

# CARDINAL TEMPERATURES FOR GERMINATION OF SIX PROVENANCES OF WHITE SPRUCE SEED

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*Résumé en français*

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## ABSTRACT

Investigations of the influence of temperature and provenance on the germination of white spruce seeds showed that temperature has a significant effect on germination; cardinal temperatures were determined for germination of seed from each of six provenances. For maximum germination 28 days after seeding, cardinal temperatures were as follows: 55F to 60F for seed from Davie Lake, B.C., and Moosonee, Ont.; 65F to 75F for seed from Acadia, N.B.; 65F to 70F for seed from Petawawa and Napanee, Ont.; and 55F and 65F for seed from Chilson, N.Y.

The results indicated a correlation between germination response to temperature and the environment at the latitude of the seed source.

## RÉSUMÉ

Cette étude sur l'influence de la température et du lieu de provenance sur le taux de germination des graines d'Épinette blanche (*Picea glauca*) démontre que la température est un facteur déterminant. Voici les températures optimales pour six provenances 28 jours après l'ensemencement: 55 à 60°F pour les graines de Davie Lake, C.-B., et Moosonee, Ont.; 65 à 75°F pour celles d'Acadia, N.-B.; 65 à 70°F pour Petawawa et Napanee, Ont.; 55 et 65°F pour Chilson, N.Y.

Il existe une corrélation entre le taux de germination à température donnée et l'environnement à la latitude du lieu de provenance.

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# CARDINAL TEMPERATURES FOR GERMINATION OF SIX PROVENANCES OF WHITE SPRUCE SEED

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J.W. Fraser<sup>1</sup>

## INTRODUCTION

Large numbers of even-aged seedlings are often required, sometimes on short notice, for container-planting programs and also for research where seedling homogeneity is desirable. Since rapid, uniform germination is an essential step in the production of such material, it is advantageous to know the cardinal temperatures for germination of the tree seed concerned. Also, knowledge of such temperature-germination relationships is helpful in understanding and explaining germination or the lack of it in natural environments.

This paper reports the effect of constant temperature on the germination of native tree seeds. It deals with cardinal temperatures for the germination of white spruce (*Picea glauca* (Moench) Voss) seed from six provenances.

The objective of the work reported here was to determine for seeds from each of the six provenances that temperature below which they do not germinate (lower cardinal temperature or LCT), that temperature above which they do not germinate (upper cardinal temperature or UCT), and that temperature or temperature range at or within which maximum germination occurs (optimum cardinal temperature or OCT).

## MATERIALS AND METHODS

### Materials

The seed from six sources or provenances were obtained for this experiment from forest geneticists engaged in tree-population studies at the Petawawa Forest Experiment Station. The location and climate of the six collection areas are summarized in Table 1. All seed lots were stored dry in sealed glass containers at 34F to 38F (1.1C to 3.3C) before use in these experiments.

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Table 1. Location and climate of provenances (seed-collection areas)

Provenance		Location				Climate			
Name*	Code	N Lat	W Long	Elevation (ft)	Number years records	Mean annual temp (F)			Mean annual precipitation (inches)
						Min	Max	Mean	
Napanee, Ont. (Trenton)	P 1	44°08'	77°03'	300	13	36	54	45	31.74
Moosonee, Ont. (Moosonee)	P 2	51°16'	80°39'	<10	17	19	40	30	30.76
Davie Lake, B.C. (Prince George)	P 3	54°32'	122°45'	2,260	27	26	51	38	19.98
Acadia, N.B. (Fredericton)	P 4	46°00'	66°22'	200-300	67	30	51	41	42.80
Petawawa, Ont. (Chalk River)	P 5	46°00'	77°26'	600	17	29	51	40	29.21
Chilson, N.Y. (Whitehall)	P 6	43°52'	73°33'	960	10	37	59	48	36.73

\* Nearest official weather station shown in brackets.

The germination medium was short-grain, black germination paper saturated with distilled water.

### Methods

In this completely randomized experiment the same methods were employed as were used to determine cardinal temperatures for germination of pine seed in earlier experiments (Fraser, 1970).

Seeds were floated in methyl alcohol to remove most of the empty seeds. The full seeds sank and were washed in running water, cold-soaked in dilute acid for 36 hours at 37F,<sup>2</sup> and then washed again in running water for several minutes. These seeds were then surface-sterilized in 1% Javex and seeded on two layers of germination paper in sterile petri dishes.

The covered dishes were placed in illuminated, forced-draft, constant-temperature cabinets at prescribed temperatures  $\pm 1F$  for 28 days. There were six dishes of 50 seeds from each of the six provenances in each of 12 temperature treatments at 5-degree intervals from 45F to 100F inclusive. In preliminary tests, no seed from any provenance germinated at 40F or 105F.

Germination was tallied daily. Percent germination data, corrected for percent full seed,<sup>3</sup> were transformed to degrees by the arc sine method to normalize the data and subjected to analyses of variance. Duncan's (1955) multiple range test was used to test the significance<sup>4</sup> of treatment-means comparisons.

## RESULTS

### General

Analyses of variance of the cumulative percent germination data presented in Figure 1 showed that temperature and provenance each had a significant effect on germination of white spruce seeds.

Seeds did not germinate below 45F or above 95F. Seeds from two provenances (P2, P3) germinated at 45F, and seeds from two other provenances (P4, P5) germinated at 95F, but in each instance germination was too low (2% or less) and too slow (14+ days) to be of any practical interest. Likewise, although seed from five of the six provenances did germinate at 90F,

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<sup>2</sup>This method of breaking dormancy was used in preference to the time-consuming 60- to 90-day pregermination stratification in moist sand recommended for white spruce seed (Anon., 1948).

<sup>3</sup>Correction factors were based on the ratio of full to empty seed determined by cutting tests of supposedly sound seeds from the flotation test.

<sup>4</sup>Probability  $p = 0.05$  throughout this publication.

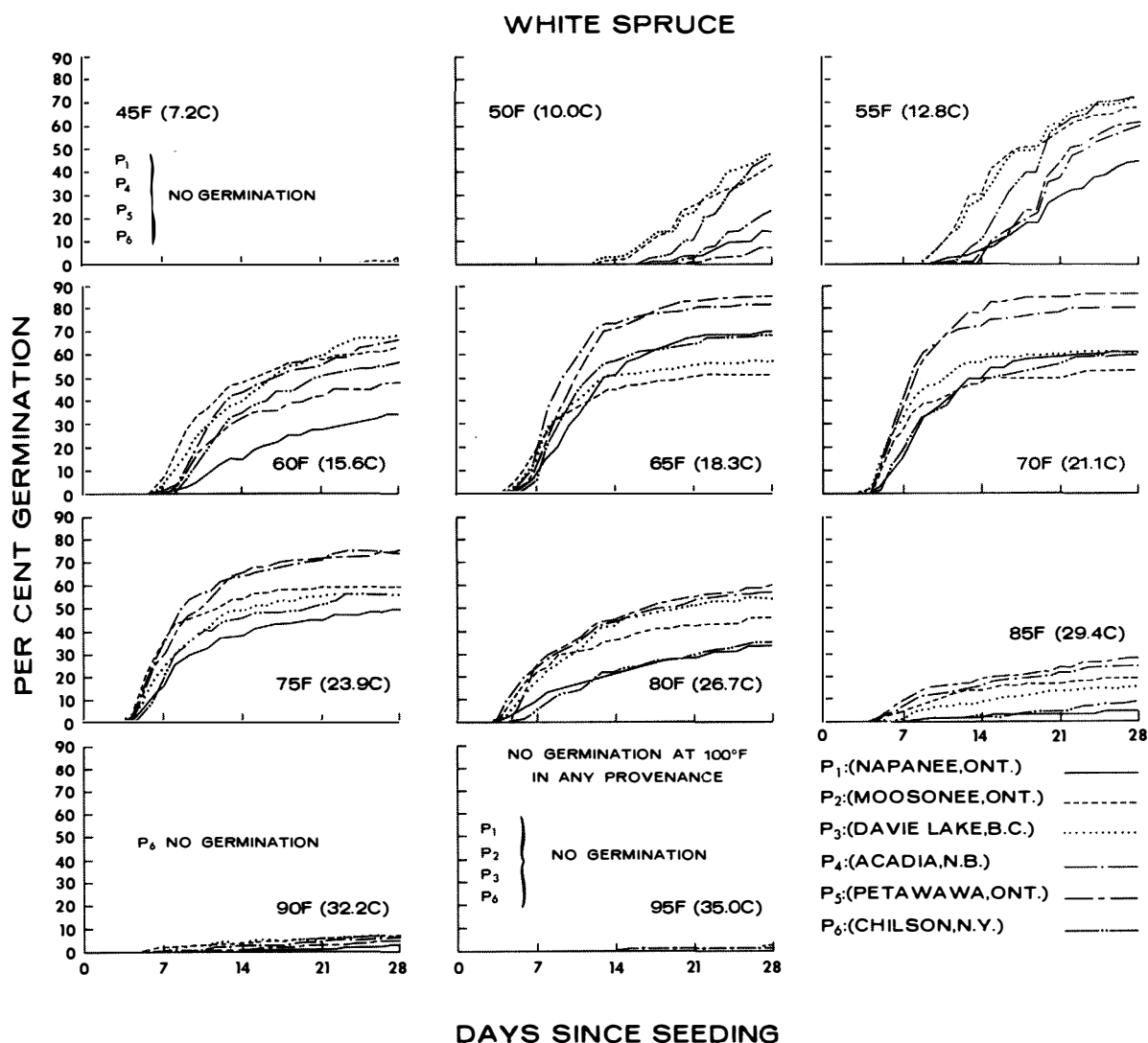


Figure 1. Percent germination of six provenances of white spruce seed at different temperatures 28 days after seeding.

with statistically significant differences among provenances, the responses at this temperature were also too low (7% or less) to be of any interest other than to establish 90F as the UCT for provenances (P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>) which failed to germinate at the next higher temperature, 95F. Seed from one provenance (P<sub>6</sub>) did not germinate above 85F.

The influence of temperature on the initiation and rate of germination of several provenances is evident in Figure 1. Excepting only provenances P<sub>2</sub> and P<sub>3</sub>, germination began sooner, proceeded more rapidly, and reached optimum levels sooner at temperatures from 65F to 75F than at any higher or lower temperatures.

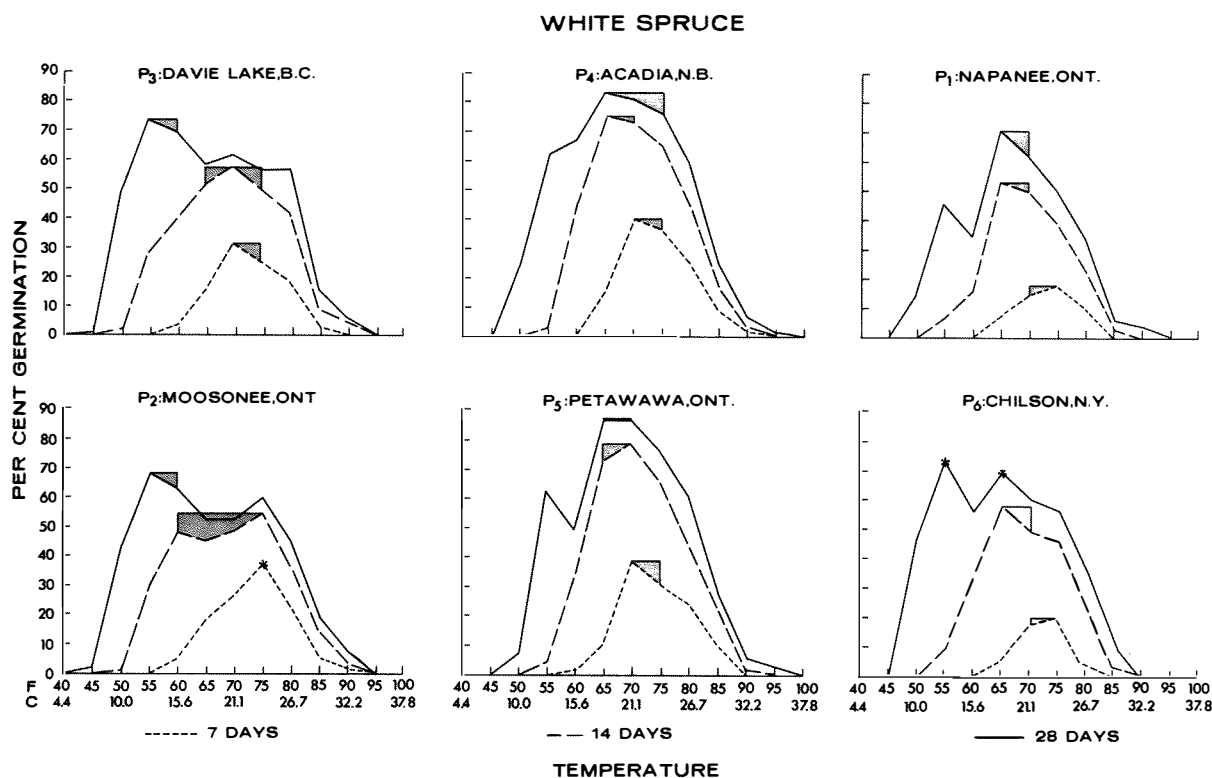


Figure 2. Percent germination, by provenance, of white spruce seed 7, 14, and 28 days after seeding. LCTs and UCTs are self-evident. OTCs, where occurring as single or double peaks, are marked with an asterisk; where occurring as consecutive temperatures producing nonsignificantly different responses, they are shown as shaded plateaus.

#### Germination Responses to Temperature, by Provenance

Germination responses to temperature, by provenance, are illustrated by plotting percent germination over temperature 7, 14, and 28 days after seeding (Figure 2).

The vertical grouping of pairs of provenances in Figure 2 was suggested by the obvious and statistical similarity of the 28-day germination response of certain pairs of provenances and by the equally obvious but significantly different response between them (cf. P4 and P5 with P1 and P6 and with P2 and P3 at 65F, Figure 1). Fortuitously, the left-to-right grouping by vertical pairs is also a ranking from the most northerly and coolest to the most southerly and warmest. There is no such apparent relationship between germination response and latitude, elevation, or precipitation, the other parameters on which data were available from the seed-collection records.



Cardinal temperatures for 7-, 14-, and 28-day germination periods are illustrated in Figure 2.

At least 75% of the seeds had germinated by the 14th day, at which time the final OCTs were established for all provenances except P2 and P3.

At the upper limit (60F) of the OCT common to P2 and P3, germination of seed from P5, P1, and P6 was obviously and significantly lower than at the next higher and lower temperatures.

#### Germination Response to Provenance, by Temperature

The 28-day germination data for all provenances are plotted over temperature in Figure 3 to facilitate comparing the germination responses of the different provenances of seed with the same temperatures.

At 50F, the LCT for P1, P4, P5, and P6, germination from P3, P6, and P2 was significantly better than that from other provenances, and only seed from P2 and P3 germinated below 50F. At 55F, the low end of the OCT common to P3 and P2, there was no significant difference in germination among P2 and P6 inclusive, and all were significantly better than P1.

At 60F, the upper end of the OCT common to P3 and P2, the response from P3, P2, and P4 was significantly better than from P1, P5, and P6, all of which were significantly worse than at 55F.

From 65F to 75F, which includes the OCT for all provenances except P3 and P2, seeds from P4 and P5 germinated equally well and significantly better than seeds from all other provenances.

At 75F and higher, germination from all provenances decreased rapidly. The response from P4 and P5 was not better than that from P3 at 80F, or that from P2 at 85F, but was consistently better than the response from P1 and P6.

There was no germination response from P6 seed above 85F, none from P1, P2, or P3 seed above 90F, and none from P4 or P5 seed above 95F.

## DISCUSSION

In addition to determining and demonstrating cardinal temperatures for each of the six provenances of white spruce seed (Figure 2), the experiment also demonstrated significant differences between provenances in germination responses to temperature (Figure 3).

Seeds from the two coolest, most northerly sources (Figure 4), Davie Lake, B.C. (P3), and Moosonee, Ont. (P2), have identical cardinal temperatures for germination after 28 days and similar responses to tempera-

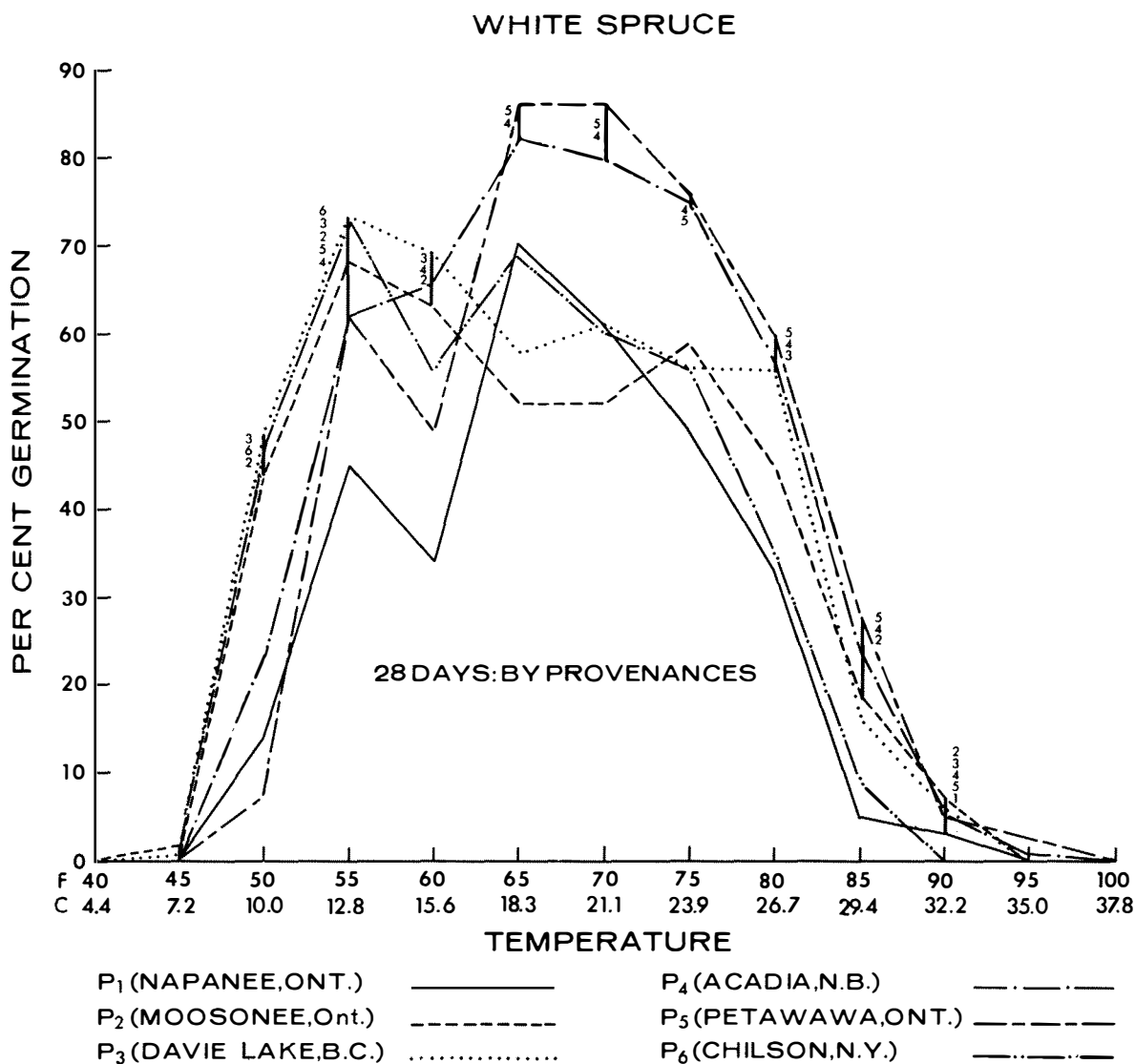


Figure 3. Percent germination of six provenances of white spruce seed at different temperatures 28 days after seeding. Vertical bars join those provenances of seed which germinated best at each temperature from 50F to 90F, inclusive, and among which there were no significant differences in germination.

ture throughout the experiment. They germinated at a lower temperature (45F) than those from the other provenances. Up to and including 60F, germination from these two seed lots also occurred sooner and ranked higher than that from any others.

Seeds from Acadia, N.B. (P<sub>4</sub>), and Petawawa, Ont. (P<sub>5</sub>), at the same latitude, some 5 degrees south of Moosonee (Figure 4), have identical LCTs and UCTs and a common OCT from 65F to 70F, with the OCT for Acadia seed extended by 5F to 75F.

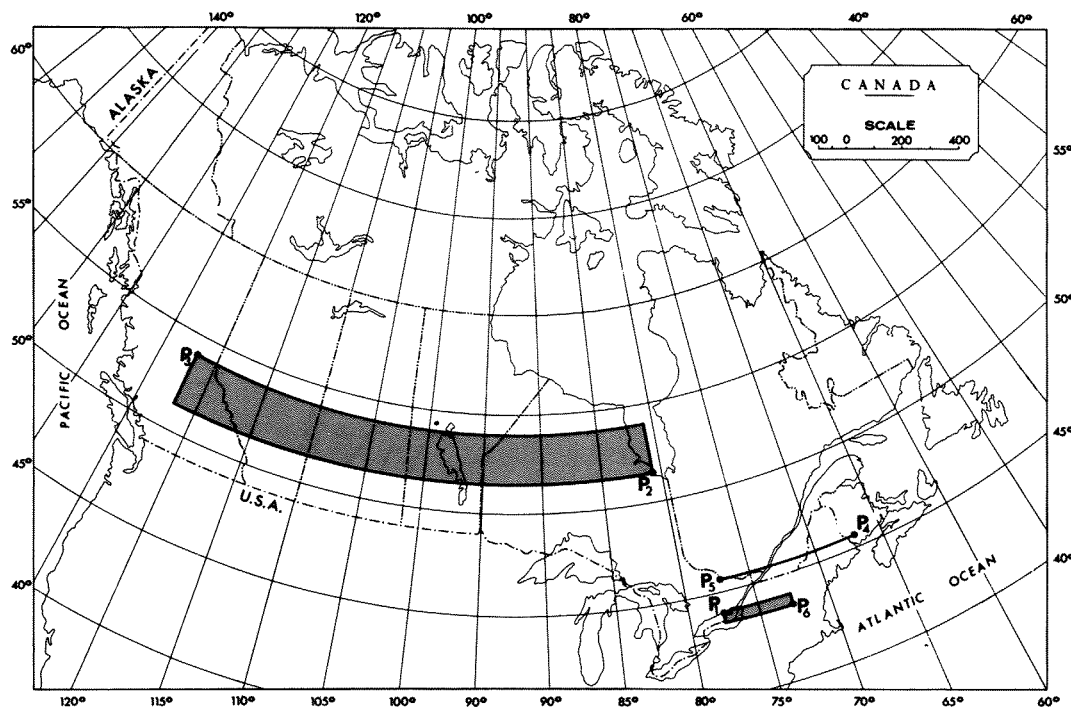


Figure 4. Location of provenances of white spruce seed used in these experiments. More precise information and means of climate parameters are given in Table 1.

Seeds from Napanee, Ont. (P1), and from Chilson, N.Y. (P6), the two warmest, most southerly sources (Figure 4), also have a common LCT identical to that for Acadia and Petawawa seed, but have different and lower UCTs; the OCTs are also different.

Although the provenances of white spruce seed used in this experiment by no means constituted a complete north-to-south range from Davie Lake to Chilson, the demonstrated cardinal temperatures and responses support Rowe's (1964) conclusions on environmental preconditioning by suggesting that the germination response to temperature was influenced or conditioned by the environment in which the seed originated. At the same time, a comparison of the identical cardinal temperatures and germination patterns for seed from Davie Lake and from Moosonee sources (spanning almost 4 degrees of latitude) with the different cardinal temperatures and germination patterns of seed from Napanee and Chilson seed sources (spanning less than 16 minutes of latitude) suggests that the indicated conditioning effect of provenance on germination response to temperature was more pronounced at southern than at northern latitudes. Cardinal temperatures and germination response patterns of Acadia and Petawawa seed (from the same latitude, 46°N) support these suggestions.

Differences in maximum germination at OCTs for the several provenances are attributed to differences in the germination capacity of seed lots. No explanation is advanced for the significant decrease in germination

of seed from three of the six provenances (Petawawa, Napanee, and Chilson) at 60F. Subsequent tests at 60F, some six months later, produced responses more in line with the pattern of germination increasing with temperature up to the OCT.

## CONCLUSIONS

1. Cardinal temperatures for laboratory germination of white spruce seed from the six provenances included in this study were as follows:

<u>Provenance</u>	<u>N Latitude</u>	<u>LCT</u>	<u>OCT</u>	<u>UCT</u>
Davie Lake, B.C.	54°32'	45	55 - 60	90
Moosonee, Ont.	51°16'	45	55 - 60	90
Acadia, N.B.	46°00'	50	65 - 75	95
Petawawa, Ont.	46°00'	50	65 - 70	95
Napanee, Ont.	44°08'	50	65 - 70	90
Chilson, N.Y.	43°52'	50	55 and 65	85

2. Provenance of the seed had a significant effect on germination responses to temperature.

3. Identical cardinal germination temperatures across a wider span of northerly, cooler provenances compared with the responses for more southerly, warmer provenances suggest a possible conditioning effect of environment at latitudes at which the seed developed.

## ACKNOWLEDGMENTS

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