establishment remained excellent at 99.6%, with only 3 trees lost from the 980 planted across both sites. Trees only grew 6cm on average across both sites (Table 4), although statistical analyses indicated significant (*p=0.039*) genotype x site interaction for height increment (Table 5). There were highly significant (*p=0.001*) differences for tree height at the end of the first growing season (2004) between provenances (Figure 3). Height increment was greatest for the Serbian and UK provenances, although these remained significantly smaller in height (*p<0.05*) than the Croatian and two Austrian provenances (Table 6).

**Table 5. Analysis of variance for first year tree height increment between planting in 2003 and 2004 in the Phase I black walnut provenance trials, based on plot means.**

| Source of variation | *d.f.* | *m.s.* | *v.r.* | *p* |
|---|---|---|---|---|
| Site | 1 | 7.955 | 0.96 | 0.330 |
| Site/Replicate | 18 | 9.930 | 1.20 | 0.286 |
| Provenance | 4 | 240.766 | 29.05 | <0.001 |
| Site x Provenance | 4 | 22.054 | 2.66 | 0.039 |
| Residual | 72 | 8.287 | | |
| **Total** | **99** | | | |

## Conclusions

The provenance/progeny trials will be assessed for survival, flushing, vigour (height and diameter), form and occurrence of anthracnose. Data will be analysed and superior progenies and individuals will be selected to form the basis of the next stage of the improvement programme after ten years. It is anticipated that clonal trials of plus trees and/or of seedling selections will be established in the future, subject to propagation techniques being readily available. In addition, it will also be desirable to establish grafted seed orchards comprising the best performing trees. It is also hoped that a collaborative research programme on the genetic diversity of these collections can be initiated with the Hardwood Tree Improvement Regeneration Center (HTIRC), Indiana, USA, with the objectives of assessing the extent of diversity in black walnut represented in the programme and potentially providing information on the origin of the European material.

A study using molecular markers of the genetic diversity of genotypes within the trials is planned early in the life of the programme to minimise genetic

loss due to thinning.

The average rotation for hardwood timber species in the UK, based on expected rotation ages for oak (150 years), cherry (55 years) and ash (70 years) is 90 years (Savill, 1991) and quality can be highly variable which threatens the sustainability of timber production. The improvement programme for walnut potentially offers substantial reductions in rotation (to 50 years) and higher proportions of veneer grade and higher class timber. Sustainable woodland strategies are built upon three recognised and balanced principles pertaining to social, environmental and economic functions. Walnut has the potential to produce high quality, valuable and greatly desired timber over a comparatively short rotation. As such, it could increase the production of home grown timber, contribute to a reduction in imports and stimulate woodland related employment. The production of high quality timber that results in positive cash flows to the woodland owner can only assist in the management of diverse, attractive and well-used woodland. Research into the production of quality timbers, such as walnut at Lount Wood and Paradise Wood, is an exemplary initiative whose results and information could demonstrate how woodlands could be considered as truly socially, environmentally and economically sustainable.

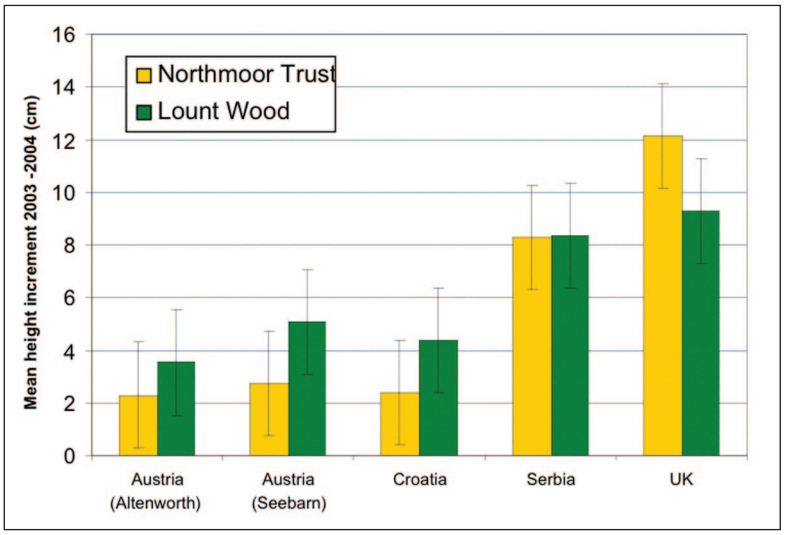


Figure 3. Mean tree height increment for provenances in Phase I across both sites in 2004.

Ultimately, it is hoped that this programme of work will identify good quality timber trees, well adapted to growing in UK conditions. This will enable the recommendation of suitable provenances and potentially the development of seed orchards. The challenges facing foresters striving to achieve profitable, and therefore, sustainable forests are considerable but the benefits from tree breeding programmes and research will help support and progress forestry through the 21st century.

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**Table 6. Mean heights of trees for the five European provenances in Phase I in 2003 and 2004, and height increment (2003-04).**

| | Mean Height 2003 (cm) | Mean Height 2004 (cm) | Mean increment 2003-2004 (cm) |
|---|---|---|---|
| Austria (Altenworth) | 58 | 61 | 3 |
| Austria (Seebarn) | 56 | 60 | 4 |
| Croatia | 57 | 60 | 3 |
| Serbia | 44 | 53 | 9 |
| UK | 35 | 46 | 11 |

graftwood, and to Alba Trees plc for raising the seedlings.

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