Forestry Commission
231 Corstorphine Road
Edinburgh
EH12 7AT
www.forestry.gov.uk

The Products of Conifer Tree Breeding in Britain

INFORMATION NOTE

BY STEVE LEE OF FOREST RESEARCH

JUNE 2004

SUMMARY

Selection and breeding of Sitka spruce was started by the Forestry Commission in 1963. Similar work with Scots pine had begun earlier, at the end of the 1940s. Corsican pine, hybrid larch, Douglas fir and lodgepole pine are all other species for which there has also been active selection and testing programmes at some stage over the past 30 years.

This Information Note gives details of the significant advances that have been achieved in the field of conifer breeding in Britain. It outlines the work carried out and the genetic gains of planting stock available now to forest managers.

Details are also given of the work which conifer breeders intend to carry out in the near future, designed to increase further the economic gain of planting stock and the rate at which it will become available to nurseries and the forest industries.

INTRODUCTION

Provenance experiments designed to identify the most suitable seed source within a species were first planted by the Forestry Commission in 1926.

Breeding and selection of individual conifer plus-trees (highly selected phenotypes with well-above average growth rates and stem quality) started with Scots pine in 1948. Testing the genetic quality of those plus-trees through a series of progeny tests followed over the next 30 years. Analysis of data collected in the progeny tests led to the reselection, amongst the original plus-trees, of those that had proved genetically most superior in terms of the growth rate and stem form. These reselected trees became known as the breeding population (Lee, 1999; 2002). Similar programmes to improve the genetic quality of Sitka spruce, Corsican pine and hybrid larch all followed in the early 1960s (Lee, 2001a; 2003a and 2003b).

Although programmes were also started for other species such as western hemlock and western red cedar, these did not continue to the progeny testing stage due to perceived lack of demand in relation to the cost of the breeding work.

Selection and breeding of lodgepole pine continued until the mid-1980s when demand for the species declined. Douglas fir breeding has been intermittent; a programme was initially started in the 1960s only to be abandoned due to perceived lack of demand, prior to recommencing in the 1990s with new funding from the European Union. A more detailed history of conifer breeding in Britain is available by visiting the tree improvement area on the Forest Research website (www.forestresearch.gov.uk/treeimprovement).

ACHIEVEMENTS TO DATE

Information on the most suitable provenance to plant on a given site type is now readily available for a wide range of conifer species (Lines, 1987). The intention is to develop this information into an 'Ecological Site Classification' (ESC) format (Pyatt *et al.*, 2001) so that managers may obtain advice on the most suitable provenance after entering site specific details (e.g. grid reference, soil, elevation, and accumulated temperature).

A summary of the within-origin breeding work carried out since the early 1960s, together with the genetic gains obtained and prospects for the future is given in Table 1.

THE CURRENT SITUATION

Tree breeding can be a time-consuming business. Using traditional methods it takes at least 25 years from plus-tree selection to establishment of tested clonal seed orchards. Depending on the species, a further period of time must then pass before the seed orchards yield seed which can be

Table 1 Summary of breeding work done, genetic gains obtained and prospects for the future according to conifer species.

Species	Breeding work already completed	Level of genetic gain obtained and availability of stock	Prospects for the future
Sitka spruce[1]	• Field testing of the genetic quality of plus-trees nearly complete. • Breeding populations selected. • Earliest tested seed orchards now nearly 20 years old. • Active vegetative propagation programmes in the public and private sector.	• Gains of 20% for diameter, 15% for stem form and 0% for wood density relative to unimproved QCI. • Gains of 12% for diameter, 12% for stem form and 9% for wood density relative to unimproved QCI. • Supplies from seed orchards are erratic but regular supplies are available via controlled pollination and vegetative propagation.	• Better ESC-type prescriptions to match origin with British site conditions. • Complete controlled pollination and establish the next generation of progeny tests. • Implement a marker-aided selection programme to both improve and increase the rate of genetic gain significantly. • Implement a clonal forestry programme of tested genotypes. • Greater emphasis on stem form and wood quality traits.
Scots pine[2]	• Field testing of the genetic quality of plus-trees complete. • Breeding populations selected. • Earliest tested seed orchards now over 20 years old.	• Gain of 8–12% for diameter and small gain for stem straightness relative to seed from registered seed stand. • Ample supplies from current seed orchards.	• Establish new seed orchards for general use offering gains of 14–20% for diameter and 5–19% for stem straightness. • Establish specialised seed orchards e.g. western Scotland origin. • No further breeding planned.
Corsican pine[3]	• Field testing of the genetic quality of plus-trees complete. • Breeding populations selected. • Earliest tested seed orchards now 10 years old.	• Gain of 5% for diameter relative to seed from registered seed stand. • Supplies from seed orchards are erratic.	• Establish new seed orchards offering gains of 9% for diameter and small gains in stem straightness. • No further breeding planned.
Hybrid larch[4]	• Field testing of the genetic quality of plus-trees nearly complete. • Breeding populations selected.	• Some untested seed orchards offering low genetic gains of 5% for diameter and 5% for stem straightness. • Seed orchards flower erratically and give a low proportion (around 20%) of hybrid larch.	• Prospects for a new vegetative propagation programme of superior hybrid larch families offering gains of around 15–20% for diameter and 20–25% for stem straightness.
Douglas fir[5]	• All progeny tests now planted. • Results from current progeny tests due soon.	• The best gains are from seed stands of the most suitable provenance.	• Possibility of access to seed from breeding programmes elsewhere e.g. USA or France. • Possibility of tested seed orchards based on progeny test results. • No further breeding planned.
Lodgepole pine	• Large programme of plus-tree selection and testing now complete. • Large programme of testing provenance hybrids now complete. • Untested seed orchards consisting of various provenance hybrids between 10 and 20 years old.	• Not known. Thought to be modest beyond the selection of the most suitable origin.	• No further breeding planned.

[1] Lee, 2001a; 2001b. [2] Lee, 1999; Lee, 2002. [3] Lee, 2003a. [4] Lee, 2003b. [5] Fletcher and Samuel, 2002.

harvested and sold to the nurseries; this is around six years for Scots pine but twelve years for Sitka spruce. Tested seed orchards are now mature enough to yield improved seed for Sitka spruce, Scots pine and Corsican pine, albeit on an irregular basis. Seed from untested seed orchards (gains only to the plus-tree level but not to the progeny tested level) are available for hybrid larch and lodgepole pine. However, it will be some time (12 or so years) before any tested Douglas fir seed orchards are planted, with the usual delay (approximately 10 years) before seed is harvested.

Tree breeders have to look hard at the gains which can be achieved over a generation of breeding, the cost of that work and how quickly that gain can be passed onto the forest manager. Current thinking is that only Sitka spruce will have an active programme which will continue into a second generation of selection and breeding. But market demands and management objectives can change so breeders are making sure that all the work invested in the other conifer species subjected to selection and testing is not lost. Every tree found to be genetically superior for the traits under selection (usually growth rate, stem straightness, branching quality and perhaps wood density) based on progeny test data, will be retained in two clonebanks (genetic archives) for possible future breeding work.

SITKA SPRUCE: A SUCCESS STORY

Sitka spruce is the most planted conifer in Britain and has received most of the conifer breeding effort over the past 20 years. The first generation of genetic testing is now complete and improved planting stock is commonly planted offering significant gains in diameter growth and stem straightness. Alternatively, genetic gain in wood density can be chosen as a priority, with reduced gains for diameter and, to a lesser extent, stem straightness. Forest managers quickly became aware of the advantages of planting improved stock since not only does there remain the promise of greater final rotation gains, the faster growth rates following planting often reduce overall establishment costs. The improved material has rightly achieved a reputation for good early growth rate and stem straightness.

Improved planting stock is derived from either seed orchards or through controlled pollination followed by vegetative propagation (VP). VP stock consistently provides around 25% of the annual Sitka spruce planting stock. In the years following good flowering in the seed orchards the 75% balance of demand is also of improved material. One of the remaining problems in Sitka spruce breeding is the relatively low frequency with which the seed orchards flower.

In common with other tree breeding programmes around the world, the emphasis in the first generation of breeding was placed on growth rate and the stem straightness. Wood density was only introduced as a selection trait about 15 years ago. While wood density remains one of the most important indirect indicators of final timber strength, there are other timber characteristics for which breeders could screen to further increase timber strength. Such traits include branch size and distribution, microbibril angle (orientation of the cell walls) proportion of late to early wood and the size of juvenile core.

In the next generation, greater emphasis will be placed on quality traits such as stem form and timber quality in an attempt to increase the proportion of Sitka spruce which meets the demands of higher value construction timber. Sitka spruce breeders remain an important part of the 'Wood Quality' research team; collecting data to help improve timber strength models while at the same time learning more about which traits we should give priority to as part of our breeding effort.

The next generation of Sitka spruce breeding will also see an increased reliance on modern biotechnology (see Lee *et al.*, 2004 for a brief summary of how these powerful tools can help tree breeding). Plans are well advanced to establish field trials aimed to help breeders identify, through a system of biochemical markers, those genotypes which have suitable wood properties, stem form and growth rate. Ultimately selection may be made in the laboratory in a matter of months rather than waiting 6–10 years for data from costly field-based trials.

Elsewhere, work with Sitka spruce on cryopreservation (deep-frozen storage of valuable genetic tissue) and somatic embryogenesis (vegetative propagation at a cellular level) is giving positive results such that the use of clones in forestry could soon be a reality. The aim of tree breeders is to select individual trees which are superior for a suite of traits at a very early age, and then multiply such trees many thousands of times over a two or three year period. Forest managers will notice a significant increase in the genetic gains of the planting stock they receive and also the uniformity of that stock as clonal forestry becomes common place at a price comparable to transplants.

HAS BREEDING AND SELECTION BEEN WORTH WHILE?

Britain was one of the first countries to attempt the genetic improvement of its commercial conifer species although this is now common practice worldwide. If British conifer breeders were to start again they could proceed much more efficiently with the benefit of knowledge gained over the years. Table 1 illustrates that, despite occasional setbacks, genetic gains have been made. The benefit of these improvements is that they are fixed in the population; they can not be taken away – only added to by subsequent generations of breeding.

Improved Sitka spruce, Scots pine and, to a lesser extent, Corsican pine are routinely available and in demand by forest managers. There is the potential for large gains in hybrid larch if current research into commercial-scale vegetative propagation proves successful.

THE FUTURE

The future of conifer tree breeding in Britain is likely to:

- centre on Sitka spruce although Douglas fir breeding has yet to be completed;
- have a greater emphasis of stem form and wood quality traits;
- show advances in clonal forestry;
- increasingly employ the tools of marker-aided selection in which screening is carried out in the laboratory based on biomolecular markers linked to the desired trait expressed in the field.

CONCLUSION

One generation of selection and breeding of conifers in Britain has provided forest managers with improved planting stock for a number of species (Sitka spruce, Scots pine, Corsican pine) although some work remains to be done with others (Douglas fir, hybrid larch). Future breeding effort is likely to be focused on Sitka spruce although all improved genotypes from other species will be retained in clonebanks in case further breeding can be justified.

Genetic gains for Sitka spruce are likely to be much improved over the next 10 years, especially for quality traits if advances in biochemical markers and clonal forestry are exploited.

REFERENCES

FLETCHER, A. M. AND SAMUEL, C. J. A. (2002).
Selection of seed sources of Douglas fir for use in Britain.
Internal Tree Improvement Branch report.
Forest Research, Northern Research Station, Roslin.

LEE, S. J. (1999).
Genetic gain from Scots pine: potential for new commercial seed orchards.
Forestry Commission Information Note 27.
Forestry Commission, Edinburgh.

LEE, S. J. (2001a).
Selection of parents for the Sitka spruce breeding population in Britain and the strategy for the next breeding cycle.
Forestry **74** (2), 129–143.

LEE, S. J. (2001b).
Revised predicted gains from Sitka spruce seed orchards.
Forestry and British Timber, March 2001.

LEE, S. J. (2002).
Selection of parents for the Scots pine breeding population in Britain. *Forestry* **75** (3), 293–303.

LEE, S. J. (2003a).
Genetic improvement of Corsican pine [Internet].
Available from: http://www.forestry.gov.uk/kirn-5lebqz
Forestry Commission, Edinburgh.

LEE, S. J. (2003b).
Breeding hybrid larch in Britain.
Forestry Commission Information Note 52.
Forestry Commission, Edinburgh.

LEE, S. J., COTTRELL, J. AND JOHN, A. (2004).
Advances in biotechnology: powerful tools for tree breeding and genetic conservation.
Forestry Commission Information Note 59.
Forestry Commission, Edinburgh.

LINES, R. (1987).
Choice of seed origins for the main forest species in Britain.
Forestry Commission Bulletin 66.
HMSO, London.

PYATT, G., RAY, D. AND FLETCHER, J. (2001).
An ecological site classification for forestry in Great Britain.
Forestry Commission Bulletin 124.
Forestry Commission, Edinburgh.

SAMUEL, C. J. A., JOHN, A., AND LEE, S. J. (2000).
Fifty years of tree breeding in Great Britain [Internet].
Available from: http://www.forestresearch.gov.uk/treeimprovement
Tree Improvement Branch internal report.
Forest Research, Alice Holt Lodge, Farnham.

Enquiries relating to this publication should be addressed to:

Dr Steve Lee
Forest Research
Northern Research Station
Roslin
Midlothian
EH25 9SY

Tel: 0131 445 2176
Fax: 0131 445 5124

Email: steve.lee@forestry.gsi.gov.uk

ISSN 1460-3802
ISBN 0-85538-628-2

FCIN058/FC(KMA)/NVSPT-1.5K/JUN04