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Regeneration dynamics of Sitka spruce in artificially created forest gaps

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Abstract

This study examined the variation in the development of naturally regenerated and planted seedlings of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) within gaps cut in a 32-year-old stand of the same species. The circular gaps were 20 m in diameter and designed to allow sunlight into only half of the gap floor at midsummer given the latitude of 56°45′N. Eight plots (8 m × 3 m) were laid out along a north–south transect through each gap (four within the gap and two each under the closed canopy north and south of the gap). Each plot was sub-divided and seedlings were planted into one part and the other part was left to naturally regenerate. In subsequent seasons, plots were further subdivided into 'weed free' and 'vegetation left untouched'. Results showed that while the two central plots within the gaps had the highest value of canopy openness, the highest accumulated temperature and lowest soil moisture were recorded in plots that received direct sunlight. However, level of germination was significantly higher in the shaded area of the gap than in the part that received direct sunshine suggesting that higher moisture levels in shaded areas are important to successful germination. Minimal germination was recorded in the plots beneath the canopy. Seedling survival was significantly influenced by the influx of competing vegetation, but only in the part of the gaps that received direct sunlight. The success of Sitka spruce regeneration within gaps appears to depend on sufficient moisture and light to support regeneration and early growth, but not too much light to encourage the development of competing vegetation. The permanently shaded areas of the gaps appeared to offer ground conditions with sufficient moisture and light to ensure successful germination and early growth of seedlings, but without excessive competition from other vegetation.

Keywords: Sitka spruce; Forest gaps; Natural regeneration

1. Introduction

The process of transforming largely even-aged plantation forests into more diverse structures has become an important feature of forest management in many temperate regions of the world. One of the simplest approaches to transformation involves creating discrete openings in regular stands and the establishment of small centres or groups of regeneration continuously over a long period until a 'balanced' distribution of size classes is achieved (Smith et al., 1997). Previous research on transformation using groups has concentrated on germination and early growth of the target species, particularly in relation to optimising gap size (e.g. Smith, 1986; Marquis, 1989; Malcolm et al., 2001) and gap light conditions (e.g. McLaughlin, 1978; Poulson and Platt, 1989; Canham, 1989; Canham et al., 1990; Lieffers et al., 1999). However, there is insufficient understanding of how variation in micro-environmental conditions, such as temperature and soil moisture, within gaps influences the process of regeneration.

The forest floor is a heterogeneous environment where a wide range of conditions can be experienced (Lieberman et al., 1989). Growth of young trees is closely associated with the amount of light received (e.g. Minckler, 1961); with the highest light level found in the centre of a gap, and the lowest at the edge. The closer young trees are to the edge of gaps, the greater the influence that the surrounding trees will have on their growth and development (Malcolm et al., 2001). However, the light environment within gaps is not uniform from the centre to the edge because of the angle of sunlight experienced in cool temperate regions at higher latitudes. In the northern hemisphere, some direct sunlight may reach the forest floor on the north side of even relatively small gaps while the south side of the gap remains in permanent shade. This creates an imbalance in the microenvironment across gaps in a north to south direction. Understanding the effect of this imbalance in environmental conditions on germination and establishment

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of natural regeneration and on the survival and growth of planted seedlings is essential if the group system is to be used successfully for transforming largely even-aged stands into irregular structures.

The aim of this study was to determine whether the variation in exposure by sunlight within artificially created gaps influences the development of natural regeneration and planted seedlings of Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Sitka spruce is classed as being moderately shade tolerant (Minore, 1979) and is considered a suitable species for group regeneration (Malcolm et al., 2001).

2. Materials and methods

2.1. Study site and creation of gaps

The experimental site is located in Kindrogan Forest in Tay Forest District, Mid-Scotland (56°45′N, 3°34′W, National Grid Reference no. 041629). The mean annual rainfall is 1164 mm. Soils are mainly well-drained iron pans with an underlying geology of Upper Dalradian quartz–mica schist. The study area (compartment 5711a) is located on a north facing slope (6°) at a mean altitude of 370 m. It was planted in 1965 with Sitka spruce and has been thinned once in 1993. Average top height of the stand at the time of the experiment was 17 m.

Six locations for cutting gaps were randomly identified in spring 1997. Taking into account the angle of the sun at this latitude and the slope of the ground, a gap diameter of 20 m (measured from the stem) was calculated to allow direct sunlight to reach the floor of up to half the gap area for a few months of the year (Fig. 1). The trees were felled and the harvest residues removed. No machines were permitted to enter the gaps to avoid soil compaction. No other site preparation was undertaken. Initial ground vegetation was very sparse. The surface mainly comprised of litter (depth ~3 cm) with a few patches of bryophytes (mainly *Polytrichum* spp.).

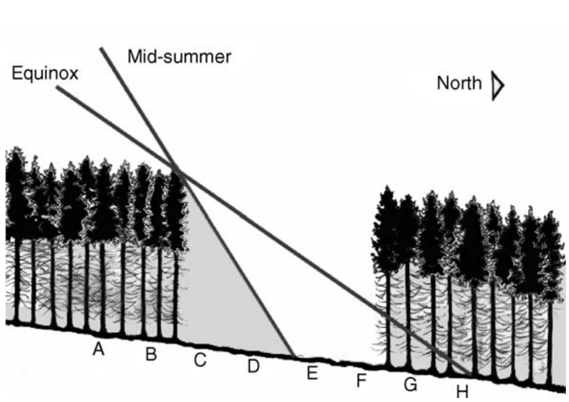

Fig. 1. Diagram of the cross-section of a gap and the location of the plots A–H. Plots E–H receive direct sunlight for part of the year whereas plots A–D are in permanent shade. The figure is approximately to scale so the sun paths are accurate.

2.2. Sample plots and treatments

Eight plots (8 m × 3 m) were laid out along a N–S transect through each gap (Fig. 1). Four plots were located within the gap area (C–F) and two each under the closed canopy south (A and B) and north (G and H) of the gap. The plots were partially protected from deer damage by 1.2 m high fences.

Three 2 m × 2 m subplots were laid out within each main plot, 0.5 m apart and 0.5 m from the fence. Each sub-plot was randomly assigned to one of three treatments: (1) planted with Sitka spruce seedlings; (2) sown with Sitka spruce seed; (3) left untouched for natural regeneration to establish from the seed rain. The purpose of sowing seed was to provide a fallback should natural regeneration fail. This was a necessary precaution since good seed years only occur with Sitka spruce every 3–5 years on average (Harris, 1990). The 2 m × 2 m subplots were designed to be subdivided in the second year of the experiment into four 1 m^2 square plots. Two of these smaller plots were randomly selected for weeding while the remaining two were left untouched. The weeded areas were hand weeded throughout the spring and summer of the second growing season to remove all herbaceous vegetation, namely *Deschampsia caespitosa* (L.) Beauv. and *Juncus effuses* (L.). Therefore, the experimental design consisted of six gaps (replicates), eight plots per gap and two weeding treatments per plot.

Forty-nine, 2-year-old Sitka spruce seedlings (22–25 cm tall) of Queen Charlotte Island (QCI) provenance were planted within the 2 m × 2 m subplots at 0.32 m spacing in April 1998. Seed, also of QCI provenance, were sown in the 2 m × 2 m subplots in parallel rows at a density of 30 m^{-2} in April 1998. No weeding treatment was applied. The experimental design consisted of six gaps (replicates) and eight plots per gap.

2.3. Measurements

Weekly measurements were made on the natural regeneration plots during the first two growing seasons (May–September). Each new germinant was marked with a numbered tag indicating the day that it was first observed. Subsequently, weekly monitoring noted stage of development (i.e. 1- or 2-year-old seedlings) and mortality. Valid measurements beyond this were not possible due to the erratic nature of seedling losses.

Weekly measurements were also made in the planted seedling plots. Due to the relatively large size of the planted seedlings in relation to the developing ground vegetation, weeding was not necessary. Level of mortality and height growth were assessed over five growing seasons. Browsing damage by deer, observed as loss of apical or side shoots, was recorded within the plots in the second year of measurement (1999).

2.4. Environmental monitoring

Temperature was monitored within each plot using Orion Tinytalk II Data Loggers (Gemini Data Loggers (UK) Ltd.)