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# Effect of soil temperature upon the root growth and mycorrhizal formation of white spruce (*Picea glauca* (Moench) Voss) seedlings grown in controlled environments

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## Introduction

The effects of root zone temperature and mycorrhizal formation on the shoot and root morphology of white spruce seedlings were examined in a controlled environment. A companion study evaluated effects of root zone temperature upon root growth at different stages of seedling growth throughout the year.

## Materials and Methods

3 mo old dormant container-grown white spruce seedlings from a northern British Columbia seed source were inoculated with: 1) *Hebeloma crustiliniforme*, 2) *Thelephora terrestris*, 3) forest floor collected from a vigorous northern spruce plantation, 4) peat:vermiculite collected from mycorrhizal (mainly E-strain and MRA) container nursery stock, and 5) nothing (control). After inoculation, the seedlings were grown at 3 root zone temperatures: 5–8, 15–17 and 25–29°C in a growth cabinet programmed for 19–21°C air temperatures, 70–90% RH and an 18 h photoperiod. The root zone temperature and inoculation treatments were factorially arranged to give 15 treatment combinations.

Seedling height and caliper were measured at the initiation of treatment, 5 and 15 wk later. At each sample date, a subsample of seedlings was harvested to estimate needle, stem and root dry weight, length of long roots, short root development and mycorrhizal formation. Mycorrhizal formation was estimated by scanning the surface of the whole root plugs at 12–40x magnification and checking whole mounts at 500–1000x (Danielson and Visser, 1984).

Treatment means for the 15 wk sample were compared by 2-way least squares analysis of covariance using SYSTAT. Initial caliper, the covariate, did not interact significantly with the treatments ($P > 0.80$).

Populations of white spruce seedlings grown in 313 styroblocks under natural conditions commencing in April were placed in controlled environment facilities for 1 mo periods on the following dates: 21/9/87, 21/12/87, 16/5/88, 18/7/88. Seedlings were dormant prior to each

**Table I.** Effect of soil temperature upon root growth of white spruce.

| *Date* | *Mean no. of active roots >1 cm in length soil temp. °C* | | |
|---|---|---|---|
| | *3* | *10* | *17* |
| Oct. 1987 | 0.8 (a) | 1.0 (a) | 5.3 (a) |
| Jan. 1988 | 24.3 (b) | 23.7 (b) | 29.7 (b) |
| Jun. 1988 | 4.1 (a) | 32.7 (c, d) | 26.7 (b, c) |
| Aug. 1988 | 8.1 (a) | 34.6 (d) | 44.8 (e) |

Numbers followed by same letter are not significantly different.

trials, but doubtless had different physiologies. Seedlings were maintained out-of-doors before the first 2 trials; were stored at 2°C in darkness for the period Dec 87–May 88, a common B.C. practice; and had recently completed the 2nd yr growth flush in July 88. The growth chambers were programmed for 14 h daily photoperiods with a constant air temperature of 20°C and soil temperatures of 3, 10 and 17°C. Seedling caliper and shoot length were measured prior to and after the treatment period. The number of actively growing roots greater than 1 cm in length was recorded when the seedlings were harvested. These data were analyzed by Duncan's multiple range test for significant differences at $P = 0.05$ (Table I).

## Results

Mycorrhizae formed following all the inoculation treatments at the 15–17°C root zone temperature. However, at the 5–8°C root zone temperature, mycorrhizae were formed only by *T. terrestris* and forest floor symbionts (*Amphinema*-like species and several unidentified ascomycetes); at the 25–29°C root zone temperature, mycorrhizae were formed only by *T. terrestris* and E-strain. Accordingly, analyses of interactions between inoculation and temperature treatments on seedling morphology were conducted using 3 classes of mycorrhizal formation: 1) no mycorrhizae, 2) mycorrhizae formed by *T. terrestris* and 3) mycorrhizae formed by other fungal species.

There was no evidence of interactions between temperature and mycorrhizal class on root or shoot morphology ($P > 0.50$). With two exceptions, root zone temperature accounted for significantly more of the variation in root data than did mycorrhizal class. The two exceptions were the number of short roots: 1) per unit root dry weight and 2) per unit root length. Root dry weight, length and short root numbers increased ($P < 0.01$) with root zone temperature up to 15–17°C. Raising the temperature to 25-29°C did not affect these root parameters ($P > 0.60$). Mycorrhizal formation by other fungal species increased the ratio of short roots produced per unit root dry weight or length ($P = 0.02$) compared to no or *T. terrestris* mycorrhizae.

Buds were dormant until 1 wk prior to final harvest when most flushed, with the flushing rate independent of root zone temperature or mycorrhizal formation

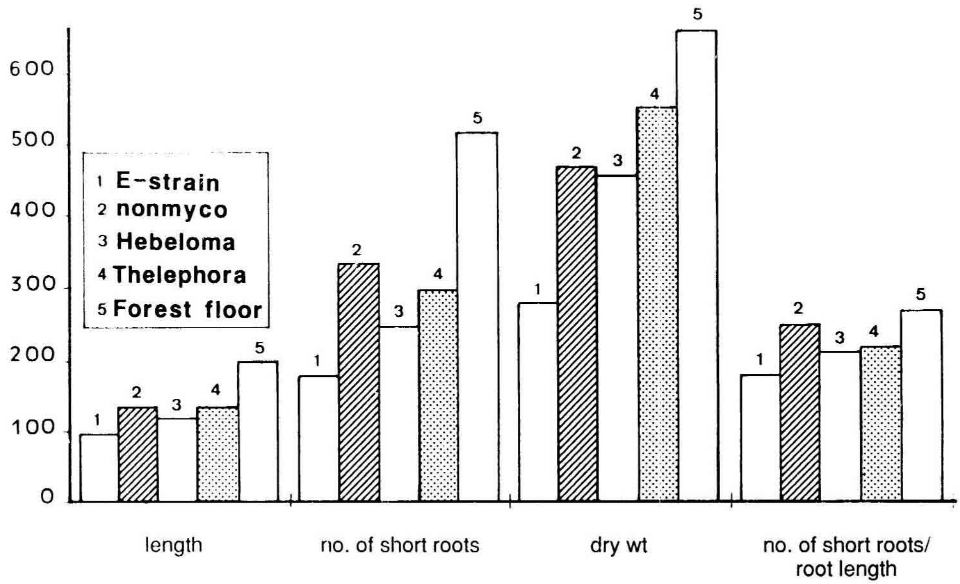


**Fig. 1.** Effect of mycorrhizae at the 15–17°C root zone temperature on white spruce seedling lateral root length (cm), number of short roots, root dry weight (mg) and number of short roots per unit root length (x100).

($P$ >0.05). Needle dry weight and caliper increased during the 15 wk experiment with final needle dry weight inversely related to root zone temperature. Mycorrhizal formation accounted for more of the variability in final caliper than did temperature. The data suggest that caliper growth was greatest when seedlings were colonized by other species ($P$ = 0.09).

The 5 inoculation treatments were compared for the 15–17°C root zone temperature. Shoot parameters were not influenced by inoculation treatments. However, forest floor inoculum increased short root development ($P$ = 0.02), root length ($P$ = 0.01) and weight ($P$ = 0.14) compared to the other treatments (Fig. 1). The comparison of mycorrhizal to non-mycorrhizal seedlings was not significant for any root parameter ($P$ >0.25).

## Discussion and Conclusion

For most shoot and root parameters, temperature accounted for more variability in the data than did mycorrhizal formation. However, for several parameters (number of short roots per unit root dry weight or length, caliper growth), mycorrhizal formation was a more important source of variation than temperature. Seedlings with *T. terrestris* mycorrhizae or no mycorrhizae were not significantly different in these parameters; seedlings with mycorrhizae formed by 'other' species, particularly from the forest floor inoculum, had higher values for these parameters.

Cold soils are believed to limit white spruce seedling growth in British Columbia. Present data (Table I) demonstrate that current cold storage procedures exacerbate this situation for a large proportion of planted spruce seedlings. Earlier data (Lavender, 1988) suggested that a daily photoperiod during cold storage could reduce the impact of this practice.

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