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Maritimes Forest Research Centre

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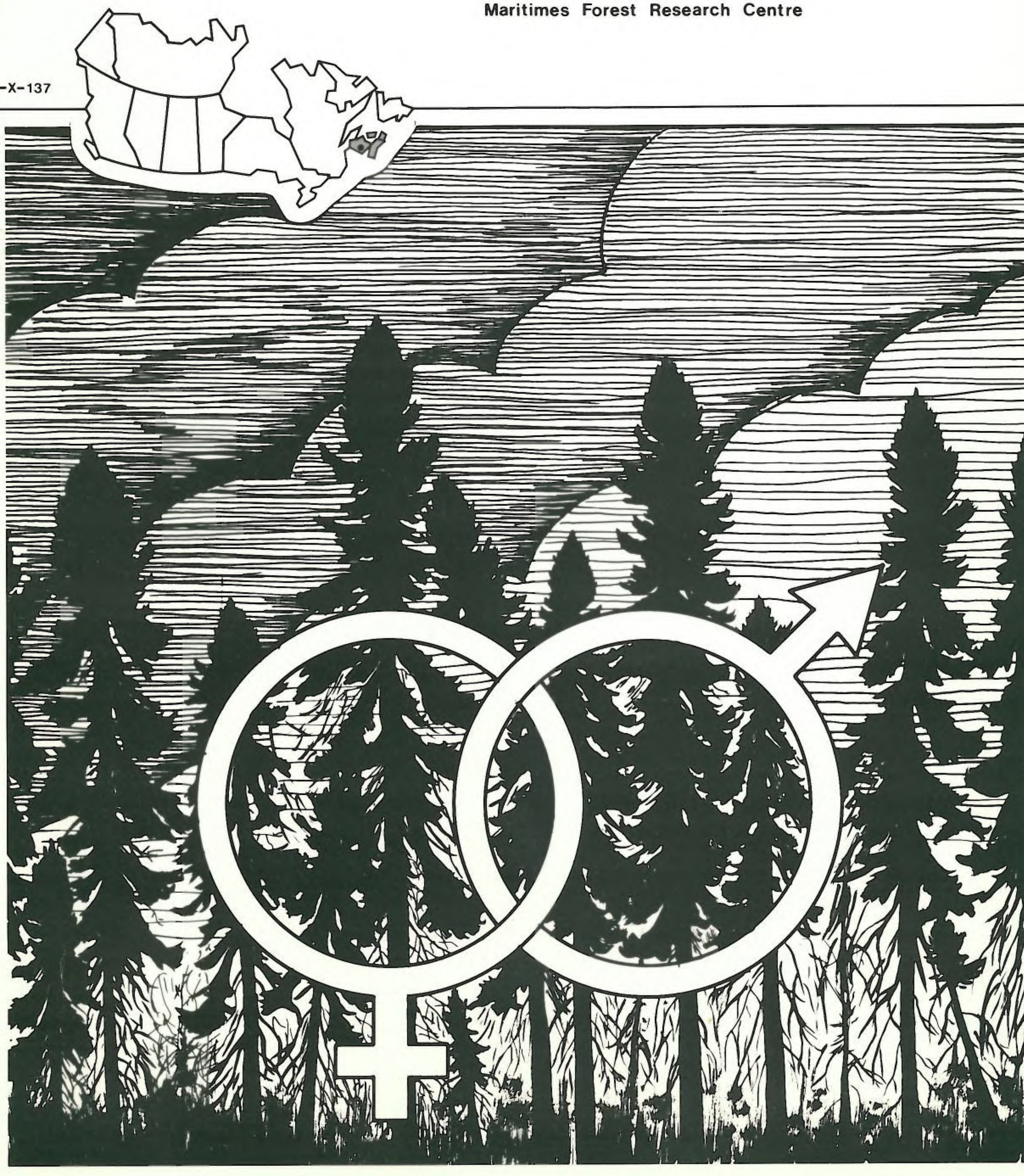

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RANGE-WIDE BLACK SPRUCE PROVENANCE TRIALS IN THE MARITIMES

by

D.P. Fowler and Y.S. Park

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Fredericton, New Brunswick

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ABSTRACT

Black spruce Picea mariana (Mill.) B.S.P. from provenances distributed throughout the species range were raised in a nursery experiment in central New Brunswick and subsequently planted at 10 test locations in the Maritimes Region. Seed and seedling characteristics, nursery performance, and 5-year (9 years from germination) survival and height data are presented. Analyses of variance, correlation, stability, and factor analyses were applied to the data.

The genetic variation pattern in black spruce is essentially clinal and no genotype x location interactions were indicated among the provenances represented at all test locations. There is a strong correlation between nursery performance and 5-year height. Black spruce of Maritime provenances appears to be more stable than those of non-Maritime provenances. Truly local provenances were generally below average in height at 5 years and only slightly above average in survival, suggesting that black spruce is not particularly well adapted, in an evolutionary sense, to many of the sites that it occupies locally.

Recommendations are made concerning choice of black spruce provenances for use in the Maritimes Region.

RESUME

Des épinettes noires Picea mariana (Mill.) B.S.P. de provenances réparties dans l'aire de cette essence ont été cultivées à titre expérimental dans une pépinière du centre du Nouveau-Brunswick puis plantées dans dix placeaux des Maritimes. On décrit les caractéristiques des semences et des semis et leur performance en pépineère, et on présente des données sur la survie et la hauteur des semis après cinq ans (neuf ans après la germination). A partir de ces données, on a effectué des analyses de variance, de corrélation, de stabilité et de facteurs.

Chez l'épinette noire, la variation génétique est fondamentalement clinale, et aucune interaction du génotype et du placeau n'a été notée chez les semis des diverses provenances dans tous les placeaux. Il existe une forte corrélation entre la performance en pépinière et la hauteur à cinq ans. Les épinettes dont la provenance est les Maritimes semblent plus stables que celles d'ailleurs. En général, à cinq ans, les arbres de provenance vraiment locale était moins hauts que la moyenne, et leur survie n'était que légèrement supérieure à la moyenne, ce qui signifierait que, dans un grand nombre de cas, l'épinette noire n'est pas particulièrement bien adaptée, du point de vue de l'évolution, aux stations qu'elle occupe.

On présente des recommandations concernant le choix des provenances pour la région des Maritimes.

INTRODUCTION

Black spruce, Picea mariana (Mill.) B.S.P., is among the most important commercial tree species in Canada, primarily because of its abundance (Heinselman 1957) and its high value as a source of fiber (Besley 1959). Its natural range extends from Newfoundland to Alaska and from the northern tree limit to central Pennsylvania (Heinselman 1957).

Black spruce is the most widely planted tree species in Atlantic Canada (Fowler 1979, Hall and Khalil 1979) and ranks among the two or three most important reforestation species in Quebec (Corriveau 1979) and Ontario (Morgenstern and Wang 1979).

An understanding of the genetic variability of a species is important for the development of effective tree improvement strategies. Unfortunately, black spruce has been the subject of studies of natural variation for only the last two decades. Despite the general paucity of reliable information on genetic variability, black spruce is the subject of genetic improvement efforts in all provinces where it is considered an important reforestation species. Clonal and, or, seedling seed orchards from phenotypically superior trees have been established in Ontario and the Maritime provinces.

The first study of genetic variation in black spruce was undertaken by Morgenstern in 1963 (Morgenstern 1969a,b). The objective of that study was to determine the variation pattern of the species along a north-south transect in central Ontario. He found the genetic variation pattern with respect to germination, phenology, survival, and growth to be clinal and independent of local site characteristics. Dietrichson (1969), using the same spruce populations as Morgenstern, reported essentially the same clinal pattern of variation with respect to early growth and hardiness.

Fowler and Mullin (1977) also working with central Ontario populations of black spruce, reported significant differences in germination, 10-year growth, and survival between populations from different stands within regions, as well as substantial differences between regions. The differences were not related to site (upland and lowland) of the provenances. The pattern of variation appeared to be clinal with a high degree of variation among stands. Khalil (1973, 1975, 1981) on the other hand considers the variation pattern of black spruce from boreal Newfoundland-Labrador to be ecotypic. Morgenstern (1978) and Khalil (1981) suggest that the ecotypic pattern is the result of the climate of Newfoundland-Labrador which does not follow simple gradients (north-south) as it does in continental parts of Canada.

More recently, regional provenance studies have been undertaken in Manitoba (Segaran 1977, Segaran et al. 1978) and in Quebec (Lamontagne 1973). Segaran (1979) reported the variation pattern to be essentially clinal but with large differences between provenances with respect to stability. Some provenances exhibited large provenance x environment interactions while others did not.

It is evident from the preceding brief review that results from regional provenance studies, based on limited sampling, have been highly variable and are insufficient to establish species-wide variation patterns (Morgenstern and Kokocinski 1976).

The first range-wide provenance test of black spruce was started in 1967. The test was coordinated by Mr. Mark Holst (retired) Petawawa National Forestry Institute (PNFI) and Dr. E.K. Morgenstern (formerly of PNFI). From 1967 to 1970, cooperators from across Canada and northern United States collected black spruce seeds from 202 provenances well distributed across the range of the species. Early results from this range-wide test suggest that the pattern of genetic variation is generally clinal (Pollard and Logan 1976, Morgenstern 1978, Segaran 1978, Corriveau and Vallée 1981) with respect to most characteristics studied. As part of the cooperative black spruce provenance tests, nursery experiments were carried out at the Acadia Forest Experiment Station (AFES) and 10 field trials were established in the Maritimes Region. In this paper we report, in detail, on the early results of these experiments.

MATERIALS AND METHODS

Nursery Procedures

In the spring of 1971, seeds representing 103 provenances were available for testing in the Maritimes. The seed lots selected for testing in the Maritimes differed substantially from those tested elsewhere. The lots were not uniformly distributed across the species range, but were concentrated on those areas which were intuitively thought to be most promising. For example, only a few of the samples from the northern and western part of the species range were included, whereas all available Maritime seed lots were used. Pertinent data on the seed lots are presented in Table 1 and their geographic distribution is illustrated in Figs. 1 and 2.

Seeds from the 103 provenances were sown in the AFES nursery in May 1971. The nursery design was randomized blocks replicated six times. In each block, the seeds were sown in three 1.2-m rows, 10 cm apart. In the spring/summer 1972, the seedlings were thinned to a spacing of 5 cm, within rows. In the spring of

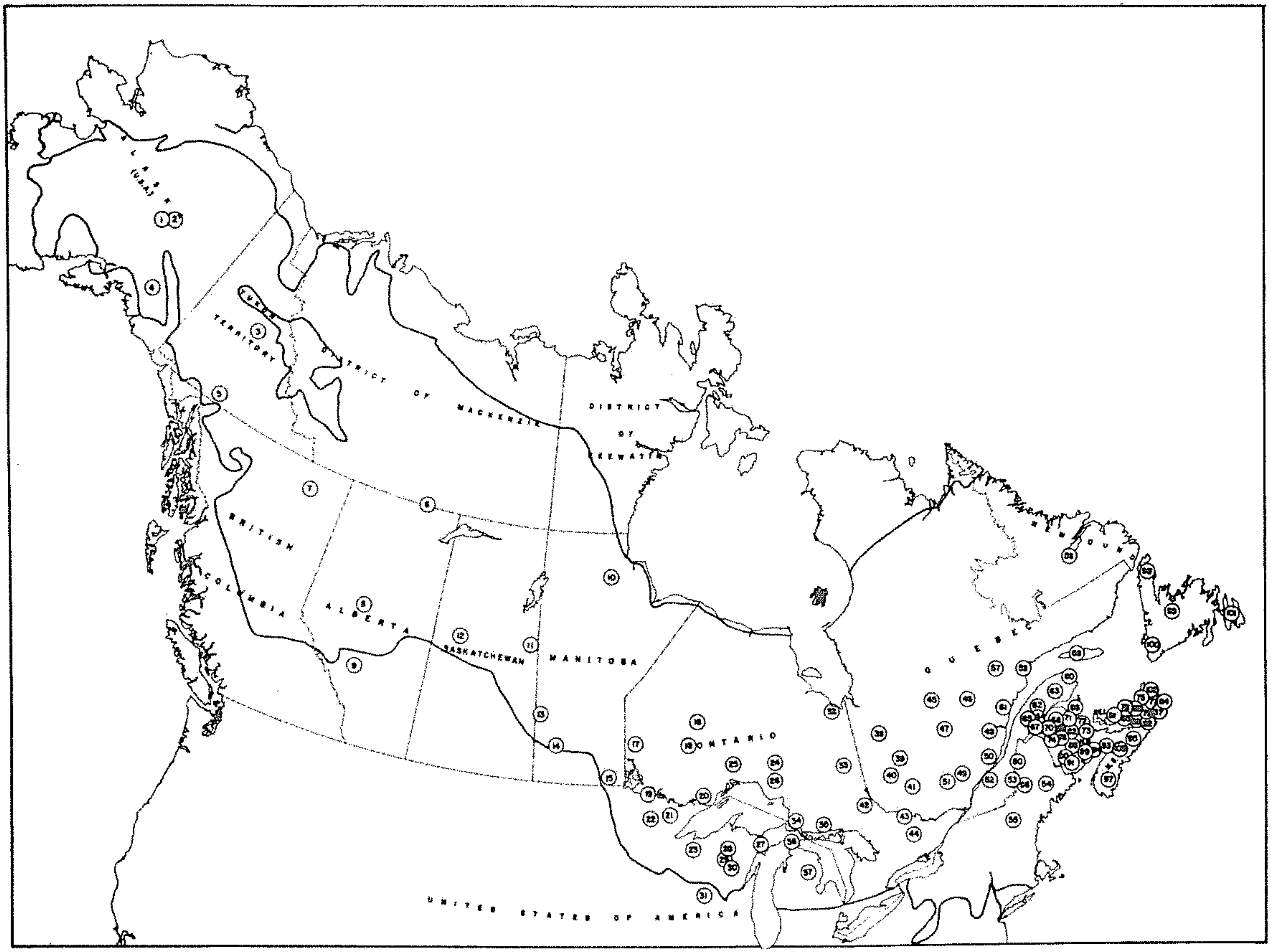

Fig. 1. Geographic distribution of seedlots indicated by plot numbers.

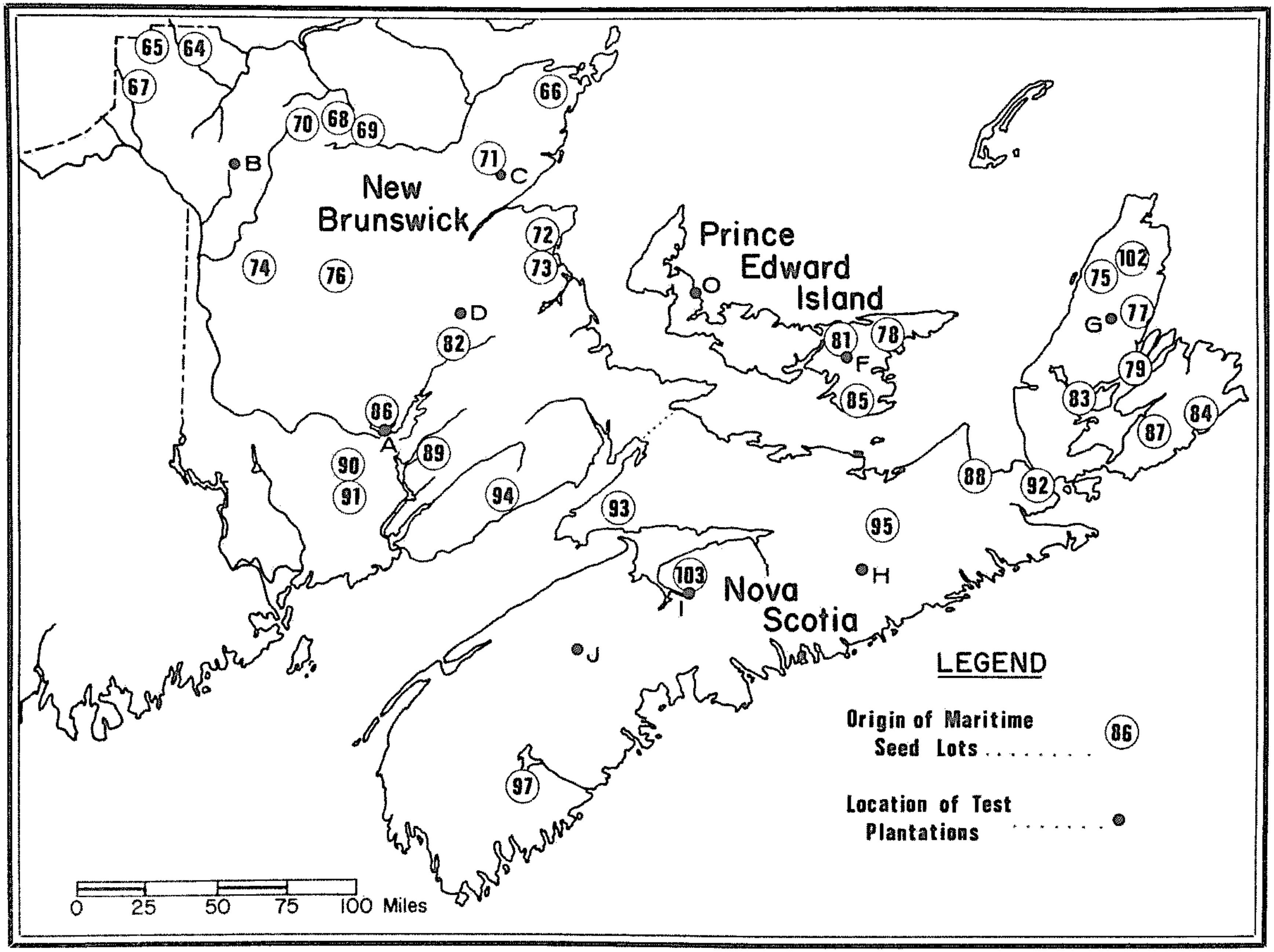

Fig. 2. Geographic distribution of Maritimes seedlots and locations of the 10 test locations.

1973, the two outer rows of seedlings in each block were lifted and transplanted at AFES. The center row of each plot was retained for nursery measurement and phenological observations.

In May 1975, 2-2 seedlings from up to 99 provenances were used to establish nine field trials in the Maritimes Region. The provenances used in each of the trials and pertinent information on the location, climate, site, and design of each trial is presented in Tables 1 and 2. The geographic distribution of the trials is illustrated in Fig. 2. Extra seedlings were nursed at the AFES nursery.

Survival counts were carried out at the end of the first growing season in the field (1975) and dead or missing seedlings were replaced the following spring with 2-3 stock of the same provenance. Mortality was low in all trials except for 60-F at Dromore, P.E.I., which had been planted on an old field without site preparation. Because of the poor initial survival of the Dromore trial, in the spring of 1977, a second trial was established on Prince Edward Island near East Bideford (60-0) using 2-4 stock.

An effort was made to control competing vegetation in the trials from 1975 to 1979. In the summer of 1979, after height growth had ceased, total height was measured for the seedlings in all 10 field trials. At this time the seedlings were 9 years from germination and except for experiment 60-0 the seedlings had completed five growing seasons in the field. Seedlings in experiment 60-0 were the same age from germination but only 3 years from field planting.

Statistical Analyses

Since unequal numbers of provenances and replicates were represented among the 10 test locations, analyses of variance and means for both height and survival were computed separately for each location. When significant differences among provenance means were found, mean separation was performed by the Scott-Knott's (1974) cluster analysis method as illustrated by Gates and Bilbro (1978). Correlation analysis was carried out using growth, survival, and geographic and climatic variables. Climatic data for each provenance were compiled from the Canadian Meteorological Service and the United States Weather Bureau (Chapman and Brown 1966, Visher 1954), using interpolation where necessary. The list of 38 variables, including 10 geographic and ecological variables and 28 growth, survival, and juvenile character variables, is presented in Table 6. Growing season and degree-days were based on 5.6°C. Correlation coefficients among means of these 38 variables were computed.

A separate correlation matrix was computed excluding elevation, height and survival at the East Bideford, P.E.I. plantation, which caused most of the imbalance in the data. This correlation matrix included day lengths on June 21 which were obtained from Withrow (1959) and was further analysed for factor analysis. The initial factor extraction was performed by principal component method, and those eigenvalues greater than 1 were retained. The final factor loadings were obtained after varimax rotation (Kaiser 1958) for improved interpretation of factors.

Analyses of variance for 52 provenances common to nine test locations, excluding East Bideford, P.E.I., were performed to detect provenance x location interactions for both total height and survival. The model used was:

$$Y_{ijk} = \mu + L_i + R_{ij} + P_k + LP_{ik} + e_{ijk},$$

where

Y_{ijk} is performance of k^{th} provenance in j^{th} replicate within i^{th} test location,

μ is experimental mean,

L_i is effect of i^{th} test location,

R_{ij} is effect of j^{th} replication within i^{th} location,

P_k is effect of k^{th} provenance,

LP_{ik} is effect of interaction between i^{th} location and k^{th} provenance, and

e_{ijk} is random error.

The analyses were based on plot means using the first four replicates in each location to provide a balanced data set.

Regression analyses for nursery and field performances on 10 ecological and two juvenile character variables, i.e., seed weight and number of cotyledons, were carried out. Stepwise regression methods were used limiting the number of independent variables to five or less and maximizing R-squared values.

RESULTS AND DISCUSSION

General Trends

Mean performances of provenances at the nursery and at each field location, results of analyses of variance, and mean separation are summarized in Tables 3, 4, and 5. Significant differences among provenance means for 5-year field heights were found at all test locations. The number of non-overlapping groups of means for height across the test locations varied from 2 to 6, and provenance means combined over locations ranged from 43.0 to 124.0 cm with a grand mean of 96.7 cm. The fastest growing provenance is from Mio, Michigan (S6941), and is followed by S6905 (Nipissing Preserve, Ont.) and MS1628 (N. Branch Black River, N.B.) which attained 124.0, 112.7 and 110.9 cm, respectively. Differences among means of test locations were large, ranging from 48.6 cm at Bartibog, N.B. to 139.1 cm at Black Brook, N.B.

Differences in mean 5-year survival were significant at only two locations, AFES, N.B. and Cape Breton Highlands, N.S., and resulted from poor survival of northwestern provenances i.e., Yukon and Alaska. Overall survival of provenances ranged from 54.2 to 95.8% with a grand mean 86.3%. Survival at the 10 test locations ranged from 79.2 (Pleasant Valley, N.S.) to 95.7% (East Bideford, P.E.I.).

A total of 341 correlation coefficients was statistically significant at 0.05 probability level (Table 6). Most ecological variables, i.e., variable numbers 1 through 11, related to origin of provenances, were interrelated and strongly correlated with most juvenile character variables, i.e., variables number 33 through 38. All the correlations between overall height and ecological variables were significant; however, significant correlation between the ecological variables and height at various test locations was random. The highest coefficients for overall height with the ecological variables were latitude (-0.811) and degree-days (0.703).

Correlations among heights at different test locations were significant except for three cases, implying a general lack of provenance x location interactions. Generally, poor correlations were found for field survival at various locations, i.e., variables number 22 through 31, with all other variables; however, significant correlations were obtained for these variables with overall survival. All the correlations among nursery heights, i.e., variables 35 through 38, were highly significant, and these were well correlated with overall height as well as heights at various locations. Seed weight was correlated with number of cotyledons and to some extent with first-year nursery height but no significant correlations were found as seedling became older, i.e., 2-, 3- and 4-year nursery heights and overall height.

Results of a rotated factor analysis are presented in Table 7. Total variance, i.e., sum of eigenvalues, amounted to 35.98. Ten factors whose eigenvalues were greater than 1.0, explained 79.3% of the variance. The factor loadings are estimates of the model:

$$X_i = \lambda_{i1}f_1 + \lambda_{i2}f_2 + \dots + \lambda_{im}f_m + e_i,$$

where

X_i is i^{th} correlated variable observed,

λ_{ij} is the loading coefficient for X_i on the j^{th} factor,

f_i is the j^{th} factor which is an unobservable random variable, and

e_i is random error associated with X_i.

The analysis resulted in 10 factors (m = 10) and the observed variables (X_i's) can be expressed in terms of these factors, for example,

$$\text{height (A)} = .67f_1 + .32f_8 + e_{11} \text{ and}$$

$$\text{height (B)} = .75\ f_1 + e_{12}, \text{ etc.}$$

An application of this result is to reduce the size of the problem by dropping certain measurements that are heavily loaded on a given factor leaving only one or a few measurements. For example, spring and fall frost date may be dropped, retaining frost-free days as these are all heavily loaded on factor 2 with similar magnitude; a similar procedure can be applied to heights and growing seasons.

Interpretation of these factors (f 's) is an important part of the analysis for explaining underlying factors that contribute to major variation patterns. The first factor had the heaviest loading on overall height and heavy loadings on height growth at all test locations. Therefore, the underlying factor is interpreted as a growth factor. This indicates that height growth is the most important measure in distinguishing variation among the provenances. The second factor had heavy loadings on frost dates with the heaviest loading on the frost-free period, and therefore, is interpreted as a temperature factor. The third factor had heavy loadings on growing season, and is interpreted as a growing-season factor. These last two factors relate to ecological conditions at the place of seed origin. Morgenstern (1969a) also reported heavy loadings on day length and temperature. This suggests that regional environmental effects are a guiding force in natural selection and that natural selection favors genotypes best-adapted to regional climates. The fourth factor had heavy loadings on longitude. The strong influence of the ecological and geographic factors (factors 2, 3, and 4), supports Morgensterns' (1969a,b) conclusion that a clinal variation pattern has been developed within the species range. The fifth factor is interpreted as a juvenile growth factor as it has heavy loadings on 1- and 2-year heights. Factors 6 through 10 had heavy loadings on survival at specific test locations, and are interpreted as being indicative of local adaptation. The variation in survival may be due to local climatic or edaphic conditions, e.g., soil moisture at the planting sites.

Analyses of variance for field height and survival using the 52 provenances common to nine test locations indicates that locations, replicates within location, and provenances are significant sources of variation (Table 8). No provenance x location interactions were found for height or survival.

Results of the best 5-variable regression analyses are presented in Table 9, and all regressions are highly significant. The important predictors of height response were beginning and end of growing seasons, which were included in five regression equations. Latitude was also an important predictor which was included in three equations directly, and was indirectly represented in other equations. Regression analyses for survival were not reliable because R-squared values were too low.

Provenance Responses to Environments

Although overall genotype x environment interactions were absent for the 52 provenances tested at nine locations, several differential responses of provenances at different environments were observed. Since fast growth and good survival are of prime importance, responses of the 21 provenances which fell into the highest two clusters of heights were further examined by comparing stability parameters derived by regression (Eberhart and Russell 1966).

A set of regressions for height was computed on an environmental index. Regressions for the 21 tallest provenances are presented in Table 10. The environmental index was computed as the mean height of the 52 provenances common to each test location and represents the relative productivity of the test locations. The stability of a provenance is determined by two parameters: one, the regression coefficient (b_1) that measures the linear response of the provenance to a range of environments, and the other, the deviation from the regression ($\bar{S}d_i^2$). For any given set of environmental indices, a regression coefficient defines a predictable portion of provenance response, while deviations measure the unpredictable irregularities in provenance response. Both aspects of stability should be considered together when evaluating the adaptability of provenances.

Since the regression coefficient measures a predictable portion of provenance response, breeders have some control over its application. By definition, a stable genotype is one that performs the same over a range of environments and implies a regression coefficient of zero. However, low regression coefficients are often associated with low yield (Eberhart and Russell 1966) and a zero regression coefficient can also be obtained when there is no linear relationship between the phenotype and the environment (Shukla 1972). Consequently, many authors choose average stability as the working definition of a stable genotype, i.e., regression coefficient of unity ($b = 1$). It follows that populations from provenances having slope values lower or higher than unity have above-average or below-average stability, respectively.

Deviations from the regression measure the unpredictable portion of provenance response and can be used by breeders to help identify linearly responding provenances. As the size of the deviation increases, the response of populations to different environments is less predictable. Considering both measures of phenotypic stability, the most stable provenances for use over a wide range of planting sites (environments) would be those with regression coefficient of unity ($b = 1$) and zero deviation ($\bar{S}d_i^2=0$).

For the purpose of provenance recommendations, the set of provenance with a mean height greater than 105 cm (the grand mean of the 21 provenances) was further examined in respect to stability parameters. As stability parameters are relative to the average performance of all the provenances in a range of environments, the stability of a specific provenance will be influenced by the performance of the other provenances (Morgenstern and Teich 1969), and provenances that respond differently from others can be identified.

Of the eight tallest provenances ($\bar{x} > 105$), two groups of provenances, namely relatively predictable and unpredictable provenances, can be identified by examining the size of the deviation mean squares. Provenances 34, 85, 72, and 90 had smaller-than-average deviation mean squares, and except at Stanley and AFES, whose environmental index values were the same, their performance improved consistently as the value of the environmental index increased (Fig. 3). On the other hand, performance of unstable provenances (numbers 27, 29, 35, and 42) was inconsistent especially at East Dalhousie and Black Brook (Fig. 4).

Some adaptive recommendations can be made by examining regression coefficients of the predictable provenances. For example, provenance 90 which is highly predictable and has a regression coefficient of $b = 1.258$, is suitable for planting in favorable environments, because it has the ability to take advantage of these environments. This same provenance ranked low in poor environments (Fig. 3) when compared with other fast-growing provenances. Similarly, provenances 34 and 85 are expected to perform consistently over a wide range of environments.

As Morgenstern and Teich (1969) noted, the application of stability criteria in forest tree breeding is promising; however, selection

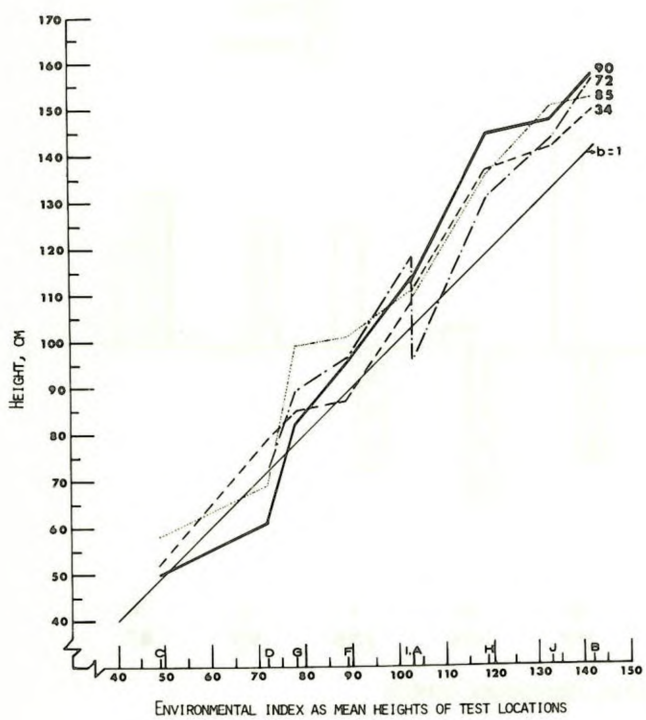

Fig. 3. Responses of fast-growing and predictable provenances on the environmental index.

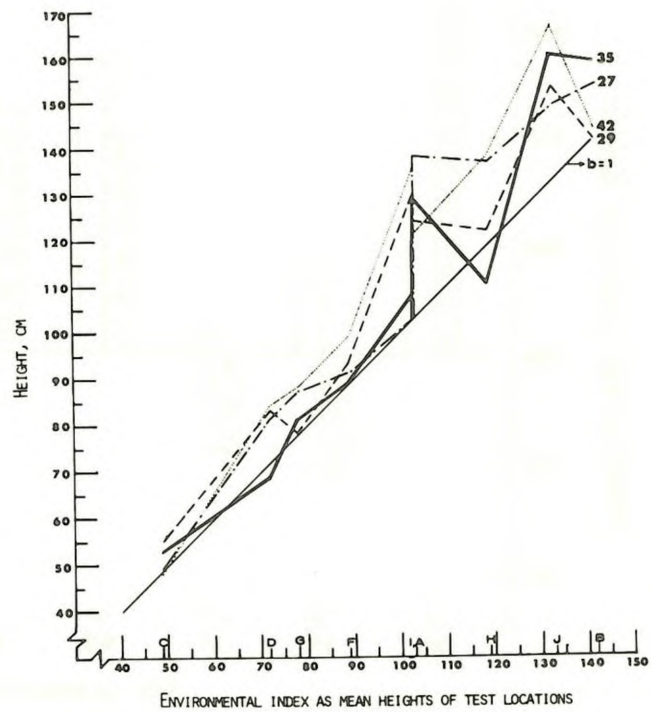

Fig. 4. Responses of the fast-growing but unpredictable provenances on the environmental index.

based on stability alone is not practical because stableness does not necessarily lead to improved performance. For the initial stage of selection, means and other specific parameters should be used. Subsequently, stability parameters can be used to identify stable and unstable provenances.

In this report, the deviation mean squares were the best criteria for identifying unpredictable provenances. Incidentally, the deviation sum of squares is closely related to Wricke's (1962) 'Ecovalence' which is another measure of stability. The regression coefficients are particularly useful for identifying provenances adapted to specific environments.

General Discussion

The information on height and survival of black spruce of different provenances is based on trees that are only 9 years from germination and have spent only 5 years growing under field conditions. Obviously, conclusions and recommendations based on this information must be considered tentative. The following facts suggest however, that the 9-year data are valid:

1. The pattern of genetic variation in height growth is essentially clinal.
2. There is a strong correlation between nursery performance and 5-year height in the field.
3. Genotype x location interactions are not important.

Height at age 5 years from planting is most strongly correlated with latitude (r = 0.81). The 10 tallest provenances over all test locations are well distributed from east to west across the species range but all are from south of latitude 47°N. There is an indication that a disproportionate number of the better growing provenances are from south of 47°N latitude in Ontario and the Lake States. However because of the young age of the trial, we suggest that it would not be wise at this time to use provenances from outside the Maritimes Region for reforestation within the Region. This suggestion is supported by the fact that of the eight best provenances, overall performance of the three from the Maritimes was "predictable" whereas four of five from non-Maritime sources were "unpredictable"

Within the Maritimes Region there is great deal of variation between provenances. Height and survival of the local provenance with respect to the test mean are presented in Fig. 5. The local provenance i.e., the one

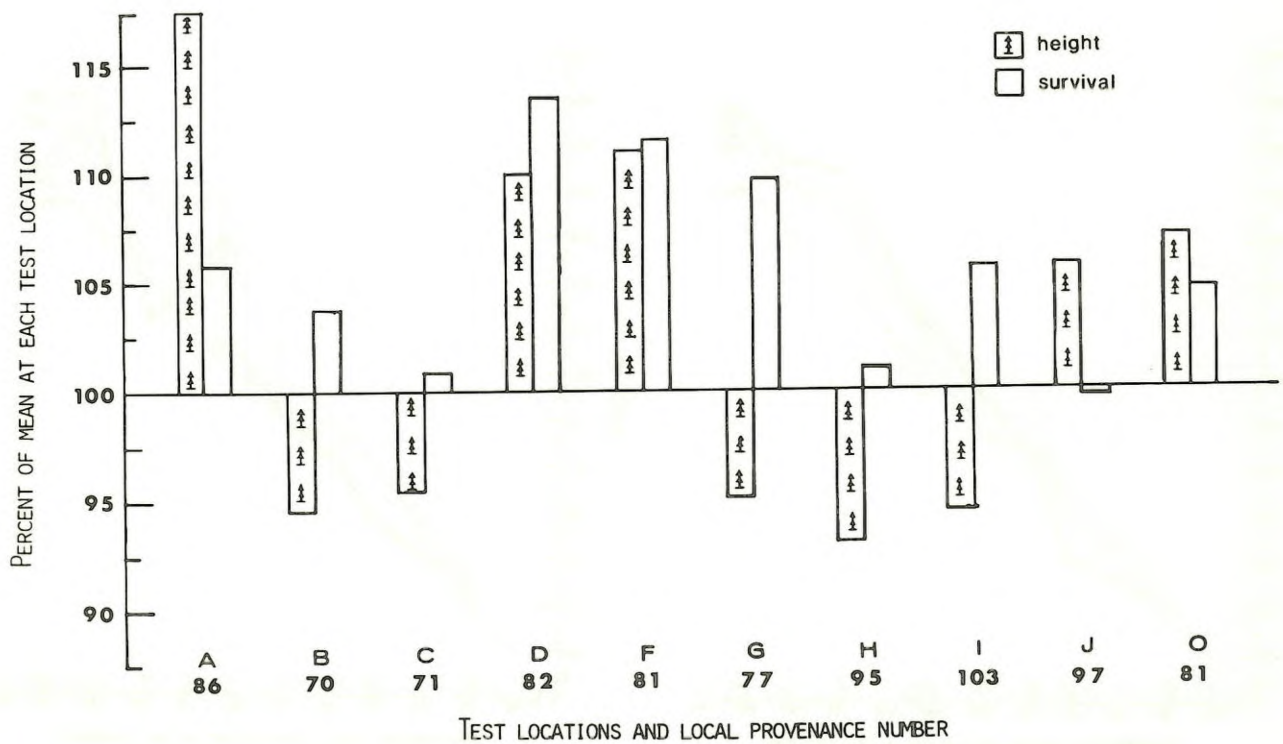

Fig. 5. Performance of local provenance compared to average performance at each location.

geographically closest to the test plantation, was among the 10 best only at three of the test locations (AFES, N.B., Dromore, P.E.I. and East Bideford, P.E.I.). At two other test locations (East Dalhousie, N.S. and Sabbies Brook, N.B.) the local provenance was taller than the mean for the test, whereas, at the other five test locations the local provenance was actually shorter than the test mean.

In respect to survival, the local provenance was above average at all locations except at East Dalhousie, N.S. where it was only marginally below average.

The generally poor performance of local provenances with respect to height is unexpected and suggests that 1) height growth is a poor measure of adaptation to local environments, or 2) black spruce is not particularly well adapted to many of the sites that it occupies locally.

Black spruce, in the absence of disturbance (usually fire), is generally confined to wet or occasionally very dry sites. Following disturbance the species is able to colonize richer upland environments. It is from such sites that most of the seeds for the provenance test were obtained. The species, however, is only able to hold these rich upland sites for one generation as it is usually not able to regenerate on these sites in the absence of further disturbance. Under this scenario, the probability that highly-adapted upland types have evolved, is limited.

The high variability among populations of Maritime provenances make it difficult to identify areas of best provenance despite the fact that genotype x environment interactions are small. One generality that can be made is that the Cape Breton Highland provenances are consistently poor even when planted on the Highland. Highland black spruce occurs in isolated small patches along water courses and certainly does not represent a panmictic breeding population. In addition, these populations are phenologically out of phase with, and thus genetically isolated from, the rest of the Region. It follows that the generally inferior growth of trees from these provenances may result from high levels of inbreeding.

RECOMMENDATIONS

An attempt is made to formulate recommendations as to the best provenances of black spruce for use in various parts of the Maritime Region. Because of the age of the trial (only 9 years from germination) and the suggestion that Maritime provenances are more predictable than non-Maritime, only Maritime provenances are considered for the recommendations. The recommendations are, in part, made with respect to seed zones as delineated by Fowler and MacGillivray (1967) (see Fig. 6).

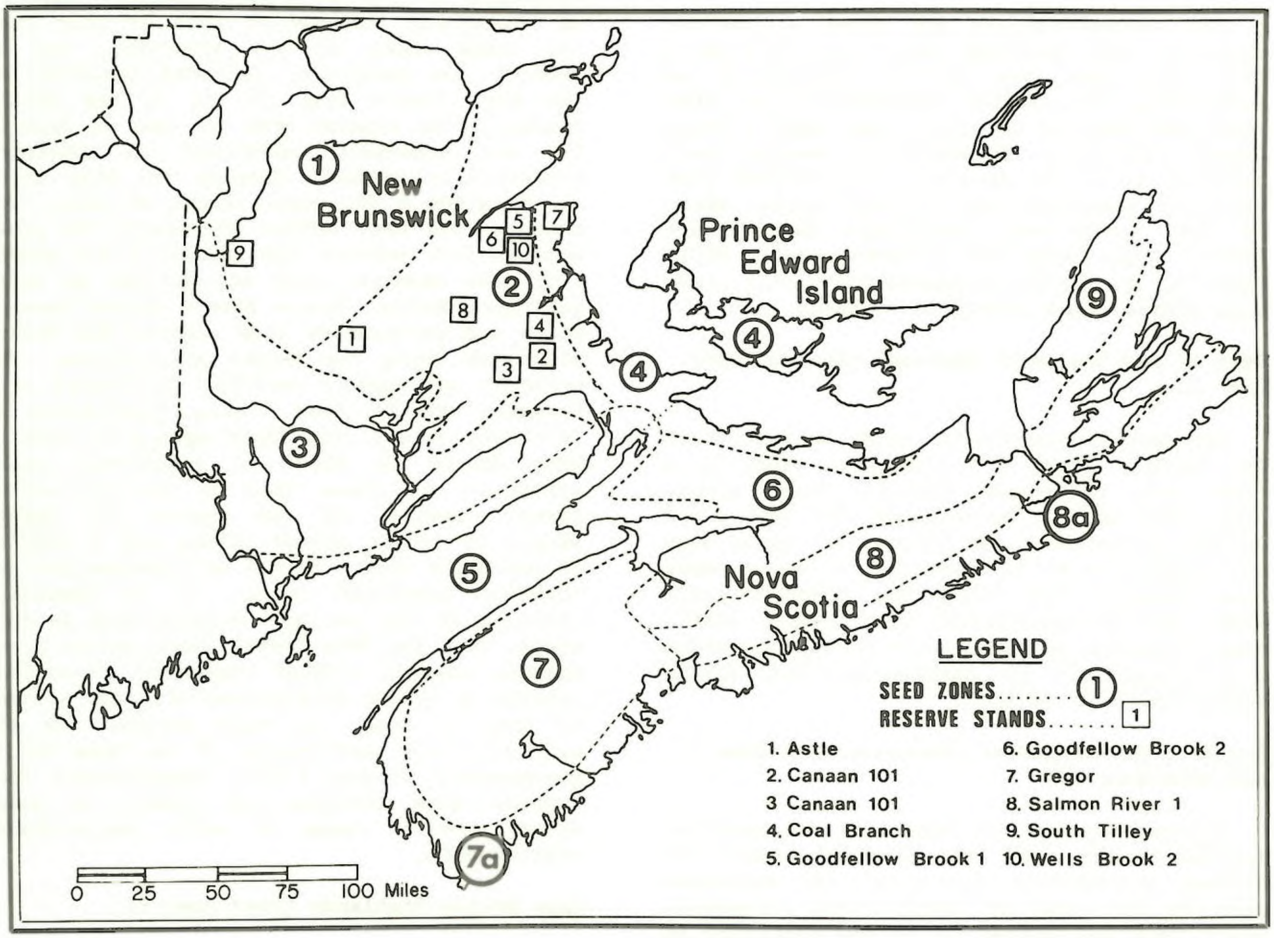

Fig. 6. Map of Maritime Provinces showing seed zones (from Fowler and MacGillivray 1967) and location of New Brunswick Department of Natural Resources reserve stands.

In 1976, the New Brunswick Department of Natural Resources established a text of 37 selected black spruce stands at six sites well distributed across the Province. The locations of reserve stands discussed in the recommendations are shown in Fig. 6. These 37 stands have been reserved as potential seed production stands. The recommendations are also partly based on 5-year height and survival information from this stand test (Moore 1982).[1]

Northwestern New Brunswick (Seed Zone 1)

The recommendations are based on performance in a single test (B) located on an exceptionally productive site at Black Brook. The tallest seedlings in this test are from central and southern New Brunswick and Prince Edward Island. Differences in survival are not significant. There appears to be an advantage in using seeds from 1 to 2° of latitude further south. For good sites in this area we recommend seeds from good stands in the southern part of Seed Zone 1, the eastern part of Seed Zone 2, and central Seed Zone 3. Provenances from Seed Zone 4 also do well. These recommendations are supported by 5-year growth data from a New Brunswick stand test (Moore 1982).[1] Seeds are recommended from the following reserve stands: Canaan 104, Canaan 101, Gregor, Astle, and South Tilley. Seeds from Cape Breton and other parts of Nova Scotia should definitely be avoided. For more severe, less productive sites in Seed Zone 1, local provenances should be favored.

[1]Moore, J.P. 1982. Five year results of a black spruce provenance test at six test sites in New Brunswick. Unpublished B.Sc. thesis, School of Forestry, University of New Brunswick, Fredericton, N.B. 40 p.

Northeastern New Brunswick (NE Seed Zone 2)

The recommendations are based on performance in the Bartibog River test (C) on a flat, dry, jack pine site of moderate to low fertility. The tallest provenances are from south and west of the test site. Again, there appears to be an advantage in moving seeds north 1 to 2° of latitude or eastward from areas of generally more fertile soils. Based on this study and unpublished data (Moore 1982)[1] seeds from the reserve stand, Wells Brook 2, are highly recommended for this area. Nova Scotia seeds should be avoided.

Central New Brunswick Lowlands (Central Seed Zone 2)

The recommendations are based on results at the Sabbies Brook (D) test site which is a flat, wet, moderately fertile, black spruce site. The tallest provenances are local, and unlike in northern New Brunswick, there does not appear to be an advantage in using seeds from southern New Brunswick. Based on this study and on unpublished data (Moore 1982)[1] seeds from the reserve stands Goodfellow Brook 1 and Canaan 104 are recommended. Nova Scotia seeds should be avoided.

Southern New Brunswick (Southern Seed Zone 2 and Seed Zone 3)

Recommendations for this area are based on results at the AFES test site (A). Again the tallest provenances are local and encompass much of the area of central New Brunswick. There does not appear to be any advantage in moving seeds north. In general, Nova Scotia provenances, especially ones from Cape Breton, are to be avoided. Seeds from good stands in central New Brunswick such as reserve stands Goodfellow Brook 1 and 2, Canaan 104, and Salmon River 1 should be highly satisfactory.

Prince Edward Island and Adjacent Mainland (Seed Zone 4)

The recommendations for this area are based on results of two tests established on fresh, moderately fertile, old-field sites on Prince Edward Island (Dromore (F) and East Bideford (O)). The tallest provenances are local with provenances from eastern Prince Edward Island and the east coast of New Brunswick perfroming well. It is recommended that local seed be used for reforestation on Prince Edward Island. Seeds from reserve stands in the eastern part of Seed Zone 2, such as Canaan 104, Canaan 101, Coal Branch, and Goodfellow Brook 1 and 2 should also be satisfactory for all of Seed Zone 4.

Nova Scotia Mainland (Seed Zones 6, 7, 8)

Recommendations for mainland Nova Scotia must be considered more tentative than for elsewhere in the Maritimes, because there is no supporting information such as that from the stand tests in New Brunswick, and in general, the geographic patterns exhibited in the Nova Scotia test (H, I, J) are highly variable. The results from the test at Stanley (I) are especially difficult to interpret (essentially random). Despite the high level of variation a few consistences do exist. For example, the Cape Breton provenance and provenances from nothern New Brunswick are generally poor wherever they are planted in mainland Nova Scotia. Prince Edward Island provenances and provenances from central New Brunswick rank among the better provenances. The mediocre and highly variable (unstable) performance of the Nova Scotia provenances is difficult to explain. Black spruce in much of Nova Scotia is found in relatively small stands on wet sites. Much of the surrounding forest consists of red spruce (P. rubens Sarg.) on richer upland sites, and a complex of red-black spruce hybrid on intermediate and recently disturbed sites. It is possible, although it has not been demonstrated in this study, that the Nova Scotia black spruce provenances contain a high component of natural hybrids or hybrid derivatives with red spruce. If this is true, it would account for the generally poor performance of the Nova Scotia provenances. Manley (1975) demonstrated that hybrids were inferior in growth to black spruce over a range of early successional environments.

Cape Breton Highlands (Seed Zone 9)

The recommendations are based on performance in a single test (G), on a flat, fresh, moderately fertile site that formerly supported a mature stand of balsam fir (Abies balsamea (L.) Mill.). Exposure to strong winds is an integral part of the local environment. Recommendations for the Cape Breton Highlands must be considered extremely tentative because, to date, the seedlings have been to a large extent protected during the winter by snow. More definitive results should be available in the next few years when the seedlings become more exposed. The local Highlands provenances are among the slowest growing provenances in the test (except for provenance from the far northwest) and have only average survival. Provenances from Prince Edward Island, northern New Brunswick, and Newfoundland are promising. Black spruce on the Highlands is found in small isolated strips along water courses. These populations are genetically isolated from the Maritimes black spruce by distance, and possibly more important, by phenology. It is quite conceivable that Highlands black spruce is inbred to the point it grows slowly no matter where it is planted in the Region.

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Table 1. Geographic origin of black spruce seed lots and distribution of these seed lots in 10 Maritimes field experiments

PNFI No S	MFRC No MS	Trial No	Origin of provenances: Place Name	Prov.	Lat. °N	Long. °N	Elev. m	No trees	Location of field experiments: AFES N.B.	Black Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton H'lands N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.
6801		101	Holyrood	Nfld.	47.3	53.1	90	16	x	x	x	x	x	x	x	x	x	x
6802		100	Jeffrey's	Nfld.	48.2	58.9	60	16	x	x	x	x	x	x	x	x	x	x
6803		99	Bishop's Falls	Nfld.	49.0	56.4	60	7	x	x	x	x	x	x	x	x	x	–
6805		56	Goose Bay Lab.	Nfld.	53.4	60.4	3	16	x	x	x	x	–	x	x	–	x	–
6804		98	Roddickton	Nfld.	50.9	56.1	50	16	x	–	x	x	–	x	x	–	x	x
7064	81	93	Chignecto	N.S.	45.5	64.5	50	30	x	x	x	x	x	x	x	x	x	–
	1530	84	Bengal Rd.	N.S.	45.9	60.2	60	20	x	x	x	x	x	x	x	x	x	x
6809	1536	77	East Br. No. River	N.S.	46.5	60.7	430	20	x	x	–	–	x	x	–	x	–	–
	1542	83	Lewis Mt.	N.S.	46.0	61.1	230	20	x	–	–	–	x	x	x	x	–	–
	1543	92	Guysborough Shore	N.S.	45.4	61.4	50	20	x	–	–	–	x	–	x	x	–	–
	1544	95	West River St. Mary's	N.S.	45.3	62.6	150	20	x	–	–	–	x	x	x	x	–	–
	1545	87	Irish Cove	N.S.	45.8	60.5	120	20	x	–	–	–	x	–	–	x	–	–
	1546	88	So. Side Harbour	N.S.	45.6	61.9	20	20	x	x	–	x	x	x	x	x	x	–
	1549	79	No. Gut, St. Ann's	N.S.	46.2	60.6	80	20	x	x	x	x	x	x	x	x	x	–
	1627	75	Benjie's Lake	N.S.	46.7	60.8	410	20	x	x	–	x	x	x	x	x	x	–
	1679	102	North Mt.	N.S.	46.8	60.7	460	20	–	–	–	–	–	x	–	–	–	–
6811	1847	97	So. West N.S.[1]	N.S.	(44.0)	(65.2)	(70)	60	x	–	–	–	x	x	x	x	x	–
	2075	103	Stanley	N.S.	45.1	63.8	60	–	x	–	x	x	x	x	x	x	x	–
	1328	81	Johnstons River	P.E.I.	46.3	62.9	20	21		x	x	x	x	x	x	x	x	x
6806	1329	85	Garfield	P.E.I.	46.0	62.8	30	18	x	x	x	x	x	x	x	x	x	–
7066	1330	78	Farmington	P.E.I.	46.4	62.5	20	22	x	x	x	x	x	x	x	x	x	–
7069	46	90	Br. Rd. Geary	N.B.	45.7	66.5	20	20	x	x	x	x	x	x	x	x	x	x
	1528	74	Stuart Plains Rd.	N.B.	46.8	67.2	170	20	x	x	x	x	x	–	x	x	x	–
6812	1529	70	Williams Brook	N.B.	47.5	66.9	440	20	x	x	x	x	x	x	–	x	x	x
6807	1531	91	Base Gagetown	N.B.	45.6	66.5	90	20	x	x	x	x	x	x	x	x	x	x
	1532	68	McCormic Fir Tower	N.B.	47.6	66.6	380	20	x	x	x	x	x	x	x	x	x	–
	1533	69	Simpson's Field	N.B.	47.5	66.4	370	20	x	x	x	x	x	x	x	x	x	x
7088	1534	67	Green River	N.B.	47.7	68.3	400	20	x	x	x	x	x	x	x	x	x	x
6808	1535	64	States Lake	N.B.	47.9	67.8	370	20	x	x	x	x	x	x	x	x	x	x

Table 1. Continued

PNFI No S	MFRC No MS	Trial No	Place Name	Prov.	Lat. °N	Long. °N	Elev. m	No trees	AFES N.B.	Black Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton H'lands N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.
			Origin of provenances						Location of field experiments									
6855		38	Matagami	P.Q.	49.6	77.7	270	9	x	x	x	x	x	x	x	x	x	x
6860		62	Causapscal	P.Q.	48.5	67.1	240	14	x	x	x	x	x	x	x	x	x	x
		53	Lac du Portage	P.Q.	45.9	70.3	550	14	–	–	–	–	–	–	–	–	–	–
		52	Blandford	P.Q.	46.3	72.0	90	5	x	x	x	x	x	x	–	x	x	–
6863		50	Valcartier II	P.Q.	46.9	71.5	180	15	x	x	x	x	x	–	x	x	x	–
6851		51	St.Michel des Saints	P.Q.	46.8	74.4	520	13	x	x	x	x	x	x	x	x	x	x
6901		44	Brancroft	Ont.	45.2	77.2	350	15	x	x	x	x	x	x	x	x	x	x
6903		43	Chalk River	Ont.	46.0	77.4	160	15	x	x	x	x	x	x	x	x	x	x
6905		42	Nipissing Preserve	Ont.	46.9	79.8	330	15	x	x	x	x	x	x	x	x	x	x
6909		24	W. Otasawian River	Ont.	49.7	85.1	210	15	x	x	x	x	x	x	x	x	x	x
6910		25	Beardmore	Ont.	49.8	87.8	300	15	x	x	x	x	x	x	x	x	x	x
6911		35	Massey	Ont.	46.3	82.8	240	16	x	x	x	x	x	x	x	x	x	x
6913		34	Goulais River	Ont.	46.8	84.4	210	15	x	x	x	x	x	x	x	x	x	x
6914		26	White River	Ont.	48.6	85.3	370	15	x	x	x	x	x	x	x	x	x	x
6919		18	Savant Lake	Ont.	50.3	90.8	400	16	x	x	x	x	x	x	x	x	x	x
6921		16	Pickle Lake	Ont.	51.5	90.2	400	15	x	x	x	x	x	x	x	x	x	x
6927		17	Minaki	Ont.	50.8	94.3	340	15	x	x	x	x	x	x	x	x	x	x
6929		19	Devlin	Ont.	48.7	93.7	350	15	x	x	x	x	x	x	x	x	x	x
6932		20	Shebandowan	Ont.	48.7	90.2	450	15	x	x	x	x	x	x	x	x	x	x
6935		33	Potter	Ont.	48.9	80.9	270	12	x	x	x	x	–	x	x	–	x	x
6937		32	Moosonee II	Ont.	51.1	80.9	60	6	x	–	x	x	–	x	–	–	–	–
6941		37	Mio, Oscoda Co.	Mich.	44.6	84.3	–	20	x	x	–	–	x	x	x	x	x	–
6943		36	St. Ignace	Mich.	46.0	84.8	–	20	x	x	x	x	x	x	x	x	x	x
6944		27	Rapid River	Mich.	46.0	86.8	–	17	x	x	x	x	x	x	x	x	x	x
6947		30	Lakewood	Wis.	45.3	88.4	–	18	x	x	x	x	x	x	x	x	x	–
6948		29	Forest Co. I	Wis.	45.7	89.0	–	15	x	x	x	x	x	x	x	x	x	x
6950		28	Forest Co. III	Wis.	46.0	88.9	–	16	x	x	x	x	x	x	x	x	x	–
6952		23	Hayward	Wis.	46.1	90.9	–	16	x	x	x	x	x	x	x	x	x	–
6946		31	Mather	Wis.	44.2	90.4	–	15	x	x	x	x	x	x	x	x	x	–

Table 1. Continued

PNFI No S	MFRC No MS	Trial No	Origin of provenances: Place Name	Prov.	Lat. °N	Long. °N	Elev. m	No trees	Location of field experiments: AFES N.B.	Black Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton H'lands N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.
	1537	71	Lt. Eskedelloc Riv.	N.B.	47.3	65.5	80	20	x	–	x	–	–	–	–	–	–	–
	1538	66	N. Caraquet Riv.	N.B.	47.7	65.1	20	20	x	x	x	x	x	x	–	x	–	–
6810	1539	73	Tweedie Br.	N.B.	46.8	65.1	60	20	x	x	x	x	x	x	x	x	x	–
7087	1541	65	S. Br. Kedgwick Riv.	N.B.	47.9	68.1	430	20	x	x	x	x	x	–	–	x	x	–
	1628	72	N. Br. Black Riv.	N.B.	46.9	65.1	30	20	x	x	–	x	x	x	x	x	x	x
	1811	76	Falls Brook	N.B.	46.8	66.6	350	20	–	–	–	–	–	–	–	–	–	–
	1813	94	Crawford Lake	N.B.	45.6	65.3	270	20	x	–	–	–	–	–	–	–	–	–
	1814	82	Trout Lake	N.B.	46.4	65.7	90	20	x	x	x	x	x	x	x	x	x	x
	1815	89	Mill Brook	N.B.	45.8	65.9	80	20	x	x	x	x	x	x[2]	–	x	–	x
7079	1848	86	Acadia F.E.S.	N.B.	46.0	66.3	40	15	x	–	–	–	x	–	–	x	–	–
6848		54	Penobscot Co.	Maine	45.2	70.0	240	57	x	x	x	x	x	x	x	x	x	–
6849		96	Somerset Co.	Maine	45.5	70.0	–	26	x	–	–	–	x	–	–	x	–	–
6847		80	Somerset Co.	Maine	46.5	69.9	370	17	x	–	–	–	x	–	–	x	–	–
6846		55	Grafton Co.	N.H.	44.2	71.6	400	15	x	–	–	–	–	–	–	–	–	–
6856		57	Manicouagan	P.Q.	50.7	68.8	–	16	x	x	x	x	–	x	x	–	x	x
6859		45	Parc Mistassini	P.Q.	50.4	73.6	370	17	x	x	x	x	–	x	x	–	x	x
		47	Parc Chibougamau	P.Q.	49.0	73.4	380	15	x	x	x	x	x	x	x	x	x	x
		59	Anticosti Is.	P.Q.	49.6	63.4	180	15	x	x	x	x	–	x	x	–	x	–
		60	Baie Gaspé Sud	P.Q.	48.9	64.6	180	15	x	x	x	x	–	x	x	–	x	x
		63	Canton Marcil	P.Q.	48.5	65.8	180	15	x	x	x	x	x	x	x	x	x	x
		58	Port Cartier	P.Q.	50.1	67.1	140	13	x	x	x	x	–	x	x	–	x	x
		61	Forestville	P.Q.	48.9	69.1	120	13	x	x	x	x	–	x	x	–	x	x
		46	Peribonka	P.Q.	49.6	71.3	–	15	x	x	x	x	x	x	x	x	x	x
6861		48	Mars Ha! Ha!	P.Q.	48.2	70.9	–	15	x	x	x	x	x	x	x	x	x	x
6852		49	Lower Mattawin	P.Q.	46.9	73.4	300	15	x	x	x	x	x	x	x	x	x	–
6857		41	Parc de la Vérendrye	P.Q.	47.1	76.5	360	13	x	x	x	x	x	x	x	x	x	x
		40	Canton Pelissier	P.Q.	47.8	77.7	340	6	x	x	x	x	x	–	x	x	x	–
		39	Senneterre	P.Q.	48.4	76.9	370	15	x	x	x	x	x	x	x	x	x	x

Table 1. concluded

PNFI No S	MFRC No MS	Trial No	Origin of provenances: Place Name	Prov.	Lat. °N	Long. °N	Elev. m	No trees	Location of field experiments: AFES N.B.	Black Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton H'lands N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.
6956		21	Virginia	Minn.	47.8	92.4	-	18	x	x	x	x	x	x	x	x	x	x
6957		22	Marcell	Minn.	47.5	93.7	-	15	x	x	x	x	x	x	x	x	x	x
6961		14	Riding Mt.	Man.	50.7	100.0	680	15	x	x	x	x	-	x	x	-	x	x
[illegible]		13	Birch River	Man.	52.4	101.1	320	15	x	x	x	x	x	x	x	x	x	-
6969		11	Jan Lake	Sask.	54.9	102.8	340	15	x	-	-	-	-	x	-	-	x	x
6971		12	Beaver River	Sask.	54.7	107.8	460	15	x	-	-	-	-	x	-	-	-	-
6973		15	N.W. Angle For.	Man.	49.3	96.3	350	16	x	x	x	x	x	x	x	x	x	x
6977		10	Buckland Lake	Man.	57.6	96.7	270	14	x	-	-	-	-	x	-	-	-	-
6978		9	Rocky Mtn. House I	Alta.	52.4	115.0	1010	8	x	-	-	-	-	x	-	-	-	-
6983-B		8	Swan Hills Rd.	Alta.	55.0	115.3	850	8	x	-	-	-	-	x	-	-	-	-
6988		7	Steamboat Mt.(Foot)	B.C.	58.7	123.6	610	6	x	-	-	-	-	x	-	-	-	-
6999		6	Fort Smith	N.W.T.	60.0	112.8	240	6	x	-	-	-	-	-	-	-	-	-
6994		5	Marsh Lake	Yukon	60.5	134.4	670	11	x	-	-	-	-	x	-	-	-	-
7000		3	Mayo	Yukon	63.6	135.9	500	10	x	-	-	-	-	x	-	-	-	-
7003		4	Copper River	Alaska	62.1	145.7	550	35	x	-	-	-	-	x	-	-	-	-
7006		1	Bonanza Cr. I	Alaska	64.7	148.3	340	15	x	-	-	-	-	-	-	-	-	-
7007		2	Bonanza Cr. II	Alaska	64.7	148.3	170	15	x	-	-	-	-	x	-	-	-	-
Number of provenances included at test sites:									99	74	73	75	75	86	74	72	75	50

[x]Provenances included.

[1]Mix of three seed lots.

[2]Two replications only.

Table 2. Black spruce provenance test: location, climate, site and design of plantations

Experiment location	Lat. °N	Long. °W	Elev. m	Annual precip. mm[1]	Summer precip. mm[1]	Frost free period days[1]	Spring phenol.	Degree days above 5.6°C[2]	Site				Design (random block)		
									Aspect	Moisture	Fert.	Cover	Proven. No.	Reps. No.	No trees/plot
60-A Acadia F.E.S. Sunbury Co. N.B.	46.0	66.4	110	99	41	115	4	2750	flat	wet-fresh	mod.	mixed	99	6	8
60-B Black Brook Victoria Co., N.B.	47.3	67.5	430	102	46	100	14	2250	10°SE	fresh	high	mixed	74	5	8
60-C Bartibog River Northumberland Co., N.B.	47.2	65.6	120	94	43	110	11	2500	flat	dry	low-mod.	jack pine	73	4	8
60-D Sabbies Brook Northumberland Co., N.B.	46.6	65.6	90	94	41	105	7	2750	flat	wet-fresh	mod.	black spruce	75	4	8
60-F Dromore Queens Co., P.E.I.	45.3	62.8	40	107	41	130	10	2750	flat	fresh	mod.	old-field	74	6	8
60-G Cape Breton Highlands Inverness Co., N.S.	46.4	60.8	460	114	43	120	21	2500	flat	fresh	mod.	balsam fir	87	5	8
60-H Pleasant Valley Halifax Co. N.S.	45.1	62.7	170	132	48	120	19	2500	flat	fresh	mod.-high	mixed	74	5	8
60-I Stanley Hants Co., N.S.	45.1	63.9	30	114	41	120	7	2600	flat	wet-fresh	mod.	black spruce	75	6	8
60-J Dalhousie East Kings Co., N.S.	44.7	64.8	230	122	41	120	5	2600	5°SW	fresh-dry	mod.	mixed	75	5	8
60-O East Bideford Prince Co., P.E.I.	47.7	64.0	10	97	41	130	12	2700	5°S	fresh	mod.	old-field	50	6	4

[1]Canada Dep. For. Rural Develop. 1967, unpublished data (days later than Fredericton).
[2]Chapman and Brown. 1966.

Table 3. Seed weight, number of cotyledons and nursery growth, of black spruce of different provenances

Plot No.	Prov. or State	Weight of 100 seeds (g)	No. of cotyl-edons	Nursery height at age 1 (cm)	2	3	4
101	Nfld.	.119	4.0	3.7	19.9	34.7	54.2
100	Nfld.	.146	4.1	4.1	21.4	36.3	59.1
99	Nfld.	.130	4.4	4.1	21.4	37.0	64.9
56	Nfld.	.105	4.0	3.4	16.1	29.1	51.8
98	Nfld.	.139	4.2	2.4	13.3	24.4	47.4
93	N.S.	.154	4.7	3.5	19.2	41.3	68.2
84	N.S.	.127	4.1	3.5	20.0	34.9	56.8
77	N.S.	.121	4.1	3.1	16.0	30.9	52.6
83	N.S.	.118	4.1	2.9	16.4	33.9	52.6
92	N.S.	.118	4.3	2.6	16.7	35.5	61.2
95	N.S.	.116	4.3	3.0	18.5	39.0	61.3
87	N.S.	.131	4.5	3.1	16.5	38.0	60.5
88	N.S.	.129	4.1	2.9	18.9	39.3	63.2
79	N.S.	.119	4.2	3.3	18.2	36.1	59.2
75	N.S.	.128	3.9	3.2	17.4	32.9	51.7
102	N.S.	.123	4.0	2.8	[illegible]	32.7	55.8
97	N.S.	.105	4.4	2.6	17.2	37.3	58.1
103	N.S.	.147	4.5	2.5	17.9	38.9	64.5
81	P.E.I.	.143	4.7	4.3	20.8	39.9	63.5
85	P.E.I.	.122	4.4	3.6	19.6	39.7	71.2
78	P.E.I.	.127	4.6	3.4	20.3	42.6	67.7
90	N.B.	.133	4.6	4.9	22.6	42.9	65.9
74	N.B.	.126	4.4	3.4	20.2	38.9	63.9
70	N.B.	.111	4.1	2.8	17.5	34.7	60.2
91	N.B.	.125	4.7	3.8	20.2	42.9	68.5
68	N.B.	.112	4.3	3.0	18.9	41.4	66.7
69	N.B.	.124	4.2	3.4	19.3	36.1	57.6
67	N.B.	.120	4.2	3.2	19.7	37.6	60.1
64	N.B.	.118	4.1	3.4	19.5	35.1	55.7
71	N.B.	.126	4.5	3.1	18.6	43.5	69.7
66	N.B.	.120	4.3	2.7	16.2	35.5	57.9
73	N.B.	.121	4.5	3.5	20.5	42.5	71.0
65	N.B.	.113	4.0	2.5	15.9	30.6	55.5
72	N.B.	.105	4.4	3.2	19.7	39.8	65.9
76	N.B.	.111	4.5	2.7	16.7	40.0	62.8
94	N.B.	.105	4.2	2.4	15.0	29.9	59.8
82	N.B.	.121	4.3	3.9	22.3	41.2	63.8
89	N.B.	.114	4.3	3.2	20.4	41.4	60.5
86	N.B.	.143	4.8	2.9	18.0	36.4	64.4
54	Maine	.119	4.3	3.4	20.2	42.4	68.6
96	Maine	.152	4.6	2.3	15.0	33.8	60.8
80	Maine	.136	4.4	3.5	19.6	43.6	67.2
55	N.H.	.181	4.5	2.7	17.6	37.8	67.7
57	P.Q.	.010	3.9	3.1	17.5	31.2	57.1
45	P.Q.	.096	4.0	2.8	16.7	32.1	53.9
47	P.Q.	.105	4.1	3.1	19.1	33.3	58.4
59	P.Q.	.108	4.1	3.2	17.6	33.0	52.9
60	P.Q.	.125	4.2	3.5	19.0	32.9	55.1
63	P.Q.	.146	4.5	4.0	21.0	35.8	61.9
58	P.Q.	.112	4.1	2.7	16.5	31.0	52.8
61	P.Q.	.114	4.1	3.0	18.1	32.7	54.3
46	P.Q.	.132	4.5	3.8	21.6	41.0	67.5
48	P.Q.	.111	4.2	4.0	21.9	37.6	61.1
49	P.Q.	.118	4.4	3.4	20.6	36.0	63.9
41	P.Q.	.098	4.2	3.2	20.2	38.6	65.1
40	P.Q.	.103	4.2	3.1	19.4	34.7	62.3
39	P.Q.	.098	4.1	3.6	20.3	37.8	64.5
38	P.Q.	.104	4.1	2.8	18.1	34.3	57.9
62	P.Q.	.129	4.3	3.2	18.9	33.9	58.0
52	P.Q.	.159	4.9	3.7	20.1	37.8	67.1
50	P.Q.	.142	4.8	3.0	19.8	40.3	62.8
51	P.Q.	.113	4.4	4.2	21.6	35.4	58.4
44	Ont.	.114	4.0	4.1	21.9	40.4	70.5
43	Ont.	.108	4.3	3.4	20.1	40.2	67.5
42	Ont.	.087	4.1	2.8	18.8	41.4	70.2
24	Ont.	.101	4.1	2.8	19.9	35.3	62.9
25	Ont.	.080	4.0	3.1	19.4	36.7	59.0
35	Ont.	.110	4.3	3.9	20.4	41.7	69.0
34	Ont.	.096	4.1	3.6	20.2	40.3	69.7
26	Ont.	.099	4.0	3.2	19.9	35.0	59.8
18	Ont.	.083	3.8	2.8	19.4	36.1	60.8
16	Ont.	.094	4.1	2.4	17.1	34.2	58.7
17	Ont.	.093	4.4	3.0	18.2	37.3	66.9
19	Ont.	.096	4.3	3.3	20.7	38.9	64.0
20	Ont.	.087	4.0	3.3	19.8	38.2	64.9
33	Ont.	.097	4.0	3.2	18.7	34.1	56.6
32	Ont.	.108	4.2	2.1	14.4	28.7	50.2
37	Mich.	.123	4.4	3.0	18.5	39.1	70.7
36	Mich.	.131	4.4	3.7	22.6	39.0	69.7
27	Mich.	.119	4.2	3.3	19.3	39.8	67.7
30	Wis.	.123	4.7	3.3	19.4	38.9	63.3
29	Wis.	.125	4.5	3.5	21.7	43.7	68.9
28	Wis.	.121	4.3	3.0	18.9	38.4	67.7
23	Wis.	.104	4.2	2.9	19.3	38.9	63.2
31	Wis.	.112	4.3	3.2	21.0	40.1	71.2
21	Minn.	.104	4.3	2.8	19.4	40.4	67.6
22	Minn.	.110	4.3	3.6	21.5	38.3	66.3
14	Man.	.092	4.2	2.4	15.7	30.8	53.7
13	Man.	.100	4.4	2.5	15.8	32.0	57.6
11	Sask.	.090	4.0	1.8	13.3	31.0	54.0
12	Sask.	.095	4.1	1.7	11.7	27.1	52.0
15	Man.	.090	4.3	3.1	19.7	40.1	68.3
10	Man.	.086	4.1	1.2	6.8	17.4	31.8
9	Alta.	.115	4.5	1.8	11.6	25.3	49.6
8	Alta.	.121	4.3	1.9	12.8	25.9	48.6
7	B.C.	.125	4.4	1.6	10.1	21.5	40.4
6	N.W.T.	.102	4.1	1.4	7.4	16.8	40.7
5	Yukon	.111	3.9	1.1	4.6	9.9	22.2
3	Yukon	.116	4.3	1.0	5.8	14.7	35.2
4	Alaska	.128	4.4	1.0	4.8	10.3	25.8
1	Alaska	.111	4.4	1.1	4.4	11.8	29.8
2	Alaska	.112	4.5	1.1	5.4	10.6	26.9
Mean		.115	4.3	3.0	17.8	35.0	59.6
Range	Min.	.010	3.8	1.0	4.4	9.9	22.2
	Max.	.181	4.9	4.9	22.6	43.7	71.2

Table 4. Five year field height of black spruce at 10 Maritime locations

		5-year field height at										
Plot No.	Prov. or State	AFES N.B.	Black-Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.	All locations
101	Nfld.	94.6D[1]	124.9A	45.2A	61.2A	91.7B	76.2D	97.5A	88.3A	104.3A	73.6B	87.5
100	Nfld.	93.1D	140.4C	44.4A	70.2A	90.4B	87.3E	105.7A	93.7A	131.6C	73.4B	95.0
99	Nfld.	114.1E	147.1C	58.5B	67.9A	97.5B	86.5E	120.6C	95.8A	140.2C	–[2]	106.0
56	Nfld.	93.7D	119.1A	48.8B	66.2A	–	77.9D	100.1A	–	105.1A	–	89.3
98	Nfld.	71.3C	–	41.8A	53.7A	–	70.4D	87.1A	–	94.2A	58.0A	68.9
93	N.S.	95.6D	145.2C	54.7B	54.5A	86.3A	78.3D	116.8B	91.5A	125.3B	–	95.3
84	N.S.	85.1C	124.3A	43.7A	67.0A	84.0A	73.6D	103.5A	86.2A	120.9B	82.6C	88.1
77	N.S.	84.2C	115.1A	–	–	81.0A	72.1D	–	80.1A	–	–	85.9
83	N.S.	77.4C	–	–	–	94.8B	82.5E	106.3A	82.7A	–	–	85.4
92	N.S.	87.3D	–	–	–	86.5A	–	125.7C	83.2A	–	–	93.4
95	N.S.	94.0D	–	–	–	86.0A	92.7E	110.1B	87.0A	–	–	93.1
87	N.S.	92.6D	–	–	–	87.3A	–	–	113.7C	–	–	94.4
88	N.S.	105.9E	130.2B	–	59.4A	94.5B	84.1E	126.2C	111.0C	140.5C	–	107.4
79	N.S.	99.1D	120.7A	42.6A	69.5A	83.3A	73.1D	112.7B	85.2A	119.1B	–	91.4
75	N.S.	77.7C	106.5A	–	62.2A	85.8A	61.0C	98.8A	78.2A	105.5A	–	83.9
102	N.S.	–	–	–	–	–	75.4D	–	–	–	–	75.4
97	N.S.	96.5D	–	–	–	92.3B	75.2D	115.1B	103.1B	136.8C	–	101.0
103	N.S.	97.9D	–	46.2A	74.6B	93.2B	90.1E	134.6C	94.5A	149.4D	–	98.6
81	P.E.I.	103.4D	146.3C	55.8B	63.3A	98.4B	84.5E	135.2C	103.6B	129.3C	84.1C	103.0
85	P.E.I.	111.4D	152.6D	57.7B	69.1A	96.0B	96.0E	132.5C	103.7B	145.3D	–	108.6
78	P.E.I.	102.5D	155.0D	49.4B	74.7B	91.5B	81.4E	123.5C	97.6A	134.7C	–	101.8
90	N.B.	107.3E	157.1D	50.8B	62.8A	92.4B	78.7D	142.1C	102.2B	148.3D	91.1D	106.3
74	N.B.	109.1E	155.5D	51.2B	87.6B	101.8B	–	121.6C	102.9B	128.3C	–	109.4
70	N.B.	96.6D	131.3B	51.3B	71.6A	82.5A	72.0D	–	93.8A	96.5A	77.3B	87.7
91	N.B.	111.6D	149.0D	49.0B	60.4A	92.8B	67.7D	128.0C	87.2A	131.1C	90.6D	99.8
68	N.B.	103.0D	141.8C	51.7B	78.2B	96.7B	83.0E	112.9B	115.0C	130.3C	–	103.5
69	N.B.	91.2D	139.9C	50.8B	65.5A	88.4A	74.9D	116.8B	80.4A	114.8B	75.0B	89.9
67	N.B.	89.5D	138.8C	49.1B	66.1A	86.9A	82.0E	128.4C	91.7A	119.6B	76.4B	94.6
64	N.B.	105.6E	133.6B	50.6B	67.4A	85.2A	86.0E	119.9C	106.1B	127.6C	79.7C	98.8
71	N.B.	117.5F	–	46.3A	–	94.5B	–	–	108.0B	–	–	93.0
66	N.B.	100.9D	137.0B	47.8A	65.5A	92.9B	86.1E	–	88.7A	–	–	91.7
73	N.B.	106.6E	150.9D	51.6B	72.9B	95.0B	84.6E	129.2C	99.8A	141.9D	–	104.2
65	N.B.	91.8D	144.3C	46.2A	62.5A	88.9A	–	–	90.6A	138.9C	–	98.5
72	N.B.	95.6D	157.7D	–	72.1B	95.2B	83.2E	131.5C	122.0C	145.0D	84.7C	110.9
94	N.B.	97.2D	–	–	–	–	–	–	–	–	–	97.2
82	N.B.	101.2D	131.4B	51.7B	78.6B	90.1B	75.2D	140.2C	107.8B	133.2C	76.7B	99.6
89	N.B.	100.7D	139.8C	50.9B	66.2A	91.9B	79.6E	–	116.8C	–	78.9C	95.3
86	N.B.	113.7E	–	–	–	86.5A	–	–	115.8C	–	–	105.7
54	Maine	98.9D	152.6D	53.3B	68.4A	87.6A	77.4D	118.1C	98.4A	127.2C	–	99.5
96	Maine	84.9C	–	–	–	87.5A	–	–	92.8A	–	–	86.6
80	Maine	104.0E	–	–	–	92.8B	–	–	102.1B	–	–	100.2
55	N.H.	99.0D	–	–	–	–	–	–	–	–	–	99.0
57	P.Q.	91.6D	119.5A	47.1A	57.6A	–	67.1D	111.9B	–	109.9A	70.6B	86.9
45	P.Q.	82.8C	117.5A	44.8A	65.4A	–	76.3D	106.4A	–	97.9A	72.2B	83.7
47	P.Q.	80.0C	127.4B	44.9A	70.3A	87.4A	77.8D	107.5A	90.6A	125.3B	78.9C	89.6
59	P.Q.	84.6C	112.8A	40.0A	65.5A	–	71.6D	94.5A	–	112.6B	–	85.9
60	P.Q.	97.8D	148.8D	46.4A	85.7B	–	71.9D	98.6A	–	120.7B	79.8C	96.2
63	P.Q.	102.1D	163.2D	50.5B	73.6B	91.6B	79.6E	126.9C	105.7B	135.4C	83.3C	102.9
58	P.Q.	94.1D	119.5A	45.1A	76.4B	–	81.4E	103.1A	–	115.8B	71.3B	90.1
61	P.Q.	92.7D	131.6B	44.9A	70.4A	–	76.8D	100.4A	–	114.2B	75.3B	89.6
46	P.Q.	102.6D	143.6C	45.1A	91.7B	90.8B	84.8E	116.4B	101.8B	130.4C	86.9D	100.3
48	P.Q.	94.4D	144.1C	46.2A	78.7B	82.5A	76.2D	129.1C	101.7B	133.1C	81.1C	98.0
49	P.Q.	106.6E	154.2D	48.7B	84.5B	88.1A	70.4D	118.6C	108.9B	133.7C	–	103.2
41	P.Q.	89.9D	137.7B	49.4B	76.6B	87.0A	73.7D	127.3C	90.4A	135.4C	82.5C	96.5
40	P.Q.	105.4E	130.1B	52.3B	68.1A	73.2A	–	121.3C	101.2B	121.0B	–	98.1

Table 4. concluded

Plot No.	Prov. or State	5-year field height at: AFES N.B.	Black-Brook N.B.	Bartibog P.E.I. N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.	All locations
39	P.Q.	101.9D	129.3B	51.0B	80.7B	81.5A	71.3D	117.4B	96.8A	124.3B	77.0B	94.6
38	P.Q.	107.5E	135.9B	45.7A	67.1A	88.6A	71.3D	123.4C	102.2B	117.1B	77.0B	96.0
62	P.Q.	95.1D	137.1B	41.9A	80.7B	90.9B	83.4E	111.2B	86.1A	115.2B	75.7B	93.5
52	P.Q.	97.4D	158.1D	50.1B	82.8B	92.3B	92.5E	–	93.8A	131.3C	–	101.4
50	P.Q.	105.0E	128.3B	47.6A	87.1B	84.9A	–	119.1B	98.7A	124.3B	–	100.7
51	P.Q.	105.4E	133.5B	48.3B	82.2B	88.3A	83.8E	105.8A	109.0B	135.6C	81.7C	99.1
44	Ont.	104.8E	153.5D	49.3B	69.1A	97.4B	85.6E	137.5C	105.7B	142.6D	81.7C	106.9
43	Ont.	104.6E	157.8D	53.9B	78.8B	90.8B	79.9E	131.6C	118.0C	153.7E	81.6C	107.1
42	Ont.	127.7F	140.8C	47.7A	83.3B	98.1B	90.0E	138.8C	115.0C	169.2E	86.6D	112.7
24	Ont.	105.5E	128.9B	50.0B	59.9A	85.6A	69.4D	113.6B	107.2B	116.2B	74.8B	93.0
25	Ont.	110.6E	143.9C	52.5B	72.5B	79.2A	72.9D	127.4C	97.7A	127.5C	83.4C	98.6
35	Ont.	122.5F	152.2D	53.6B	68.9A	86.6A	80.2E	116.6B	113.2C	158.4E	79.0C	107.3
34	Ont.	102.0D	152.1D	50.2B	85.8B	84.7A	82.2E	137.8C	101.5B	141.7D	74.0B	103.1
26	Ont.	103.0D	133.1B	49.4B	80.1B	86.9A	80.8E	119.1C	101.5B	140.1C	88.4D	99.4
18	Ont.	109.6D	150.1D	48.6B	81.4B	88.7A	75.7D	133.2C	98.0A	137.8C	78.7C	101.8
16	Ont.	98.5D	137.2B	46.4A	76.1B	85.0A	77.9D	112.5B	93.6A	133.1C	79.8C	95.8
17	Ont.	102.7D	151.9D	51.7B	84.7B	90.8B	75.9D	127.6C	106.9B	143.0D	79.4C	103.1
19	Ont.	100.7D	143.6C	56.1B	74.5B	82.7A	68.4D	105.6A	115.0C	143.6D	77.5B	98.5
20	Ont.	102.9D	142.1C	45.9A	60.7A	89.3A	79.9E	119.3C	104.9B	131.6C	80.5C	96.9
33	Ont.	86.7C	133.7B	48.4B	75.7B	–	70.3D	105.1A	–	107.7A	80.8C	89.5
32	Ont.	79.8C	–	44.1A	79.0B	–	63.9C	–	–	–	–	68.2
37	Mich.	123.6F	163.8D	–	–	98.2B	73.1D	140.3C	119.7C	154.7E	–	124.0
36	Mich.	109.3E	144.5C	49.1B	74.3B	89.2A	79.8E	114.1B	90.6A	132.4C	87.8D	98.5
27	Mich.	130.8F	153.1D	49.5B	79.0B	88.2A	86.4E	134.0C	103.1B	114.8B	87.5D	108.6
30	Wis.	91.0D	128.2B	45.6A	68.3A	72.2A	69.4D	101.1A	98.7A	110.8A	–	88.0
29	Wis.	118.8F	141.4C	54.6B	83.0B	98.2B	83.2E	124.3C	120.5C	154.0E	87.8D	108.4
28	Wis.	92.6D	154.9D	49.8B	74.5B	91.7B	75.2D	129.8C	106.9B	136.8C	–	101.1
23	Wis.	100.2D	150.7D	46.2A	70.6A	80.7A	77.7D	125.4C	107.2B	129.7C	–	100.0
31	Wis.	91.0D	144.9C	43.3A	59.4A	83.0A	78.5D	116.4B	115.6C	137.6C	–	99.1
21	Minn.	89.9D	123.1A	46.7A	58.4A	86.0A	75.3D	122.3C	103.7B	124.8B	62.0A	91.6
22	Minn.	112.0D	127.4B	47.7A	80.9B	80.7A	75.6D	103.3A	98.4A	143.1D	76.3B	95.3
14	Man.	97.7D	122.5A	43.3A	57.1A	–	76.6D	109.2B	–	129.8C	74.4B	93.0
13	Man.	89.8D	120.5A	41.9A	53.0A	79.3A	67.8D	102.0A	89.3A	111.0A	–	84.6
11	Sask.	88.5C	–	–	–	–	64.2C	–	–	118.0B	68.2B	85.2
12	Sask.	90.7D	–	–	–	–	63.8C	–	–	–	–	78.9
15	Man.	96.6D	130.4B	49.1B	73.2B	87.0A	69.0D	115.4B	90.3A	125.6B	76.3B	93.1
10	Man.	60.6B	–	–	–	–	53.3B	–	–	–	–	57.3
9	Alta.	84.4C	–	–	–	–	69.2D	–	–	–	–	78.0
8	Alta.	83.8C	–	–	–	–	64.3C	–	–	–	–	74.4
7	B.C.	76.1C	–	–	–	–	54.1B	–	–	–	–	66.1
6	N.W.T.	76.0C	–	–	–	–	–	–	–	–	–	76.0
5	Yukon	52.1A	–	–	–	–	38.6A	–	–	–	–	46.9
3	Yukon	64.6B	–	–	–	–	51.7B	–	–	–	–	60.5
4	Alaska	46.5A	–	–	–	–	36.7A	–	–	–	–	43.0
2	Alaska	50.7A	–	–	–	–	46.4A	–	–	–	–	48.9
Mean		96.7	139.1	48.6	71.6	88.9	75.7	118.4	100.0	129.5	78.7	96.7
Significance		*	*	*	*	*	*	*	*	*	*	–
Range Min.		46.5	106.5	40.0	53.0	72.2	36.7	87.3	78.2	94.2	58.0	43.0
Max.		130.8	163.8	58.5	91.7	101.8	96.0	142.1	122.0	169.2	91.7	124.0
Number of clusters		6	4	2	2	2	5	3	3	5	4	–

[1]Mean separation by cluster analysis (Gates and Bilbro 1978): data followed by different letters fall into different, discrete, non-overlapping groups.

[2]No tests were made.

*Significant at $p = 0.05$ from analysis of variance.

Table 5. Five-year field survival of black spruce at 10 Maritime locations

		5-year field survival at										
Plot No.	Prov. or State	AFES N.B.	Black Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.	All locations
101	Nfld.	95.0B	90.0	87.5	81.3	95.8	97.5C	85.0	93.8	65.0	95.8	88.8
100	Nfld.	91.7B	95.0	87.5	87.5	91.7	100.0C	75.0	89.6	82.5	95.8	89.6
99	Nfld.	93.8B	85.0	84.4	62.5	93.8	90.0C	75.0	83.3	97.5	-	85.0
56	Nfld.	91.7B	85.0	84.4	78.1	-	100.0C	75.0	-	92.5	-	86.7
98	Nfld.	97.9B	-	87.5	84.4	-	97.5C	65.0	-	77.5	95.8	86.9
93	N.S.	95.8B	92.5	84.4	87.5	93.8	87.5C	65.0	89.6	82.5	-	86.5
84	N.S.	91.7B	90.0	84.4	75.0	95.8	92.5C	55.0	91.7	87.5	95.8	85.9
77	N.S.	95.8B	85.0	-	-	70.8	97.5C	-	75.0	-	-	84.8
83	N.S.	91.7B	-	-	-	83.3	92.5C	62.5	91.7	-	-	84.3
92	N.S.	91.7B	-	-	-	97.7	-	80.0	64.6	-	-	83.6
95	N.S.	83.3B	-	-	-	95.8	80.0C	80.0	83.3	-	-	84.5
87	N.S.	89.6B	-	-	-	91.7	-	-	83.0	-	-	88.1
88	N.S.	93.8B	77.5	-	68.8	87.5	95.0C	80.0	85.4	82.5	-	84.1
79	N.S.	97.9B	92.5	81.3	81.3	89.6	97.5C	85.0	85.4	90.0	-	88.9
75	N.S.	93.8B	77.5	-	84.4	97.9	95.0C	72.5	83.3	87.5	-	86.5
102	N.S.	-	-	-	-	-	85.0C	-	-	-	-	85.0
97	N.S.	87.5B	-	-	-	83.3	95.0C	75.0	75.0	82.5	-	83.1
103	N.S.	89.6B	-	87.5	96.9	83.3	85.0C	92.5	89.6	77.5	-	87.7
81	P.E.I.	91.7B	93.8	84.4	87.5	100.0	90.0C	72.5	93.8	75.0	100.0	90.7
85	P.E.I.	92.5B	77.5	84.4	90.6	89.6	87.5C	90.0	87.5	87.5	-	87.5
78	P.E.I.	89.6B	87.5	90.6	78.1	81.3	87.5C	70.0	97.9	77.5	-	84.4
90	N.B.	91.7B	92.5	78.1	78.1	87.5	85.0C	85.0	83.3	82.5	100.0	86.2
74	N.B.	95.8B	85.0	84.4	66.7	89.6	-	80.0	81.3	72.5	-	81.9
70	N.B.	93.8B	90.0	87.5	87.5	97.9	95.0C	-	87.5	75.0	87.5	86.2
91	N.B.	95.8B	85.0	87.5	56.3	91.7	92.5C	92.5	87.5	85.0	95.0	86.8
68	N.B.	95.8B	95.0	84.4	87.5	81.3	90.0C	67.5	91.7	85.0	-	86.5
69	N.B.	97.9B	75.0	81.3	71.9	93.8	95.0C	70.0	91.7	67.5	95.8	84.0
67	N.B.	91.7B	87.5	84.4	84.8	93.8	97.5C	82.5	81.3	90.0	91.7	88.5
64	N.B.	81.3B	97.5	81.3	87.5	95.8	90.0C	92.5	91.7	82.5	95.8	89.6
71	N.B.	91.7B	-	84.4	-	87.5	-	-	100.0	-	-	90.9
66	N.B.	93.8B	95.0	84.4	81.3	93.8	95.0C	-	79.2	-	-	88.9
73	N.B.	97.9B	87.5	87.5	71.9	97.9	90.0C	72.5	85.4	70.0	-	84.5
65	N.B.	89.6B	97.5	90.6	53.1	93.8	-	-	81.3	85.0	-	84.4
72	N.B.	93.8B	97.5	-	90.6	91.7	95.0C	82.5	89.6	82.5	87.5	90.1
94	N.B.	95.8B	-	-	-	-	-	-	-	-	-	95.8
82	N.B.	89.6B	80.0	81.3	90.6	97.9	97.5C	82.5	87.5	80.0	83.3	86.8
89	N.B.	93.8B	87.5	87.5	53.1	97.9	87.5C	-	91.7	-	100.0	87.4
86	N.B.	95.8B	-	-	-	92.5	-	-	85.0	-	-	91.1
54	Maine	83.3B	92.5	84.3	90.6	91.7	92.5C	85.0	85.4	87.5	-	88.1
96	Maine	83.8B	-	-	-	87.5	-	-	75.0	-	-	82.1
80	Maine	95.8B	-	-	-	82.5	-	-	82.5	-	-	86.9
55	N.H.	95.8B	-	-	-	-	-	-	-	-	-	95.8
57	P.Q.	89.6B	90.0	87.5	75.0	-	82.5C	80.0	-	75.0	100.0	84.9
45	P.Q.	89.6B	87.5	78.1	81.3	-	100.0C	75.0	-	72.5	95.8	85.0
47	P.Q.	89.6B	72.5	78.1	68.8	91.7	95.0C	87.5	85.4	80.0	95.8	84.2
59	P.Q.	97.7B	82.5	68.8	78.1	-	90.0C	82.5	-	95.0	-	84.7
60	P.Q.	95.8B	87.5	81.3	65.6	-	92.5C	82.5	-	82.5	95.8	85.4
63	P.Q.	93.8B	85.0	93.8	90.6	95.8	95.0C	92.5	87.5	85.0	100.0	91.9
58	P.Q.	93.8B	96.9	90.6	78.1	-	100.0C	92.5	-	77.5	90.0	89.9
61	P.Q.	85.4B	80.0	93.8	75.0	-	92.5C	75.0	-	87.5	96.4	87.7
46	P.Q.	93.8B	82.5	93.8	90.6	93.8	95.0C	85.0	93.8	92.5	100.0	92.1
48	P.Q.	97.9B	80.0	81.3	83.3	89.6	87.5C	77.5	87.5	85.0	100.0	87.0
49	P.Q.	91.7B	95.0	87.5	87.5	77.1	90.0C	82.5	93.8	77.5	-	87.2
41	P.Q.	85.4B	97.5	90.6	90.6	91.7	100.0C	97.5	87.5	85.0	100.0	92.6
40	P.Q.	90.0B	82.5	78.1	87.5	83.3	-	85.0	85.4	82.5	-	84.3

Table 5. concluded

Plot No.	Prov. or State	5-year field survival at: AFES N.B.	Black Brook N.B.	Bartibog N.B.	Sabbies Brook N.B.	Dromore P.E.I.	Cape Breton N.S.	Pleasant Valley N.S.	Stanley N.S.	East Dalhousie N.S.	East Bideford P.E.I.	All locations
39	P.Q.	93.8B	90.0	84.4	87.5	83.3	90.0C	77.5	83.3	87.5	95.8	87.3
38	P.Q.	91.7B	80.0	71.9	93.8	97.9	90.0C	90.0	89.6	90.0	91.7	88.6
62	P.Q.	100.0B	90.0	81.3	93.8	93.8	90.0C	82.5	97.9	85.0	100.0	91.4
52	P.Q.	87.5B	90.0	75.0	81.3	95.8	92.5C	-	70.8	70.0	-	82.9
50	P.Q.	95.8B	96.9	78.1	84.4	85.4	-	82.5	91.7	80.0	-	84.4
51	P.Q.	93.8B	82.5	93.8	93.8	89.6	90.0C	65.0	91.7	92.5	95.0	88.8
44	Ont.	95.8B	85.0	65.6	79.2	91.7	92.5C	80.0	85.4	90.0	91.7	85.7
43	Ont.	93.8B	92.5	87.5	87.5	97.9	80.0C	75.0	91.7	82.5	100.0	88.8
42	Ont.	95.8B	85.0	84.4	87.5	87.5	97.5C	85.0	91.7	92.5	100.0	90.7
24	Ont.	89.6B	85.0	68.8	87.5	93.8	90.0C	80.0	95.8	85.0	95.8	87.1
25	Ont.	87.5B	95.0	93.8	84.4	77.1	95.0C	67.5	91.7	97.5	83.3	87.3
35	Ont.	93.8B	95.0	71.9	78.1	93.8	87.5C	75.0	81.3	90.0	100.0	86.6
34	Ont.	87.5B	90.0	78.1	71.9	91.7	92.5C	82.5	87.5	75.0	91.7	84.3
26	Ont.	89.6B	92.5	71.9	90.6	97.9	97.5C	87.5	83.3	75.0	95.8	88.2
18	Ont.	100.0B	87.5	93.8	84.4	97.9	90.0C	87.5	93.8	87.5	100.0	92.2
16	Ont.	93.8B	92.5	87.5	81.3	85.4	90.0C	87.5	93.8	80.0	87.5	88.3
17	Ont.	91.7B	84.4	84.4	71.9	89.6	85.0C	95.0	89.6	87.5	95.8	85.8
19	Ont.	92.5B	87.5	90.6	81.3	87.5	90.0C	80.0	91.7	82.5	95.8	87.5
20	Ont.	93.8B	92.5	78.1	84.4	72.9	97.5C	70.0	87.5	80.0	100.0	84.9
33	Ont.	91.7B	85.0	87.5	81.3	-	97.5C	82.5	-	77.5	95.0	87.3
32	Ont.	91.7B	-	71.9	56.3	-	87.5C	-	-	-	-	76.8
37	Mich	87.5B	87.5	-	-	95.8	77.5C	77.5	81.3	95.0	-	85.7
36	Mich	95.8B	85.0	81.3	84.4	91.7	90.0C	75.0	85.4	80.0	100.0	86.9
27	Mich	93.8B	82.5	93.8	68.8	91.7	78.1C	75.0	81.3	92.5	91.7	84.9
30	Wis.	97.9B	80.0	81.3	78.1	72.9	95.8C	77.5	89.6	77.5	-	85.5
29	Wis.	87.5B	85.0	93.8	75.0	89.6	87.5C	80.0	87.5	80.0	100.0	86.6
28	Wis.	89.6B	87.5	93.8	96.9	87.5	87.5C	70.0	89.6	77.5	-	86.6
23	Wis.	100.0B	92.5	93.8	81.3	87.5	90.0C	87.5	93.8	75.0	-	89.0
31	Wis.	91.7B	92.5	65.6	87.5	85.4	85.0C	65.0	85.4	77.5	-	81.7
21	Minn.	87.5B	82.5	87.5	87.5	95.8	92.5C	80.0	91.7	92.5	91.7	88.9
22	Minn.	89.6B	90.0	81.3	87.5	87.5	89.6C	82.5	85.4	80.0	95.8	88.2
14	Man.	91.7B	90.0	65.6	71.9	-	92.5C	77.5	-	77.5	100.0	83.3
13	Man.	97.5B	77.5	81.3	78.1	97.9	97.5C	75.0	91.7	72.5	-	85.4
11	Sask.	91.7B	-	-	-	-	97.5C	-	-	82.5	100.0	92.9
12	Sask.	95.8B	-	-	-	-	90.0C	-	-	-	-	92.9
15	Man.	93.8B	97.5	87.5	84.4	85.4	85.0C	67.5	87.5	85.0	87.5	86.1
10	Man.	87.5B	-	-	-	-	87.5C	-	-	-	-	87.5
9	Alta.	100.0B	-	-	-	-	87.5C	-	-	-	-	93.8
8	Alta.	83.3B	-	-	-	-	92.5C	-	-	-	-	87.9
7	B.C.	95.0B	-	-	-	-	80.0C	-	-	-	-	87.5
6	N.W.T.	90.0B	-	-	-	-	-	-	-	-	-	90.0
5	Yukon	66.7A	-	-	-	-	50.0A	-	-	-	-	58.3
3	Yukon	95.8B	-	-	-	-	55.0A	-	-	-	-	75.4
4	Alaska	58.3A	-	-	-	-	50.0A	-	-	-	-	54.2
2	Alaska	72.9A	-	-	-	-	67.5B	-	-	-	-	70.2
Mean		90.6	86.9	83.7	79.9	89.7	89.0	79.2	85.1	82.7	95.7	86.3
Significance		*	N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	-
Range Min.		58.3	70.0	65.6	53.1	70.8	50.0	55.0	70.8	65.0	83.3	54.2
Max.		100.0	97.5	93.8	96.9	100.0	100.0	97.5	100.0	97.5	100.0	95.8
Number of clusters		2	1	1	1	1	3	1	1	1	1	-

* Significant at $p = 0.05$ from analysis of variance.

Table 6. Significant correlation coefficients among 38 ecological and growth variables

Variable	1. Latitude	2. Longitude	3. Elevation	4. Spring Frost	5. Fall Frost	6. Frost Free Period	7. Begin Growing Season	8. End Growing Season	9. Length Growing Season	10. Degree Days	11. AFES N.B. (A)	12. Black Brook N.B. (B)	13. Bartibog N.B. (C)	14. Sabbies Brook, N.B. (D)	15. Dromore P.E.I. (F)	16. Cape Breton N.S. (G)	17. Pleasant Valley N.S. (H)	18. Stanley N.S. (I)	19. East Dalhousie N.S. (J)	20. East Bideford P.E.I. (O)	21. All locations
	Ecological characters										Height at										
Latitude	1.000																				
Longitude	0.783	1.000																			
Elevation	0.422	0.616	1.000																		
S. Frost	0.419	0.000	0.444	1.000																	
F. Frost	-0.652	-0.579	-0.588	-0.706	1.000																
F.F.Period	-0.612	-0.446	-0.570	-0.890	0.932	1.000															
BGS	0.553	0.300	0.000	0.461	-0.365	-0.461	1.000														
EGS	-0.684	-0.640	-0.424	-0.329	0.529	0.508	-0.619	1.000													
LGS	-0.625	-0.493	-0.342	-0.447	0.506	0.546	-0.886	0.757	1.000												
DEGDAY	-0.805	-0.378	-0.373	-0.613	0.615	0.679	-0.528	0.417	0.525	1.000											
HT(A)	-0.677	-0.455	-0.296	-0.363	0.423	0.432	-0.402	0.220	0.368	0.584	1.000										
HT(B)	-0.401	0.000	0.000	-0.383	0.000	0.333	-0.316	0.000	0.000	0.395	0.550	1.000									
HT(C)	-0.317	0.000	0.000	-0.288	0.000	0.277	-0.318	0.000	0.000	0.321	0.522	0.530	1.000								
HT(D)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.348	0.347	0.000	1.000							
HT(F)	0.000	-0.347	-0.387	0.000	0.245	0.242	0.000	0.000	0.000	0.000	0.330	0.508	0.290	0.000	1.000						
HT(G)	-0.775	-0.706	-0.457	-0.315	0.497	0.478	-0.471	0.474	0.536	0.570	0.722	0.434	0.293	0.241	0.542	1.000					
HT(H)	-0.409	0.000	0.000	-0.291	0.000	0.000	-0.376	0.000	0.000	0.456	0.586	0.677	0.515	0.248	0.418	0.390	1.000				
HT(I)	0.000	0.282	0.000	-0.258	0.000	0.000	0.000	0.000	0.000	0.340	0.555	0.500	0.355	0.263	0.276	0.211	0.431	1.000			
HT(J)	-0.450	0.246	0.000	-0.465	0.240	0.376	-0.384	0.000	0.243	0.567	0.704	0.665	0.446	0.383	0.475	0.526	0.704	0.655	1.000		
HT(Q)	-0.497	0.000	0.000	-0.340	0.000	0.287	-0.421	0.000	0.370	0.499	0.621	0.589	0.401	0.401	0.379	0.379	0.504	0.000	0.590	1.000	
HT(All)	-0.811	-0.593	-0.371	-0.459	0.520	0.534	-0.517	0.368	0.494	0.703	0.898	0.801	0.606	0.389	0.546	0.818	0.775	0.702	0.859	0.734	1.000
SURV(A)	-0.461	-0.462	0.000	0.000	0.000	0.000	0.000	0.213	0.233	0.224	0.416	0.000	-0.257	0.000	0.000	0.431	0.000	0.000	0.000	0.000	0.446
SURV(B)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.271	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURV(C)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.233	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURV(D)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.046	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURV(F)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURV(G)	-0.417	-0.459	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.264	-0.339	-0.288	0.000	-0.283	0.368	-0.415	-0.325	-0.415	0.000	0.338
SURV(H)	0.000	0.000	0.000	0.000	0.000	-0.250	0.000	0.000	0.000	0.000	0.263	0.000	0.000	0.238	0.000	0.000	0.242	0.000	0.000	0.000	0.000
SURV(I)	0.247	0.000	0.000	0.000	0.000	0.000	0.250	-0.238	-0.317	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURV(J)	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.288	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.232	0.000	0.244
SURV(O)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SURV(All)	-0.461	-0.430	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.325	0.506	0.000	0.000	0.000	0.000	0.567	0.000	0.000	0.000	0.000	0.523
SEED Wt.	-0.269	-0.266	-0.303	0.000	0.000	0.276	-0.408	0.393	0.490	0.000	0.000	0.279	0.000	0.000	0.286	0.221	0.000	0.000	0.000	0.000	0.000
COTYL	0.000	0.000	-0.263	-0.388	0.246	0.349	-0.464	0.211	0.452	0.340	0.000	0.433	0.284	0.000	0.000	0.000	0.256	0.000	0.290	0.405	0.203
HT 1	-0.748	-0.694	-0.440	-0.338	0.531	0.496	-0.393	0.296	0.419	0.526	0.670	0.362	0.418	0.000	0.000	0.700	0.236	0.000	0.264	0.517	0.745
HT 2	-0.841	-0.670	-0.400	-0.363	0.518	0.500	-0.451	0.362	0.444	0.661	0.773	0.493	0.465	0.333	0.000	0.777	0.444	0.336	0.480	0.604	0.855
HT 3	-0.885	-0.648	-0.425	-0.475	0.586	0.596	-0.558	0.431	0.531	0.792	0.814	0.594	0.516	0.249	0.378	0.796	0.667	0.501	0.661	0.606	0.886
HT 4	-0.845	-0.558	-0.372	-0.463	0.535	0.549	-0.535	0.386	0.490	0.778	0.837	0.676	0.529	0.263	0.311	0.775	0.691	0.522	0.711	0.525	0.908

Variable	22. AFES N.B.	23. Black Brook N.B.	24. Bartibog N.B.	25. Sabbies Brook N.B.	26. Dromore P.E.I.	27. Cape Breton N.S.	28. Pleasant Valley N.S.	29. Stanley N.S.	30. East Dalhousie N.S.	31. East Bideford P.E.I.	32. All Locations	33. Seed Weight/100	34. Number Cotyledons	35. Height At Age 1	36. Height At Age 2	37. Height At Age 3	38. Height At Age 4
	Survival at											Juvenile characters					
SURV(A)	1.000																
SURV(B)	0.000	1.000															
SURV(C)	0.000	0.000	1.000														
SURV(D)	0.000	0.264	0.000	1.000													
SURV(F)	0.000	0.000	0.000	0.000	1.000												
SURV(G)	0.418	0.000	0.000	0.277	0.000	1.000											
SURV(H)	0.000	0.000	0.000	0.000	0.000	0.000	1.000										
SURV(I)	0.000	0.000	0.000	0.280	0.234	0.000	0.000	1.000									
SURV(J)	0.000	0.000	0.000	0.000	0.000	-0.248	0.000	0.000	1.000								
SURV(O)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000							
SURV(All)	0.588	0.470	0.357	0.647	0.285	0.690	0.390	0.414	0.255	0.000	1.000						
SEED Wt.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.314	0.000	0.000	0.000	1.000					
COTYL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.254	0.000	0.000	0.000	0.619	1.000				
HT 1	0.374	0.000	0.000	0.000	0.000	0.378	0.000	0.000	0.000	0.000	0.402	0.201	0.000	1.000			
HT 2	0.446	0.000	0.000	0.000	0.000	0.444	0.000	0.381	0.000	0.000	0.522	0.000	0.000	0.920	1.000		
HT 3	0.472	0.000	0.000	0.000	0.000	0.389	0.000	0.000	0.000	0.000	0.511	0.000	0.277	0.802	0.923	1.000	
HT 4	0.459	0.000	0.000	0.000	0.000	0.372	0.000	0.000	0.000	0.000	0.538	0.000	0.299	0.741	0.882	0.955	1.000

Non-significant correlations at .05 level are replaced by zero. Degrees of freedom for testing varied from 41 to 99.

Table 7. Factor loadings on first 10 factors with loading coefficients smaller than 0.25 replaced by zero

Factor:	1	2	3	4	5	6	7	8	9	10
Variance:	6.65	4.41	3.55	2.98	2.21	2.04	1.91	1.79	1.53	1.48
Cumulative percent of total variance:	18.5	30.7	40.6	48.9	55.0	60.7	66.0	65.7	75.2	79.3
Variables	Loading coefficients									
Latitude	0	-0.60	0.25	0	-0.31	0	0.30	0.32	0	0
Longitude	0	0	0	-0.83	-0.26	0	0	0	0	0
Spring frost	0	-0.82	0	0	0	0	0	0	0	0
Fall frost	0	0.88	0	0	0	0	0	0	0	0
Frost free period	0	0.92	0	0	0	0	0	0	0	0
Begin growing season	0	0	-0.93	0	0	0	0	0	0	0
End growing season	0	0.33	.78	0.26	0	0	0	0	0	0
Length growing season	0	0.25	.91	0	0	0	0	0	0	0
Day length (June 21)	0	-0.59	0	0	0	0	0.31	0.35	0	-0.27
Degree-days	0.31	0.67	0	-0.33	0	0	-0.29	-0.35	0	0
Height (A)	0.67	0	0	0	0	0	0	0.32	0	0
Height (B)	0.75	0	0	0	0	0	0	0	0	0
Height (C)	0.63	0	0	0	0	0	0	0	0	-0.45
Height (D)	0.42	0	0	0	0.36	0	0.34	0	0	0.26
Height (F)	0.58	0	0	0.59	0	0	0	0	0	0
Height (G)	0.54	0	0	-0.53	0	0	0	0	0	0
Height (H)	0.73	0	0	0	0	0	0	0	0.30	0
Height (I)	0.70	0	0	-0.30	0	0	0	0	0	0
Height (J)	0.84	0	0	0	0	0	0	0	0	0
Height (overall)	0.95	0	0	0	0	0	0	0	0	0
Survival (A)	0	0	0	0	0	0	0	0	0	0.89
Survival (B)	0	0	0	0	0	0.73	0	0	0	0
Survival (C)	0	0	0	0	0	0	0.77	0	0	0
Survival (D)	0	0	0	0	0	0.80	0	0	0	0
Survival (F)	0	0	0	0.57	0	0	-0.26	0	0.43	0
Survival (G)	-0.57	0	0	-0.26	0.31	0	0	0	0.26	0
Survival (H)	0	0	0	0	0	0	0	0	0.85	0
Survival (I)	0	0	0	0	-0.33	0.29	0.62	0	0	0
Survival (J)	0.25	0	0	0	0	0	0	0.78	0	0
Survival (overall)	0	0	0	0	0	0.68	0.31	0	0.53	0
Seed weight	0	0	0.47	0.65	0.30	0	0	-0.30	0	0
No. cotyledons	0	0	0.55	0	0	0	0.35	-0.46	0	0
1-year height	0	0	0	0.46	0.78	0	0	0	0	0
2-year height	0	0	0	0	0.84	0	0	0	0	0
3-year height	0.62	0.43	0.35	0	0	0	0	0	0	0
4-year height	0.71	0.33	0	0	0	0	0	0	0	0
Factor interpretation	Growth	temperature	Growing season	Longitude	Juvenile growth	Survival in local adaption				

Table 8. Analyses of variance for field height and survival

Source	df	Height SS	Height MS	Survival SS	Survival MS
Location (L)	8	1507831.40	188478.9*	33634.48	4204.3*
Replicates in L	27	41992.36	1555.3*	14350.41	531.5*
Provenances (P)	51	69733.69	2922.6*	15353.48	301.0*
L x P	408	100015.26	245.1^{ns}	85063.43	208.5^{ns}
Error (R x P)	1377	354175.21	257.2	264438.65	192.0
Total (Corr)	1871	2073747.92		412840.43	

* Significant at .05 level.
ns Not significant.

Table 9. Regression of growth characters on five ecological variables

Dependent variables	Inter- cept	Regression coefficients for independent variable										R^2 (%)
		Lati- tude	Longi- tude	Eleva- tion	Spring frost	Frost free period	Begin growing season	End growing season	Length growing season	Day length	Seed weight	
Nursery height at age 1	13.255	-0.082*	-0.016*	-	-	0.005	-0.010	-0.015*	-	-	-	63.2
Nursery height at age 2	96.961	-0.041*	-0.041	-	-0.031	-	-0.061*	-0.092*	-	-	-	75.3
Nursery height at age 3	206.569	-	-	-0.005*	-	0.055*	-0.182*	-0.170*	-	-6.431*	-	84.8
Nursery height at age 4	335.812	-	0.149*	-0.013*	-	-	-0.277*	-0.232*	-	-4.269*	-	80.0
Overall field height	368.360	-2.833*	-	-	-	0.111*	-0.341*	-0.337*	-	-	-81.589	75.2

[a] Nursery heights included as independent variables.
* Significant at p = 0.05 level for each component.

Table 10. Stability parameters for the 21 tallest provenances

Trial number and origin	Height mean (cm)	Stability parameters		
		Regression (b_i)	Deviation ($\bar{S}d_i^2$)	R^2
42 Nipissing Pr., Ont.	114.00	1.182	136.87	91.4
72 N. Br., Black Riv., N.B.	112.68	1.132	56.97	94.4
27 Rapid Riv., Mich.	109.92	1.157	110.82	92.6
85 Garfield, P.E.I.	109.66	1.082	49.94	96.0
90 Br. Rd. Geary, N.B.	108.93	1.258	56.02	97.1
29 Forest Co. I., Wis.	108.78	1.038	117.19	90.5
35 Massey, Ont.	106.38	1.188	138.91	91.3
34 Goulais Riv., Ont.	105.39	1.088	24.10	98.1
43 Clalk River, Ont.	104.86	1.083	47.70	96.2
63 Canton Marcil, P.Q.	103.87	1.130	34.21	97.5
17 Minaki, Ont.	103.84	1.046	17.80	98.5
78 Farmington, P.E.I.	103.67	1.136	42.78	96.9
18 Savant Lake, Ont.	102.85	1.044	33.51	97.1
81 Johnsons River, P.E.I.	102.54	1.033	69.05	94.0
99 Bishop's Falls, Nfld.	102.07	0.916	100.10	89.7
73 Tweedie Br., N.B.	102.03	1.081	36.96	97.0
46 Peribonka, P.Q.	100.98	0.911	64.00	93.1
49 Lower Mattawin, P.Q.	100.92	1.024	45.08	96.0
28 Forest Co. III, Wis.	100.85	1.065	22.00	98.2
82 Trout Lake, N.B.	100.59	0.961	184.69	83.8
44 Bancroft, Ont.	99.70	1.174	30.31	97.9
Mean:	104.98	1.082	67.57	
Standard error:	4.17	0.088	45.90	
Range:	99.7-114.0	0.911-1.258	17.80-184.69	83.8-98.5