OUTCOMES FROM 15 YEARS OF HARDWOODS RESEARCH AT THE NORTHMOOR TRUST

Jo Clark and **Gabriel Hemery** look back at the research carried out and the practical lessons learnt in improving hardwood forestry by the Northmoor Trust in Oxfordshire.

The Northmoor Trust initiated a programme of forestry research, devoted to hardwoods, in 1993. A new woodland has been created on its estate in South Oxfordshire and named Paradise Wood. In one sense it is typical of any new farm woodland in lowland England, containing a wide mixture of hardwoods and using different silvicultural approaches. However, Paradise Wood has another unique dimension, namely a hardwoods field research centre. Some 42 separate field trials have been established since 1993, many of them collaboratively with partners from around the world. These have concentrated on ash, beech, oak, wild cherry and walnut. There have been two main themes to the research; breeding to improve the amount of recoverable timber from trees, and developing their silviculture.

This article summarises the main outcomes after 15 years of research, both strategic and practical. Some results are supported by published papers, and details are included where appropriate, whilst other findings are the result of practical solutions to issues experienced in the field.

Tree improvement

Tree improvement breeding programmes begin with the selection of the best parental material for any desired trait, and these form the foundation breeding stock. This material enters the breeding programme with several aims, namely to:

1. Reduce the rotation time by selecting individuals with faster growth rates.

2. Increase recoverable volume by selecting for traits such as reduced forking, finer/lighter branching.

3. Maintain tree health, such as increased resistance to pests and pathogens. For example, bacterial canker resistance in wild cherry.

4. Investigate adaptation and gene flow. With the projected impacts of climate change, it is increasingly important to understand the adaptive capacity of trees, and to maintain a broad genetic base.

The majority of field trials managed by the Northmoor Trust were established as provenance and progeny tests from which to select individuals to meet aims 1-3 above. The same trials are now recognised as valuable resources in a wider context (aim 4), for example, evaluating impacts that projected climate change may have on hardwood species.

Strategic context

Historically tree improvement in Great Britain has focussed on coniferous species, most notably, Sitka spruce. Hardwood tree improvement has received a low level of support that has slowed the development of high quality

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hardwood planting stock and its availability. For a limited period, funding from the Department of Food and Rural Affairs (Defra) supported advanced tree improvement with wild cherry, using micro-propagation to bring improved material to the industry. This work was undertaken by East Malling Research but their farm woodland programme was terminated in 2007. Forest Research, the Government research agency of the Forestry Commission, has supported a modest programme of hardwood research.

It is unfortunate that woodland owners seeking to include improved material in to new plantings are still faced with very little choice in terms of improved hardwood planting stock. In the future improved material for ash, oak, walnut and cherry may be developed from the field experiments hosted and/or managed by the Northmoor Trust and its partners through the British and Irish Hardwoods Improvement Programme (BIHIP). Currently the only material available is Wildstar™ wild cherry and birch from clonal orchards for Scotland. Two clonal ash orchards exist, for regions of provenance 30 and 40, which are anticipated to produce improved seed by 2012. Eight breeding seedling orchards for oak species were planted in 2003 but seed will not be produced from these for another 30 years. If more funding is made available, research into reproductive techniques may accelerate the availability of improved material to the industry.

Figure 1. Roguing the ash breeding seedling orchard with volunteers.

Uptake of improved material is also limited by the British forestry policy that restricts provenance choice to 'local' seed zones (Herbert et al., 1999). This has recently been reviewed and new policies are emerging that promote a range of provenances, in order to support robust woodlands in light of projected climate change (Hubert and Cottrell, 2007). However, forestry policies are still concerned with health (robustness) and do not usually consider quality for timber production.

Some practical lessons

Establishment of new farm woodland on former arable sites, both at Paradise Wood and at other sites around Great Britain, benefited greatly by adopting some of the following techniques. Preparation of the ground by sub-soiling, to alleviate compaction, was found to be highly beneficial. Sowing bare ground with a low rate of a cereal (typically adopted one-third of the

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normal rate of barley) drastically reduced the strength of undesirable competing vegetation. The cereals are easily controlled by applying a graminicide spot treatment early in the summer. The tall cereal crop acts as a natural tree shelter, improving the micro-climate for the young trees. A practical establishment guide was published (Savill et al., 2006) that summarised some of these experiences.

Species research

***Ash** (Fraxinus excelsior)*

Breeding seedling orchards (BSOs) were established in 1993 (Savill et al., 1999) across four sites. BSOs combine the testing phase (field trials) of research with the production phase (seed orchards). Work with the trials has highlighted the need to select late-flushing material to avoid frost damage and thereby minimise forking. Three of the trials were rogued in 2008 (Figure 1), and improved seed from the selected families should be available from 2010. A second generation trial (arising from selected families of the original trial) will be developed by 2015, seeking to generate a 20% increase in recoverable timber volume.

A clonal seed orchard differs from a BSO in that the material from a selected parent is grafted onto a rootstock. This method is relatively quick and inexpensive compared to a BSO, although the levels of genetic gain are minimal in comparison. A clonal seed orchard for region of provenance 40 (lowland England excluding the south west; Herbert et al, 1999) was established in 2007, and seed should be available from this orchard by 2012.

A provenance trial of ash, established in partnership with Forest Research in 1995, sourced material from across Great Britain and continental Europe. The trial has demonstrated the importance of provenance choice. More continental origins of material (e.g. Romania) have suffered multiple frost injuries due to early flushing compared to western sources (e.g. France, GB) (unpublished data). The early-flushing provenances are often multi-forked and of very poor form.

A trial from the EU's Fraxigen (2005) programme comprised controlled crosses, and will be used to study inbreeding effects and gender viability for use in evolutionary models.

A reciprocal transplant experiment (where seed from each of the trial sites is planted at its own site and each of the other trial sites) was established in 2008 at five sites along a latitudinal transect from the Pyrenees (43°N) to Inverness (57°N) to investigate adaptation to climate change. This work forms part of a PhD study currently underway, funded by Northmoor Trust, Forest Research and the Scottish Forestry Trust. Early results suggest that local material may not be suitable for projected future climates across the range of sites studied. Seed germination testing of ash has indicated that chilling requirements to break dormancy may not be met with milder winters (Clark, unpublished data), thus promoting the use of a wider range of provenance material.

***Beech** (Fagus sylvatica)*

A Europe-wide provenance trial, hosted by 17 countries, was established in Paradise Wood in 1998. Data from these trials is becoming increasingly interesting as beech is one of the species projected to do less well in southern England with a warming climate. The trial at Paradise Wood is of particular interest to researchers as this trial is the most northerly site in the programme. Data from this trial feeds in to a broader Europe-wide programme looking at growth, genetics and adaptation of beech.

***Oak** (Quercus petraea and Q. robur)*

Eight BSOs comprising families from 66 parent trees from Great Britain, Ireland, northern France and the Netherlands were established across Britain and Ireland as part of a BIHIP programme in 2003 (Savill et al., 2003). Five year data revealed differences between families (Clark, 2007) with the top five families in terms of vigour all originating from lowland England. Although these orchards contain both species common to Britain, they will be probably be rogued to one species once the testing phase has been completed, and the trials become functioning seed orchards.

Seed may be commercially available from the BSOs by 2040. However, because mast years are

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infrequent (about every 7 years) in oak, a seed orchard will only provide acorns sufficient to reforest an area two to three times its own size. The eight BSOs already established for oak, totalling 7.5 ha, will therefore only support 15-20ha of new planting per year. If sufficient funding and support were to become available, techniques such as micro-grafting, could be developed to bulk up planting stock.

A provenance trial, comprising four British, four French, two Dutch and one Spanish provenance was planted in 2005 to investigate provenances that may be suitable for growing in Great Britain in a changing climate. This trial was established as part of the 200th anniversary of the Battle of Trafalgar, and is planted in a small woodland that borders Paradise Wood, named after one of the Admiral Nelson's ships – Neptune Wood.

Figure 2. Walnut being grown with a nurse *Elaeagnus umbellata*.

Walnuts *– common (Juglans regia), black (J. nigra) and hybrids*

Provenance selection for common walnut is very important. As part of a DPhil research project with the Department of Plant Sciences, Oxford (Hemery, 2000), a collection of 25 provenances and 375 half-sib progenies was made in 1997 representing the natural range of the species, including those from high altitudes in the mountains of Kyrgyzstan (Hemery, 1998). The research has demonstrated wide-ranging responses to conditions in England. Frost tolerance is of major importance and is affected by flushing time, which is highly heritable (Hemery et al., 2005b).

Collections of black walnut from 24 provenances were undertaken across Europe and America in order to identify suitable provenances for Great Britain (Russell and Hemery, 2004; Clark et al., 2005). The trees are still young, but phenological (bud burst) assessments will be carried out over the next three years to identify those provenances that flush late and thus are more suitable for British climatic conditions.

A field trial of hybrid walnuts has revealed great promise for these trees in England. NG23 and NG38 (both *Juglans nigra* x *J. regia*) and MJ209 (*J. major* x *J. regia*) hybrids establish well and demonstrate excellent hybrid vigour. NG23 has performed particularly well with five year old plants growing more than 1m in height per year for the last two years (Clark and Hemery, in prep.). Hybrid walnuts may be suitable in short rotation forestry schemes, for example grown for veneer in 40 year rotations.

Silvicultural research

Lessons from walnut research

Growing quality trees for timber production relies on a combination of improved genetic material and silviculture (e.g. for walnut; Hemery, 2004). Building on experience in the genetic improvement of walnut, a series of field trials using tree and shrub nurse species, was established in 2002 (Figure 2). Autumn olive *Elaeagnus umbellata* (Clark and Hemery, 2006), a nitrogen-fixing shrub, was found to promote walnut height growth by 100% and improve tree form (reduced branchiness and forking) (Clark et al., 2008). Great Britain's largest walnut

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plantation was established at Lount in the National Forest, in a joint project with the National Forest Company in 2000, by adopting the above techniques (Clark, 2008).

An establishment trial revealed that common walnut is favoured by 0.75m tall tree shelters, whereas taller shelters (1.2m) often had a negative impact on tree form (Hemery and Savill, 2001). This has also been observed in other species.

Direct seeding of common walnut was found to promote rapid tree growth with reduced stem dieback, compared to planting transplant stock (unpublished data). The technique adopted was to erect 0.75m tree shelters in prepared ground, drop a seed down the shelter, and cover it with one handful of neutral pH soil or peat.

Understanding the growth dynamics of hardwoods

Analysis of the ratio of crown diameter to stem diameter of hardwood trees allowed the modelling of ideal spacings, basal areas, thinning regimes, and the management of overstoreys in shelterwood systems (Hemery et al., 2005a). In the absence of published yield class information for many hardwood species, this work offered many practical applications for forest managers. Walnut has the largest crown diameter at any given age, for any of the common hardwood trees, whilst light-demanding species such as birch, the smallest.

Formative pruning techniques and experience were developed for the common hardwood species. High pruning techniques were applied rigorously and techniques honed. Practical guidelines have been published in conjunction with Woodland Heritage on both these topics (Hemery et al., 2002; Hemery et al., 2003).

Novel agroforestry research

A silvo-poultry system (Poultry In Natural Environments – PINE) was developed and investigated for three years (Hemery, 2005) with multiple partners. This demonstrated significant benefits for the welfare of free-range broiler chicken due to increased ranging behaviour under newly planted trees (Jones et al., 2007). Initial capital investment was high. However, the Northmoor Trust achieved a running profit margin of £20,000 per ha per year. The long term cost-benefits were projected to be very positive (Yates et al., 2007). Unfortunately funding for the research elements of the project was limited, and, in combination with marketing difficulties, ultimately led to the demise of this project.

Concluding remarks

Paradise Wood was established to address a specific need for hardwood tree improvement. In 15 years over 40 trials have been established for five of our most important economic hardwood species. This research has been disseminated through conferences, field meetings and many published papers.

One of the main successes in the forestry work undertaken by the Northmoor Trust has undoubtedly been the level of partnership working. Genetically improved planting stock is already available for wild cherry, whilst seed of improved ash and oak may be available in the next three and 30 years respectively.

While the original goals of improving timber quality and reducing rotation times are being met, a unique collection has also been established. As a genetic conservation woodland, Paradise Wood is unparalleled in the UK, and is a valuable resource at the European level. Using climate modelling, yield class can be predicted (Broadmeadow et al., 2005) and this shows that if we continue to use local seed sources, productivity will decrease for most species by 2080. Therefore, we anticipate an increasingly important role for the work undertaken at Paradise Wood, and for the genetic resources it contains. Given the short-term funding available for most research projects, typically 3-5 years, the independence of the Northmoor Trust's forestry research programme ensures its long term survival.

Resources

British & Irish Hardwoods Improvement Programme	www.BIHIP.org
Forest Research	www.forestresearch.gov.uk
Northmoor Trust	www.NorthmoorTrust.co.uk
Sylva Foundation	www.Sylva.org.uk

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References

Broadmeadow, M., Ray, D. and Samuel, C. (2005) Climate change and the future for broadleaved tree species in Britain. *Forestry*. **78**, 145-161.

Clark, J.R. (2007) Oak breeding seedling orchards. Research report 2007. In: *British and Irish Hardwoods Improvement Programme*. http://www.bihip.org/species/oak.html. pp. 13.

Clark, J.R. (2008) *National Forest Research Report*. www.NorthmoorTrust.co.uk/forestryresearch/species/walnut.

Clark, J.R. and Hemery, G. (2006) The use of autumn olive (*Elaeagnus umbellata* Thunb.) in British forestry. *Quarterly Journal of Forestry*. **100**, 285-288.

Clark, J.R. and Hemery, G.E. (in prep.). Hybrid walnuts in the UK – fast growing quality hardwoods.

Clark, J.R., Hemery, G. and Savill, P. (2008) Early growth and form of common walnut (*Juglans regia* L.) in mixture with tree and shrub nurse species in southern England. *Forestry*. **81**, 631-644.

Clark, J.R., Hemery, G.E., Russell, K. and Williams, H. (2005) The future of black walnut in Britain. *Quarterly Journal of Forestry*. **99**, 207-212.

Cundall, E.P., Cahalan, C.M. and Connolly, T. (2003) Early results of ash (*Fraxinus excelsior* L.) provenance trials at sites in England and Wales. *Forestry*. **76**, 385-399.

Fraxigen. (2005) *Ash species in Europe: biological characteristics and practical guidelines for sustainable use*. University of Oxford, Oxford Forestry Institute. pp. 128.

Hemery, G.E. (1998) Walnut (*Juglans regia*) seed-collecting expedition to Kyrgyzstan in Central Asia. *Quarterly Journal of Forestry*. **92**, 153-157.

Hemery, G.E. (2000) *Juglans regia L: genetic variation and provenance performance*. DPil Thesis. Department of Plant Sciences. University of Oxford. http://ora.ouls.ox.ac.uk/objects/uuid:160d3486-f71c-4575-84e7-85dc64b3222f pp. 176.

Hemery, G.E. (2004) Genetic and silvicultural research promoting common walnut (*Juglans regia*) for timber production in the United Kingdom. In: *Black walnut in a new century, proceedings of the 6th Walnut Council research symposium*; 2004 July 25-28; Lafayette, IN-Michler, C.H., Pijut, P.M., Van Sambeek, J., Coggeshall, M., Seifert, J., Woeste, K. and Overton, R., eds. General Technical Paper NC-243, St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 188 p. pp. 138-145.

Hemery, G.E. (2005) A novel silvo-poultry system. *Quarterly Journal of Forestry*. **99**, 131-133.

Hemery, G.E., Savill, P. and Pryor, S.N. (2005a) Applications of the crown diameter - stem diameter relationship for different species of broadleaved trees. *Forest Ecology and Management*. **215**, 285-294.

Hemery, G.E., Savill, P. and Thakur, A. (2005b) Height growth and flushing in common walnut (*Juglans regia* L.): 5-year results from provenance trials in Great Britain. *Forestry*. **78**, 121-133.

Hemery, G.E. and Savill, P.S. (2001) The use of treeshelters and application of stumping in the establishment of walnut *Juglans regia*. *Forestry*. **74**, 479-489.

Hemery, G.E., Savill, P.S. and Kerr, G. (2002) *High pruning for profit*. Woodland Heritage Leaflet. pp.

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Table 1.

Species	Planting Year	No. of Trails	Design	Publications
Ash – *Fraxinus excelsior*				
Breeding seedling orchard	1993	4	36 half sib families from the UK	Savill et al. (1999)
Provenance trial	1995	6	15 provenances from across Europe	Cundall et al. (2003)
RAP provenance trial	2003	7	EU reciprocal provenance trial of 39 provenances	http://www.teagasc.ie /advisory/forestry/rap
Fraxigen	2006	1	Controlled crossed material from the UK	Fraxigen (2005)
Clonal orchard	2007	3	Clonal orchards of UK material by region of provenance	Clark (in prep)
Reciprocal transplant experiment	2008	5	10 provenances from UK and France	
Beech – *Fagus sylvatica*				
Provenance trial	1998	21	25 provenances from across Europe	http://www.biomatnet.org /secure/Air/S287.htm
Wild Cherry – *Prunus avium*				
Clonal Trial	1999	3	Micropropagated clones from 20 selected parent trees	
Oak – *Quercus robur and Q. petraea*				
Breeding Seedling Orchard	2002	8	66 half sib families from UK, Ireland, France and Holland	Clark (2007)
Provenance trial	2005	3	11 provenances from UK, France, Spain and Holland	
Walnut – *Juglans regia and J. nigra*				
Establishment trial	1996	1	Various tube height and stumping treatments	Hemery and Savill (2001)
Provenance and progeny trial	1998	3	375 progeny from 18 provenances from Europe and Asia	Hemery (1998); Hemery et al. (2005)
Direct seedling trial	2000	1	4 seed stratification treatments	
Silviculture trial	2000	4	4 tree and 3 shrub nurse treatments	Clark and Hemery (2006); Clark et al. (2008)
Hybrid trial	2003	1	5 hybrids	Clark and Hemery (in prep)
Black walnut provenance and progeny trial	2003, 04,05	6	10 European and 14 north American provenances	Clark et al. (2005); Russell and Hemery (2004)

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Hemery, G.E., Savill, P.S. and Kerr, G. (2003) *Formative pruning*. Woodland Heritage Leaflet. pp.

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

Hubert, J. and Cottrell, J. (2007) The role of forest genetic resources in helping British forests respond to climate change. In: *Information Note June 2007, FCIN08*6. Edinburgh, Forestry Commission, http://www.forestry.gov.uk/pdf/fcin086.pdf/$FILE/fcin086.pdf. pp. 12.

Jones, T., Feber, R., Hemery, G., Cook, P., James, K., Lamberth, C. and Dawkins, M. (2007) Welfare and environmental benefits of integrating commercially viable free-range broiler chickens into newly planted woodland: a UK case study. *Agricultural Systems*. **94**, 177-188.

Russell, K.R. and Hemery, G.E. (2004) A new tree improvement programme for black walnut in the United Kingdom. In: *Black walnut in a new century, proceedings of the 6th Walnut Council research symposium; 2004 July 25-28;* Lafayette, IN-Michler, C.H., Pijut, P.M., Van Sambeek, J., Coggeshall, M., Seifart, J., Woeste, K. and Overton, R., eds. General Technical Paper NC-243, St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 188 p. pp. 134-137.

Savill, P., Burley, J. and Hemery, G.E. (2003) Improving oak: the first steps towards a breeding programme. In: *International Oak Society meeting*. Winchester, UK.

Savill, P., Hemery, G. and Wilson, T. (2006) *Establishment of broadleaves*. Woodland Heritage Leaflet. pp.

Savill, P.S., Spencer, R., Roberts, J.E. and Hubert, J.D. (1999) Sixth year results from four ash (*Fraxinus excelsior*) breeding seedling orchards. *Silvae Genetica*. **48**, 92-100.

Yates, C., Dorwood, P., Hemery, G. and Cook, P. (2007) The economic viability and potential of a novel poultry agroforestry system. *Agroforestry Systems*. **69**, 13-28.

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