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The Potential for Direct Seeding of Birch on Restock Sites

INFORMATION NOTE

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SUMMARY

Direct seeding is a silvicultural technique that has potential for the creation of new broadleaved woodlands on certain better quality lowland sites in Britain. There has also been recent interest in using direct sowing instead of planting to establish birch in some upland situations, as a way of reducing the cost of restocking. Birch is a pioneer species that can freely regenerate on many sites without the aid of artificial sowing. However, where natural regeneration fails to occur, issues such as sowing date, seeding rate, site selection, preparation and aftercare, have yet to be satisfactorily addressed for artificial sowing in British conditions. It is concluded that currently, direct seeding of birch to achieve a woodland cover on restock sites is at best unproven, and that no large-scale operational sowing, or machinery purchase or development, should take place until the fundamental underlying information gaps for the technique have been addressed. For any continuing small-scale operational trials, it is recommended that a minimum of one million viable seeds per hectare are sown into weed-free and brash-free seedbeds no later than the middle of March, and browsing mammals and insects are controlled or excluded. In addition, 10% of the site should be clearly marked and left unsown to allow assessment of the extent of any natural regeneration that might occur.

BACKGROUND

A recent Forestry Commission Practice Guide (Willoughby *et al.*, 2004) provides comprehensive guidance on the use of direct seeding for the creation of new broadleaved woodlands. The guidance concludes that the technique of direct seeding can have a number of potential advantages over conventional planting: it can be cheaper, require fewer herbicides, and result in naturalistic, denser spaced, more rapidly growing trees. However, this is the case for only certain very specific, lowland situations and species. In general, direct seeding is usually less reliable and technically more exacting than conventional planting, so even when appropriate silviculture is put in place, it is currently only recommended for certain broadleaved species on a limited range of new woodland sites.

In addition to work on broadleaved woodland creation, we have recently carried out small-scale silvicultural investigations on the direct seeding of Sitka spruce (*Picea sitchensis*) on upland restock sites, and monitored seedling establishment on larger-scale operational sowings carried out by the Forestry Commission in Wales. Initial results from these trials have shown that seedling establishment is very variable, and in the majority of cases unsuccessful, indicating that there are some key limiting factors that are currently not fully understood. However, with further work, sowing of conifers on less fertile upland restock sites may have some potential in the future (Mason *et al.*, 2005).

Pilot trials using silver birch (*Betula pendula*) and downy birch (*Betula pubescens*) sown on a variety of upland site types in Scotland and England have also been set up, however, initial assessments have not yet confirmed that the technique can give satisfactory establishment. Despite the limited research into direct seeding for upland

Figure 1

First year birch seedling.

restocking, there is considerable interest in using this technique on an operational scale. This Note summarises the potential for using direct seeding for birch, and includes some recent interim trial results.

BIRCH SEEDLING ECOLOGY

Birch is a wind-dispersed, pioneer species native to the British Isles that often regenerates freely on many sites. Established birch woodland provides a valuable conservation habitat for a wide range of wildlife (Patterson, 1993; Worrell, 1999) and it can help to increase the biodiversity within predominantly coniferous upland forests (Humphrey *et al.*, 1998). Information on the germination ecology of birch has been summarised by Cameron (1996) and Karlsson (1996a; 1996b). However, most of this work is based on North American and Scandinavian research, therefore it needs careful evaluation before it can be adapted and applied to British conditions.

There are two basic requirements for successful regeneration from seed: an adequate supply of seed dispersing onto a site, and suitable microsites that favour seed survival and seedling establishment. Seed rain from established birch trees is estimated to range from 3–530 million filled seeds per hectare (Atkinson, 1992). Most of this seed falls within about 50 m of the source, but some can be dispersed up to a kilometre or more. Birch seed can form an important part of the diet of birds, both before and, to a lesser extent, after dispersal (Atkinson, 1992). An absence of seedlings in the presence of an adequate seed source would suggest that regeneration is microsite limited, and thus it is very unlikely that direct sowing an additional few tens or hundreds of thousands of viable seeds per hectare would have any worthwhile effect without further silvicultural manipulation of the site. In the absence of an adequate seed source, some management input will be required for direct sowing to be successful, given the relatively low seeding rates used compared to those associated with successful natural regeneration.

High soil moisture is crucial for seedling emergence (Linteau, 1948; Marquis *et al.*, 1964), however heavy rainfall may disturb seeds and hence germination (Palo, 1986 cited in Karlsson, 1996a,b). The limited water-holding capacity of litter or moss, and its extremes of temperature, make it a poor germination and growth medium compared to mineral soil (Linteau, 1948). Consequently, treatments such as burning and cultivation that expose mineral soil, tend to favour birch regeneration (Perala and Alm, 1989; Karlsson, 1996a,b). More radical soil preparation methods, such as removal of topsoil or deep ploughing, have also been shown to favour seedling survival, in part by reducing competing vegetation (Karlsson, 1996a,b). However, the retention of a partial cover of some types of tall vegetation can reduce frost-heaving, depending on soil properties.

Germination may be reduced by very high as well as low temperatures. Seedlings are also killed by high surface temperatures (Linteau, 1948; Marquis *et al.,* 1964), for example, seedling survival has been found to be ten times higher on cooler, sloping beds with a northerly aspect than on level seedbeds (Luke and McPherson, 1983). Some shading during the first growing season can increase germination and seedling survival. There is also some evidence to suggest that texturing the soil surface with small depressions to promote seed–soil contact, and sowing in the autumn, can improve germination (Godman and Krefting, 1960).

Even when germination is successful, seedling mortality is usually very high (80–90%) during the first three years (Kinnaird, 1974). As well as abiotic factors, biotic causes of damage and mortality reported in the literature include fungi, insects, rodents, browsing mammals, and competing vegetation.

SUMMARY OF THE POTENTIAL FOR DIRECT SEEDING BIRCH

Characteristics of birch seed that make it potentially suitable for direct seeding are:

- Seed is produced almost annually and in relatively large quantities.
- Seed can be collected relatively easily.
- Seed is relatively cheap to purchase (around £100 per kg which usually contains at least 300 000 viable seeds).
- Seed is tiny and relatively easy to dry, store, and transport.
- Seed predation by small mammals is usually insignificant.
- Germination can be very quick compared with other tree species (within 7–14 days at around 20ºC).

• Seedlings can emerge over a relatively wide range of conditions.

Characteristics of birch seed that detract from its potential suitability for direct seeding are:

• Seed lots are frequently contaminated with large proportions of the fleur-de-lys shaped catkin bracts, which are remnants from extraction (Figure 2).

• Seed lots often contain up to 80% of empty seed, resulting in a low germination percentage.

• Seed may be susceptible to predation by insects.

• Seed may be readily blown or washed away from the sowing site.

• Seed and young seedlings are highly susceptible to death by desiccation during the earliest stages of germination and establishment, a situation that may sometimes be exacerbated by some forms of cultivation such as mounding or ridge and furrow ploughing, which can result in rapid drying of surface soil layers.

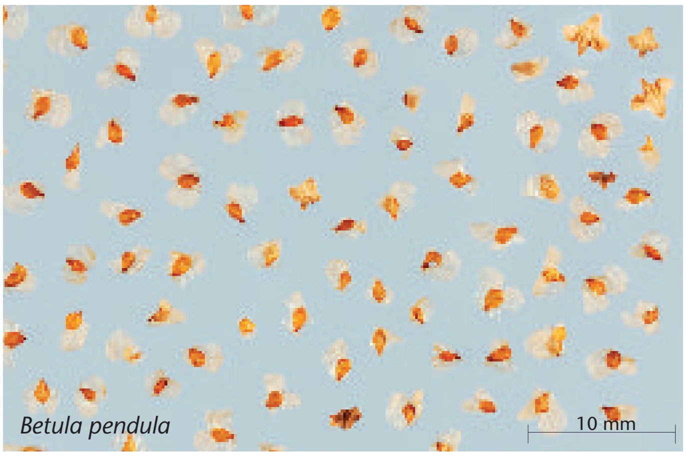
• Seed and young seedlings are highly susceptible to death from frost-heave in their first winter, particularly on frost-prone upland sites with mineral soils.

• Dry, winged seed readily acquires electrostatic charge, causing it adhere to neighbouring surfaces, leading to problems with mechanical sowing.

• Seed is highly hygroscopic, and it will readily clump and stick to damp surfaces, making sowing difficult in all but the driest conditions.

Figure 2

Close-up of silver birch seeds, also showing fleur-de-lys shaped catkin bracts, top right.



RECENT RESEARCH

Over the past five years, there has been renewed interest in direct seeding as a potentially cheap method of establishing native tree cover in recently felled, upland conifer plantations. However, little research appears to have taken place into the direct seeding of birch for restocking in British forests. Even where successful regeneration has apparently occurred, in most cases it is unclear whether this was a result of the artificial seeding, or simply due to natural regeneration.

Forestry Commission research in the 1990s (G. Patterson, unpublished data) suggested some potential for direct seeding. An experiment using 12 million viable birch seed per hectare sown into small plots achieved survival rates of between 56 000 and 135 000 seedlings per hectare after 1.5 years (98.8–99.5% mortality), although an unknown proportion of these seedlings may have resulted from natural regeneration. Fenced, screefed or scarified spots appeared to give better results than unfenced spots, scarification spoil or intact brash mats. A further experiment gave seedling survival rates after six years of around 1% of the viable seed sown.

Recent operational trials carried out in North Wales and Kielder resulted in some useful birch germination, but it was generally at very low densities. With only limited information available on the quantity and viability of seed used, the amount of natural regeneration present, and uncertainty over the future fate of the existing seedlings, success is difficult to judge and will in any case depend on local management objectives. However, it is impossible at this stage to recommend any reliable approach for the direct seeding of birch on other sites, based solely on these operational trials.

Two small-scale research experiments have recently been set up at Rowardennan and Dornoch.

Rowardennan

The Rowardennan site is located on the eastern side of Loch Lomond, Scotland (NS 369 957), at an elevation of 300 m, on an upland brown earth soil with annual rainfall of in excess of 1200 mm. The previous Sitka spruce stand had been felled in 2004, and by the time of sowing in spring 2005 there was only scattered brash present outside the old extraction routes. The area was left unfenced, then partially cultivated and mechanically sown using a pneumatic seed gun mounted on a forwarder-based tracked scarifier. The system sowed 60 000 viable, de-winged birch seeds per hectare, theoretically targeted at the brash-free and weed-free cultivated trace. A survey of 25, 0.01 ha sample plots in September 2005 indicated the site was still relatively weed free, with a mean density of birch regeneration of 880 seedlings per hectare. However, seedling distribution was extremely variable, with 12% of the plots containing no birch at all, and this was not associated with cultivation, suggesting that attempting to target seed onto cultivated strips had been ineffective. The results also indicate that the relatively weed-free and disturbed ground that can result after harvesting may provide some suitable germination sites, without the need for further cultivation. In this instance, the mechanical sowing proved ineffective because it failed to target seed into the scarified traces. Recent informal assessments suggest that much of the birch present in 2005 has subsequently died, probably as a result of insect and mammal browsing. However, the scarified ground produced as part of the seeding process will lessen the cost of any enrichment planting necessary to supplement stocking.

Dornoch

This experiment was located near Lairg, Scotland (NC 583 065) and investigated the hand sowing of birch onto screefed planting spots at three sites: Rogart, North Dalchork and South Dalchork, each with different soil types (Table 1). The previous Sitka spruce stand had been felled in 2004, with brash cleared from the site into windrows prior to sowing. Seed was surface sown by hand at a rate of either 6, 9 or 12 viable seeds per spot (15 000–30 000 per hectare) in both April and October 2004. The site was unfenced, and remained weed free for the first two years after sowing.

The October sowing failed completely on all sites, though the reasons for this are not clear. The April sowing was more successful, and the results from the highest sowing rate are summarised in Table 1. The definition of what might constitute an 'acceptable' stocking level is of course entirely dependent on the specific management objectives for a site. In general however, to have a reasonable chance of achieving a long-term native woodland cover of birch, a sensible target stocking at year 5 might be 400–800 healthy, established stems per hectare. Where timber production of any sort is an aim, the target should be 2500 healthy established stems per hectare at year 5. Based on these assumptions, with an uneven distribution of 200 seedlings per hectare at year 2, the direct sowing at Rogart is unlikely to result in a satisfactory woodland cover at maturity. By the end of the second growing season, both North and South Dalchork had around 1400 and 1600 seedlings per hectare respectively (95% mortality based on the amount of viable seed sown); however based on previous experience (Kinnaird, 1974; Patterson, unpublished data), it is likely that seedling numbers will continue to decline. Therefore at this stage, it cannot be guaranteed that sufficient numbers will survive to form a native woodland cover. Mortality to date is probably a result of unfavourable microsite conditions for seedling survival and early growth, frost heave, and subsequent damage from a large population of *Hylobius abietis*, and from other insect and mammal browsers. No natural regeneration occurred in the unsown control plots despite the presence of mature birch in the vicinity of all sites. This suggests that reliance on natural regeneration to obtain a woodland cover is probably inappropriate, at least in the short term, and that the prevailing sowing conditions were relatively unfavourable for birch.

Table 1

Site details, and seedling survival rates for spring sowing, for research experiments carried out at Dornoch.

Site/grid reference	Soil type	Elevation (m a.s.l.)	Accumulated temperature[1] (days)	Moisture deficit[2] (mm)	DAMS[3]	Aspect	Viable seed[4] sown ha^{-1}	Seedlings ha^{-1} year 1[4]	Seedlings ha^{-1} year 2[4]	Total % mortality since sowing
Rogart NC 722 014	Upland brown earth	100	1007	104	7	North east	30 000 (12)	1446 (0.58)	207 (0.08)	99.3
North Dalchork NC 534 223	Deep peat	200	993	74	16	South west /flat	30 000 (12)	5151 (2.06)	1371 (0.55)	95.4
South Dalchork NC 573 087	Peaty podzol	130	1081	93	13	West	30 000 (12)	10 128 (4.05)	1650 (0.66)	94.5

Notes

[1]Annual average number of growing degree days above 5°C, from Pyatt *et al.* (2001).
[2]Annual average soil moisture deficit, from Pyatt *et al.* (2001).
[3]Detailed Aspect Method of Scoring, for assessing the exposure of a site, from Pyatt *et al.* (2001).
[4]Figures in brackets are actual average number of seeds sown per plot, or number of surviving seedlings found per plot.

Therefore, unless techniques are developed to mitigate seed and seedling mortality, far higher, possibly uneconomic, sowing rates would be required to compensate for sub-optimal conditions on these sites, and guarantee sufficient seedlings to reliably establish a woodland cover of 1100 stems per hectare or more.

Implications of the experimental work

- Cultivation may not be always be necessary on all sites, provided extraction has broken up brash mats and given suitable weed-free sites with exposed mineral soil.

- Where an adequate natural seed source is present, but natural regeneration fails, it is likely that very high seeding rates (probably in excess of 10 million viable seed per hectare), or alternatively lower seeding rates (probably at least 1 million viable seeds per hectare) combined with techniques to reduce seed and seedling mortality, will usually be required to achieve successful regeneration using direct seeding.

- Judgements of the success of the stocking rates achieved from any direct seeding will depend on management objectives. However, insufficient evidence has so far been collected to be able to recommend a wholly reliable and repeatable method for the successful direct seeding of birch.

- Woodland cover can however be guaranteed relatively cheaply by planting and maintaining 1100 transplants per hectare (Table 2).

Table 2

Indicative relative cost[1] of establishing birch on infertile upland sites, assuming fixed mortality and different direct seeding/planting rates.

Seeding rate (viable seed ha^{-1})	Cost of seeds[2] (£ ha^{-1})	Cost including seeding[4] (£ ha^{-1})	Cost of maintenance[6] (£ ha^{-1})	Total cost (£ ha^{-1})	Anticipated final stocking (stems ha^{-1}) assuming 99.9% mortality[7]	Cost per established tree (£)
30 000	10	60	105	165	30	5.50
100 000	30	80	120	200	100	2.00
200 000	60	110	135	245	200	1.23
700 000	210	260	220	480	700	0.69
1 000 000	300	350	275	625	1 000	0.63
2 000 000	600	650	450	1 100	2 000	0.55
Planting rate (trees ha^{-1})	**Cost of plants[3] (£ ha^{-1})**	**Cost including planting[5] (£ ha^{-1})**	**Cost of maintenance[6] (£ ha^{-1})**	**Total cost (£ ha^{-1})**	**Anticipated final stocking (stems ha^{-1}) assuming 10% mortality[7]**	**Cost per established tree (£)**
1 100	275	385	300	685	990	0.69
2 500	625	875	540	1 415	2 250	0.63

Notes

[1]Costs are indicative and for comparison purposes only – actual cost will vary depending on site specific maintenance requirements.

[2]At £0.30 per thousand viable seed. Seed viability will vary with seed lot, and detailed seed test information should always be obtained from seed suppliers. As a guide, viability for marketed seed is often in the range of 300 000–1 000 000 viable seeds per kg.

[3]At £0.25 per plant.

[4]At £50 per hectare for hand seeding.

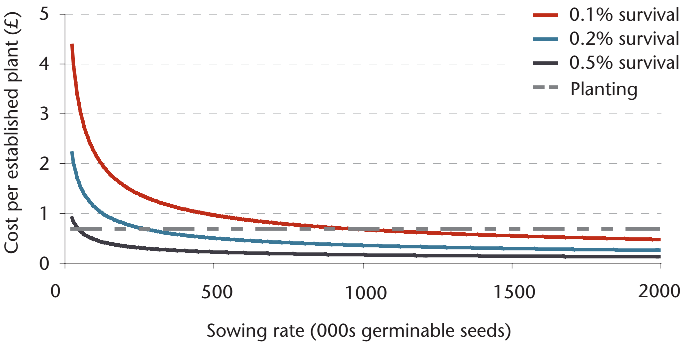
[5]At £0.10 per plant.

[6]Maintenance in this example includes initial site preparation (£100 ha^{-1}), two herbicide weeding operations (£200 ha^{-1}) and four applications of insecticide (£240 ha^{-1}) to prevent damage from *Hylobius abietis*. Where deer or rabbit populations are high, the cost of fencing a site, or controlling populations levels, would need to be added for both direct seeded and planted trees. For scenarios with stocking levels lower than 2500 stems ha^{-1}, weeding and insecticide costs have been reduced proportionately. All maintenance operations are assumed to be required for both direct seeded or planted trees established on the same site. The only exception to this may be if sufficient seeded plants were established to mitigate losses from weed competition and *Hylobius* damage. Actual seedling numbers that would be required to achieve a final stocking of 1100 stems ha^{-1} in this situation are unknown, but likely to be in the region of at least 50 000 seedlings ha^{-1}. With high browsing pressure, regardless of initial stocking rates, sufficient trees are unlikely to establish to form a woodland cover without some form of fencing or population control.

[7]Varying the estimated mortality rate has a large influence on relative costs. Based on limited research experience, at seeding rates of 30 000 ha^{-1}, mortality will often in fact be 100%. Managers may wish to make their own scenario analysis based on different anticipated survival rates and costs. For example, Figure 3 shows variation in cost per tree assuming different survival rates.

Figure 3

The effect of different assumed seedling survival rates on the cost per established tree, compared to planting at 1100 stems ha^{-1} (see Table 2).



Notes

Assuming 0.5% survival, at least 200 000 viable seeds per hectare would be required to be sown to achieve 1100 established trees per hectare, for 0.2% survival 500 000 viable seeds per hectare, and for 0.1% survival 1 000 000 viable seeds per hectare. Currently there is little research evidence to suggest it is possible to reliably achieve more than 0.1% survival.

INFORMATION GAPS REGARDING THE DIRECT SEEDING OF BIRCH

Key operational decisions and research questions regarding the use of birch for direct seeding in restocking situations still need to be addressed for British conditions. For example:

- What is the optimum sowing period? Autumn sowings may suffer from seed predation, rotting and frost damage to early emerging seedlings. Conversely, when seed is sown in the spring, most seedlings tend to emerge later and can be easily killed if hot, dry weather occurs in April and May.

- What is the appropriate seeding rate? Evenly spread, naturally regenerated birch probably results from several million viable seed per hectare raining onto a site.

- Other key issues include:
  - a consideration of what sites are appropriate;
  - how microsites should be prepared;
  - whether mechanised sowing is practical or even desirable;
  - if mechanical methods such as hydro-seeding need to be developed to permit the use of pre-treated seed;
  - if other species characteristic of new native woodlands could be sown, or whether they should be planted;
  - what level of weeding, respacing, and protection from mammals and insects is required for different site types.

CONCLUSIONS

Although theoretically attractive due to its potentially low cost, the technique of direct seeding of upland sites with birch, whether for restocking, reforestation or restoration, is as yet unproven. Despite the low cost of birch seed, unless very high sowing rates are used and high initial stocking rates are achieved, maintenance operations may still need to take place to ensure sufficient survival to form a woodland cover. With the high mortality rates anticipated for direct seeding on restock sites, planting may actually give a lower cost per established tree (Table 2), and is always a more reliable way of achieving a woodland cover where natural regeneration has failed.

Insufficient research has taken place to date to be able to confidently recommend the technique of direct seeding as a method for establishing birch on British restock sites, and there are several examples of unexplained failure. It is recommended that further machinery development or large-scale operational sowing of birch on restock sites does not take place until the underlying information gaps for the technique have been addressed.

For small-scale operational trials, the following provisional, untested regime is suggested:

- Create a well-drained mineral soil seedbed. If necessary, cultivate the site in the September before sowing. Preferably, where site conditions allow, cultivate as extensively as possible across the complete site (e.g. through line or total scarification), rather than in discrete spots or mounds. Seedbeds must be free of brash and weeds (spray if necessary) at the point of sowing.

- Avoid fertile sites where weed growth is likely to be profuse, sites subject to winter waterlogging, or other sites normally considered unsuitable for birch growth. Sites with soil nutrient status ‘very poor’ to ‘poor’, soil moisture status ‘fresh’ to ‘slightly dry’, following the Forestry Commission Ecological Site Classification system (Pyatt *et al.*, 2001), probably have more potential for success than other areas.

- Leave a minimum of 10% of the core of the site unseeded, and clearly marked on the ground, to monitor natural regeneration. Take care not to confuse birch seedlings for bramble (*Rubus fruticosus*) in any assessment (see Figures 4 and 5).

Figure 4

Newly emerged silver birch seedling with cotleydons and first true leaf.

Figure 5

Newly emerged bramble seedling. Although looking superficially very similar to birch, bramble is distinguishable by the cotyledon margin, bordered with glandular hairs, which are not present on birch.

- Purchase dry, untreated seed with a known viability from a reputable seed merchant. Keep seed cool and dry (e.g. in a domestic refrigerator), and handle it with the same care as would be afforded ripe soft fruit. Self-collected seed should be tested for germination percentage before sowing.

- **Sow at least 1 million viable seeds per hectare.**

- Sow from the middle of October to the middle of April (or the middle of March on lowland sites <250 m in altitude), but no later, to avoid hot and dry spring weather damaging seed and young seedlings.

- Broadcast sow by hand across the entire site onto prepared seedbeds, rather than into discrete spots. Seed should be mixed with a carrier such as fine dry sand to make sowing easier.

- Control browsing mammals or fence the sown area.

- If seedlings establish, monitor site and spray as necessary to limit damage from *Hylobius abietis*. Alternatively, treat the site with nematodes before sowing.

- Monitor the site for ingress of weeds and control if necessary. The aim should be to keep the site 80% weed free for the first 3–5 years after germination.

- Record details of the techniques employed, and any success or failure, and archive in a safe place for future reference.

- See Willoughby *et al.* (2004) for more details on seed sourcing and handling, insect and mammal protection and weed control for direct seeding systems. For details of methods of protection against *Hylobius abietis* damage, see www.forestry.gov.uk/pesticides.

When restoring ancient semi-natural woodland sites, if locally native genotypes exist, natural regeneration or colonisation is preferable to planting or direct seeding using material of non-local origin. If no natural seed source exists, and birch direct seeding proves to be successful, the woodland could be diversified at a later date by planting other species components of upland native woodlands, such as willow (*Salix* spp.), oak (*Quercus robur*, *Q. petraea*), holly (*Ilex aquifolium*), rowan (*Sorbus aucuparia*), alder (*Alnus glutinosa*) and ash (*Fraxinus excelsior*). Sowing of these species on restock sites is not currently recommended. See Rodwell and Patterson (1994) for information on species choice for new native woodlands, and Thompson (2004) for guidance on encouraging the natural colonisation of birch.

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