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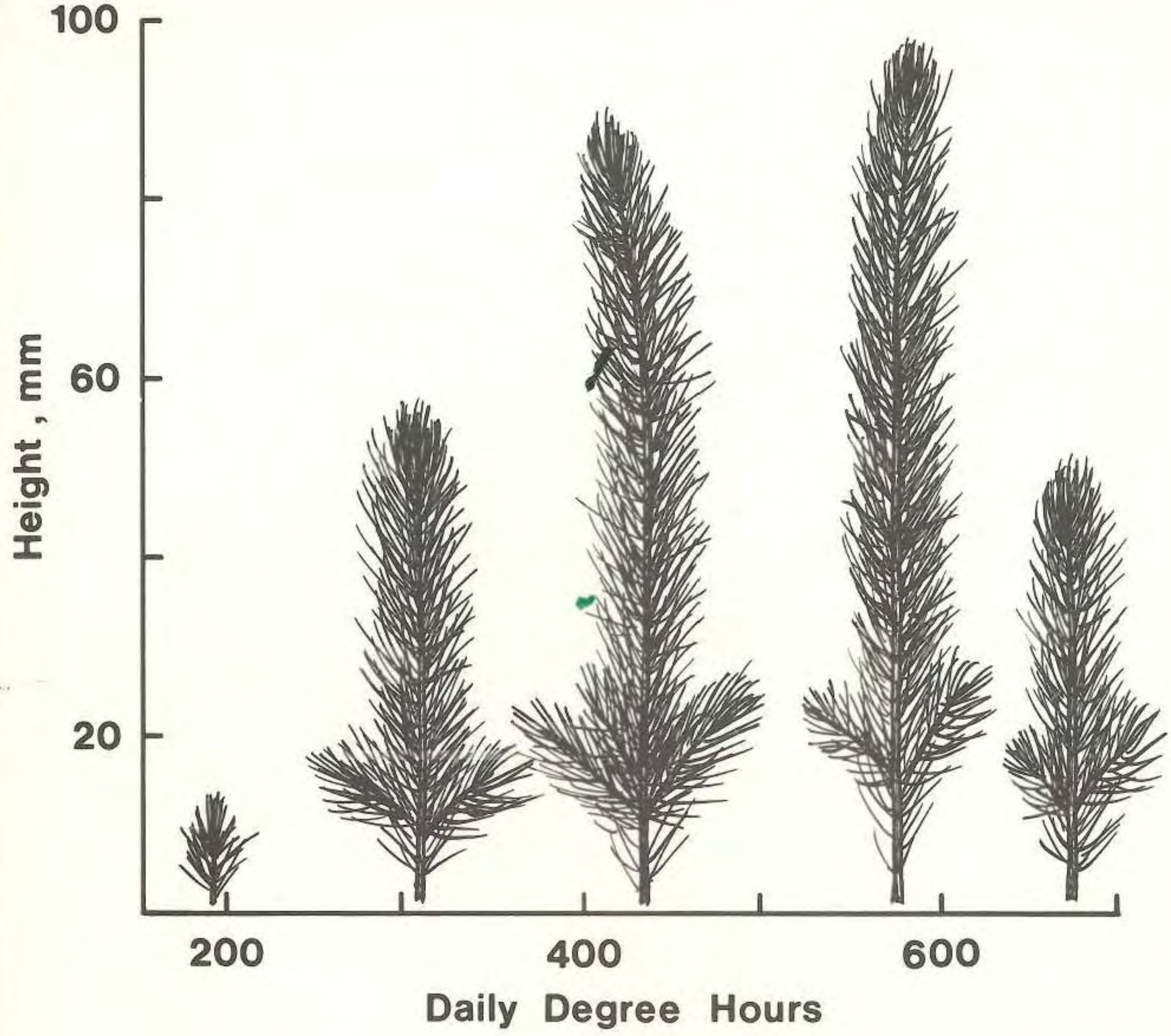

Growth Response of Sitka Spruce and White Spruce Seedlings

TO TEMPERATURE AND LIGHT INTENSITY

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GROWTH RESPONSE OF SITKA SPRUCE AND WHITE SPRUCE SEEDLINGS TO TEMPERATURE AND LIGHT INTENSITY

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ABSTRACT

Seedlings from two seed sources of Sitka spruce and of white spruce were grown in growth rooms under nine temperature regimes and two light intensities (450 and 1000 ft-c) for 130 days following germination. Temperatures ranged from 8 to 28 C; in some regimes, it differed between day and night; in others, it was constant. Seedlings were thereafter analyzed for total dry matter production (d.m.p.), stem height and basal diameter, and for dry matter distribution to leaves, stem, roots and branches. With constant day-night temperatures, d.m.p. increased greatly in the 8 to 18 C range. With an increase from 18 to 24 C, the growth response varied with seed source and light intensity but, in most cases, there were no changes in growth. A further increase in temperature to 28 C decreased growth considerably, except for white spruce, at low light intensity. Some day-night temperature differential was beneficial for d.m.p.; the 24 C day and 18 C night combination generally was best for both species. Height growth was optimum for Sitka spruce in the 18 to 24 C range, but best at 24 C for white spruce. Stem diameter growth was greatest in the 18 to 24 C range for Sitka spruce, but 28 C was equally favorable for white spruce at low light intensity. Dry matter distribution was affected little by temperature between 13 and 24 C, but a higher or a lower temperature decreased the percentage of roots and increased the percentage of leaves at the high light intensity. An increase in light intensity from 450 to 1000 ft-c greatly increased d.m.p. and stem diameter, but had no effect on height growth. Sitka spruce was more shade tolerant than was white spruce. An increase in light intensity decreased the percentage of leaves and stem and increased the percentage of roots at all temperatures except the lowest (8 C) and the highest (28 C).

INTRODUCTION

Knowledge of environmental effects on growth of tree seedlings is required for selection of nursery sites and for development of good nursery practice. It is also needed for appropriate preparation of regeneration sites, selection of microsites during planting and for subsequent cultural treatments aimed at securing good survival and growth. With the growing reliance on planting and a consequent increasing demand for high-quality nursery stock in British Columbia, there is an urgency for improved knowledge of environmental effects on seedling growth. Previous reports have dealt with light and temperature effects on growth and physiology of Douglas-fir and western hemlock seedlings (Brix 1967, 1969, 1971). This study is concerned with the effect of the same factors on growth of Sitka spruce (*Picea sitchensis* (Bong.) Carr) and white spruce (*Picea glauca* (Moench) Voss) seedlings.

MATERIALS AND METHODS

Two seed sources were studied for Sitka spruce (SSI: Moresby, Queen Charlotte Islands and SS2: Kalum River, Terrace, B. C.) and two for white spruce (SWI: near Prince George, B. C. and SW2: Hazelton, B. C.). After stratification, seeds were sown and germinated in a mixture of equal parts of peat moss and sand. When cotyledons had just unfolded, the seedlings were transplanted in 7-inch plastic pots containing equal parts of peat moss and course sand, with added fertilizers (Brix 1967). Plants were well watered and fertilized throughout the growing period; seven were planted in each pot, and the number was later reduced to five. After a 5-day establishment period at 18 C under a low light intensity (450 ft-c), pots were transferred to growth rooms with different temperature regimes. They were placed at a distance from the light source giving either a 450 ft-c or 1000 ft-c light intensity at the top of the plants. Cool white fluorescent tubes (General Electric) supplemented with incandescent bulbs were used as light source. For a similar light source, Friend et al. (1962) determined the energy value in the 400-720 nm spectral range to be 0.00 54 g cal. cm^{-2} for 100 ft-c.

Nine day-night air temperature combinations were used, corresponding to the 16-h light and 8-h dark periods. The following combinations were tested, with day temperatures (°C) listed first: 28/28, 28/13, 24/24, 24/18, 24/13, 18/18, 13/24, 13/13 and 8/8. Temperature regimes were selected to give a wide range of temperatures, and to test the effect of a constant versus a differential day-night temperature regime. Air temperature varied less than $\pm$ 1 C from that stated throughout the experiment, and leaf temperature did not exceed the ambient air temperature by more than 1 C at any of the light intensities. Leaf temperature was measured with an infrared thermometer (Barnes Engineering Co. Model PRT-10L). Water vapor pressure deficit of the air was kept at 4.5 mm Hg except at low temperatures (8 and 13 C), where it was about 3 mm.

For each temperature-light combination and for each seed source, 20 seedlings were harvested 130 ($\pm$1) days after they were transplanted in the 7-inch pots. Measurements were taken of root length, basal stem diameter, stem length, fresh weight of root and top, and oven-dry weight of stem, branches, leaves and roots. Data were analyzed by Duncan's new multiple range test. In all figures, points not followed by the same letter are significantly different ($p = 0.05$).

RESULTS

Dry Matter Production

Total dry matter production (d.m.p.) for seedlings of the two species is given in relation to the daily heat sum supplied for each of the two seed sources and two light intensities (Figs. 1 & 2). The heat sum is expressed as daily degree hours and is calculated as day temperature (°C) times hours of daylength (16) plus night temperature times hours of darkness (8). Curves are drawn for temperature regimes with equal day and night temperatures.

All variables, i.e., species, seed source, temperature and light intensity, as well as interaction between light intensity and temperature, affected dry matter production.

Sitka spruce. With a constant day-night temperature regime, dry matter production increased approximately linearly with increase in temperature from 8 to 18 C (Fig. 1). A further increase to 24 C produced some growth increment for the SS1 seed source; for the SS2 source, there was no further increase at low light and a slight decrease at 1000 ft-c. An additional raise in temperature to 28 C produced a marked growth decrease for both seed sources at both light intensities. A differential day-night temperature regime was beneficial; the 24/18 regime was outstanding. The high temperature (28 C) was not harmful if combined with a cool (13 C) night. Seedlings did not benefit much by a warm night (24 C) if the day was cool (13 C).

Light intensity affected the temperature response, in that a high constant temperature (28 C) reduced d.m.p. less at low than at high light. Light intensity also affected d.m.p. at all temperatures except the highest. An increase from 450 ft-c to 1000 ft-c almost doubled d.m.p. with temperatures up to 24 C.

White spruce. The response of this species to temperature was similar to that of Sitka spruce, with constant temperatures up to 24 C (Fig. 2). However, a constant high temperature (28 C) was less detrimental to white spruce; in fact, at low light intensity, growth was unaffected by temperatures between 18 and 28 C for one seed source (SW2) and best at 28 C for the other. The 24/18 regime was better than the constant temperature with the same daily degree hours at both light intensities, and the 28/13 regime was favorable at low light.

Light intensity affected d.m.p. response to temperature, since a high temperature (28 C) was only detrimental at high light intensity. An increase in light intensity from 450 to 1000 ft-c was more beneficial to growth of white spruce than to Sitka spruce and d.m.p. more than doubled at most temperatures with this increase in light, especially for the SW2 seed source. This was a result of better growth of Sitka spruce than of white spruce at low light, rather than a species difference in growth at high light.

Height growth

In contrast to d.m.p., height growth was not affected significantly by light intensity at any temperature; conversely, temperature had the same height-growth effect at both light intensities (Figs. 3 & 4). For white spruce, height growth was somewhat better at 24 than at 18 C, whereas growth was similar for Sitka spruce at these temperatures. Although some benefit of a differential day-night temperature regime was noticed, it was not as great as the benefit of this regime on d.m.p.

Stem diameter growth

With a constant temperature, diameter growth of Sitka spruce at both light intensities was best at 24 C for one seed source (SS1), and from 18 to 24 C for the other (Fig. 5). White spruce had a broader optimum range from 18 to 28 C, with the exception of one seed source at high light for which 28 C was above optimum (Fig. 6B). However, for both species, the differential day-night temperature regime of 24/18 appears to be best.

An increase in light from 450 to 1000 ft-c greatly increased diameter growth, except at the highest temperature (28 C). On the average, the light effect was greater for white spruce than for Sitka spruce, but differences in response between seed sources for each species were apparent.

Dry matter distribution

Light and temperature effects on the distribution of dry matter to roots, leaves, stem and branches were not significantly different for the two seed sources of each species, and only the average values for the two sources are presented (Figs. 7&8). Also, the two species responded in the same manner to light and temperature, although the relative amounts of the different plant parts differed between the species; i.e., white spruce had a higher percentage of stem and root and less leaves and branches than Sitka spruce.

The temperature effect between 13 and 24 C was only slight; decreasing the temperature below and increasing it above this range decreased the percentage of root and increased the percentage of leaves at high light, but not at low light. An increase in temperature produced a small but significant increase in percentage of branches, but it had no effect on percentage of stems.

An increase in light intensity decreased the percentage of stem and leaves and increased the percentage of roots at all temperatures except the lowest (8 C) and the highest (28 C).

DISCUSSION

Extensive studies have not previously been made of temperature effect on growth of Sitka spruce and white spruce seedlings, but there have been several investigations of growth in the field in relation to different intensities of shading. For Sitka spruce in a nursery, Fairbairn and Neustein (1970) recorded an increase in shoot and root length, as well as in dry weight and basal stem diameter, with increasing light intensity up to full light. This condition was more favorable to Sitka spruce than to any of the other five conifers studied (Douglas-fir, western hemlock, grand fir, European silver fir and Norway spruce). Four-year-old white spruce grown in the field under different shading intensities were almost twice as high at 60 as at 20 percent of full light (Eis 1967). A further increase to full light had little effect on height growth, but increased diameter growth and seedling dry weight. Logan (1969) grew white spruce and other conifers outdoors for 9 years under various degrees of shade. The heaviest white spruce plants were produced under full light, but height growth was equally good at 45 and 100 percent light. Similar results were obtained by Shirley (1945) with 4-year-old white spruce seedlings. In a study of natural regeneration in the Rocky Mountains, Day (1964) found that nearly all white spruce seedlings grew in locations with some shade during part of the day; less than 5 percent of the seedlings were entirely in the open. The beneficial effect of shade found in some field studies appears to result from a reduced evapotranspiration and avoidance of lethal soil surface temperatures (Place 1955; Glew

1963; Waldron 1966). This would explain the difference in growth response to shade where plants are irrigated (e.g. nurseries) or well established, and in some field conditions where they are not. Also, the light requirement for optimum growth is likely to change with plant size since, the bigger the plants, the more mutual shading of leaves is provided.

The d.m.p. of Sitka spruce approximately doubled with increase in light from 450 to 1000 ft-c for temperatures up to 24 C. With this increase in light, Krueger and Ruth (1969) found a doubling of the rate of photosynthesis of Sitka spruce seedlings; maximum rates were reached only with light intensities of 2300 ft-c and above. Hodges and Scott (1968) showed that seedlings of Sitka spruce and some other conifers growing in a border strip, near a stand with diffuse light, during most of the day, had a higher rate of photosynthesis per day than seedlings in the open or inside the stand. This was the result of better seedling water relations in the border strip than that attained in the open.

At high light intensity, d.m.p. differed little between the two species except at high temperature; here, white spruce was the most productive. At low light, d.m.p. of Sitka spruce was considerably better than that of white spruce at most temperature regimes, and thus Sitka spruce was more shade tolerant.

Whereas light intensity in this study greatly affected d.m.p. and stem diameter of both species, it had little or no effect on height growth. This follows the pattern in the above-mentioned studies, and similar results were obtained for western hemlock and Douglas-fir seedlings (Brix 1971).

Differences in growth response to temperature and light intensity were found between seed sources for each of the two species, especially at 24 and 28 C. Considering the extensive geographic range of both species, even greater differences are likely to exist. Species differences could also be recognized. Sitka spruce showed a greater sensitivity than white spruce to high (28 C) temperature; in fact, at low light, d.m.p. and stem diameter growth of the latter were not adversely affected by this temperature. This appears to be an ecological adaptation to their native habitat, since Sitka spruce grows under a cooler coastal climate where temperatures as high as 28 C are infrequent. Since the 24/18 C regime was superior to all others for both species, some difference between day and night temperatures will be beneficial.

Working with a constant air temperature (21.1 C), Chalupa and Fraser (1968) found a considerable effect of soil temperature on growth of white spruce seedlings. In the present study, air and soil temperatures could not be varied independently and were about equal in constant day-night temperature regimes. The relative contribution of air and soil temperatures to growth therefore could not be determined.

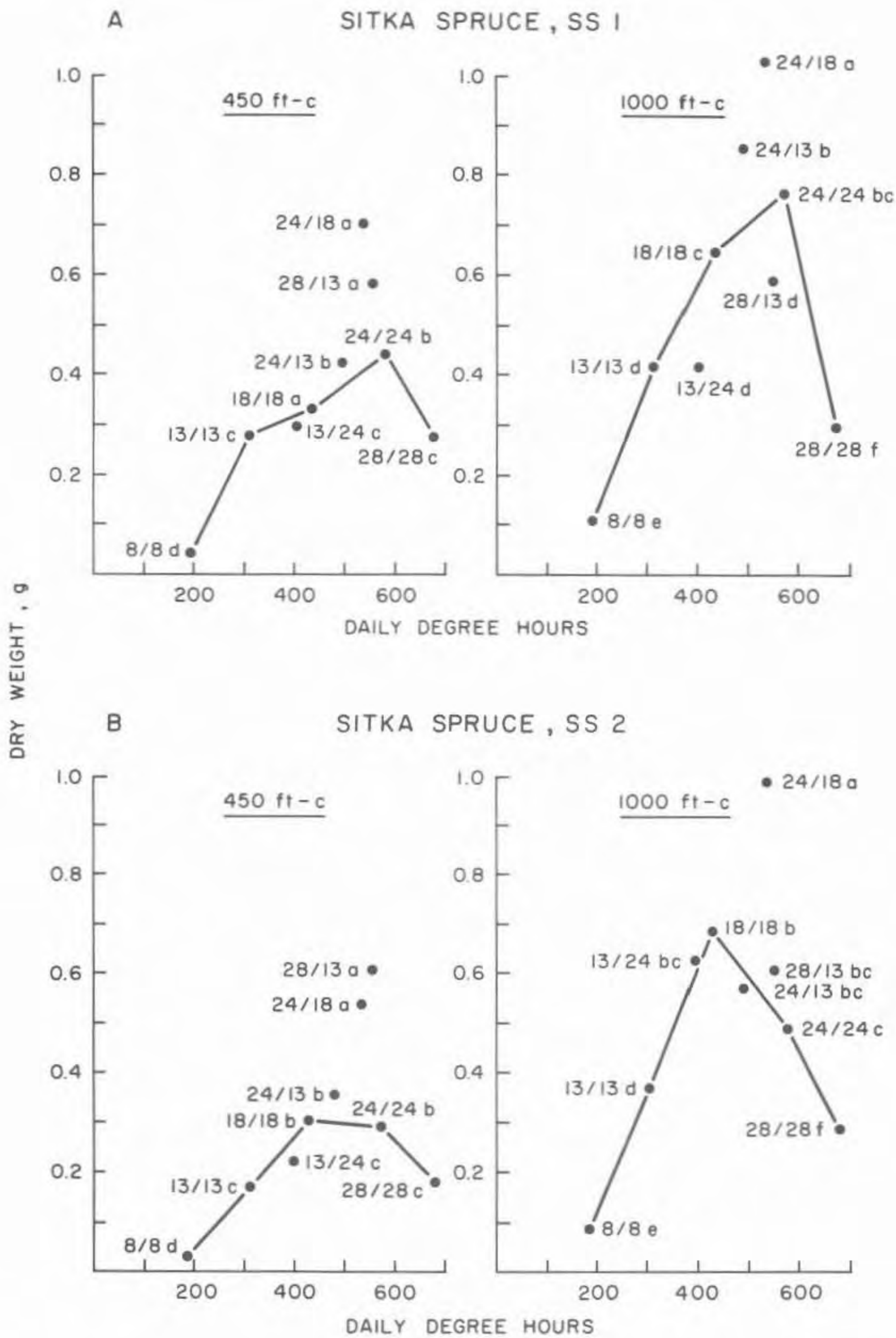

Fig. 1. Dry matter production of Sitka spruce in relation to temperature at light intensities of 450 and 1000 ft-c.
Seed source in A: Queen Charlotte Islands, B. C.
" " in B: Terrace, B. C.

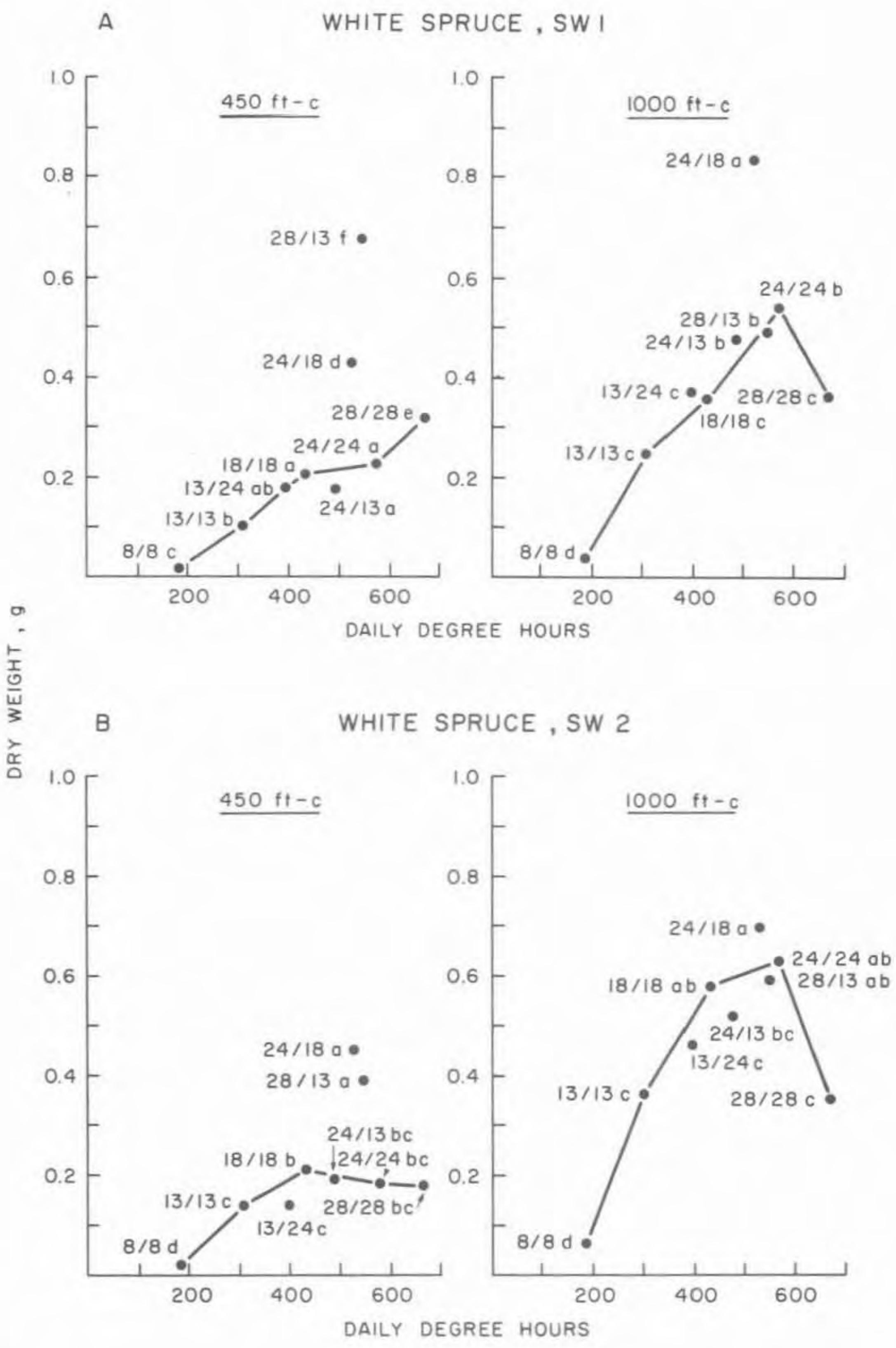

Fig. 2. Dry matter production of white spruce in relation to temperature at light intensities of 450 and 1000 ft-c.
Seed source in A: Prince George, B. C.
" " in B: Hazelton, B. C.

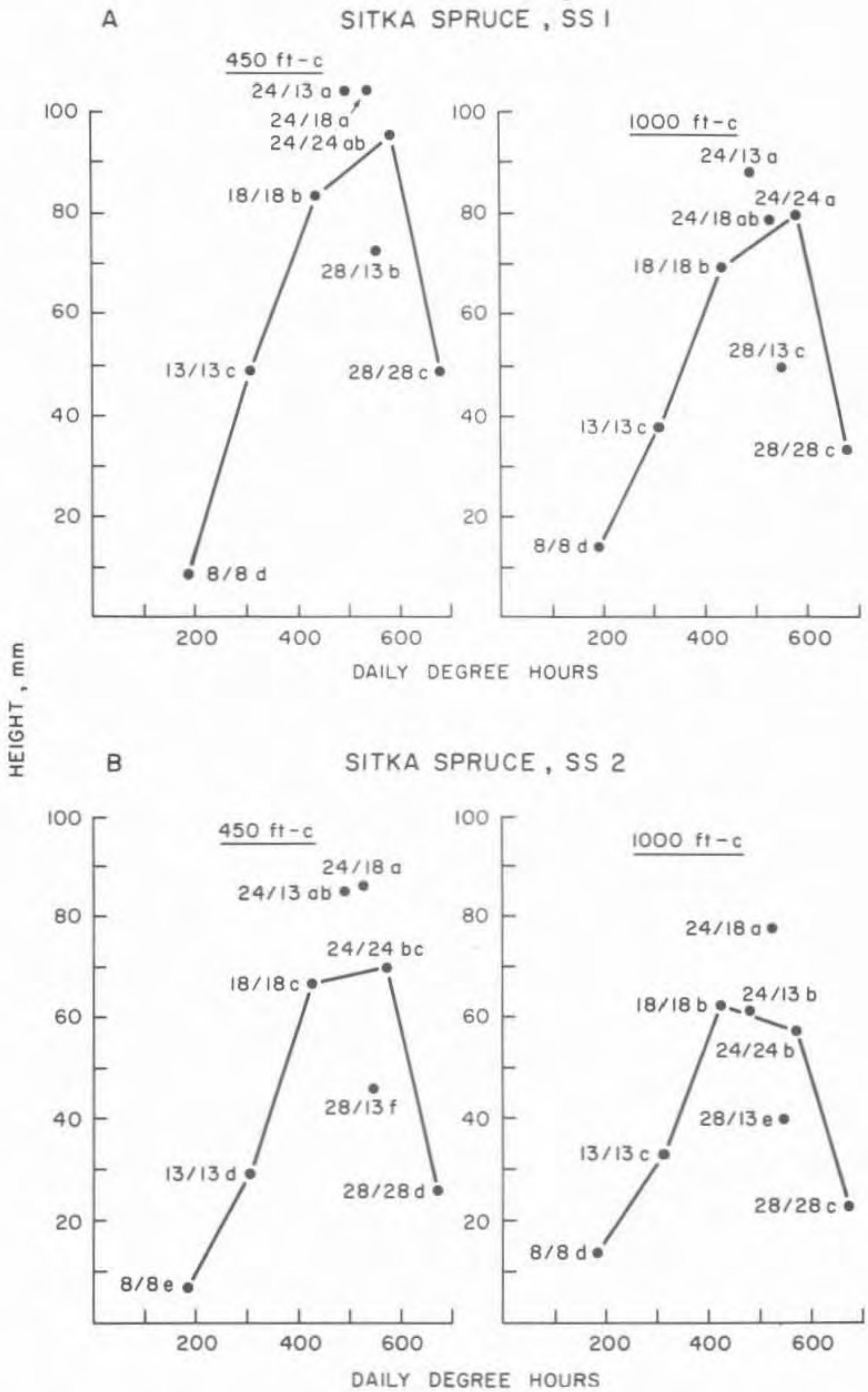

Fig. 3. Height growth of Sitka spruce in relation to temperature at light intensities of 450 and 1000 ft-c.
Seed source in A: Queen Charlotte Islands, B. C.
" " " B: Terrace, B. C.

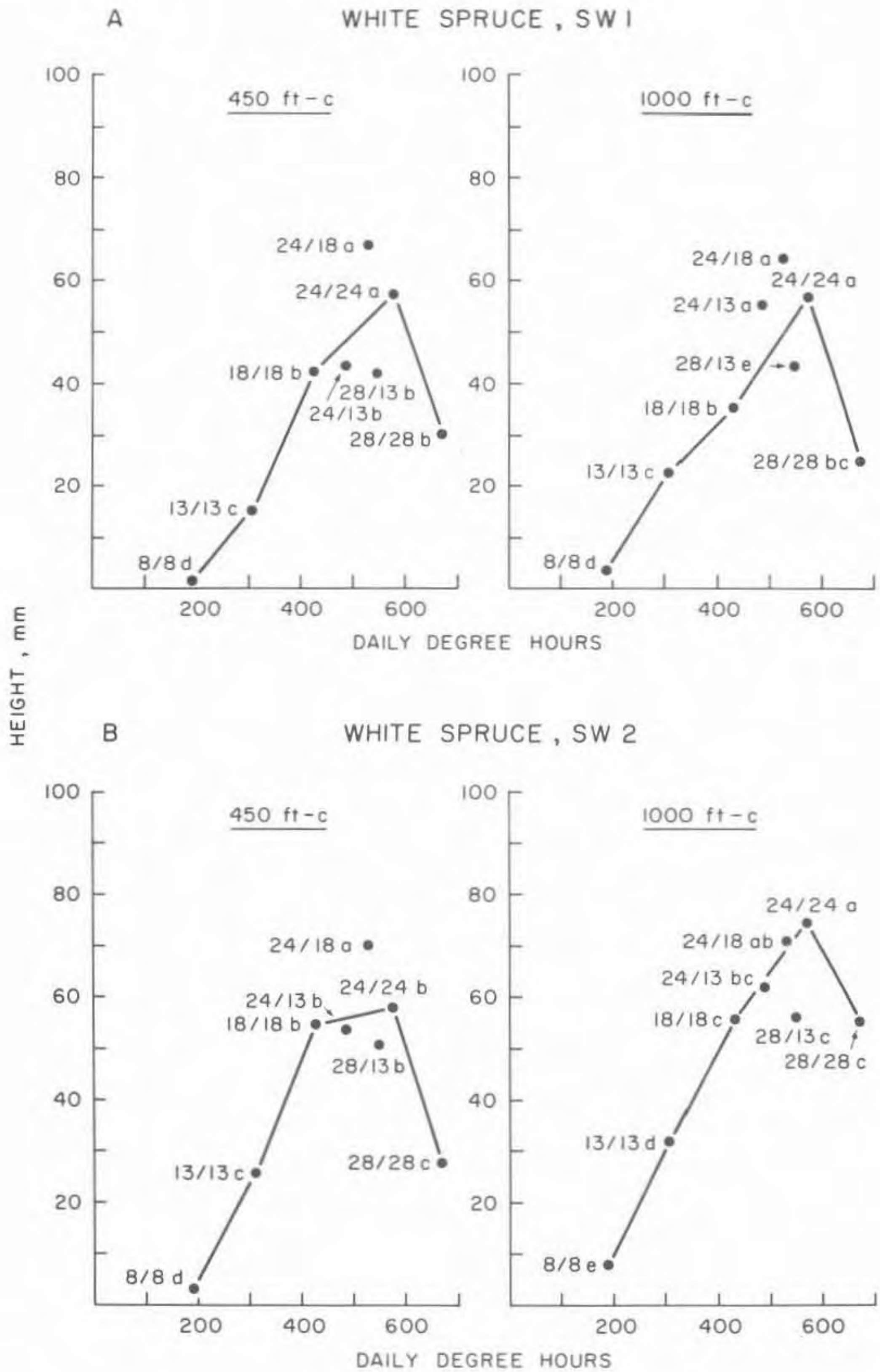

Fig. 4. Height growth of white spruce in relation to temperature at light intensities of 450 and 1000 ft-c.
Seed source in A: Prince George, B. C.
" " " B: Hazelton, B. C.

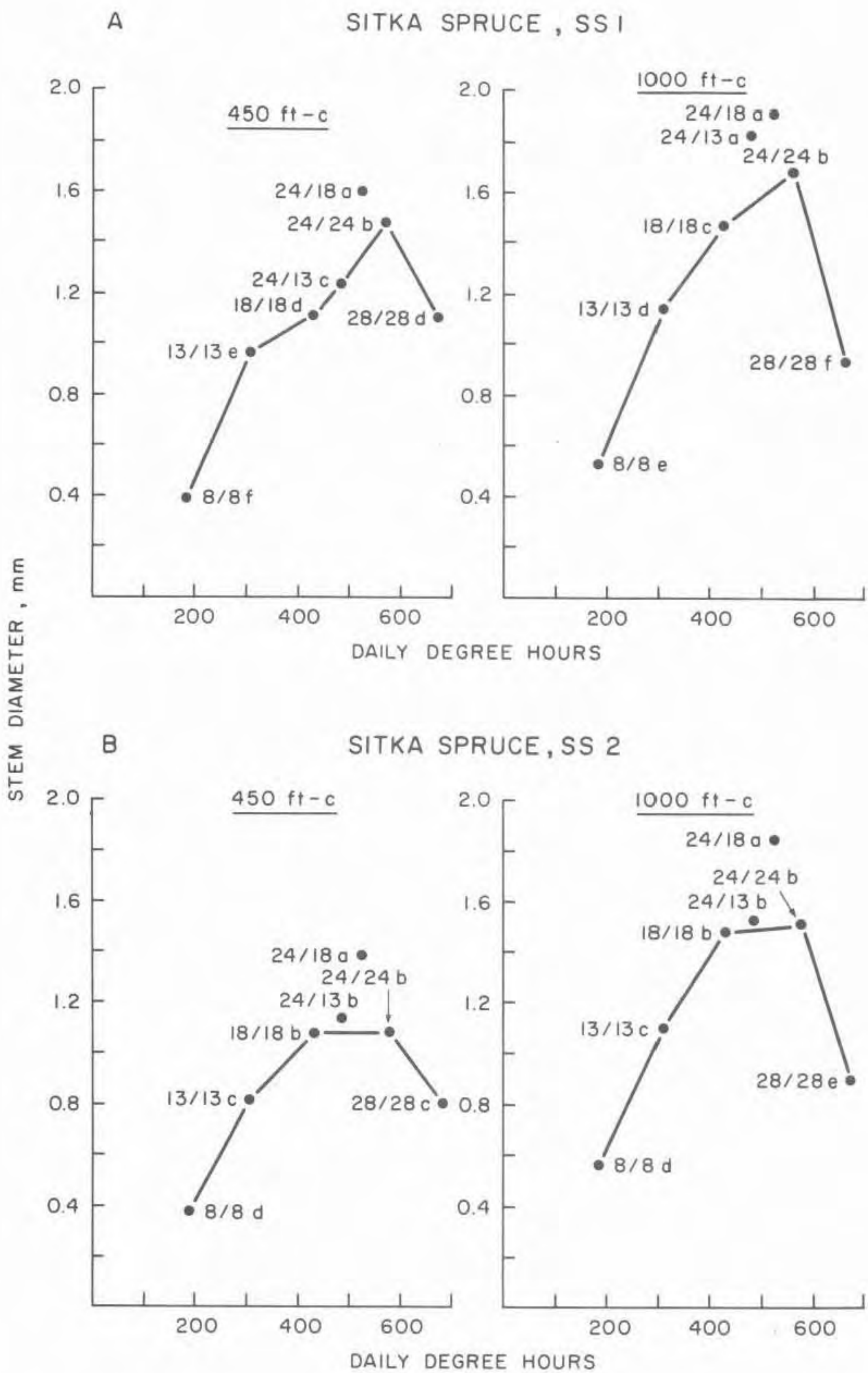

Fig. 5. Stem diameter growth of Sitka spruce in relation to temperature at light intensities of 450 and 1000 ft-c.
Seed source in A: Queen Charlotte Islands, B. C.
" " " B: Terrace, B. C.

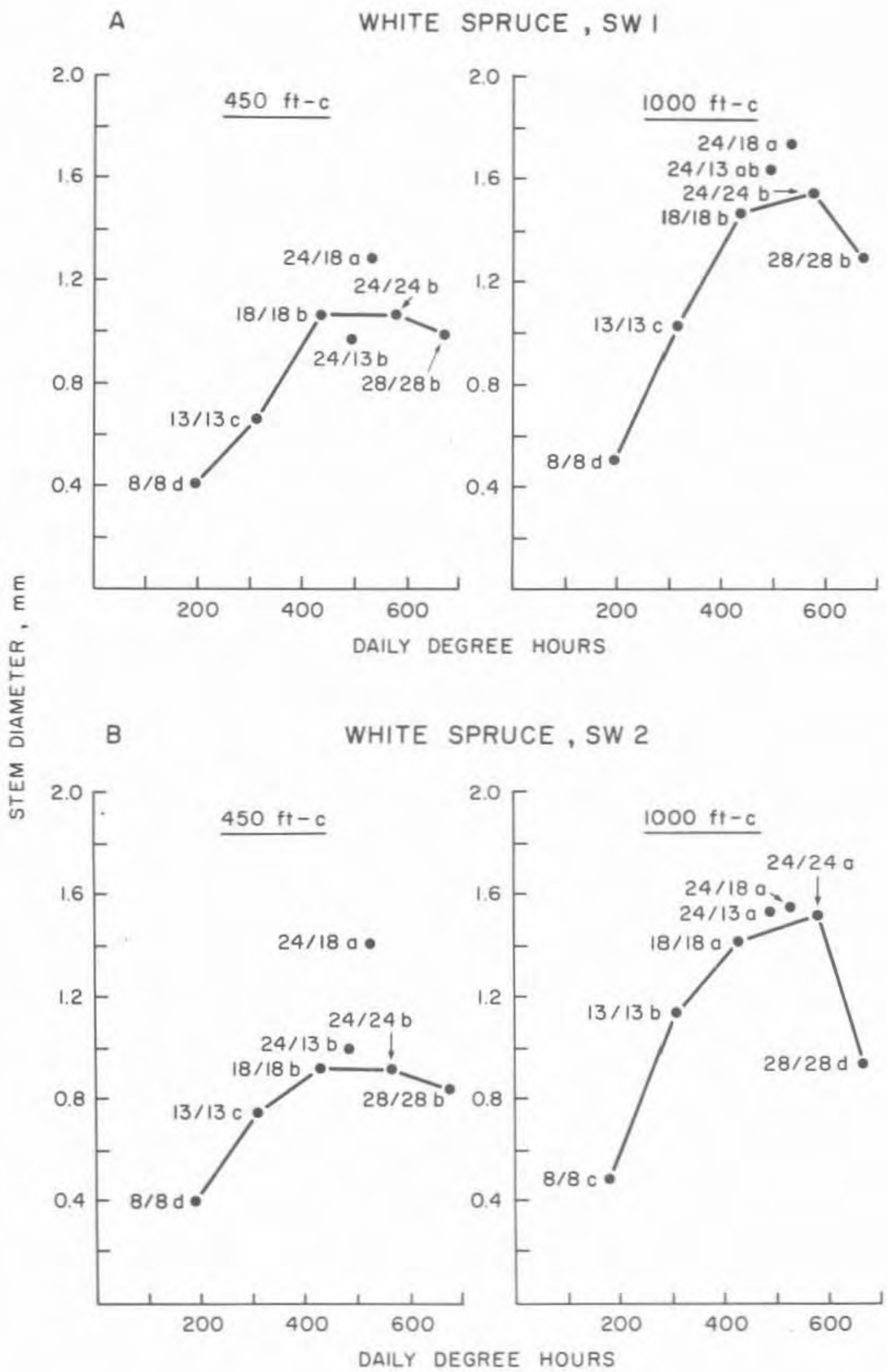

Fig. 6. Stem diameter growth of white spruce in relation to temperature at light intensities of 450 and 1000 ft-c.
Seed source in A: Prince George, B. C.
" " " B: Hazelton, B. C.

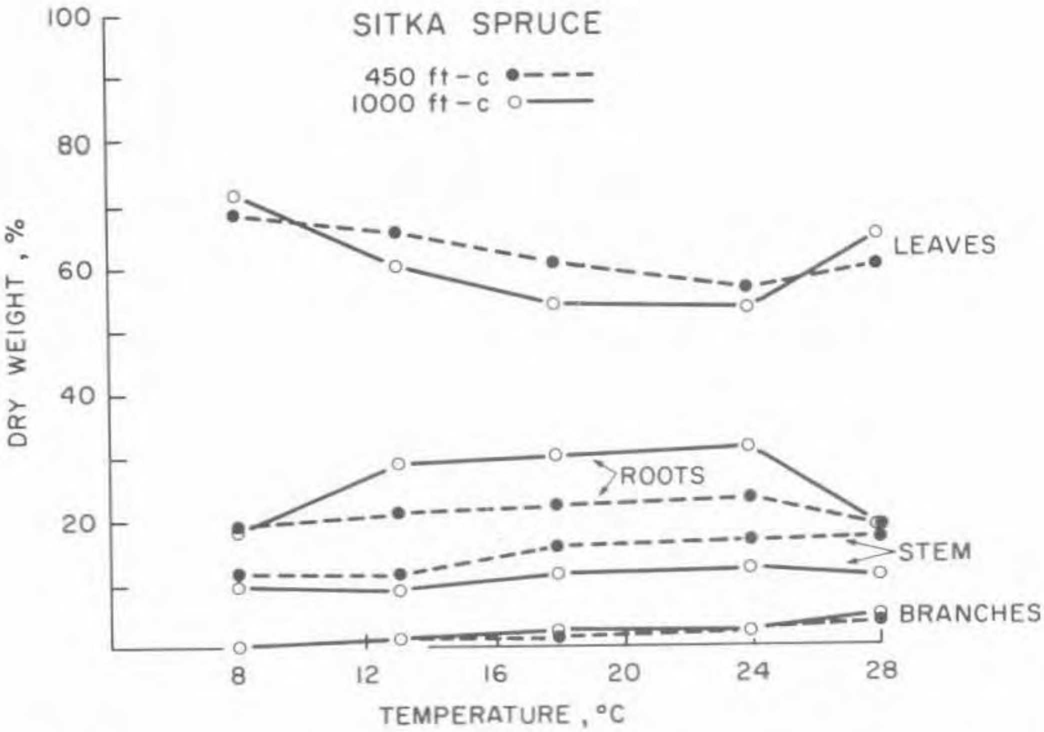

Fig. 7. Dry matter distribution to leaves, stem, roots and branches for Sitka spruce in relation to temperature at light intensities of 450 and 1000 ft-c.

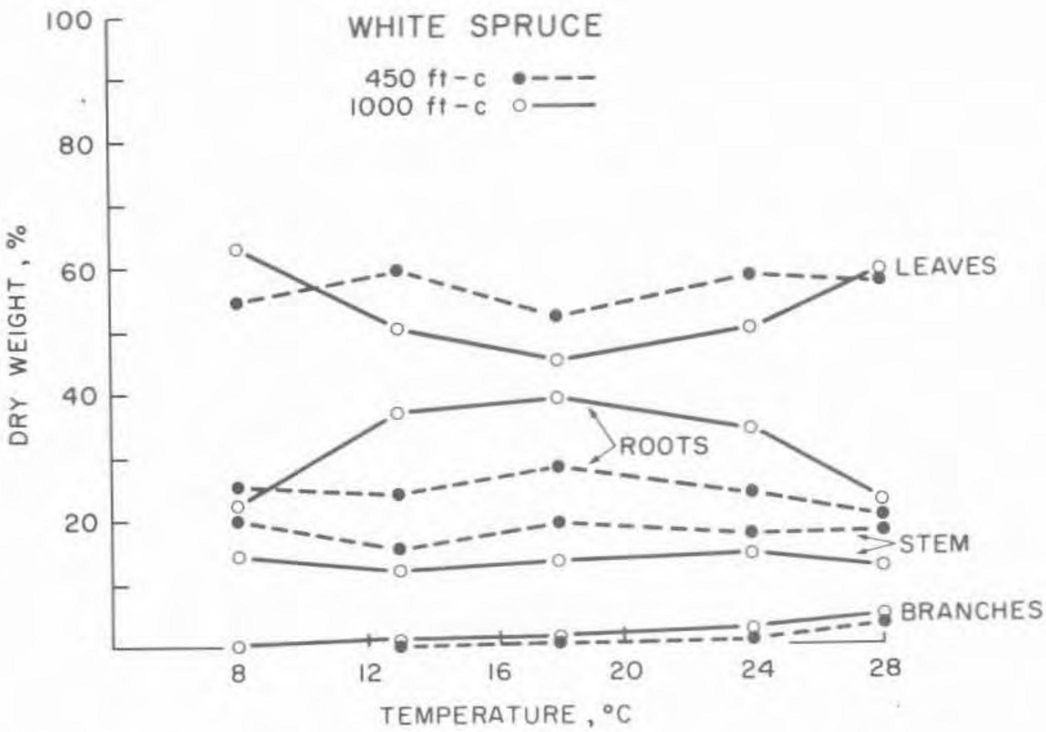

Fig. 8. Dry matter distribution to leaves, stem, roots and branches for white spruce in relation to temperature at light intensities of 450 and 1000 ft-c.

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