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# Managing Mixed Stands of Conifers and Broadleaves in Upland Forests in Britain

INFORMATION NOTE

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## SUMMARY

**Mixtures of conifers and broadleaves are developing on many sites in upland forests and are favoured by current policies designed to diversify conifer plantations. The commonest species found in mixture are Sitka spruce, Scots pine, birch and a range of other broadleaves. Evidence from a number of experiments in upland Britain suggests that both Scots pine and Sitka spruce will eventually dominate the broadleaves so that intimately mixed conifer–broadleaved stands are not sustainable over time. A better approach for fostering mixed stands will be to develop a mosaic where clumps of pure broadleaves alternate with conifers. Attempts to use conifers to 'nurse' broadleaved species have generally been unsuccessful in upland Britain. The only exception was one trial on a very nutrient poor soil where growth and stem form of a number of broadleaves was improved when grown in a managed mixture with larch.**

## INTRODUCTION

A common aim of forestry policies in England, Scotland and Wales is to increase the species diversity of the conifer forests planted in the last century. For example, the Scottish Forestry Strategy (Forestry Commission Scotland, 2000) sees the development of more mixed forests as a priority for action under the strategic direction of creating '*a diverse forest resource of high quality that will contribute to the economic needs of Scotland…*'. While the benefits associated with more mixed forests, such as providing higher environmental and aesthetic values of forest stands are widely agreed, the means of achieving such mixtures and of managing them successfully over time are less clear. This is particularly true for mixtures of conifers and broadleaves, of which there is little experience in upland Britain. The purpose of this Note is to review some recent results from experiments that have examined different aspects of the silviculture of mixed conifer–broadleaved stands.

## TYPES OF MIXTURE

The most recent national inventory data suggest that there are some 75 000 ha of mixed conifer–broadleaved forest in upland Britain (defined here as all of Scotland, Wales, and Cumbria and Northumberland in England). Mixed stands are identified whenever each category in the mixture occupies at least 20% of the canopy. Scots pine and Sitka spruce are the conifer species most often found in such mixed stands while birch and/or a range of broadleaved species ('mixed broadleaves') are the most common broadleaved element.

There are two types of conifer–broadleaved mixture that can be found in upland forests. The first is a single-canopied mixture where the various component species occur in a single canopy layer (termed **simple mixture** in this Note). This is the commonest type to be found in upland conifer forests at the present time and is the main focus of this Note. The second is a **stratified mixture** where faster growing species occupy the upper canopy layers and slower growing, usually more shade-tolerant, species are found in the lower canopy. While stands of the

**Figure 1**

A young plantation of Sitka spruce and Douglas fir with birch regeneration in Wales.

latter type are comparatively rare in British conifer forests, they may become more widespread because of the increasing interest in both continuous cover forestry and the gradual conversion of conifer plantations to native woodlands. Both of the latter can involve the establishment of broadleaved species in a conifer stand – either through natural regeneration or by underplanting.

## Simple mixtures

In broad terms, simple mixtures can develop in two different ways. The first is where broadleaved species, often dominated by birch, colonise a clearfelled conifer site during the restocking period. The result of this process can be a dense thicket of birch and replanted conifers. An important management decision is whether or not to intervene to remove the broadleaves to favour the conifers. This usually takes place when the trees are between 2 and 4m tall and can cost several hundred pounds per hectare, depending upon the density and size of the broadleaved trees. The second situation occurs when broadleaves are planted in mixture with conifers, where the aim is generally to favour one or other element through differential thinning. These are frequently referred to as 'nursing mixtures' (see discussion in Pommerening and Murphy, 2004).

### Scots pine–birch

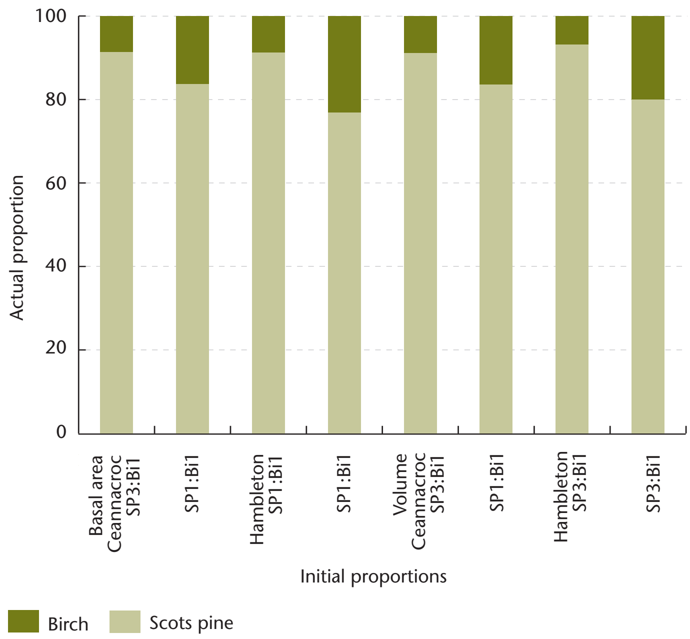
Mixtures of Scots pine and birch (silver and/or downy) are frequent in the native pinewoods of the Scottish Highlands. Indeed, it is argued that birch would be more abundant in these woodlands if it had not been removed by thinning or disadvantaged by preferential browsing by deer (Mason *et al*., 2004). Whatever the reason, mixtures of birch and pine can now be found in both planted new native woodland schemes, and where pinewoods are being extended through regeneration.

Two 40-year-old experiments, located in Ceannacroc forest in Glen Moriston (Inverness) and in Hambleton (North Yorkshire), provide some guidance on the management of such mixtures. Each experiment contains pure plots of birch and Scots pine as well as two proportions of mixture, namely 3:1 Scots pine to birch, and 1:1 pine to birch. The mixtures were achieved by planting square groups of 25 trees of one species in an alternating or variable pattern with similar sized groups of the other species. At each site plot size is 0.2 ha and there are three replicates of each treatment laid out in a randomised block design. The sites involved would be classed as either 'very poor' (Ceannacroc) or 'very poor to poor' (Hambleton) in terms of the Ecological Site Classification Soil Nutrient Regime (SNR) (Pyatt *et al*., 2001). Other details can be found in Malcolm and Mason (1999).

Some 30 years after establishment, and before any thinning had taken place, Scots pine had become the dominant element of these mixtures, representing between 75 and 90% of the stands by basal area and 80 and 93% by volume (Figure 2). Pine tended to be slightly taller than birch and to be of larger diameter. The trends in the results of the two experiments are quite similar, despite the plots occurring in different climatic regions of the country, and suggest that Scots pine will progressively dominate birch when the two species occur in intimate mixture.

**Figure 2**

Proportions of Scots pine and birch after 30 years in two experiments carried out at Glen Moriston and Hambleton.




### Sitka spruce–birch

The occurrence of birch within Sitka spruce restocking sites has been noted for several decades. A survey in the early 1990s examined the density of birch on a range of Scottish restocking sites where the spruce averaged 20 years of age. The amount of birch colonisation was strongly influenced by the closeness of the nearest seed source (Wallace, 1998). Where the seed source was closer than about 400 m, densities of birch were 500–1500 stems ha$^{-1}$ or more with spruce densities of between 1500 and 1900 stems ha$^{-1}$. The same study suggested that there was appreciable competition between birch and spruce in such mixtures and that birch was out competed by the spruce wherever the latter exceeded 40% canopy cover. The pattern of mixing between the two species has not been rigorously described, but appears to be one of dense clumps of birch scattered throughout the more regular distribution of planted spruce.

Using the evidence from this survey, and information on early height growth of the two species, Humphrey *et al.* (1998) thought that there would be little chance of stratified mixtures of birch and Sitka spruce persisting on sites managed under a clearfelling and restocking regime. This is unlike the situation that occurs in Scandinavia where stratified mixtures of birch (in the overstorey) and Norway spruce (in the understorey) are widely reported (Mard, 1996). The main reason for the difference in Britain is the much faster early height growth of Sitka spruce than of Norway spruce, combined with the former's lesser shade tolerance. Given these factors, Humphrey *et al.* (1998) considered that most Sitka spruce–birch mixtures would develop into dense thickets where inter-tree competition could result in reduced yields of spruce unless cleaning operations were undertaken to remove the birch.

Two experiments were established in the late 1990s to test these assumptions: one in Gisburn Forest (Lancashire), the other near Lampeter in mid-Wales. The experiments were carried out on sites where young restocked stands of Sitka spruce had been colonised by high densities of birch and other broadleaves. Both sites have SNRs varying from poor to moderate. In each case, an unrespaced control plot was contrasted with pure Sitka spruce (i.e. all birch removed), pure birch (i.e. all spruce removed) and a spruce–birch mixture where the broadleaved component was respaced to 100–150 trees ha$^{-1}$. At each site plot size was about 0.06 ha and there were four replicates of each treatment set out in a randomised block design.

Although these experiments have only been monitored for six years, the initial results reveal some interesting trends. Neither experiment showed any evidence for a decline in Sitka spruce height or numbers when growing in intimate mixture with birch. At the Welsh site, after six years the spruce was nearly 2 m taller than the birch despite being of a similar height at the start of the experiment. The tentative inference is that Sitka spruce will gradually dominate simple mixtures of these two species and it is unlikely that birch will survive in intimate mixture much beyond 30 years of age. The only exception is where poor spruce survival allows birch to form a dense thicket over an area of at least 20 m$^2$ – such that there is sufficient space for one or two birch trees to survive and grow to maturity. While the presence of birch may cause some damage to the crowns of spruce through 'whipping' of the crowns, this is unlikely to have a substantial effect upon the long-term development of the stand.

## Conifer–broadleaved mixtures on poor to moderate soils

The planting of conifer–broadleaved mixtures, where the former are progressively removed in thinning to eventually produce a pure broadleaved stand, has a long history in lowland Britain (Kerr *et al.*, 1992). Benefits that are attributed to the use of such 'nursing' mixtures include the enhancement of the early growth of the broadleaves, protection from frost damage, and improvements in form of the final crop trees. There may also be early financial returns gained from the removal of the nurse conifer species. The success of such mixtures clearly depends upon ensuring that the growth rate of the conifer nurse is not so fast as to disadvantage the slower growing broadleaves. Evans (1984) devised a rule-of-thumb stating that the anticipated yield class of the conifer should not be more than 1.5 to 2 times greater than that of the broadleaved species in question.

There have been few experimental evaluations of these conifer–broadleaved mixtures in northern or upland Britain. One study that has been carried out was based upon two 40-year-old experiments located in forests near Annan (Dumfries and Galloway). This examined the performance of pedunculate oak grown as a single species and in mixture with Norway spruce and European larch. The sites involved would be classed as either 'poor' or 'moderate' in terms of SNR.

The results (Table 1) suggested that the guidance on comparative growth rates devised in lowland Britain also applies in more upland regions – in that the mixtures with Norway spruce were less successful because the conifer species grew much faster than the oak after the initial establishment phase. Even in the seemingly more compatible mixtures with larch, the crowns of the oak were damaged by interference from the conifer. A conclusion from this study was that the faster growth rates of conifers expected over much of the uplands would tend to make such mixtures with broadleaves difficult to manage, and there would be an appreciable risk of the conifer suppressing the broadleaves. Full details can be found in Mason and Baldwin (1995).

**Table 1**

Top height, mean DBH, and estimated general yield class of pedunculate oak after being grown for 40 years 'pure' and in mixture with Norway spruce and European larch at Whitehill (W) and Brownmoor (B). Significant differences are indicated as * = $p$ <0.05; **= $p$ <0.01.

| Treatment | Top height (m) | | DBH (cm) | | GYC | |
|---|---|---|---|---|---|---|
| | W | B | W | B | W | B |
| Oak in EL | 14.6 | 14.6 | 12.3 | 13.1 | 6 | 6 |
| Oak in NS | 12.6 | 12.2 | 11.2 | 11.1 | 4 | 4 |
| Pure oak | 14.8 | 14.8 | 14.7 | 14.8 | 6 | 6 |
| Significance | NS | ** | NS | * | | |
| SED | 1.13 | 0.78 | 1.75 | 1.08 | | |
| EL nurse | 15.9 | 17.8 | 16.7 | 19.3 | 6 | 8 |
| NS nurse | 16.6 | 19.7 | 20.1 | 23.4 | 12 | 14 |

Adapted from Table 4 in Mason and Baldwin (1995).

Another experiment in the uplands where the performance of planted conifer–broadleaved mixtures were followed for a reasonable period is the classic experiment in Gisburn Forest (Lancashire) where Norway spruce, Scots pine, common alder, and sessile oak were each grown in pure plots and in all six possible two species combinations. The mixed plots consisted of each species planted in alternating 18 plant groups to give an initial 50:50 mixture. A randomised block design with three replicates was used. The soils would again suggest a poor to moderate SNR. The experiment was planted in 1955 and clearfelled in the late 1980s after some plots suffered severe windblow.

When last measured at nearly 30 years of age, the initially balanced mixtures had all tended towards a higher proportion of conifers in the stand. Thus in the Scots pine:sessile oak mixture, the pine proportion of the total volume of the mixed plots was 84%. In the Scots pine:alder, Norway spruce:sessile oak, and Norway spruce:alder mixtures, the equivalent figures were 85%, 93% and 92% respectively (adapted from Brown, 1992; Table 2). The results are another indication that, in the absence of systematic management to favour broadleaves, conifer–broadleaved mixtures in upland Britain will tend to move towards conifer dominated stands over time.

## Conifer–broadleaved mixtures on very poor soils

An interesting exception to the trend of there being few growth benefits to broadleaves from conifer–broadleaved mixtures in the uplands is provided by a 50-year-old experiment on an ironpan soil in the North York Moors (Gabriel *et al*., 2005). A range of broadleaves (sessile oak, beech, sweet chestnut, and silver birch) were planted pure and in mixture with Japanese larch on a site of 'very poor' SNR. The conifer nurses were largely removed by the time the trees were 35 years of age.

For all the broadleaved species except silver birch, there were substantial improvements in height growth and stem form following mixture with conifers (Table 2). The increases in height growth were greatest at 15 years but were still evident at 47 years – some 12 years after the last conifers had been removed from most plots. The improvement in growth in the mixtures was matched by better stem quality which was sufficient to provide some sawlog products from what would otherwise be a largely firewood crop. These improvements are thought to be due to the same 'nursing mixture' process whereby growth of Sitka spruce on nitrogen poor soils is improved by being grown in mixture with pine or larch (Taylor, 1991).

**Table 2**

Height and stem straightness of four broadleaved species grown pure and in mixture with Japanese larch in an experiment in the North York Moors.

| Species | Treatment | Height at 15 years (m) | Height at 47 years (m) | Stem form* at 47 years |
|---|---|---|---|---|
| Sessile oak | Pure | 2.1 | 11.9 | 2.5 |
| | With JL | 4.0 | 14.2 | 4.8 |
| Beech | Pure | 1.7 | 11.6 | 2.0 |
| | With JL | 4.1 | 13.9 | 4.4 |
| Sweet chestnut | Pure | 1.7 | 12.3 | 1.6 |
| | With JL | 4.5 | 16.3 | 7.1 |
| Silver birch | Pure | 4.2 | 15.4 | 5.1 |
| | With JL | 4.5 | 17.2 | 3.1 |

Adapted from Gabriel *et al.*, 2005.
*Stem form is based upon a scoring system where 1 is low quality and no straight 1 m logs in the bottom 6 m of the stem. A straight 6 m stem would score 26.

The relative lack of benefit from growing silver birch in mixture is probably due to the species being better adapted to the heathland soils of the North York Moors and therefore not requiring the 'nursing' from the conifers to the same extent as the other broadleaves. The poorer form of the birch in mixture is probably a consequence of the trees struggling to compete with the conifers for light and being disadvantaged in a manner analogous to that found at Glen Moriston and Hambleton (see above).

There have been attempts to plant mixtures of Sitka spruce and broadleaves in various experiments in the uplands on 'very poor' soils to see if broadleaves could provide the nursing benefits described for mixtures of spruce with pine or larch. Examples include mixtures with downy birch in Shin forest (Highland) and with various alders in Glentrool (Dumfries and Galloway). In general terms these trials have not been successful, either because the broadleaves have not established well (Glentrool) and/or the nursing benefit has been appreciably less than that found with more traditional conifer nurses (Shin; see Humphrey *et al*., 1998).

### Stratified mixtures

There are no experiments recorded in the uplands where broadleaves have been introduced under a canopy of conifers either through regeneration or through planting. However, greater use of extended rotations and/or gradual conversion to native woodlands is likely to make such practices more widespread in the future. Certain principles will need to be observed for such trials to succeed:

- The light climate within the conifer stand will need to be adequate for satisfactory growth of the introduced broadleaves. This will almost certainly require that the chosen conifer stand has a history of thinning. In general, it is unlikely that a suitable state for planting/ regeneration can be achieved much before the conifer stand has reached 40–50 years of age, although a younger age would be feasible in a well-thinned stand of larch.

- It is probably desirable to plant or regenerate the broadleaves in gaps or less dense areas within the conifer stand. Such gaps should be at least 0.1 ha in size to provide areas that are reasonably easy to identify and manage in the future.

- There will need to be continued thinning of the conifer matrix to open up the stand and provide a favourable light climate for the regenerating broadleaves. This will require the progressive opening of groups using a group shelterwood or group selection silvicultural system.

- There is likely to be conifer natural regeneration occurring alongside the broadleaves and respacing may be necessary to ensure the broadleaves are not outcompeted by faster growing conifers.

- These groups of broadleaves will be vulnerable to browsing by deer. Even limited pressure on the broadleaves could favour any conifer regeneration, therefore rigorous deer control is essential.

## CONCLUSIONS

The following general conclusions can be drawn from experimental experience to date and from observations in forests throughout the uplands:

- Simple mixtures between conifers and broadleaves are likely to become more frequent throughout upland conifer forests.

- This trend is to be welcomed since, everything else being equal, these mixed stands will support greater biodiversity and will be more visually attractive than the pure conifer stands that characterised the first rotation forests.

- In many cases, the faster growth of conifers means that intimate simple mixtures between conifers and broadleaves are unlikely to be sustainable over time unless stands are specifically managed to favour broadleaved trees at the expense of conifers. Such a strategy may both be costly to implement and result in reduced stem quality in conifers (e.g. large branches on the lower stem leading to high knot incidence). These points probably apply to planted mixtures of Scots pine and birch in new native woodland schemes as much as they do to broadleaved–Sitka spruce mixtures on restocking sites.

- A more realistic strategy may be to manage mixed stands to eventually produce a mosaic where pure broadleaves alternate with pure conifers. The minimum size of the broadleaved elements in this mosaic should be equivalent to that occupied by three or four broadleaved trees at maturity (perhaps 250 $m^2$ or more). The dynamics of such mosaics over time have been discussed by Humphrey *et al.* (1998) with particular reference to birch–spruce mixtures.

- There appear to be few situations where planting conifers in intimate ‘nursing’ mixtures with broadleaves is justifiable since, in the uplands, faster conifer growth makes these difficult to manage. However, where the intention is to try and establish a mainly broadleaved stand on soils of ‘very poor’ nutrient status and timber production is an objective of management, the use of nursing mixtures between the broadleaves and pine or larch is worth consideration.

- Stratified mixtures where groups of broadleaves occur under a conifer overstorey are likely to be more common in future. These will need careful management, with progressive opening up of the groups through thinning and application of continuous cover forestry principles.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