Managing birch woodlands for the production of quality timber

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Summary
Interest in silver birch (Betula pendula Roth) and downy birch (Betula pubescens Ehrh.) has greatly increased in recent years partly as a result of pressures to restore and expand native woodlands but also due to renewed interest in birch as a tree capable of producing quality timber. Despite the many advantages of birch as a commercial timber tree—ease of establishment, fast growth on good sites, high value timber and a short rotation, it has a poor reputation in Britain largely as a result of the poor form of the existing, mainly unmanaged resource. The following points need to be considered if stands of quality birch trees are to be produced in an economical timescale. (1) Sites: silver birch needs good sites that are relatively well drained with light mineral soils. Downy birch does well on moist to wet sites. (2) Regeneration: natural regeneration through a shelterwood is the preferred system of regenerating birch as some overhead protection is beneficial to germination success. About 20-40 seed trees should be left per hectare. Good ground preparation and control of grazing are essential. The vast majority of seedlings are recruited in the first year of the regeneration cycle therefore planting should be considered if the initial regeneration success is poor. Direct seeding is also a successful method of regeneration. Birch readily regenerates naturally into suitably prepared open areas next to existing birch woods but these should not be too big, e.g. gaps or strips 20–60 m wide have been suggested in the literature. (3) Maintenance: density of regeneration needs to be reduced to about 2500–3000 stems ha\(^{-1}\) by the time the trees are about 3–6 m tall. Birch seedlings must always be taller than the competing vegetation. (4) Thinning: thinning should begin when the mean height of the stand is about 8–10 m. At this point at least half the number of trees should be removed with the emphasis on retaining dominants and co-dominants of good form. The aim is to maintain about half the height of the tree as living crown to sustain a high rate of growth. Additional thinnings will be required at intervals of 5 to 7 years and final thinning should leave around 300–500 stems ha\(^{-1}\). (5) Rotation: a rotation of 40–50 years is possible on good sites and perhaps 50–55 years on less favourable sites.

Introduction
Birch is the commonest native woodland tree in Britain and yet until recently its potential for timber production has been virtually ignored. Birch produces a finely textured timber, white in colour and bright in appearance. It is one of the strongest timbers commonly grown in Britain with a basic density of around 530 kg m\(^{-3}\) (Lavers, 1983), and when dried to 12 per cent moisture content the total weight per m\(^{3}\) is 630
kg. This is only slightly less than the value for home-grown beech (690 kg m\(^{-3}\)) and greater than for sycamore (560 kg m\(^{-3}\)). The wood works and finishes well and can be used for a variety of purposes including fittings, furniture and paper. Birch, however, has a poor reputation as a timber tree in Britain, probably as a result of the poor form of the existing stands of trees. By contrast, birch is an important timber species in Finland, for the manufacture of veneer boards, plywood and pulp, although even here unmanaged birch was long considered a weed (Koski, 1991). Frivold and Mielikäinen (1990) state that one of the factors that lead to the negative attitude towards birch throughout Fennoscandia was the habit of foresters comparing well-managed coniferous stands with unmanaged or poorly managed stands of downy birch. If British birch is to achieve an economic status similar to that found in Finland, then appropriate management techniques must be adopted with the aim of quality timber production in a financially acceptable timescale.

The aim of this paper is to draw together the relevant literature on birch silviculture, productivity and timber properties from Northern Europe and North America and to make silvicultural recommendations appropriate to British conditions based on this review.

### Distribution and site requirements

The genus *Betula*, belonging to the family *Betulaceae*, comprises around 40 species distributed throughout North America, Europe and Asia south to the Himalayas (Mitchell, 1976). In Britain there are two arborescent species—silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.). The main distinguishing morphological characteristics of silver and downy birch are listed in Table 1.

The birches are pioneer species with life spans of around 50 to 100 years although in Scotland it can be much older than this (Mitchell, 1976). They show the characteristic early period of fast development after which growth is slow (Kinnaird, 1968). Silver birch is associated with relatively well drained, light soils and downy birch with moist to wet and frequently peaty soils (Clapham et al., 1981). Two sub-species of downy birch are recognized in Britain; ssp. *pubescens* (Ehrh.) found in the lowlands and glens and ssp. *odorata* (Bechst.), a shrubbier tree of the moors and mountains (Clapham et al., 1981). In Britain the range of silver and downy birch overlap but with the tendency for silver birch to be more common in the south and east of the country and downy birch more frequent in the north and west at higher altitudes on more exposed sites (Kinnaird, 1968, Forbes and Kenworthy, 1973) although distribution maps

<table>
<thead>
<tr>
<th></th>
<th>Silver birch</th>
<th>Downy birch</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Height</strong></td>
<td>up to 30 m</td>
<td>up to 20 m</td>
</tr>
<tr>
<td><strong>Bark</strong></td>
<td>pinkish-white with horizontal grey bands; white with big black diamonds in older trees</td>
<td>red-brown becoming smooth greyish-white, variable horizontal bands grey or brown often cherry-like in appearance until big</td>
</tr>
<tr>
<td><strong>Crown</strong></td>
<td>narrow, pointed and upswept in young trees; domed at the top with long pendulous branchlets</td>
<td>irregular, soon losing pointed top, rather spreading and twisted branches, shoots spreading, crowded and not pendulous</td>
</tr>
<tr>
<td><strong>Foliage</strong></td>
<td>shoots purplish-brown, covered with raised white warts; leaves slightly rounded-triangular tapering to a fine point with tapering teeth separated by 2-3 small triangular teeth; petiole slender with no hairs</td>
<td>shoots greyish red-purple, covered in short, soft, shiny white hairs; leaves rounded, often nearly circular, broad rounded teeth; petiole densely pubescent</td>
</tr>
</tbody>
</table>
show that both species have been recorded in most 10 kilometre squares of mainland Britain (Perring and Walters, 1976). It often grows in mixtures with other species particularly oak in the south and west and pine in the north and east, although pure birch stands are common in the Highlands.

The birches are more sensitive to soil physical and chemical properties than most other north temperate tree species (Helliwell, 1974; Helliwell and Harrison, 1978). They are, however, known to ameliorate unfavourable soils, their deep root systems bringing up and depositing nutrients on the ground surface through leaf fall (Gardiner, 1968), and have been found to reverse the process of podzolization leading to the formation of mull type humus (Dimbleby, 1952). Raulo (1978) emphasized that silver birch grows well and produces stems of good quality only on nutrient rich sites. Raulo also noted that silver birch seedlings grow poorly or may even die if the ground water table lies close to the soil surface.

Although birches do best on protected sites with rich, fresh soils, they are noted for their ability to survive and grow on the most forbidding landscapes. Many mine spoils, landslides and drained peatlands have regenerated naturally with birch (Game et al., 1982; Kaunisto and Paivänen, 1985; Kulagin, 1985) although soil N must reach at least 700 kg ha$^{-1}$ through weathering before silver birch can invade by seeding (Marrs et al., 1981). Silver birch is also widely planted on unweathered spoil heaps because it tolerates soil pH as low as 3.3 (Brissof, 1975; Plass, 1975).

Establishment

Seed production

The birches are monoecious with flowers borne on catkins. Low spring temperature is related to poor pollen production in silver and downy birches and appears to be more important than rain during pollen shed (Sarvas, 1952, 1956, 1967). When the weather is favourable 70–80 per cent of silver and downy birch pollen is shed within 2–3 days (Sarvas, 1952). The percentage of germinable seed is directly related to the amount of pollen shed; seed with the highest viability will be produced during years of abundant flowering (Sarvas, 1952). Birch seed ripens from July to October depending on species with the rate of ripening dependent on temperature sums (Sarvas, 1956). With each silver and downy birch catkin containing about 450 seed, seed falls can be very large with levels of 177 000, 157 000 and 258 000 seeds per m$^2$ recorded for paper birch (Betula papyrifera Marsh.), silver and downy birches respectively (Koski and Tallqvist, 1978).

Seed dispersal

Silver and downy birch disperse seed mostly in September and October (Fries, 1984). The dispersal range of the seed is limited by its small size and by much more than may be expected. Sarvas (1948) observed that silver and downy birch seed dispersal declined exponentially with distance from seed source, and very few seeds travelled more than 50 m. The theoretical maximum dispersal distance for 20 m tall trees in a 5 m s$^{-1}$ wind without turbulence is 192 m for silver birch and 145 m for downy birch. Given the relatively limited dispersal of birch seed, the shelterwood system, where seed trees remain on a site, has been suggested for regenerating stands of yellow birch (Betula alleghaniensis Britton) (Tubbs et al., 1983), paper birch (Peral, 1988) and for both silver and downy birch (Sarvas, 1948).

Germination requirements

Seed viability of silver and downy birch on the forest floor declines dramatically after one year to about 6 per cent (Granström and Fries, 1985). Stratification is not required for birch seed regenerated under light (Brinkman, 1974). Vaartaja (1959) showed that silver, downy and paper birch seed germinated well in both darkness and light at 25–35°C. At temperatures lower than 25°C, germination depended on photoperiod, however, no light was needed if the seed was stratified to break down the seed coat (Black and Wareing, 1955, 1959). Sarvas (1950) found that while silver and downy birch germinated much faster in light than darkness, total germination was unaffected and advised that field sown seed should only have a light covering.
Although silver birch will readily regenerate into open spaces where ground conditions are suitable (Kinnaird, 1974), birch seedlings do not need full sunlight to grow well and an optimum figure of 43 per cent full light has been recorded for silver birch (Helliwell and Harrison, 1979) and similar figures have been published for the North American yellow and paper birches (Logan, 1965). Older birch trees, however, do not tolerate shade (Lyr et al., 1963) although precise light requirements vary for different species. For example, downy birch tolerates shade better than silver birch (Lappi-Sepala, 1947). Figures of 20–40 per cent canopy cover appear to be appropriate to regenerate most birch species (Perala and Alm, 1989, 1990).

Brown (1984) emphasized that successful establishment of regeneration requires a vegetation-free substrate where the seedling is not subjected to frost or to summer drought and, initially at least, freedom from competing vegetation. The birches appear to regenerate and survive better on mineral soil than on litter or mosses (e.g. Linteau, 1948; Sarvas, 1948; Kinnaird, 1974). The extreme surface temperatures of litter and its limited moisture-holding capacity make it a poor germination medium (Linteau, 1948). The presence of sufficient moisture and moderate temperatures during the growing season are known to be important for the survival of birch seedlings. For example, a good link has been found between the poor survival of paper birch seedlings and hot, dry weather (Zasada et al., 1978).

Exposing mineral soils through burning greatly benefits birch regenerating (e.g. Lutz, 1956) due to greater availability of soil moisture and nutrients. Fires, however, must be hot enough to burn most of the surface organic layer to provide good seedbeds (Mork, 1944; Sarvas, 1948; Tubbs et al., 1983). Mechanical cultivation either by scarifying (Raulo and Mäkelä, 1976; Perala and Alm, 1989) and ploughing (Perala and Alm, 1989) may also be used to provide a suitable seedbed. With few exceptions, carrying out a seeding felling without scarification will not be sufficient to regenerate birches (e.g. Sarvas, 1948; Filip, 1973). Almgren (1990) found that site preparation substantially improved the regeneration of silver birch. It is not sufficient simply to exclude grazing animals as mere enclosure will allow the regrowth of grazed vegetation thus reducing the sites available for incoming birch seed. For example, Kinnaird (1974) found in his study that while first-year seedlings were numerous on a range of sites visited, few survived for 2 years and the survivors became fewer with age. Grazing, shading and slope did not affect seedling establishment. Prepared seedbeds have been found to remain receptive to birch germination and establishment for only 2–3 years (Sarvas, 1948; Zasada et al., 1978) and that the vast majority of seedlings were recruited in the first year of the regeneration cycle (Zasada et al., 1978).

Heavy grazing by domestic and wild animals is known to reduce the number of birch saplings (e.g. Kinnaird, 1974) and that some form of protection such as fencing is required. New growth of previously grazed seedlings, which may have survived in this form for as long as 15 years, is often very rapid when grazing is reduced, although the danger is that trees from such a source will be multi-stemmed (Brown, 1984).

Direct seeding

Direct seeding is widely used in many parts of the United States to regenerate clear-cut strips (Björkblom, 1969). Downy birch may be sown in either autumn or spring (Arnborg, 1947) whereas silver and paper birches have been found to germinate better when autumn sown (Nash and Duda, 1951). Seedbeds that are too warm should be avoided. For example, two years after seeding silver birch on scarified soils, Luke and McPherson (1983) found 10 times as many seedlings on cooler, sloping seedbeds with a northerly aspect than on level seedbeds. Stratifying seed before sowing is not normally done, however, there is evidence that pre-soaking seeds of silver birch improves germination (Kosnikov, 1982). The germination requirements for directly sown seeds are the same as those described for natural regeneration.

Planting

Birch is commonly planted in Europe and is the most practical method of introducing genetically improved plants. Nurseries often sell birch
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under the name white birch (Betula alba L.) which covers both silver and downy birch. Care must be taken over choice of provenance as non-local birch provenances may be susceptible to late frost (Blackburn and Brown, 1988).

Soil preparation greatly facilitates the establishment of planted birch particularly by reducing competing vegetation (Raulo, 1978), although some recently harvested areas may need no further preparation (e.g. Bagaev, 1984). Ploughing has been successfully used for the establishment of plants of paper birch (Björkblom, 1972) and silver and downy birch (Söderström, 1975; Pohrtilla, 1977; Raulo and Rikala, 1981). Kaunisto and Päivänen (1985) noted that mounding provided good planting sites on peat soils.

Birch is available from nurseries in a range of sizes both as bare-root or container plants. Small plants are more adaptable and consequently they establish more easily, however, large seedlings (60–80 cm) are sometimes used in Finland where weeds are a problem so that planted trees are clear of competing vegetation (Raulo, 1987). Good handling of birch plants is essential as high temperatures and low humidity will quickly kill the fine roots (Insley, 1979). Planting in spring is best because autumn planting, even if successful, is often associated with die-back during the winter months (Blackburn and Brown, 1988). A stocking density of a minimum of 2500 plants/ha (2 × 2 m) is generally used in Finland on sites with little or no natural regeneration; the density reduced accordingly depending on existing regeneration (Raulo, 1978).

While fertilizer is appropriate on nutrient deficient sites, care must be taken to avoid killing the seedlings by direct root contact with the fertilizer (Kaunisto and Päivänen, 1985). Birch plants are vulnerable to browsing damage (e.g. Raulo and Lahde, 1977; Hannah and Turner, 1981; Billtoft, 1983; Hoyle, 1984) so fencing may be necessary.

Regeneration systems

Clearcutting is widely used for the regeneration of birch species (e.g. Sarvas, 1948; Nash, 1949; Lehto, 1960; Filip, 1973; Safford, 1983; Kaunisto and Päivänen, 1985) with the coupes large enough to admit sufficient light but small enough to accommodate the seed dispersal range. Size of felling coupes varies greatly with strip width suggested from 20 m to 60 m depending on species. For example, Mork (1944) recommended 40 m wide strips to regenerate silver and downy birch whereas Sarvas (1948) suggested two tree heights (50–60 m) as the maximum seeding distance. Generally, larger coupes are possible where the climate is cool and moist and good seed crops are frequent whereas smaller areas are more successful in warm, dry conditions with small or infrequent seed crops (Perala and Alm, 1990).

On cutting larger coupes than that already described, use of the shelterwood system is favoured. The value of overhead canopy to enhance the germination of birch has already been described in this review. A two-cut shelterwood system is recommended for yellow birch (Tubbs et al., 1983) and shelterwood systems may be suitable for paper birch (Safford, 1983; Perala, 1988) and for both silver and downy birch (Sarvas, 1948). For paper birch, Safford (1983) recommends removing 60 per cent of stand basal area leaving at least 10–12 seed trees per hectare as a uniform shelterwood. Frivold and Mielikäinen (1991) suggest leaving 20–40 seed trees of silver or downy birch per hectare. The shelterwood should be removed after 1 to 2 years to minimize birch suppression (Nash, 1949; Perala, 1988) and to control shade tolerant species. This may also be important as shade may favour downy birch over silver birch as the former tolerates shade better (Lappi-Sepälä, 1947). An irregular shelterwood similar to group selection was suggested by Sarvas (1948) to regenerate mixed stands of birch and Norway spruce (Picea abies (L.) Kast.) on mineral soils and indicated a canopy cover of 20–40 per cent.

Although many species of birch can be coppiced, the practice is generally not recommended. Sarvas (1948) noted that silver and downy birch coppice was of inferior quality to seedlings, a view supported by Kauppi et al. (1988) who found that young downy birch trees that developed from coppice had more branches than seedling trees. Similar findings were indicated by Cameron and Sani (1994) with silver birch. Sarvas (1948) also noted that the capacity
of downy birch to coppice is strong in comparison with silver birch suggesting that downy birch would be favoured in stands regenerated this way. Almgren (1990) suggests that coppice should only be used to fill in gaps.

Stand management

**Weeding and cleaning**

If regeneration is good and stocking high, then cleaning will be required. In a review of birch silviculture in Scandinavia, Frivold and Mielikäinen (1991) suggest cleaning down to around 2-m spacing when the trees are 3–6 m tall depending on initial stocking and the likelihood of damage through browsing and snow. Cutting the top off the tree is usually sufficient to kill birch (Raulo, 1987). The initial growth of birch is fast, however, it is important that the top of the plant is clear of competing vegetation if it is to be successful (Raulo, 1987). Raulo emphasized that this is particularly important for planted trees and good weed control is essential. He also emphasized the importance of completing the weeding by the beginning of the summer to always ensure good light conditions for the plants. Perala (1988) increased the stocking but not growth of paper birch seedlings by pre-treating the ground with glyphosate beneath a shelterwood.

**Thinning**

As light demanders, birch stands need heavy thinning to ensure minimal competition from surrounding trees. Raulo (1987) suggests first thinning when dominant height is between 12 and 14 m with stocking reduced from 2000–3000 stems ha⁻¹ to 700–900 stems ha⁻¹. Frivold and Mielikäinen (1991) emphasize the importance of maintaining a minimum living crown length of 40–50 per cent and not to allow the expected maincrop trees to be overtopped by competing trees. Cameron et al. (1995) found no significant difference in the length of merchantable stem between heavily thinned stands of birch—where around half the height of the tree is maintained as living crown, and lightly thinned stands—where about one third of the height of the tree is maintained as living crown. The importance of maintaining the crowns of shade intolerant species is underlined by Dawkins (1963) who found a strong linear relationship between tree crown diameter and breast height diameter in shade intolerant species; shade tolerant species do not show this clear relationship. Once a tree is constrained, with less than one half its height as living crown, it responds poorly to further thinnings and, once neglected, birch stands rarely recover. Cameron et al. (1995) showed that relatively high rates of growth of silver birch were possible through heavy thinning without affecting the technical properties of the timber. They state that logs of veneer dimensions and quality could be produced in rotations of perhaps as little as 40 years if heavy thinning is adopted.

Pruning may be done but it is not essential as thinning operations alone may be enough to remove many of the dead branches (Raulo, 1987). Dead branches can be removed at any time of year, however, green pruning should only be carried out after sapflow in spring or shortly before leaf-fall in autumn, otherwise there is a considerable risk of discoloration and rot (Raulo, 1987).

**Protection**

Birch is relatively tolerant of exposure although in exposed locations it has poor form. In hot dry summers birch is one of the first species to show damage as premature browning, defoliation and death of the bark (Evans, 1984). Birch is susceptible to damage by fire, however, young trees usually recover producing vigorous coppice shoots and the exposed soil surface for 2–3 years after a fire is ideal for natural regeneration. Sheep, cattle, deer and rabbits will all browse birch seedlings and young trees and ultimately may eliminate natural regeneration and stunt the growth of trees (Evans, 1984).

Birches are sometimes defoliated by the sawfly Croesus septentrionalis L., and the leaf rust Melampsoridium betulinum is very common but only causes significant damage to seedlings and young natural regeneration. Witches’ brooms, caused by Taphrina betulina Rostrup, are found on downy birch—very rarely
on silver birch, but these appear to have little effect on the growth of trees. Cherry leaf roll virus has been isolated from silver birch and causes bushiness and small leaves on affected branches. It may also be the cause of the 'flamy birch' figuring in the wood (Cooper, 1979). Birch wood is not durable and the bracket fungus *Piptoporus betulinus* (Bull. ex Fr.) Karst. is common on standing trees. Birch is often attacked by honey fungus *Armillaria* spp. Birch that is not under stress, however, is unlikely to succumb to serious pests or diseases.

**Wood quality and end use**

Birch is a diffuse porous timber, light in colour with usually no obvious distinction between sapwood and heartwood. There is apparently no appreciable difference in wood properties between silver and downy birch (Krames and Krenn, 1986) and these compare well with the properties of the American or Canadian white birch. The grain is normally straight in timber cut from trees of good form. Occasionally the wood may exhibit figuring such as 'flamy' or 'curly' birch. Birch produces a remarkably dense and strong timber and compares well with beech and oak (Table 2).

Birch timber dries quickly but has a tendency to distort (Pratt, 1986), however, drying under restraint would help to reduce this defect. Birch wood can be worked without difficulty with both hand and power tools, the blunting of which is moderate (Farmer, 1972). The wood glues well and can be stained and polished to good effect (Lincoln, 1986). Birch can be bent satisfactorily provided knots and cross-grain are absent (Farmer, 1972). Both sapwood and heartwood possess no natural durability against fungal attack; their life in ground contact is less than 5 years. Fortunately the sapwood and heartwood can be penetrated completely by preservatives during pressure treatments (Farmer, 1972).

Birch is commonly used for plywood and blockboard manufacture in Finland and Russia. Straight-gained material with few knots is desirable for plywood veneers. The uniform texture and density of birch make it well suited for plywood commanding high prices even when the core plies are interleaved with spruce. The timber is equally well suited for particle board production and Krames and Krenn (1986) found it of intermediate quality between pine and spruce particle board. The relatively high density of birch, however, indicates that ideally it should be used in mixtures with other, less dense species. Birch produces good quality hardwood pulp, and it is used for this purpose in northern

*Table 2: Density and strength properties of British beech, birch, oak, sycamore and Sitka spruce and 12 per cent moisture content (Lavers, 1983)*

<table>
<thead>
<tr>
<th>Wood property</th>
<th>Beech</th>
<th>Birch</th>
<th>Oak</th>
<th>Sycamore</th>
<th>Sitka spruce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg m⁻³)</td>
<td>690</td>
<td>670</td>
<td>690</td>
<td>560</td>
<td>384</td>
</tr>
<tr>
<td>Bending strength ( modulus of rupture) (N mm²)</td>
<td>118</td>
<td>123</td>
<td>97</td>
<td>99</td>
<td>67</td>
</tr>
<tr>
<td>Modulus of elasticity (stiffness) (N mm²)</td>
<td>12 600</td>
<td>13 3000</td>
<td>10 100</td>
<td>9 400</td>
<td>8 100</td>
</tr>
<tr>
<td>Compressive strength parallel to grain (N mm²)</td>
<td>56</td>
<td>60</td>
<td>52</td>
<td>48</td>
<td>36</td>
</tr>
<tr>
<td>Impact strength (toughness) (m)</td>
<td>1.14</td>
<td>1.04</td>
<td>0.84</td>
<td>0.84</td>
<td>0.51</td>
</tr>
</tbody>
</table>
Europe and North America. The high volumetric content of the fibre material, lack of extractives, relatively high length/width ratio of the fibres and moderate fibre cell wall width all contribute to the suitability of birch for pulping (Koch, 1985). Birch is very suitable for furniture manufacture and high quality joinery (Lincoln, 1986), and in the USA it is one of the principal furniture woods (Panshin and de Zeeuw, 1980). Treated birch is suitable for fencing (Farmer, 1972), and for boxes, pallets, crates and cooperage. Where logs produce decorative veneers they are used in panelling and marquetry (Lincoln, 1986).

Productivity and potential profitability

Brown (1991) recommends that anyone interested in growing birch in Britain with the aim of obtaining the best possible yield of timber should only consider silver birch given its generally better form and rate of growth. In Sweden, Finland and Norway, studies have shown that silver birch gives a 15–20 per cent greater yield by volume than downy birch (Koivisto, 1959; Fries, 1964; Braastad, 1966, 1967, 1977). Knowledge of the yield of birch in Britain is sketchy but is generally believed that on reasonable sites it will achieve YC 6–8 although on the best sites it may achieve YC 10. In Sweden, Finland and Norway, silver birch will typically yield 8–10 m³ ha⁻¹ a⁻¹ on fertile sites (Koivisto, 1959; Fries, 1964; Braastad, 1966, 1967, 1977; Oikarinen, 1983).

Based on the heavily thinned stands used in the study by Cameron et al. (1995), potential production on good sites after 40 years (estimated to be close to the age of maximum mean annual increment at YC 8) is around 170–200 m³ ha⁻¹. As a comparison, the YC 8 yield model by Oikarinen (1983) for plantation silver birch in southern Finland with two thinnings at age 15 and 30 reducing stem number by about one half

Table 3: Current Finnish veneer birch quality and dimensions standards (Keskusmetsolautakunta Tapio, 1991)

<table>
<thead>
<tr>
<th>Log minimum diameter top end over bark</th>
<th>18 cm</th>
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</thead>
<tbody>
<tr>
<td>Log length</td>
<td>3.1 m minimum to 7.0 m maximum (by 30 cm intervals)</td>
</tr>
<tr>
<td>Branch and knot number (per 150 cm length)</td>
<td></td>
</tr>
<tr>
<td>• live branches</td>
<td>no limit</td>
</tr>
<tr>
<td>• dead branches</td>
<td>5</td>
</tr>
<tr>
<td>Maximum branch thickness and knot size</td>
<td></td>
</tr>
<tr>
<td>• live</td>
<td>7 cm</td>
</tr>
<tr>
<td>• dead or decayed</td>
<td>4 cm</td>
</tr>
<tr>
<td>Stem bend (per log) measured on one side (dependent on top diameter)</td>
<td></td>
</tr>
<tr>
<td>• 18–23 cm</td>
<td>2 cm</td>
</tr>
<tr>
<td>• 24–35 cm</td>
<td>4 cm</td>
</tr>
<tr>
<td>• 36 cm+</td>
<td>5 cm</td>
</tr>
<tr>
<td>Firm wounds</td>
<td>On one side up to 90 cm in length, and depending on top diameter, 2–4 cm deep or 10% in diameter.</td>
</tr>
<tr>
<td>Decayed wounds are not permitted</td>
<td></td>
</tr>
<tr>
<td>If there are more than two quality defects then that log is not acceptable</td>
<td></td>
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</table>
each time starting from 2300 stems ha\(^{-1}\) yields 235 m\(^3\) ha\(^{-1}\) at 40, close to the age of maximum mean annual increment.

Timber value is critical to the success of birch as a timber producing species. While there is a substantial industry based on birch in Scandinavia, particularly Finland, this is not the case in Britain where markets are mainly for firewood and pulpwood. Lorrain-Smith (1991) showed that using current prices for these products makes birch, even on good sites, a poor investment when compared with conifers even when the higher grants for broadleaves are taken into account. If, however, a modest improvement in prices were possible based on typical softwood prices then birch would become a profitable exercise at YC 6. Lorrain-Smith (1991) pointed out that it only takes a small increase in the price and productivity of birch for it to become more profitable than YC 8 Scots pine. The assumption that birch timber from British stands on good sites could attract better prices than firewood and pulpwood was recently demonstrated by Cameron et al. (1995). They showed that much of the timber from managed stands in Britain could meet the current Finnish veneer birch quality and dimension standards (Table 3). They found that even unmanaged stands contain some veneer standard logs. They also showed that heavy thinning greatly enhances growth on individual trees, significantly shortening rotation length, without compromising the technical properties of the timber, thus further improving the economic potential of birch.

Birch in mixtures

In Scotland, birch often grows in mixtures with other species, particularly oak in the south and west, and pine in the north and east, although pure birch stands are common in the Highlands. In Scandinavia, much of the birch resource is found in mixture with spruce and/or pine. Frivold and Mielikäinen (1990) found silver birch to be a stronger competitor than spruce in young and middle-aged stands and, in the first decade after stand establishment, height growth was greater than that of spruce. Downy birch was found to be an approximately equal competitor with spruce with similar height growth. While the competition from the birch reduces volume production in the spruce, studies have shown that total volume yield in mixed silver birch–spruce stands exceeds that of pure spruce stands if the spruce is felled early (Mielikäinen, 1985). Total volume production in mixed silver birch–pine stands can be equal to or exceed that of pure pine stands, if thinnings are directed at the birch, while total volume production in mixtures with downy birch is slightly inferior (Mielikäinen, 1980). In Finland, such mixed stands using silver birch are financially superior to pure stands. In a review of the subject Gardiner (1968) notes that such mixtures are also less prone to insect attack and catastrophic windthrow. In addition, conifer form is usually significantly improved, as is timber quality, owing primarily to a reduction in early growth producing a smaller juvenile core.

The main problem with even-aged spruce–birch mixtures is the damage caused to spruce trees by whipping and it is the main reason in Britain to remove birch from stands of Sitka spruce. In Scandinavia, whipping damage is severe in about 10 per cent of the spruce trees (Frivold and Mielikäinen, 1990).

Conclusion

Birch has many valuable attributes as a timber tree and its commercial potential has been well demonstrated in Fennoscandia and North America. It can produce valuable timber in relatively short rotations if grown on good sites. When regularly and heavily thinned, with the aim of maintaining about half of the height of the tree as living crown, diameter growth is fast and rotations as short as 40 years may be possible on the best sites. The technical properties of British birch timber have been shown to be equivalent to that from continental stands and is capable of being used for many purposes—veneers for plywood, sawn timber, turnery, pulp and particle board. In comparison with many broadleaved species commonly grown in Britain, birch is relatively easy and cheap to regenerate and, providing that young trees are protected from browsing, there should be no serious pest and disease problems.
Table 4: Area and standing volume of the birch resource in Britain (Forestry Commission, 1984)

<table>
<thead>
<tr>
<th></th>
<th>High forest</th>
<th>Scrub woodland</th>
<th>Standing volume</th>
<th>High forest</th>
<th>Scrub woodland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(× 1000 ha)</td>
<td></td>
<td>(× 1 million m³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scotland</td>
<td>16.7</td>
<td>41.7</td>
<td>1.45</td>
<td>0.081</td>
<td></td>
</tr>
<tr>
<td>England</td>
<td>45.9</td>
<td>20.4</td>
<td>4.04</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>Wales</td>
<td>5.6</td>
<td>1.1</td>
<td>0.61</td>
<td>0.102</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>68.2</td>
<td>63.2</td>
<td>6.09</td>
<td>0.372</td>
<td></td>
</tr>
</tbody>
</table>

There is a substantial area of birch in Britain, much of which is classed as scrub woodland with many of the stems below 20 cm average d.b.h. (Table 4). At the same time high forest trees are frequently of poor form and this too detracts from the value of those larger sized logs that may be available (Brazier, 1990). These birch woodlands must come under appropriate management if the commercial potential of British birch is to improve. The main effort should concentrate on bringing existing birch woodlands located on favourable sites back into management. The emphasis should be on natural regeneration using local provenances where possible. Expansion of the birch resource should take place on good sites by a combination of natural regeneration, planting and/or direct seeding.

The following silvicultural recommendations have been prepared based on this review; their aim to ensure quality timber production in an economical timescale. These recommendations largely assume pure stands of birch and no distinction has been made between silver and downy birch unless otherwise stated.

Silvicultural recommendations

Sites

- If birch is to produce quality timber in a reasonable time then it must grow on good sites capable of sustaining a relatively high growth rate. Good silver birch sites are characterized by having freely drained and light mineral soils. Downy birch does well on moist to wet sites.
- Silver birch is generally the preferred species due to its good growth and stem form although downy birch can develop into good quality stands particularly where the climate is cooler and wetter.
- Many birchwoods growing on infertile, exposed, upland sites are unlikely to produce high quality timber even with intensive management and are probably best managed for non-timber benefits such as wildlife conservation and amenity, although some useful timber such as firewood and pulpwood may be produced.

The normal silvicultural cycle of birch woodlands

1. Regeneration felling

- Natural regeneration is the preferred method of regenerating a prolific seed producer such as birch although planting is quite acceptable where seed supply is restricted or where new sites are involved. Birch produces seed every year so there is no need to wait for a seed year to carry out a regeneration felling.
- The shelterwood system is generally favoured as some overhead protection benefits regeneration success. The first step is to selectively fell the overstorey leaving about 20–40 trees ha⁻¹ with well-developed crowns and no obvious defects such as twists and forks.
- Birch will readily regenerate into open areas on the edge of woodlands or clear-cut coppices but these should not be too big as young
seedlings suffer badly from warm dry conditions without the benefit of some shelter. In addition, the dispersal range of birch seed is much less than that generally perceived. As a rule, felling coupes or strips 20–60 m wide appear to be appropriate in most situations with perhaps larger coupes where the climate is cool and moist and smaller areas in warm, dry conditions.

2. Ground preparation
- Birch needs a weed-free site with a minimal litter layer to ensure successful regeneration. Felling and removal of the timber may be sufficient to prepare the ground surface for natural regeneration, however, preparing seedbeds by scarifying or ploughing is usually needed both to control competing vegetation and to provide the optimum medium for seed germination and seedling growth. Burning may be an option but the fire must be hot enough to burn most of the litter layer.
- Time of greatest seed-fall is usually between September and November so ground preparation should occur just before this.
- Planting or direct seeding may be required if natural regeneration fails or is not possible through the lack of seed trees. Container plants have been found to be successful but carefully stored, handled and planted bare-rooted plants will produce good results. Collecting seed for direct seeding is readily done during the months of August and September.
- There is a general presumption that plants and seed should be of native origin as these are better adapted to local climate.
- Control of grazing animals by fencing or other means is essential for good survival and growth. Browsed plants often become multi-stemmed.

3. Regeneration
- It is important that good regeneration is achieved in the first year of the regeneration cycle as studies have shown that very little is recruited in subsequent years. If the level of regeneration in the first year is inadequate then planting may have to be considered. Maintaining a relatively high stocking density during the early years of a birch rotation is essential for the development of stem form and to reduce the number and size of knots in the timber.
- When full regeneration has been achieved the seed trees should be removed to prevent suppression of the seedlings although leaving a few enhances the landscape.
- Collecting seed and scattering it over bare areas is one method of improving the prospects of regeneration. Direct seeding can take place either in late autumn or spring.
- If a site is planted then a stocking density of at least 2500 plants ha$^{-1}$ should be used.
- Birch seedlings must always be taller than competing vegetation to survive and grow. Weed control, therefore, is essential during the first few years.

4. Maintenance of regeneration
- Density of regeneration needs to be reduced, in steps if the initial stocking is very high, to about 2500–3000 stems ha$^{-1}$ by the time the trees are perhaps 3–6 m tall. Cutting the top off the tree is usually sufficient to kill a shade intolerant species such as birch. The aim during this period is to maintain about one half of the height of the tree as living crown.
- Emphasis should be placed on removing poor quality trees (forked, misshapen, poor vigour, etc.) and having the selected dominants and co-dominants evenly spaced.

5. Thinning
- Thinning of birch should begin when the mean height of the stand is around 8–10 m that may occur at anything from 15 to 25 years old depending on growth rate. At this point at least half the trees should be removed as birch, particularly silver birch, must have light to grow well. The emphasis should be on retaining dominants and co-dominants of good form. The aim is to maintain about half the height of the tree as living crown to maintain a high rate of growth.
- Further thinnings will be required at intervals of 5–7 years to maintain crown depth and to favour the best stems (straight, healthy, few branches on the lower half of the tree).
- The final thinning should leave around 300–500 stems ha$^{-1}$.
- Pruning may be done but it is not essential as thinning operations alone may be enough to
remove many of the dead branches. Green pruning should only be done after sapflow in spring or shortly before leaf-fall in autumn, otherwise there is a considerable risk of discolouration and rot.

6. Felling and regeneration
- On good sites (say around YC 8) it is possible for birch to achieve an average d.b.h. of about 30 cm in a rotation of 40-45 years, however, rotation length will need to vary depending on site quality and markets. On less good sites (around YC 4-6) a rotation of about 50-55 years is more appropriate.
- Seed trees should be left at harvesting and the cycle begins again.
- Coppicing birch is generally not recommended as the quality is inferior to that of seedlings, however, it may be used to fill in gaps.

Bringing neglected birch woods back into management
- While young birch seedlings grow well under a modest canopy, older trees will not tolerate shade and suppression of the crown is the inevitable result if thinning is not done. The longer that a birch woodland remains unmanaged the less is its response to thinning and its capacity to produce quality timber.
- Young woodlands up to the age of around 15 to 25 years with at least 2000-3000 trees ha⁻¹ with reasonably well developed crowns and relatively even height are worth investing time and money into with the aim of producing some quality timber. Such stands should be managed according to the prescription given above.
- Lack of cleaning and respacing may have led to dense regeneration where the intense competition will have reduced the crown size and thus vigour of many of the trees. Thus, cleaning and thinning should favour dominant and co-dominant trees of good form with about one third to one half of the height of the tree as living crown. It is important to avoid leaving spindly trees with greatly reduced crowns (less than one third of the height of the tree) in the open as these are vulnerable to wind and snow damage. Very suppressed trees will not respond to thinning.
- Trees in older, neglected woodlands decline in vigour over time, as their crowns become reduced through competition, and will not respond to thinning. These stands should undergo the regeneration cycle described above.

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