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Sitka Spruce and Douglas fir Seedlings in the Nursery and in Cold Storage: Root Growth Potential, Carbohydrate Content, Dormancy, Frost Hardiness and Mitotic Index

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SUMMARY

Seedlings (transplants) of 2+ 1 Sitka spruce *(Picea sitchensis* (Bong.) Carr.) and 1+1 Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco) were grown in a nursery at the Bush Estate, Scotland. Batches were lifted and cold stored at 0.5 °C in November, December and January. Changes in growth, shoot apical mitotic index, root growth potential (RGP), carbohydrate content, bud dormancy and shoot frost hardiness were monitored throughout the winter by taking samples at intervals from the nursery and from cold storage.

Frost hardening occurred during the later stages of bud development (as mitotic indices decreased); autumn hardening was arrested when seedlings were put in cold store, and some dehardening occurred in cold storage, especially in spring. *Bud dormancy* started, and was greatest, just after bud growth (mitotic activity) virtually ceased; chilling in cold store was almost as effective in releasing dormancy as natural chilling. The concentration of *total nonstructural carbohydrates* stayed more or less constant at 100- 150 mg g^{-1} from September to April in the nursery; in cold storage carbohydrates were depleted at 0.4-0.6 mg g^{-1} d^{-1} (corresponding to respiration at 0.03-0.05 mg CO_2 g^{-1} h^{-1}) until there was only 40-50 mg g^{-1}.

Root growth potentials in the nursery increased in December, once the buds ceased growth, became dormant *and* had received some chilling. Sitka spruce was 'storable' in November, before RGPs increased, but they then failed to achieve maximal frost hardiness or RGP. Winter RGPs were high in Sitka spruce and were increased or maintained in cold storage, whereas RGPs were low in Douglas fir and decreased immediately after storage (except when stored in January). By the end of April, the RGP of cold stored Sitka spruce was much higher than that of direct lifted plants. RGP changes in the nursery and in cold storage were not *consistently* related to changes in seedling carbohydrate contents, shoot frost hardiness or bud dormancy.

In practical terms, it was concluded that (1) the optimum date to start lifting bare-rooted conifer transplants in the autumn is when their shoot apical mitotic indices have decreased to near zero, and their RGPs have risen sharply; (2) high RGPs may depend as much on the morphology of the roots (e.g. number of undamaged root apices) as on the physiology of the shoots (e.g. carbohydrate status, dormancy and frost hardiness); and (3) in spring, transplants kept in cold storage since November. December or

January are more frost hardy, slightly more dormant, and (in May) have higher RGPs than transplants lifted from the nursery.

INTRODUCTION

There is compelling evidence that one of the preconditions for the survival and rapid initial growth of outplanted tree seedlings is a high root growth potential (RGP) - the ability of a bare-rooted seedling to produce new roots rapidly (Ritchie and Dunlap, 1980; Burdett *et al.,* 1983; Feret and Kreh, 1985). RGP depends on the morphological and physiological status of the seedlings, which can in turn be affected by treatments in the nursery, lifting date, cold storage and handling (Duryea and Brown, 1984; Duryea and Landis, 1984; Duryea, 1985; South, 1985; Tabbush, 1986).

Since Stone *et al.* (1962) introduced the notion of RGP, there has been a growing literature on its relationship with seedling physiology, and on relationships between different physiological parameters *(locs. cit.).* The physiological parameters measured have been mainly seedling carbohydrate content, bud dormancy, shoot frost hardiness and shoot apical mitotic index.

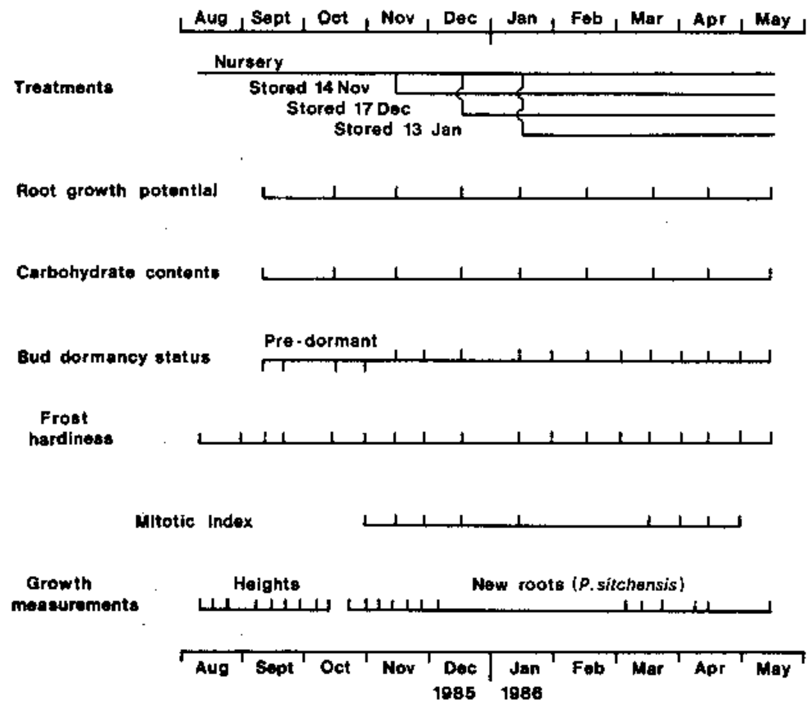

Figure 1. Experimental details, showing the periods of three cold storage treatments, and the dates when different measurements were taken on the seedlings.

However, without exception, only one or two of those parameters have been related to RGP in any one study. This paper describes a study in which all those parameters were measured simultaneously within seedlings of Sitka spruce and Douglas fir both in the nursery and during different periods of cold storage. The study gave useful practical information on the optimum times of lifting, and on the effects of cold storage on seedling physiology and RGP.

MATERIALS AND METHODS

Plant material

The study was conducted on 2+ 1 seedlings (strictly `transplants') of Sitka spruce *(Picea sitchensis* (Bong.) Carr.) of Queen Charlotte Islands, BC origin (provenance no. 79 (7111)1) and 1 + 1 seedlings of Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco.) of Washington (Darrington) origin (provenance no. 78(7974)3).

In spring 1985, the seedlings (2-year-old Sitka spruce, and 1-year-old Douglas fir) were lined out in nursery beds of clay loam at the Forestry Commission, Northern Research Station, near Edinburgh, Scotland (55°51'N, 185 m altitude). The Sitka spruce were spaced 10 cm in rows 20 cm apart (6 rows per bed; 50 plants m^{-2}); the Douglas fir were spaced 5 cm in rows 20 cm apart (100 plants m^{-2}).

The seedlings were unaffected by weeds, pests, pathogens or mineral deficiencies. However, the soil was saturated during periods of heavy rainfall in the autumn of 1985, and some roots died, especially on the Douglas fir. About 50 per cent of the roots of Sitka spruce were mycorrhizal, but few mycorrhizas could be seen on the roots of Douglas fir.

Treatments and design

There were four treatments for each species.

1. Seedlings were left to grow in the nursery, and batches were lifted and measured on up to 18 occasions between August 1985 and May 1986. Dead and small seedlings were omitted. Not all measurements were made on all occasions (see Figure 1). The number of seedlings used for each measurement was 20 for root growth potential, 20 for carbohydrate analysis and seedling dry weights, 15 for estimates of bud dormancy and 15 for estimates of frost hardiness, 10 of which were used to measure shoot mitotic indices.
2. Seedlings were lifted on 14 November 1985 and stored in the dark in polythene bags at 0.5°C (± 0.5°C). Pre-assigned batches were removed from store for measurement on up to 11 occasions between November 1985 and May 1986 (Figure 1).
3. Seedlings were lifted on 17 December 1985 and stored as above, and batches were removed and measured on up to nine subsequent occasions.