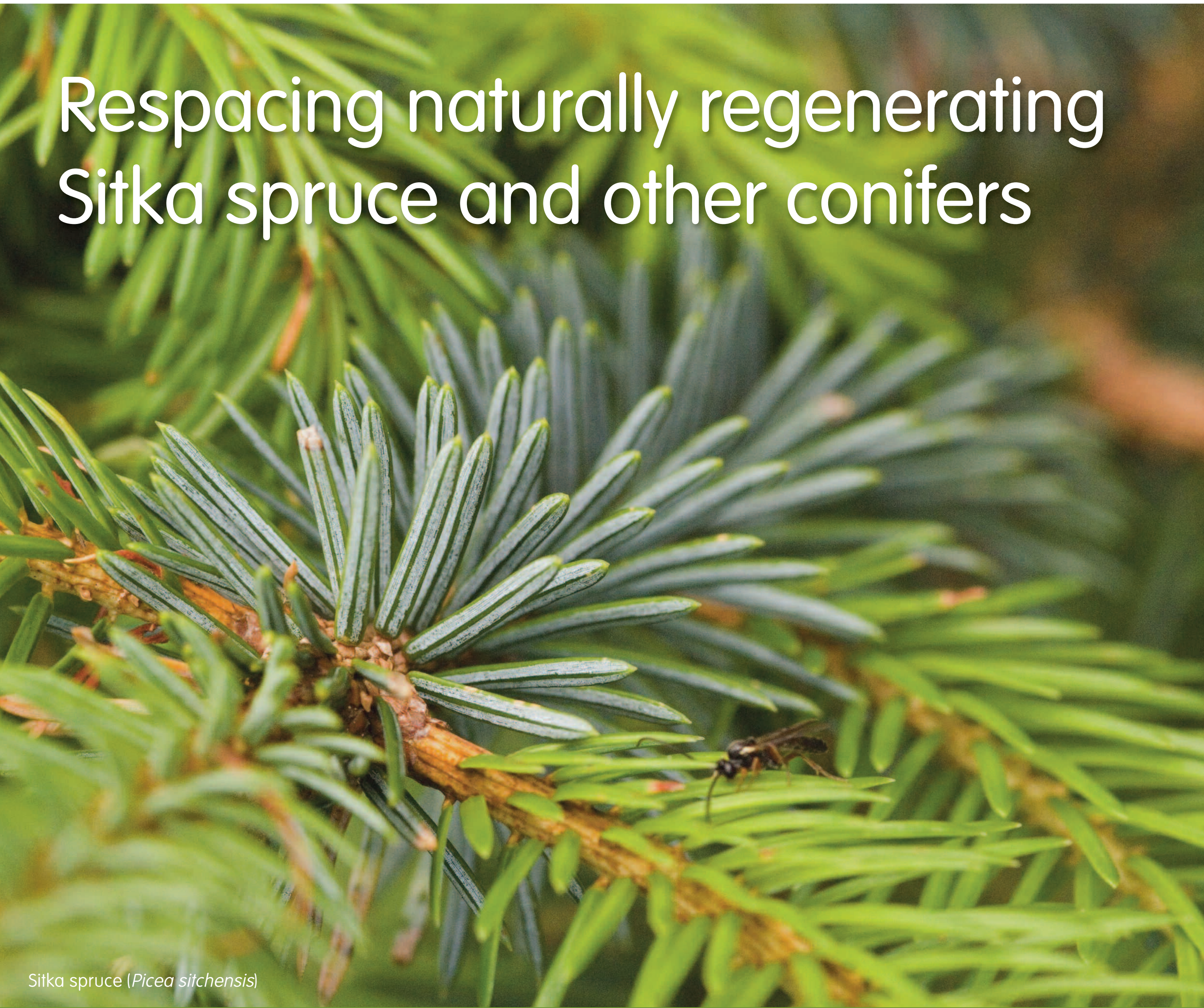
Forestry Commission

Respacing naturally regenerating Sitka spruce and other conifers



Sitka spruce (*Picea sitchensis*)

Practice Note

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Dense natural regeneration of Sitka spruce and other conifers is an increasingly common feature of both recently clearfelled sites and stands managed under continuous cover forestry in upland forests of the British Isles. This regeneration can be managed by combining natural self-thinning in the early stages of stand establishment with management intervention to cut access racks and carry out selective respacing to favour the best quality trees. The target density should be about 2000–2500 stems per hectare in young regeneration or on windfirm sites where thinning will take place. On less stable sites that are unlikely to be thinned, a single intervention to a target density of 1750–2000 stems per hectare should improve mean tree diameter without compromising timber quality. Managing natural regeneration in continuous cover forestry or mixed stands can be based upon similar principles but the growth of the regenerated trees will be more variable.

Introduction

Dense natural regeneration of conifers in upland Britain has become increasingly common as forests planted during the last century reach maturity. The density of naturally regenerated Sitka spruce (*Picea sitchensis*) can exceed 100 000 seedlings per hectare on suitable sites in forests throughout northern and western Britain – examples include Fernworthy, Glasfynydd, Radnor, Clocaenog, Kielder, Ae and Newcastleton. Natural regeneration of many other conifer species can also be found in British forests, although the densities are generally less than with Sitka spruce. Natural regeneration is often variable, so that when trees are around 2–3 m tall, stands can appear as clumps of closely-spaced saplings interspersed with lightly-stocked areas and gaps.

Forest managers need to decide whether or not to intervene to respace naturally regenerating trees to a density and pattern closer to that found in conventional stands. This decision requires assessing the benefits from respacing, the choice of an appropriate target density if the decision is made to respace, and the age (or height of stand) at which this intervention should be made.

These factors can have appreciable financial implications because current costs of respacing are in the order of £500–£1000 per hectare, depending upon size of tree and methods used. This type of management intervention is similar to thinning undertaken in older stands, but unlike the extensive research on response of trees to thinning, there have been few long-term studies following the response of naturally regenerated stands after respacing.

Figure 1 Natural seedlings of Sitka spruce and pine.

Natural self-thinning

Management intervention to respace young trees is sometimes justified on the basis that stands of dense natural regeneration will 'stagnate' if no respacing is carried out. However, with the exception of stands of lodgepole pine (*Pinus contorta*) on very poor-quality sites in Canada, there are few examples of 'stagnation' occurring. By contrast, there are many reports of high mortality in naturally regenerated stands because of the intense competition between the trees which results in 'self-thinning' whereby stocking density declines over time.

For example, in the natural range of Sitka spruce, high natural mortality and good differentiation in height has been found in dense naturally regenerated stands after 25–30 years. The relationship can be predicted using existing yield models so that managers can use these to explore the development of naturally regenerated stands over time.

Guidance on respacing

Existing guidance on respacing natural regeneration in British conditions was first developed in the 1990s. This was based on prescriptions developed for Sitka spruce that used information from an experiment established in the 1970s (see Box 1 for more information) supported by a number of operational studies.

This Practice Note updates this guidance using information from the original and more recent experiments. It also sets out the implications for regeneration in both regular stands and areas being managed under continuous cover forestry.

Figure 2 Dense natural regeneration of Sitka spruce in Glasfynydd forest.

Box 1 – Experimental evidence

Original experiment

The 1973 Ae experiment was a pilot study to test the effect of a range of respacing methods on the growth and development of Sitka spruce natural regeneration. Five treatments were compared: (1) a control with no respacing; (2) selective respacing to favour taller trees at approximately 2 m square spacing and the remainder cut at or near ground level using a brush cutter; (3) selective respacing combined with chemical control of the regrowth from cut stumps and any new seedlings; (4) simulated mechanical respacing whereby 1 m wide swathes were cut at right angles with a brush cutter to leave small clumps of plants approximately 2 x 2 m wide; and (5) mechanical respacing combined with chemical control of regrowth in the cut swathes.

Stem numbers

At the start of the experiment, the trees were around 6–7 years in age with an average height of 1.6 m (ranging from 0.1 to 3.2 m). Stocking densities varied from over 47 000 stems per hectare to 13 500 stems per hectare. After respacing, the stocking in the selectively respaced treatments was higher than the target 2500 stems per hectare as a result of regrowth from cut stumps and/or development of seedlings that had been too small to cut. Stem numbers declined in all treatments over time with numbers after 25 years ranging from just below 2000 stems per ha (Treatment 2) to nearly 3000 stems per hectare (Treatment 1, control). The decline was due to tree deaths following inter-tree competition and nearly 90% of the trees in the control plots had died by 2003. Most mortality appeared to occur in the period between 1980 and 1993. Thus in both 1986 and 1993 there were between 14 and 16 thousand dead stems per hectare recorded in the control plots. By contrast, no mortality was noted in the selective treatments in 1986 and in 1993 it only amounted to a few hundred trees per hectare.

Diameter growth

The mean diameter was greater in the selectively respaced treatments throughout the experiment but this difference was only significant in 1986 when both (2) and (3) were appreciably larger than the other treatments. Values in the control and the mechanically respaced treatments were similar at all times of assessment. Examination of diameter distributions in the control and selectively respaced treatments in 1986 and 1997 showed that the benefit from respacing declined over time. Thus in 1986 the percentage of small stems (up to 10 cm dbh) was appreciably higher in the control than in respaced treatements while larger stems (>20 cm dbh) were only found in the latter. However, by 1997 the major difference was between the replicates rather than between treatments.

Other considerations

The risk of windthrow was evaluated using the ForestGALES model, assuming a turf planted stand on a soil with moderate drainage. A non-thin option was assumed to be the most likely stand management strategy given the soils and exposure of the Ae site. The risk of wind damage was greater in the control stand than with respacing to 2 m spacing. A wind risk 6 status (i.e. a return period of <10 years for damage) would be reached in only 36 years for the control stand on the Ae site compared to about 57 years for respaced stands.

The timber properties of fifteen trees from each treatment were examined when the experiment was felled and no differences were noted for parameters such as wood density, compression wood percentage and grain angle. All values were similar to those found in samples taken from a nearby planted stand.

More recent experiments

In the late 1990s, three experiments were established in naturally regenerated Sitka spruce at Ae, Radnor, and Fernworthy, to examine the impact of a wider range of respacing densities. The Ae experiment was installed in 1997 in 5–6 year old regeneration on a peaty gley soil with stocking densities of 200–300 thousand stems per ha and an average height of around 1.3 m. The treatments compared were an unrespaced control, systematic respacing to 1.8 m, 2.1 m, and 2.6 m spacings, plus a worker selective respacing to a target 2 m spacing. There were four replicates of these treatments which were implemented using a brushcutter with an attachment which treated cut stumps with a 10 per solution of glyphosate. After 10 years, the density in the control plots was still much greater than in all the respaced treatments but there were already some 82 000 dead stems per ha in these plots showing that self-thinning was well underway. The height of the trees in the controls was significantly less than in all the respaced treatments while the worker select trees were significantly taller than those in the systematic respacings.

Advice for forest managers

Managers should consider the following points when planning how to manage regeneration.

Deciding whether to re-space

On sites of very low wind risk, where damage by wind or snow is unlikely before the trees reach 15–20 m in height, it may be possible to delay any intervention until the trees have self-thnned. However, such sheltered sites are rare in upland conifer forests, and respacing will usually be necessary to reduce tree density and increase the stability of the stand. This will also limit the number of small-sized dead and suppressed stems that will hamper the use of most harvester heads during mechanised thinning.

Other than on very stable sites, perhaps the only justification for not respacing is if the decision is made to manage the stand as short rotation forestry. Under this management regime, trees would be grown for 15–20 years and then all the standing stems harvested for wood fuel. This option would also allow subsequent restocking to take place using alternative species or genotypes.

When should respacing take place?

Respacing operations often take place when stands are around 1.5–2 m in height. This decision is influenced mainly by the ease of access to the regenerated trees. However, it can be difficult to see stem form when respacing regeneration at this low height, and therefore to select for better quality trees. Studies have shown appreciable changes in dominance ranking over the early years of the development of a regenerated stand, which suggests that respacing should be delayed until the tallest trees are 3–4 m tall. However, this can result in dense stands that can be extremely difficult to access and to work.

Figure 3 Advance regeneration of Sitka spruce in continuous cover forestry stands in Clocaenog forest.

Figure 4 Respacing of Sitka spruce natural regeneration.

A solution to this problem is the use of mechanised flails to cut access racks through the regenerated stand when the trees are 1–2 m tall. This should be followed by selective respacing some 3–5 years later when the retained trees are tall enough to make selection for better stem form more feasible. The racks could be cut at 15–20 m spacing to provide a safer working environment for subsequent manual operations. However, the practicality of this option requires more systematic operational studies.

What target density should be used?

The smaller the height at which respacing occurs, the more the target density should conform to that used in conventional plantations. Thus, if the operation is carried out when trees are 1–2 m tall, a target density of 2500 stems per hectare is recommended for Sitka spruce. However, if the trees are taller, around 3–4 m, and the site is a stable one where thinning is likely, the target density could be reduced to 2000–2250 stems per ha. On sites where windthrow risk is high, then a lower density of 1750–2000 stems per ha is more appropriate. The selection process should be based on moving the desired distance through the stand (i.e. 2–2.5 m for the examples above) and then favouring the best form tree and removing all its competitors. It is very important that the trees are cut below the bottom live whorl to prevent regrowth from the cut stump.

What about conifers other than Sitka spruce?

Natural regeneration of conifer species other than Sitka spruce is also often found in British forests, as well as mixtures of conifers and broadleaves. The same general principles of stand development will apply as for Sitka spruce – namely that self-thinning will progressively reduce stand density over time and that this process can be speeded up by respacing. It is generally easier to work dense regeneration of other species than Sitka spruce, so respacing to select better quality stems can be carried out when the trees are taller. Results from experiments with conifer–broadleaved mixtures suggest that faster growing conifers will progressively dominate broadleaves, and that respacing can be a useful means of maintaining a more varied species composition in mixed stands.

How should dense natural regeneration in continuous cover forestry be managed?

The principles of managing regeneration in continuous cover forestry stands are similar to those described above for even-aged stands. The main difference is that the presence of the overstorey trees will create a variable environment for the developing seedlings so that, at a given height, the range of tree sizes within the regeneration will be greater than on a restocking site. Studies in Scandinavia and other countries suggest that the overstorey trees will supress the growth of regenerated seedlings within a radius of 5–10 m. This variable environment can result in understorey trees with large branches – these potential 'wolf' trees should be removed to favour better quality stems.

Felling some or all of the overstorey trees can offer a chance of respacing the regeneration, either through physical damage to the seedlings caused by the felling and extraction, or because of the need to provide greater visibility for operator safety.

Figure 5 A mixed conifer forest undergoing transformation to continuous cover forestry.

Box 2 – Summary of advice for forest managers

Naturally regenerating stands of conifers will self-thin over time. Managers can influence this process by respacing operations where appropriate and should aim to:

- Use respacing if it provides benefits for future stand stability, particularly on sites that are marginal for thinning.
- Use selective respacing to favour better quality stems, or preferred species in mixtures.
- Delay respacing until the tallest trees are 3–4 m tall if quality improvement is a key objective, to allow better choice of trees with good stem form.
- Respace stands on the most productive (i.e. highest yield class) sites first.
- Respace the lowest windthrow risk sites first.
- Respace the densest stands first.
- Use a target density of 1750–2500 stems per hectare, with the lower figure applicable to sites of higher windthrow risk where no subsequent thinning is planned.
- Use respacing to remove any small dead stems that could hamper harvester operations in early thinnings.
- Cut racks at regular intervals in areas with extensive regeneration to provide easy access and safer working conditions.

Useful sources of information

Publications

An ecological site classification for forestry in Great Britain.
Forestry Commission Bulletin 124.
Forestry Commission, Edinburgh.

Forest Gales
A PC-based wind risk model for British forests.
Forestry Commission, Edinburgh.

Forest Yield (in prep).
A PC-based yield model for forest management in Britain
Forestry Commission, Edinburgh.

Managing mixed stands of conifers and broadleaves in upland forests in Britain.
Forestry Commission Information Note 83.
Forestry Commission, Edinburgh.

Natural regeneration of conifers in Britain.
Forestry Commission Bulletin 120.
HMSO, London.

The identification of soils for forest management.
Forestry Commission Field Guide.
Forestry Commission, Edinburgh.

Ecology and management of Sitka spruce, emphasising its natural range in British Columbia.
UBC Press, Vancouver.

Forest stand dynamics.
John Wiley and Son, New York.

Research articles and other literature

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