- *This note introduces the birch selection and improvement programme and presents early results from field trials.*
- *Two species of birch are native to Ireland: Betula pendula (silver birch), and Betula pubescens (downy birch). Poor stem quality has been the main factor limiting the commercial exploitation of birch in Ireland.*
- *A selection and improvement programme was started in 1998. An initial survey found that good stands of mature birch were rare and that downy birch was more common than silver birch.*
- *Breeding seedling orchards were established in 2001. These sites combine seed orchard development with field testing.*
- *Early results show significant provenance and family differences in growth and stem form in both species. This provides a good basis for improvement. Early results also show that both species contain high levels of variation.*

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Progress in the selection and improvement of Irish birch

***Dr Ellen O'Connor*[1]**

Introduction

According to Nelson and Walsh (1993), *The native birches of Ireland and Britain are complicated, perplexing plants ... They seem interminably valuable, and often the variation apparent to the naked eye is deceptive. For example, a birch tree with sweeping, slender twigs and white bark can be* Betula pendula *(silver birch) but it can also be* Betula pubescens *(downy birch). The only way to be certain is to study the seeds and chromosomes of that particular tree; as the latter are invisible, except under a power microscope after complicated treatment of the root tips or flower buds, such study is the reserve of laboratory botanists*.

Two species of birch are native to Ireland: *Betula pendula* and *Betula pubescens.* The bark of *B. pendula* (silver birch, sometimes called the European white birch) is smooth and silvery white, although in young trees (up to 10 years old) the bark can sometimes be brown, while in older trees the lower trunks can sometimes be black and vertically fissured. Older branches are pendulous and there is a characteristic double-serrated leaf edge but the key identifier is the presence of small warts on the young twigs, hence its old name *B. verrucosa*. The bark of *B. pubescens* (downy birch) can be brown, white or grey. Downy birch can also display great variation in leaf shape and growth habit; branches tend to have an upright or spreading habit but sometimes display pendulous growth. It can therefore be difficult to tell the two species apart, but the leaves of downy birch are single-toothed and hairy and the young twigs have small hairs rather


Leaves of the downy birch (*B. pubescens*).


Leaves of the silver birch (*B. pendula*).

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than the rough warts of silver birch. Silver birch grows best on free-draining mineral soils but also grows on shallow peat and gravels. Downy birch grows well on fertile mineral soils but is tolerant of heavy clays and deeper peat. The two species do occur together. With a rotation period of about forty years, birch trees rarely exceed 20 m in height or 35 cm in diameter.

The demand for native tree species, including birch, has increased in recent years. Both species are included in the Native Woodland Scheme[2], and are used for landscaping and to increase forest biodiversity. Occasionally, birch is used as a nurse species to provide frost protection and encourage straight growth in main crop species. Currently birch is not on the Forest Service list of recommended species for afforestation, because most native birch has poor stem quality and because of poor survival and growth in imported material, especially from Scandinavian countries. However, the Forest Service recognises the potential of birch, and both species are listed as having commercial potential in the *Code of Best Forest Practice – Ireland* (Anon 2000).

Downy and silver birch are pioneers and can be grown on sites that cannot support other, more demanding, broadleaves. They have a shorter rotation period than most broadleaved trees and, for afforestation, an initial crop of birch improves site soil conditions.

The timber is pale and fine-grained. Its strength and density is similar to beech and it can be sawn, pulped, turned or veneered. Birch timber is becoming increasingly popular for furniture, kitchens and flooring. This demand is mainly met by imports.

The provision of improved planting stock would secure the place of birch in commercial Irish forestry and provide a home-grown source of quality hardwood timber in the future.

The overall aim of the birch improvement project is to provide a source of selected and improved planting stock for the Irish forest sector, with good stem quality and good growth rate potential.

The improvement programme began in 1998 with the COFORD-funded 'Pilot project for the genetic improvement of Irish birch' (1998 – 2000), followed by the current project 'Selection and improvement of Irish birch' (2001 – 2006). An outline of the earlier work was published by COFORD (O'Dowd 2004).

Identifying good stands and plus-trees

The improvement programme includes both birches, and is based on the conventional tree improvement approach, with the identification of good stands, and the selection of plus-trees within these stands as a first step.

Information was sought from the forestry sector and wider public regarding the location of good quality birch. Over eighty sites were visited during an initial survey (1998/1999) (Figure 1). Good stands of mature birch were less common than anticipated, and downy birch was more common than silver birch. Often the trees were in small groups or were scattered throughout an area. Most of the stands were unmanaged.

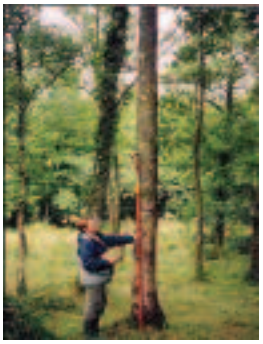
Overall, birch of good quality was rare, and was found mainly in the east of the country. Seed was collected from a range of stands of varying quality, as well as the best trees, to ensure a broad genetic base. The best trees were designated as plus-trees (Table 1). (A plus-tree, or elite tree, is a superior individual; selected plus-trees form the basis of a breeding population.)

Figure 1. Locations of the first birch selections.

[2] *The Native Woodland Scheme is aimed at encouraging the proactive protection and expansion of Ireland's native woodland resource and associated biodiversity using appropriate 'close-to-nature' silviculture.*

Table 1. The desired characteristics of a birch plus-tree are:

- retention of leader
- straight stem of > 6 m
- light branches at 90° angle to the stem
- circular stem
- low taper
- narrow crown
- smooth peeling bark
- absence of fluting



Establishment of breeding seedling orchards

Provenance testing, progeny testing and seed orchards are among the major components of tree improvement programmes:

- *Provenance testing* involves seed collection from stands and the establishment of field trials to compare the growth of the seedlings from the sampled population.
- *Progeny testing* is the testing of individual plus-trees based on the performance of their offspring in field trials. The plus-trees are tested for their ability to pass on good characters. The design and management of the field trials emulate the conditions to be found in commercial forest operations.
- *Seed orchards* are stands planted especially for the production of seed. Spacing and pruning encourage flowering and seed production.
- A *seedling seed orchard* is established with seedlings from selected plus-trees. While the ultimate aim is to have indoor or covered seed orchards comprising plus-trees, a breeding seedling orchard is an intermediary step.
- A *breeding seedling orchard* combines a field performance trial with seed production as the best trees are retained.

Three birch breeding seedling orchards were established in 2001, but one site was damaged by hares. The remaining sites are located at Ballyredmond in Co Carlow and at Castletown in Co Tipperary (Table 2). While these stands are destined to become seed orchards, their establishment was modified so that they can be used as field trials in the earlier years. The sites and the stocking density, 3,300 ha^{-1}, allow field testing in conditions representative of farmland afforestation, i.e. conditions expected in future afforestation/reforestation programmes. Seeds collected from stands and individual plus-trees were germinated and planted as one-year-old seedlings. The sites are 3 ha and contain about 10,000 trees derived from 33 Irish provenances (silver birch and downy

▲ A birch specimen with good stem form.

Table 2. Birch field trials/breeding seedling orchards established in 2001.

	Castletown	Ballyredmond
County	Tipperary	Carlow
Soil	Grey brown podzolic	Brown earth
pH	Basic mineral	Acidic mineral
Exposure	Moderately exposed	Moderately sheltered
Altitude	30 m	130 m
Drainage	Moderate to well drained	Well drained
Aspect	SW	NE
Previous use	Arable	Grazing

birch) and from 37 controlled crosses of Irish plus-trees (downy birch). In addition, silver birch from seven Scottish provenances, one French provenance and two German breeding populations were included for comparison. As time progresses, the stands will be thinned, including the removal of the overseas provenances, leaving the best trees derived from selected parents to provide a seed source. A number of trees are already producing seed.

The breeding seedling orchards allow the comparison of provenance performance, and new plus-trees can be identified within the trials. They are also used to increase our scientific and breeding knowledge of birch with the estimation of genetic parameters, such as the level of variation present. These trials also provide an opportunity to study the growth potential of birch in managed, even-aged stands.

▲ A birch breeding seedling orchard at Castletown, Co Tipperary, in the early stages of growth.

Early results from field testing

Growth rates

Comparison of growth rates are important as the selection of plus-trees was primarily based on stem quality. In most instances, the age of the parent trees, and therefore annual growth estimates, were unknown. Growth assessments were carried out at both experimental sites at the time of planting and after one, two and four growing seasons.

Mean height and diameter values obtained after four years are presented in Table 3. The data for the different groups (species/provenance/progeny) have been analysed separately. Generally, better growth rates were recorded at the Castletown site, possibly reflecting better soil quality. Slightly lower mean values were recorded at Ballyredmond. As a group, the Scottish trees had the slowest growth rates. The German trees had the fastest growth rates; this may reflect that they have already been through one cycle of selection.

Significant differences in growth rates occurred within the different groups (height results for silver birch provenances are shown in Figure 2). This showed that early growth performance was dependent on where the seed was collected (provenance) or the parents used (progeny test). The ranking of individual families at each site, while not exactly the same, was similar and the best families did well at both locations.

Table 3. Mean height and diameter values at two birch field trials after four years (2004).

	Mean Height (cm)					
	Castletown			Ballyredmond		
	n	Mean ± sd	Range	n	Mean ± sd	Range
B. pendula						
Irish	478	299.9 ± 61.1	140 - 486	463	273.8 ± 68.6	100 - 515
Scottish	176	274.2 ± 57.2	151 - 417	175	232.2 ± 53.0	115 - 381
German	49	328.7 ± 60.8	215 - 471	49	302.6 ± 76.0	156 - 527
French	25	290.6 ± 52.7	193 - 378	26	312.0 ± 47.7	220 - 433
B. pubescens						
Irish	664	297.6 ± 55.3	145 - 468	657	253.8 ± 61.7	80 - 460
Controlled crosses	889	301.6 ± 55.7	110 - 508	876	268.5 ± 64.1	100 - 511
	Mean DBH (mm)					
	Castletown			Ballyredmond		
	n	Mean ± sd	Range	n	Mean ± sd	Range
B. pendula						
Irish	478	20.8 ± 8.7	3.7 – 59.1	460	17.2 ± 8.5	1.3 – 49.1
Scottish	176	15.1 ± 6.8	2.0 – 39.1	173	10.3 ± 5.4	1.6 – 26.9
German	49	24.8 ± 8.3	9.8 – 43.7	49	21.6 ± 11.6	2.4 – 55.5
French	25	19.1 ± 9.2	4.6 – 38.4	26	25.3 ± 8.6	11.3 – 42.2
B. pubescens						
Irish	664	20.8 ± 8.2	1.1 – 49.2	651	14.6 ± 7.3	1.4 – 44.6
Controlled crosses	888	20.7 ± 8.3	1.1 – 49.2	865	16.2 ± 8.1	1.7 – 50.5

n = the number of trees measured

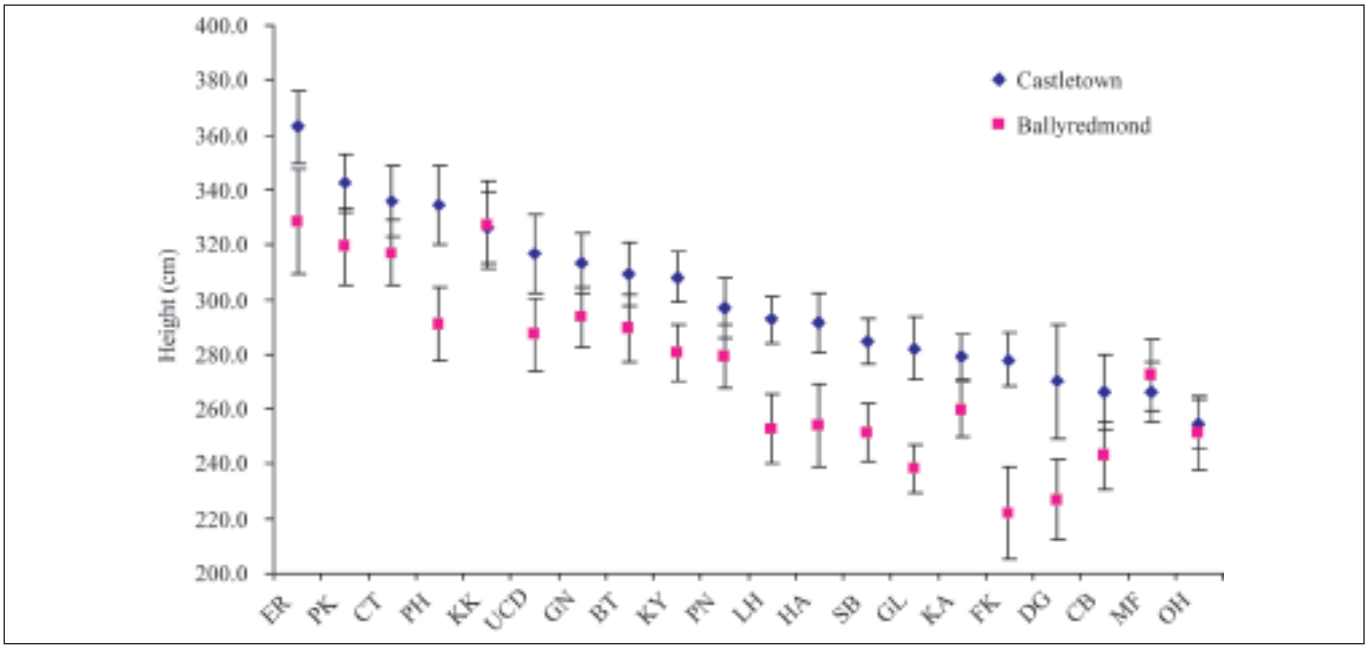


Figure 2. Mean height values (± standard error) of twenty *B. pendula* provenances after four years. Early growth performance was dependent on provenance and ranking was similar at both sites.

Stem form

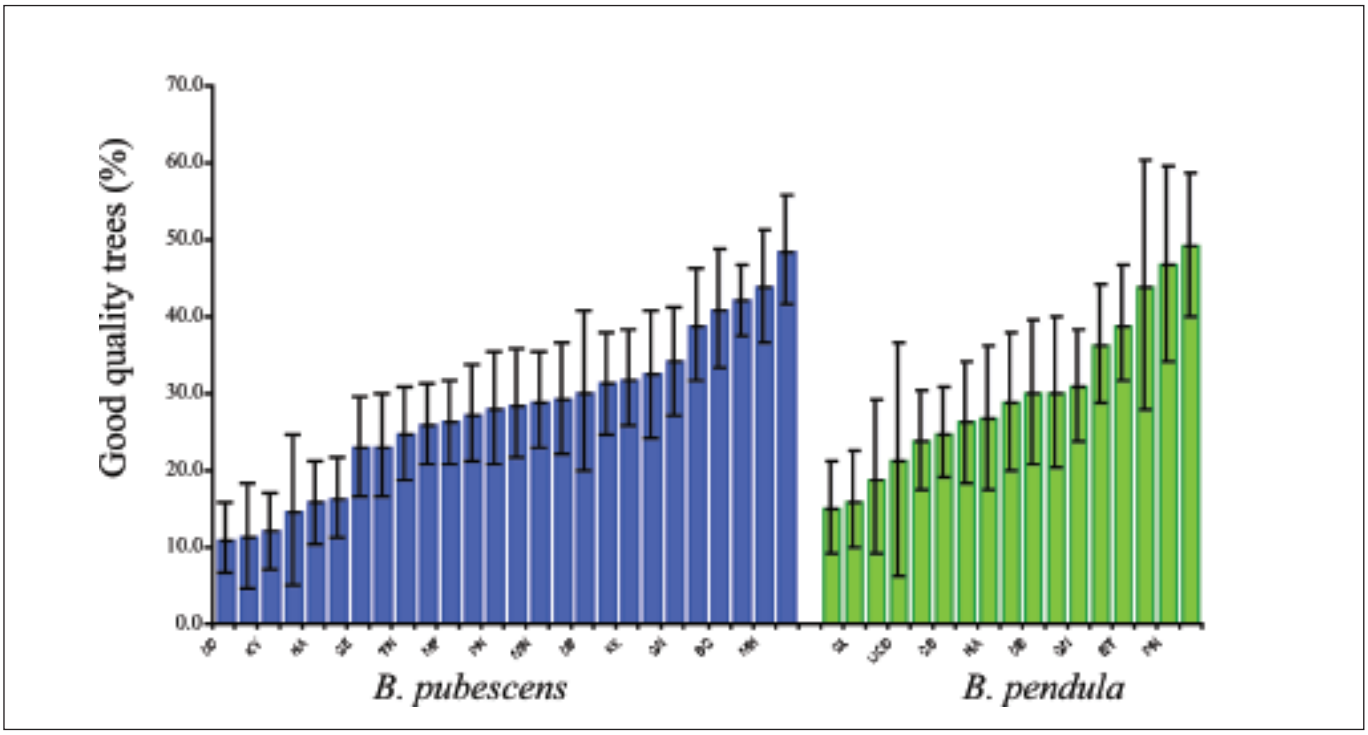
Environment has a large effect on the stem quality of birch and micro-variation within the site can make it difficult to identify provenance and family differences (Koski and Rousi 2005). To accommodate for the expected large environmental influence, all trees at the most uniform site (Castletown) were assessed to determine if provenance/family differences in stem quality could be identified. Stem form was assessed using Bulfin and Radford's (1998) method, with trees placed into one of four classes: Q1 - Q4, where Q1 represented very good stem form and Q4 represented the worst stem form. Overall, the site contained about 30% good quality trees (Q1 and Q2 combined). There were significant differences in the percentage of good quality of trees recorded between the provenances (Figure 3) and between families of the *B. pubescens* controlled crosses.

Birch has a large number of potential defects. These were recorded during the assessment so that their occurrence in different families could be compared. Certain defects, such as forking, occurred more frequently in some groups than in others (Figure 4).

Variation

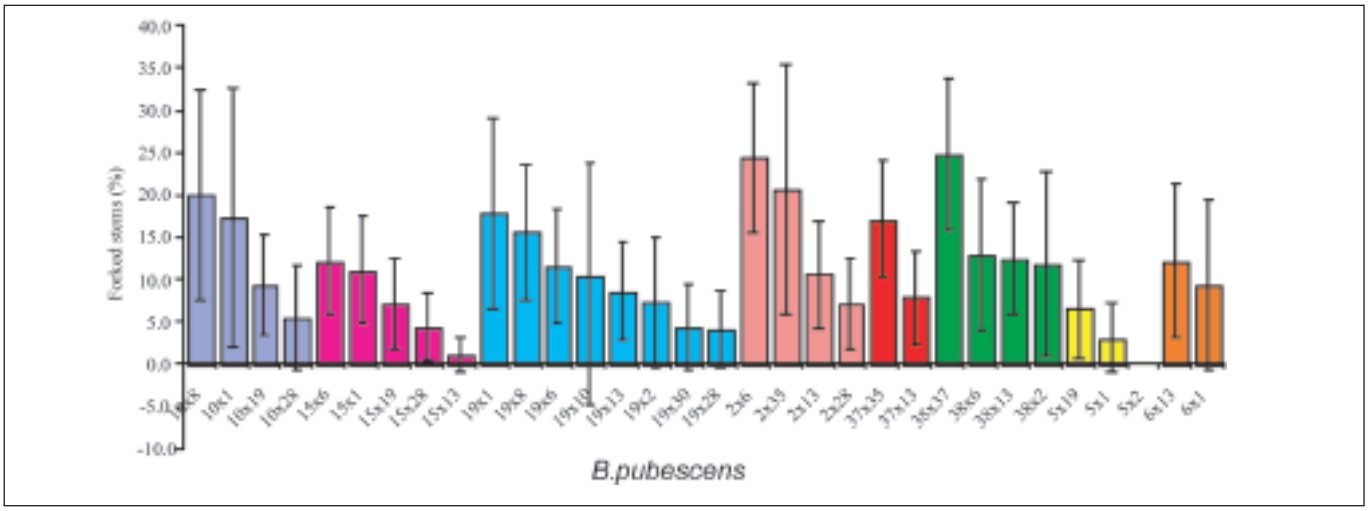
In agreement with other research (Velling 1985), we have found that, for both species, there were high levels of variation within the provenances and families.

The combination of out-breeding reproduction and wind pollination results in gene flow between populations of birch. This variation facilitates survival and regeneration of a population in changing environments. Such high levels of variation impede the development of a uniform crop population by requiring large sample sizes and many cycles of selection. The improvement programme aims to develop a superior crop population rather than an unvarying population. The improved population will be generally superior in productivity and stem form quality to current planting stock but will still maintain a level of variation. This will facilitate adaptation and provide buffering against future stresses that may occur during the rotation.



The vertical bars are the 95% confidence intervals; $\chi^2 = 564.87$, df = 102, $p \leq 0.001$

Figure 3. Percentage of good quality trees by provenances at the Castletown site.



The vertical bars are the 95% confidence intervals. χ^2 = 38.892, df = 18, p ≤ 0.01

Figure 4. The occurrence of stem forks in controlled crosses of *B. pubescens* ranged from zero to 24.7 % with a median of value of 10.6 %.

Establishment of birch genebank

Genetic conservation ensures that native diversity is not lost and that genetic resources are available for current and future improvement programmes. Gene conservation is becoming an important issue, as imported birch threatens to dilute the native gene pool (Fennessy et al. 2000). Birch genebanks have been established at the Teagasc Research Centre, Kinsealy, Co Dublin (Figure 5), and at the Coillte Tree Improvement Centre at Kilmacurra, Co Wicklow. At present the Kinsealy genebank contains nine *B. pendula* and twenty-six *B. pubescens* genotypes. Scion wood was collected and grafted onto rootstock to provide a genetic replica, or clone, of the original tree. The genebank at Kinsealy will be expanded to include a core collection of clones of all plus-trees used in the improvement programme. In addition, clones from lesser quality indigenous populations will be included to ensure that the genebank is representative of the geographic distribution of birch in Ireland.

Figure 5. The birch genebank at Kinsealy, Co Dublin.

Acknowledgements

The project team is grateful for all communications that they have received regarding the location of birch trees/stands. This information has formed the foundation of the improvement programme.

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▲ Birch breeding seedling orchard field trial at Ballyredmond, Co Carlow.

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