Survival of all fall-planted stock was equal to or better than that of spring-planted stock. This result is supported by the silvicultural recommendation by Mullin (1968; 1980) of either spring or fall planting for black and white spruce.

Type of container had little impact on growth or survival of these species. Selection of container system would seem to be largely a matter of user logistics and preference rather than field performance.

Mullin (1980) makes a good case for use of transplant stock rather than seedlings for black and white spruce. His results tend to support those presented in this report as the 2-2 stock generally outperformed the 3-0 stock.

Comparison studies of this type must be repeated to account for variation in establishment conditions between

growing seasons to provide reliable results. Additional field seasons may change the results, otherwise Mullin's recommendations remain after 15 years of growth (Mullin 1980).

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Genetic and Environmental Variance in Seed and Cone Characteristics of Black Spruce in a Northwestern Ontario Seed Orchard

by

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Abstract

Germination and some seed yield components were evaluated using 1981 cones from ramets of nine clones in a Northwestern Ontario seed orchard. No evidence of dormancy was observed in seed which received no chilling and were germinated under light. Hierarchical analyses of variance indicated that both clones and ramets within clones accounted for substantial amounts of variation in germination percent, filled seed percent, number of seed per cone and cone size. Cone size was only weakly correlated with number of seed per cone ($r = .44$).

Résumé

La germination et quelques valeurs de rendement de semences furent évaluées à partir de cônes prélevés sur des ramets de clones d'épinette noire (*Picea mariana* (Mill.) B.S.P.) dans un verger à graine du Nord-Ouest de l'Ontario. Aucune dormance n'a été observée chez des semences non stratifiées au froid et qui ont germé à la lumière. Des analyses de variance hiérarchisées indiquaient que les clones et les ramets dans les clones montrent beaucoup de variation dans le % de germination, dans le nombre de graines par cône, dans le % de semences pleines et dans la grosseur des cônes, cette dernière étant faiblement en relation avec le nombre de graines par cône ($r = 0.44$).

Introduction

Sound black spruce (*Picea mariana* (Mill.) B.S.P.) seed germinate rapidly and completely under normal greenhouse and nursery conditions if extracted via recommended procedures (Safford 1974) and stored dry at 1° to 5°C. While the above handling procedures suggest that seed have no dormancy, Santon (1970) clearly demonstrated mild dormancy in seed from southeastern Ontario (Long. 77°W, Lat. 46°N) which had not been exposed to low temperature (< 5°C). Other studies have shown that long periods of stratification or storage in forest soil reduces germination (MacGillivray 1955, Fraser 1976) and that viable seed will germinate at low temperatures (3°-4°C) after lengthy chilling (McArthur and

Fraser 1963). Evidence of geographic variation in cardinal germination temperature (Fraser 1970) suggests that there may also be genetic variation in the degree of dormancy. In this study we have (1) evaluated dormancy of seed from parents in northwestern Ontario and (2) estimated genetic and environmental variance in seed and cone characteristics through use of these parents cloned in a seed orchard.

Methods

Cones from the 1981 crop only were collected on September 5, 1981, from nine clones in a grafted seed orchard (Mattawin) at Long. 90° 05'W, Lat. 48°, 23'N. Ortets for the clones are all located between Long. 88° and 91°W at latitudes between 48° and 50°N. Orchard records indicate that all scions came from the upper crowns of ortets and were bench grafted to seedlings. The 10-ha orchard contains 18 0.2-ha blocks each of black spruce and white spruce (*Picea*

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glauca (Moench) Voss) and is located in a clearcut section of an even-aged jack pine (*Pinus banksiana* Lamb.) stand. Each block contains 12 ramets from each of 12 clones planted at 3.6 × 3.6 m spacing and distributed so that ramets of the same clone are not adjacent. In the three blocks used for this test, chosen ramets were planted in 1966 or 1967 and were all 4 to 5 metres in height.

At least 50 cones were collected from each of three ramets per clone. None had been exposed to temperatures below 5°C. Five randomly selected cones from each ramet were set aside for cone analysis. The remainder were extracted following procedures described by Safford (1974). Seed from each ramet was divided into two lots. Germination of one lot was evaluated immediately and the second lot was chilled on moist filter paper 3°C (stratified) for three weeks, then evaluated.

Three replicates of randomly selected seed from all ramets of the nine clones were incubated at a constant 20°C. The number of seed in replicates of individual ramets varied from 10 to 50 due to variance in size of seed crops. Seed from ramets of three clones were also incubated at 10°C and at 30°C. Each replicate was incubated on moist filter paper in separate 15-cm petri dishes. Small controlled environment chambers programmed for 16-hour day lengths were used as incubators. Numbers of germinating (radical at least 2 mm long) seed were recorded daily. Germination was considered complete when no additional germination occurred for 7 consecutive days; remaining ungerminated seed were sliced open under a dissecting microscope and classified as either empty (containing no embryo) or filled. This examination allowed germination percents to be based on both all seed and number of filled seed.

Nested analyses of variance using the arc sine transformations of the square root of germination percent and percent filled seed were performed using data from all replicates germinated at 20°C. In this analysis, variance components were computed for (1) clones, (2) ramets within clones, and (3) samples within ramets. Variance associated with "ramets within clones" gives an estimate of the effects of environmental variation within the orchard and/or environmental preconditioning of ramets. An additional analysis of variance was performed using data from seed of the three clones germinated at 10°, 20°, and 30°C. Effect of stratification was evaluated in both analyses.

Volumes of five freshly collected cones per ramet were determined by water displacement. These cones were then extracted and the number of seed per cone determined. Each cone was then dissected to remove any seed not obtained by extraction. A nested analysis of variance was performed on cone volume data and number of seeds per cone.

Results

The average germination in the study was 40 percent for all seed and 94 percent for filled seed. Neither stratification nor temperature significantly influenced final germination percent. Germination speed, measured by number of days to reach 90 percent of final germination, was significantly slower (17 days) at 10°C than at 20°C (5 days) and 30°C (4 days). Stratified seed completed germination 1 to 2 days before unstratified seed, probably due to the fact that they had completed imbibition at the beginning of incubation while unstratified seed began imbibition on the first day of incubation.

There was significant variation among clones and ramets within clones in germination percent based on all seed. Clone means ranged from 23 to 56 percent at 20°C (Table 1). The analysis of variance of data from seed incubated at 20°C indicated that clones and ramets within clones each accounted for around 20 percent of variance in both germination and percent of seed which were filled (Table 2). Thus clone and ramet variance in germination percent is largely a function of percent filled seed, not germination potential of filled seed. The relatively large amount of variance within ramets is at least partly due to the small samples dictated by limited seed from some ramets.

Wide variation in cone volume and number of seed per cone (Table 1) was also related to both clones and ramets within clones, with the latter source of variance especially substantial (Table 2). While there was a statistically significant ($p < .05$) positive correlation between cone volume and number of seed per cone, it had a coefficient (r) of only .44. Mean number of filled seed per cone was 15 for the total sample, and clone means (computed using percent of filled seed and mean number of seed per cone) ranged from 5 to 24.

Discussion

Our data demonstrate that current year's seed collected before natural chilling from trees at Long. 90°–91°W and Lat. 48°–49°N exhibit no dormancy under a range of incubation temperatures and a 16-hour photo-period. The only equivalent published study is that of Santon (1970) in which seed from around Long. 77°W and Lat. 46°N responded to stratification. Thus the limited evidence to date suggests that there may be geographical variation in the degree of dormancy at fall collection. However, since seed are usually dispersed after some chilling and germination of cold-stored seed is commonly high, this variation in chilling is probably of little practical or ecological significance.

Of more interest is the variance in seed quality associated with both clones and ramets within clones in this young seed orchard. O'Reilly *et al.* (1982) have already observed some within-clone variation in cone production in this orchard that is

Table 1. Mean cone and seed characteristics for nine grafted black spruce clones.

Clone No.	Germination percent at 20°C based on:				Percent of seed filled		Cone Volume cm ³		Number of seed per cone	
	All seed		Filled seed		Mean	Ramet range	Mean	Ramet range	Mean	Ramet range
	Mean	Ramet range	Mean	Ramet range						
284	40	31-52	90	88-94	45	33-57	1.6	1.1-2.6	25	12-40
285	56	41-70	96	95-97	58	43-72	2.4	2.0-2.9	26	23-31
290	35	24-44	95	89-100	37	26-47	1.4	1.1-1.8	14	15-33
291	34	29-38	86	83-90	40	33-47	2.5	2.3-2.6	34	24-42
303	23	18-27	100		23	17-27	2.3	2.0-2.6	49	38-61
374	40	33-54	96	93-98	43	36-50	1.8	1.1-2.5	43	36-48
383	53	37-62	95	92-100	56	38-68	2.2	1.9-2.4	30	22-40
386	53	32-67	88	76-100	59	42-68	1.9	1.7-2.1	32	18-48
492	51	38-59	98	96-99	52	40-59	2.0	1.6-2.5	46	40-51
Mean	43		94		46		2.0		33	

Table 2. Components of variance in cone and seed characteristics in a black spruce seed orchard.

Source of variation	Variance components expressed as percent of total variance			
	Percent germination at 20° C	Percent filled seed	Cone volume	Number seed per cone
Clones	21	20	20	26
Ramets within clones	17	22	32	42
Within ramets	62	56	48	31

not related to ramet size. Particularly noteworthy in our study was the relatively high level of variance in cone size among ramets of uniform origin and history. Broad-sense heritability, a measure of genetic control, was not estimated for cone and seed characteristics due to the small sample size (9 clones). However, it is clear that if the relationships we observed are typical of larger populations, the broad-sense heritability for cone size, seed per cone, and filled seed percent may be low. This may have important implications for seed orchard management since selection for fecundity will not be very effective given this relatively low level of genetic control. Because of our limited sample size, these conclusions are tentative, and the study should be followed by broader examination of this orchard as it ages and similar evaluation of other black spruce clonal orchards.

McPherson *et al.* (1982) have shown that in a similar orchard (Long. 86° 30'; Lat. 49° 47') mean number of sound seed per cone varies widely from year to year and averages only about 11, a figure slightly lower than our observed 1981 value (15). The generally low filled seed percent in these young orchards may be partly due to a pollen isolation barrier and/or limited male strobili production in the orchards. O'Reilly *et al.* (1982) noted that in 1979, clones from the blocks used in our test produced from 150 to 4550 male strobili per

ramet, with a few clones contributing most of the pollen. Maximum pollen dispersal and female receptivity coincided. Thus, while there was probably a substantial orchard pollen cloud in 1981, no direct measurements of pollen abundance and periodicity have been made. Before orchard management recommendations for improving yield can be made, seed yield analysis should be supplemented by pollen sampling and observations of pollen dispersal patterns for individual parents.

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