ECOTYPIC VARIATION OF BLACK SPRUCE IN NORTHWESTERN ONTARIO

by

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Dr. Ashley Thomson Major Advisor	Dr. Jian Wang Second Reader

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ABSTRACT

Antler, J. I. 2020. Ecotypic variation of black spruce in northwestern Ontario.

Key Words: black spruce, ecotypic variation, northwestern Ontario, *Picea mariana*, provenance, seed source.

The success of reforestation can be improved by selecting the appropriate seed source for the site type. However, not much is known about the differences in using upland versus lowland black spruce seed sources when making seed transfer decisions. A black spruce provenance test consisting of 50 seed sources from across northwestern Ontario was analyzed to determine if adaptive divergence of provenances originating from different soil types was evident. Differences in height and diameter of black spruce provenances planted at the 25th Side Road Tree Farm near Thunder Bay, Ontario were examined. Soil categories were created based on the northwestern Ontario Forest Ecosystem Classification (FEC) program. One-way and two-way ANOVAs were run for each of the measured variables. The results suggest an absence of ecotypic variation concerning soil types in black spruce.

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INTRODUCTION

Black spruce (*Picea mariana* (Mill.) BSP.) is the most dominant tree species in North America's boreal forest whose natural range covers most of Canada (Farrar 1995). Because the species can regenerate both from seed and layering, its range extends into the northern parts of Canada (Payette and Delwaide 1994). It is both an economically and ecologically important species. In Ontario, black spruce accounts for 80% of the annual allowable forest cut and is the most important reforestation species (OMNRF 2015). It is a highly sought-after tree due to its value as pulpwood and lumber. Anticipated climatic changes, along with an increasing demand for these wood products have placed additional pressures on accelerating black spruce regeneration (Morgenstern 1978, Beaulieu *et al* 2004). Given the need for efficient and sustainable forest practices, provenance trials have become increasingly important to ensure forests and their constituent populations in situations where changing environmental conditions are anticipated.

Adaptive variation in black spruce populations has been related to geo-climatic factors (Morgenstern 1978, Beaulieu *et al* 2004, Parker *et al* 1994). While many studies have looked at patterns of adaptive variation concerning climate, few have investigated ecotypic differentiation. A previous study conducted by Dr. William Parker found that populations of black spruce from upland and lowland sites in northwestern Ontario were adaptively differentiated, suggesting that site type is important when making seed transfer decisions (1996). If this is true, current seeding practices may be causing reduced survival and yield in black spruce forests. Most of the black spruce seed collected in Ontario originate from lowland organic soils. However, the seed is often then used on upland non-organic soils (Fowler and Mullen 1977).

To further investigate the ecotypic variation of black spruce, this thesis aims to discover if there exists significant ecotypic variation in population mean heights of black spruce populations originating from different soil types in northwestern Ontario. This work will expand upon the original study conducted by Dr. Parker by including seed sources from a wider geographic area of Ontario, and by investigating whether ecotypic differences observed at the seedling stage persist in populations greater than 20 years of age.

The objective of this study is to examine evidence for the occurrence of ecotypic variation in population mean heights of black spruce originating from different soil types in northwestern Ontario. Based on the results of Parker (1996) I predict that there will be a significant difference amongst mean heights of black spruce populations originating from different soil types in northwestern Ontario.

LITERATURE REVIEW

SILVICS OF BLACK SPRUCE

Black spruce occurs in the northern parts of North America. Its range stretches throughout most of Canada (Figure 1). It does extend into the northern ranges of the United States of America to include New Jersey, Connecticut, Pennsylvania, Minnesota, Michigan, and Wisconsin.

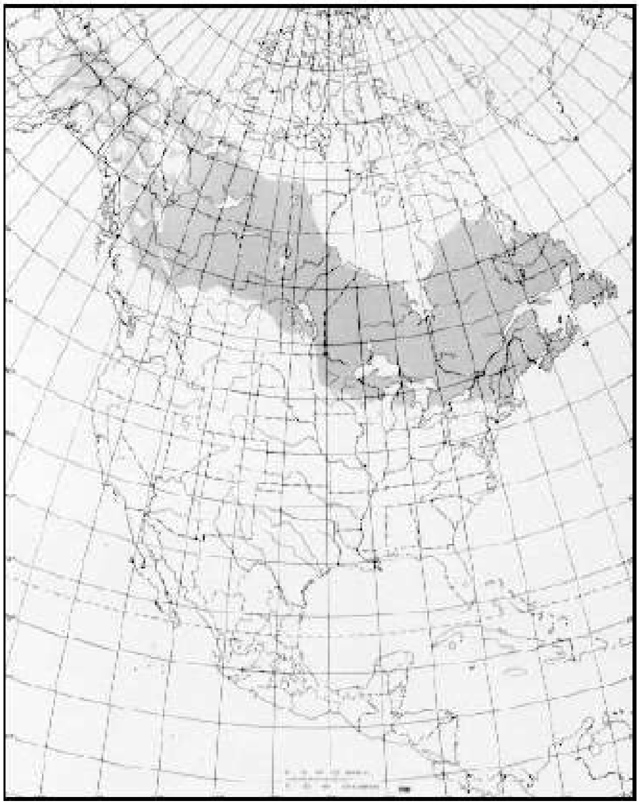

Figure 1. Native range of black spruce. Source: Burns (1990).

Black spruce commonly grows as pure stands but can also be found in forests mixed with white spruce, balsam fir, jack pine, and tamarack. What is unique to this species is its ability to grow on a variety of different soil types. As a result, black spruce is often classified as “upland” or “lowland” based on soil conditions. Upland sites are found on clay soils and are often found to be more productive. In contrast, lowland sites contain organic soils with a high moisture regime (Burns 1990).

ADAPTIVE VARIATION OF BLACK SPRUCE

The threat of climate change has caused many researchers to study the effects of temperature on various tree species using the common garden technique. Some studies look at the adaptive variation of tree species across different provinces (Morgenstern 1978), while others focus on adaptation amongst sources across short geographic distances (Beaulieu *et al* 2004, Parker *et al* 1994). A study completed by Morgenstern (1978) examined the genetic variation of black spruce from three different regional groups: Acadian, Great Lakes, and Boreal. He found temperature and photoperiod (latitude) to be the two main geographical and ecological factors influencing phenology and growth. Height followed a clinal pattern because of the sequential differences in the growing period with regards to latitude. Accordingly, mean tree heights increased with decreasing latitude. Variation was also found between stands within the ecological regions. The boreal sites showed the most variation and it was recommended that these stands be studied in future breeding programs.

A black spruce study in Quebec used similar growth and phenological traits to determine if adaptive variation exists across the province (Beaulieu *et al* 2004). Thirty different seed sources were planted at three different sites. It was found that differences in growth and phenological traits were the result of latitude and elevation. Differences were also found between provenance and family-within-provenance components, suggesting that changes can be seen at even finer levels of latitude and elevation. Parker *et al* (1994) completed a similar study with black spruce in northwestern Ontario. Again variation was found to be clinal, but some differences in performance were noted between seed sources relatively close in proximity. For example, seeds located close to Lake Nipigon and Lake Superior tended to show reduced growth. However, there remain inconsistencies in growth and needle flushing periods within these seed sources. Changes in height and flush period was dependant on which side of the lake the source came from. It is suspected that the Lake effect may be the reason for irregular variation in growth patterns. Also, it was found that seed sources originating from deep organic soils performed differently than the other soil types. However, this was not statistically proven in the study since the seed sources in deep organic soils were not evenly distributed and only came from sites in the southern portion of the study area.

ADAPTIVE VARIATION SHOWN IN OTHER SPECIES

Significant adaptive variations have also been found for other tree species including sugar maple (Ledig and Korbobo 1983) and jack pine (Niejenhuis and Parker 1996). Ledig and Korbobo (1983) studied the adaption of sugar maple across different altitudes. Significant differences were found in photosynthesis, respiration, and specific leaf weight from populations less than 0.8 km apart. Variation gradually changed with transitions in altitude. Rates of photosynthesis increased with elevation, while specific leaf weight decreased.

Adaptive variation for jack pine in north-central Ontario was also found to be clinal (Niejenhuis and Parker 1996). Seedlings in the southern portion of the study area grew taller compared to seedlings originating from the northern portion. Climatic variables along with soils and vegetation elements of the Forest Ecosystem Classification System (S-Type and V-Type) were used during linear regression analysis. Plant associations and soils had a weak correlation with phenotypic variation. It was noted that climatic variables were needed in addition to the Forest Ecosystem Classification (FEC) System to improve model regressions. In the future, both the FEC and climate data should be included when making models for seed transfer decisions.

Eastern white cedar is similar to black spruce in that it can be found on both very dry and very wet habitats. Their morphology is notably different between cliff and lowland environments. This has caused many researchers to investigate whether ecotypic variation exists within *Thuja occidentalis* populations. A study by Matthes-Sears and Larson (1991) investigated the differences between white cedar growing on wet and dry habitats. Their results indicate no ecotypic variation in foliar nutrients, photosynthetic light response, canopy cover index, and productivity. A similar study concluded that ecotypic variation did not influence the form and function of eastern white cedar growing in southern Ontario (Briand *et al* 1991). They suggested that the low degree of variability may be because the trees studied were part of a larger homogenous population. Results may have been different if they collected seed from a larger geographical area.

Pokharel *et al* (2014) used the Ecological Land Classification system for Ontario to determine if black spruce populations located on productive sites had better wood characteristics than unproductive sites. Site productivity was defined by specific moisture regimes. The two categories used in that study were dry sandy sites (upland) and wet mineral organic sites (lowland). Differences were found between the contrasting sites because trees grown in the lowland areas grew slower when compared to the upland site.

Several studies have investigated genetic differences between black spruce in upland and lowland sites. Boyle *et al* (1990) examined multilocus genotypes between sites located 2 km apart and observed minor variation in allele frequencies between the sites. Observed heterozygosity for the lowland site was higher than the upland site. This may be because of the required vigorous growth on the nutrient-poor sites or the influence of past disturbance. The upland stand had been regenerated from fire, while the lowland stand was much older and had been undisturbed for a long time. A similar study by Wang and Macdonald (1991) found no genetic differentiation between upland and lowland black spruce populations in Alberta. However, seed sources from upland sites germinated better due to selection and/or maternal effects.

A study by Abidine (1993) examined water relations of black spruce, but no significant variation in gas exchange was found between upland and lowland black spruce populations. However, differences were found between Ontario and Quebec seed source locations, suggesting adaptive variation associated with climate. Also, minimal differences in osmotic potential for the Ontario upland-lowland pair were found but not for Quebec. This could be an indication of very slight adaptive divergence among upland and lowland populations in Ontario. A second study (Abidine 1994) looked at the drought tolerance of black spruce from upland and lowland ecosites. After previous studies found no relation between upland and lowland spruce grown in a common garden, he decided to study if there would be a difference if the trees were subjected to water stress. However, no significant differences in water relations between the two sites were found. Variability among families is mentioned to be a source of error. Similarly, Fowler and Mullin (1977) found no significant differences in seedling height growth and survival between upland and lowland spruce populations. They did, however, find differences across the three geographical locations.

A study by Parker *et al* (1996) did find variation in growth characteristics amongst populations of jack pine and black spruce in northwestern Ontario. Significant differences in Soil Types (S-Types) and Vegetation Types (V-Types) were found for jack pine across all variables. It was noted that black spruce did not demonstrate significant ecotypic differentiation when grown in the greenhouse trial but significant variation amongst upland and lowland populations was found in the field trials.

METHODS AND MATERIALS

SEED SOURCES

Seed sources of black spruce (*Picea mariana* (Mill.) B.S.P.) was used to establish a provenance trial at the former Thunder Bay Forest Nursery on 25th Sideroad, Thunder Bay (Parker n.d.). A total of 50 seed sources from across northwestern Ontario are represented in the provenance trial (Figure 2). Seed from these populations was collected in 1989 and 1993 then seeded in leach tubes at the Lakehead University greenhouse in winter of 1994. The locations, including latitude and longitude, are shown in Table 1 of Appendix I. In the summer of 1994, the seedlings were transplanted to the field at the former Thunder Bay Forest Nursery. Seedlings were planted at 2 m spacing with two

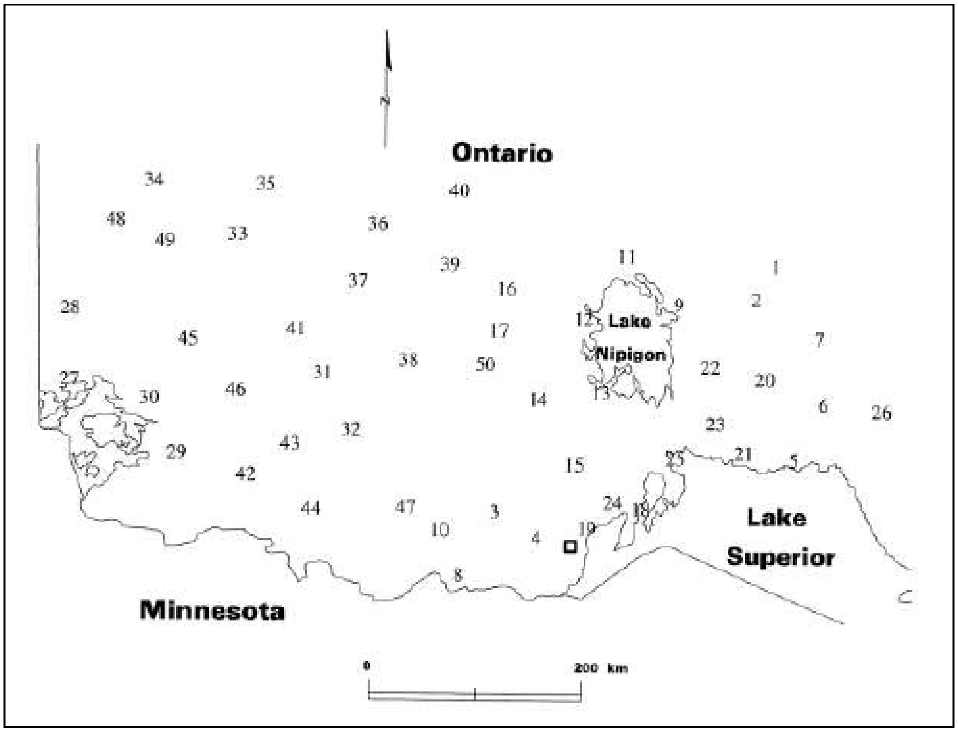

Figure 2. Seed source locations for the L.U. black spruce provenance test planted summer, 1994. Source: Parker (n.d.).

rows or border trees planted on the perimeter. However, some of the border trees have since been removed to allow space for vehicle travel and test maintenance. The provenance trial has three completely randomized blocks, each containing ten seedlings from each source. Manual tending was used to control competition and reduce weeds and grasses.

DATA COLLECTION

In the fall of 2019, the heights and diameters for each tree in the provenance test were collected. To ensure precise height measurements were obtained, a Vertex hypsometer was used. A diameter tape was used to measure the diameter at breast height (dbh ~1.3m above ground) for each tree. Before measuring each tree, the metal identification tag was used to ensure the right information was collected for each seed source. Any tree that was dead or removed from the stand was given a code number (999) to ensure their removal during data cleaning. Any trees with defects or multiple stems were noted.

STATISTICAL ANALYSES

Data collected in the field was entered into a Microsoft Excel spreadsheet. Data cleaning was conducted to improve data quality and remove typographical errors. All dead trees were removed from the dataset, along with any trees with missing tops that would affect the height calculations. Normality tests for the dbh and height values were conducted using SPSS software. Both height and dbh were skewed a bit to the right but overall, the data was reasonably normal. A few outliers occurred but were deemed to be within a reasonable range of variation and were retained for further analysis. The 50 provenances were assigned to different groups based on their FEC soil categories. Two different grouping schemes were used: Grouping A included (i) dry-very fresh (S1-S6 and SS1-SS7), (ii) moderately moist-very moist (S7-S11 and SS8), and (iii) wet organic (S12S and S12F). Grouping B included (i) dry-moist (S1-S11 and SS1-SS8) and (ii) wet organic (S12S and S12F). Not all preferred soil groupings were included in the study due to an absence of SS9 soil types. One-way analysis of the variances (ANOVAs) were conducted to determine the significance between soil groups (Grouping A and Grouping B) and height or dbh. Two-way ANOVAs were also done by block number for dbh and height to better examine whether differences were present among the groups. To determine whether there exists a significant difference between the soil groupings and block locations, a Bonferonni post hoc test was conducted.

RESULTS

ONE-WAY ANOVA

Variation among soil types was not significant for all of the variables (p>0.05), regardless of the soil grouping scheme used (Tables 1-3). The results from Group A interaction for height were found to have the lowest p-value (Table 1). The post hoc test results show no significant differences in height or dbh between soil groupings. As such, the results of the post hoc tests are not presented here.

Table 1. One-way ANOVA for height amongst provenances originating from dry-very fresh (S1-S6 and SS1-SS7), moderately moist-very moist (S7-S11 and SS8), and wet organic (S12S and S12F) soils.

Interaction	df	MS	F	p
Between Groups	2	3.967	2.775	0.063
Within Groups	890	1.429		
Total	892			

Table 2. One-way ANOVA for height amongst provenances originating from dry-moist (S1-S11 and SS1-SS8) and wet organic (S12S and S12F) soils.

Interaction	df	MS	F	p
Between Groups	1	3.889	2.715	0.100
Within Groups	891	1.432		
Total	892			

Table 3. One-way ANOVA for diameter amongst provenances originating from dry-very fresh (S1-S6 and SS1-SS7), moderately moist-very moist (S7-S11 and SS8), and wet organic (S12S and S12F) soils

Interaction	df	MS	F	p
Between Groups	2	2.674	0.325	0.723
Within Groups	890	8.232		
Total	892			

Table 4. One-way ANOVA for diameter amongst provenances originating from dry-moist (S1-S11 and SS1-SS8) and wet organic (S12S and S12F) soils.

Interaction	df	MS	F	p
Between Groups	1	0.198	0.024	0.877
Within Groups	891	8.228		
Total	892			

TWO-WAY ANOVA

Results from the analysis of variance conducted for height are shown in Tables 5, 6, and 7. Analysis of variance for provenance and block interactions was compared to account for block effects. The block by provenance effects were not significant for all variables F (94) = 0.953, p = 0.605. Although, there were significant differences between seed locations F (47) = 1.746, p = 0.002. The post-hoc test found 4 pairs of provenances that varied significantly from the others (2 and 10, 2 and 37, 24 and 37, 36 and 37).

Table 5. ANOVA test results between provenance and block number for height.

Interaction	df	MS	F	p
Provenance	47	2.393	1.746	0.002
Block	2	4.020	2.933	0.054
Prov*Block	94	1.307	0.953	0.605

Additional two-way ANOVAs were completed to control block effects on soil groups. Even though variation among blocks was controlled, there remained no significant differences among soil groups. There was no significant difference between soil groups for Group A F (2) = 2.275, p = 0.103. Similarly, no differences were found for Group B F (2) = 2.404, p = 0.121. The post-hoc comparison for block number found interactions between blocks 3 and 1, along with blocks 3 and 2 across all height ANOVA tests.

Table 6. Two-way ANOVA for height amongst provenances originating from dry-very fresh (S1-S6 and SS1-SS7), moderately moist-very moist (S7-S11 and SS8), and wet organic (S12S and S12F) soils.

Interaction	**df**	**MS**	**F**	**p**
Soil group	2	3.224	2.275	0.103
Block	2	4.250	2.999	0.050
Soil group*Block	4	1.946	1.373	0.241

Table 7. Two-way ANOVA for height amongst provenances originating from dry-moist (S1-S11 and SS1-SS8) and wet organic (S12S and S12F) soils.

Interaction	**df**	**MS**	**F**	**p**
Soil group	2	3.415	2.404	0.121
Block	1	6.974	4.909	0.008
Soil group*Block	2	2.395	1.686	0.186

A two-way ANOVA between provenance and block interactions for dbh were compared to determine if there was a significant effect on growth. There was not a significant effect of provenance and block number on height F (94) = 0.931, p = 0.661. The Bonferroni test did not find any significant differences amongst provenances. However, there was a significant difference between dbh measurements between blocks 1 and 3. In addition, there were no significant differences in growth between soil types in Group A F (2) = 0.190, p = 0.827. Similarly, no differences were found for growth in Group B soil types F (2) = 0.821, p = 0.749 (Tables 9 and 10).

Table 8. ANOVA test results between provenance and block number for dbh.

Interaction	df	MS	F	p
Provenance	47	7.656	0.951	0.568
Block	2	97.375	12.097	0.000
Prov*Block	94	7.498	0.931	0.661

Table 9. Two-way ANOVA for diameter amongst provenances originating from dry-very fresh (S1-S6 and SS1-SS7), moderately moist-very moist (S7-S11 and SS8), and wet organic (S12S and S12F) soils

Interaction	df	MS	F	p
Soil group	2	1.520	0.190	0.827
Block	2	102.495	12.796	0.000
Soil group*Block	4	9.380	1.71	0.322

Table 10. Two-way ANOVA for diameter amongst provenances originating from dry-moist (S1-S11 and SS1-SS8) and wet organic (S12S and S12F) soils.

Interaction	*df*	MS	F	p
Soil group	2	0.821	0.103	0.749
Block	1	105.859	13.248	0.000
Soil group *Block	2	16.789	2.101	0.123

DISCUSSION

In an earlier study, Parker *et al* (1996) found adaptive variation between northwestern Ontario black spruce seedlings originating from different soil types. Since many of the seed sources used in this study are original to the 1996 study, I hypothesized that variation between upland and lowland seed sources would persist in populations greater than 20 years. Results from the current study disprove this hypothesis. The negligible differences between upland and lowland seed sources found in this study support the results of previous studies completed by Zine *et al* (1993, 1994).

My finding of a lack of ecotypic variation amongst black spruce populations of different soil groups might be the result of inadequate soil and provenance sampling. The soil types provided were classified using the FEC Guide in the field. However, the guide is seldom able to describe the exact soil being sampled due to the intrinsic variability of soil conditions (Sims 1997). The FEC uses broad categories to classify soil types, whereas continuous description of soil types including percent sand, silt, clay; percent organic matter, and cation exchange capacity would be preferred. As a result, laboratory soil testing would be superior because it can determine more precise soil/site variables and would reduce errors associated with interpretation. Also, the provenance sample size was not large enough to determine a statistical effect. Because of the need for at least three provenances per category, the number of provenances for some soil groups was not large enough to enable statistical analyses. This also caused restrictions when creating soil group categories. Several preferred soil groupings were not included in the study due to the absence of certain soil types. For example, differences in shallow soils versus deep soils could not be studied since there weren't any seed sources originating from shallow organic soils (SS9).

Geoclimatic variation may also cause inconsistent results in studies. As mentioned earlier, studies have found variation in growth within both small and large geographical regions (Beaulieu *et al* 2004, Parker *et al* 1994). Latitude and elevation, along with other climatic influences have been proven to influence phenology and growth (Beaulieu *et al* 2004). As mentioned earlier, Morgenstern found that changes in temperature and photoperiod resulted in clinal growth variations of black spruce (1978). Additionally, lake effect has been found to cause interprovenance variation (Parker *et al* 1994). It may be hard to quantify changes in cases where provenance and family-within-provenance variations occur. In this study, provenance locations occurred within a large area of northwestern Ontario. Distances between provenances extended as far as 500 km apart. Therefore, climatic effects may confound inter-soil group variations.

Significant adaptive variation amongst black spruce populations in originating from different soil types was found in a common garden greenhouse experiment (Parker *et al* 1994). It is possible that the optimum growth conditions of the greenhouse allowed provenances to reach their full growth potential, which might result in greater among-provenance variation than would occur in field test sites. Growing conditions in this field study were not as regulated, as trees were exposed to seasonal changes and inclement weather. These less favourable growing conditions could partially account for the lack of significant variation observed amongst soil groups. It can also be noted that trees growing in the southern portion of block 3 were heavily influenced by the neighbouring jack pine provenance trial and were overtopped. The post hoc test results for height indicate significant differences between blocks 3 and 1, and 3 and 2. Because no buffer was placed between the two provenance trials, fast-growing jack pine suppressed the growth of trees in block 3. This greater environmental variation in the field test site compared to the greenhouse experiment means that a larger portion of the variation in phenotypes amongst provenances would be due to environmental variation, as opposed to additive genetic variation.

Boyle *et al* (1990) report that differences in ecological history may influence the genetic organization of populations. Sites originating from a fire may have increased levels of inbreeding depending on the size and intensity of the fire, along with the level of seed production following disturbance. As a result, lower genetic variation is expressed on sites originating from fire when compared to undisturbed sites. Therefore, the origin of a stand should be considered when choosing which seed sources to test.

It may be possible that *Picea mariana* can acclimate to variations in moisture availability. This may be why they can successfully grow in such contrasting environments. Collier and Boyer (1989) came to this conclusion when studying water relations of *Thuja occidentalis* in dry upland populations and wet lowland populations. They found that ecotypic differentiation was not the cause of successful growth over a range of moisture conditions. Rather, their results supported the tolerance theory originally proposed by Muselman *et al* (1975). Cedar from upland and lowland sites are not genetically different but can modify their resources partitioning to achieve reasonable growth on different soil types.

Further research is needed to support the significant differences in growth and phenological traits expressed among black spruce from different soil types reported by Parker *et al* (1994). Using adjacent pairs of upland and lowland seed sources coupled with in-depth soil analysis would provide more reliable results. Also, samples should be collected from stands with similar disturbance histories and be located uniformly across the study area. Finally, annual dbh and height measurements should be recorded to track adaptive variation expression at multiple ages.

CONCLUSION

This study failed to demonstrate significant adaptive variation between seedlings from lowland and upland black spruce populations in northwestern Ontario. This is in agreement with a variety of studies who found no evidence of edaphic variation in this species (Fowler and Mullin 1976, Zine El Abidine 1993, Zine El Abidine 1994). The study does, however, provide recommendations for future research developments. Nonetheless, it is still important to determine the best seed sources when making seed transfer decisions in breeding and reforestation programs. Thus, future provenance experiments are needed to reveal a definitive answer as to whether adaptive variation exists in northwestern Ontario black spruce populations.

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APPENDIX I

Table 11. Locations of black spruce provenances (Parker N.d.).

Genetics #	Seed Source	Latitude			Longitude		
1	12.89	50	12	25	86	54	8
2	13.89	49	59	8	87	9	15
3	15.89	48	36	45	90	15	30
4	16.89	48	24	26	89	49	25
5	17.89	48	47	8	86	56	55
6	18.89	49	9	40	86	33	39
7	24.89	49	38	30	86	30	52
8	27.89	48	10	25	90	42	18
9	29.89	50	0	6	88	1	42
10	35.89	48	30	36	90	55	36
11	37.89	50	23	25	88	36	45
12	39.89	49	57	48	89	9	28
13	44.89	49	24	50	89	2	32
14	45.89	49	24	8	89	44	36
15	48.89	48	54	40	89	24	0
16	50.89	50	13	28	90	0	5
17	51.89	49	55	30	90	7	15
18	53.89	48	32	47	88	42	55
19	56.89	48	26	37	89	19	37
20	61.89	49	23	50	87	13	25
21	63.89	48	52	50	87	32	20
22	64.89	49	31	46	87	48	17
23	67.89	49	6	50	87	48	45
24	69.89	48	36	51	89	0	50
25	70.89	48	53	33	88	17	40
26	73.89	49	4	10	85	59	15
27	8.93	49	41	31.6	94	55	42.5
28	11.93	50	12	41.1	94	54	21.4
29	12.93	49	8	51.9	93	45	51.4
30	14.93	49	33	6.2	94	3	11.2
31	25.93	49	41	32.1	92	7	24.2
32	27.93	49	16	8.5	91	50	20.4
33	32.93	50	43	37.1	93	0	48.8
34	37.93	51	7	51	93	56	33.3
35	39.93	51	4	42.2	92	40	17.4
36	42.93	50	45	18.2	91	24	50.9
37	44.93	50	20	59.8	91	40	36.2

Table 11. Locations of black spruce provenances (Parker N.d.) continued.

Genetics #	**Seed Source**	**Latitude**			**Longitude**		
38	46.93	49	45	15.8	91	9	16.3
39	48.93	50	25	48.4	90	37	1.6
40	51.93	50	57	40	90	27	20
41	53.93	50	1	9.8	92	23	25
42	60.93	48	58	48	93	0	52.1
43	65.93	49	11	12.9	92	30	49.8
44	67.93	48	42	46.7	92	18	42.8
45	71.93	49	58	18.5	93	36	12.6
46	74.93	49	35	34.1	93	5	18.3
47	84.93	48	41	20.7	91	16	40.2
48	85.93	50	50	54.9	94	22	53.7
49	86.93	50	41	37.2	93	49	48.7
50	21.93	49	41	5.2	90	17	43.7

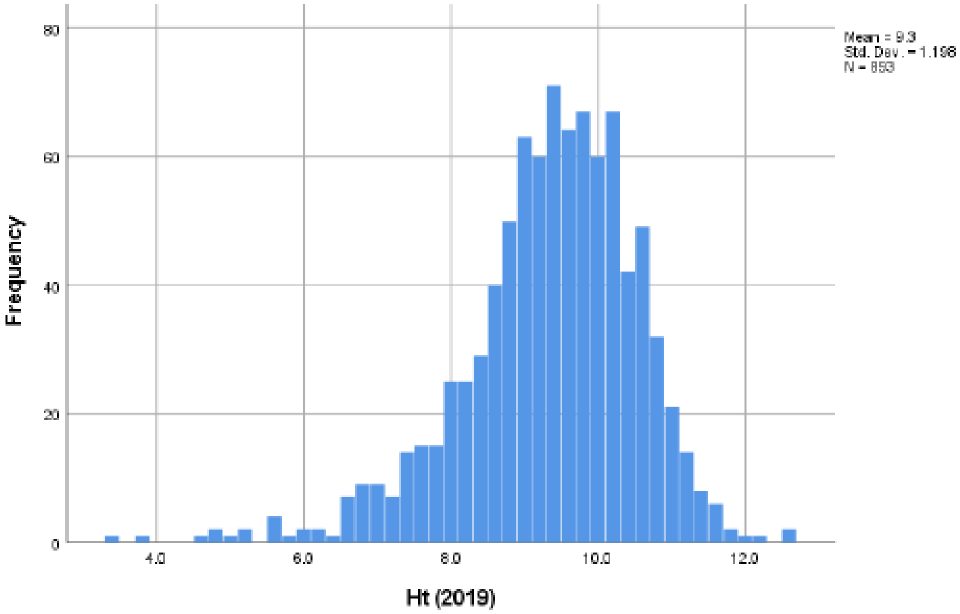

Figure 3. Histogram distribution for height (m) measurements.

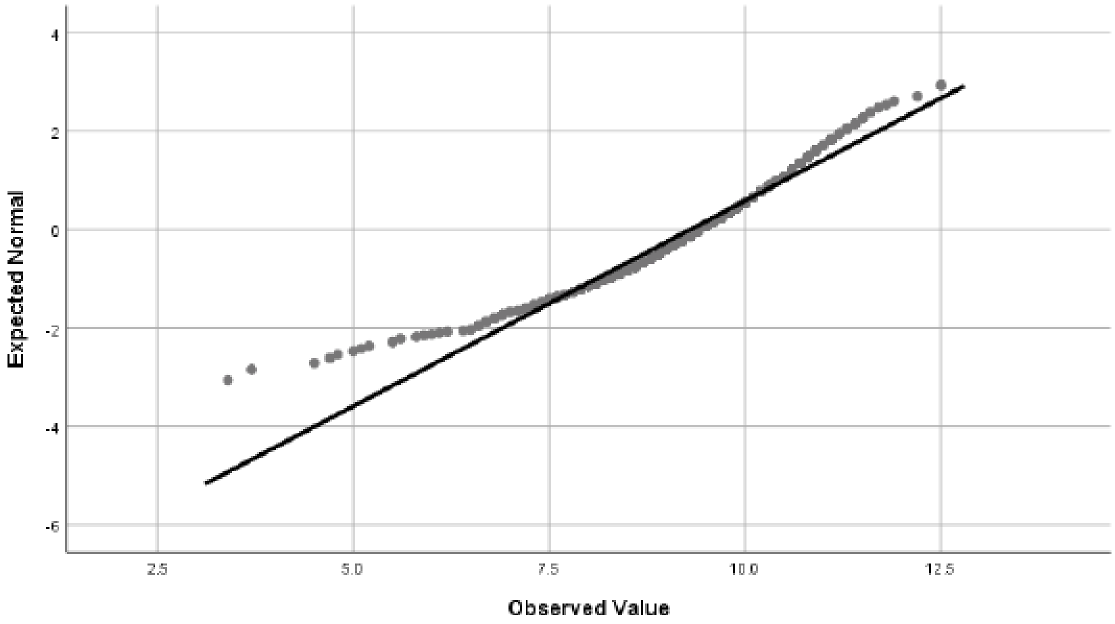

Figure 4. Normality Q-Q plot of height (m) measurements.

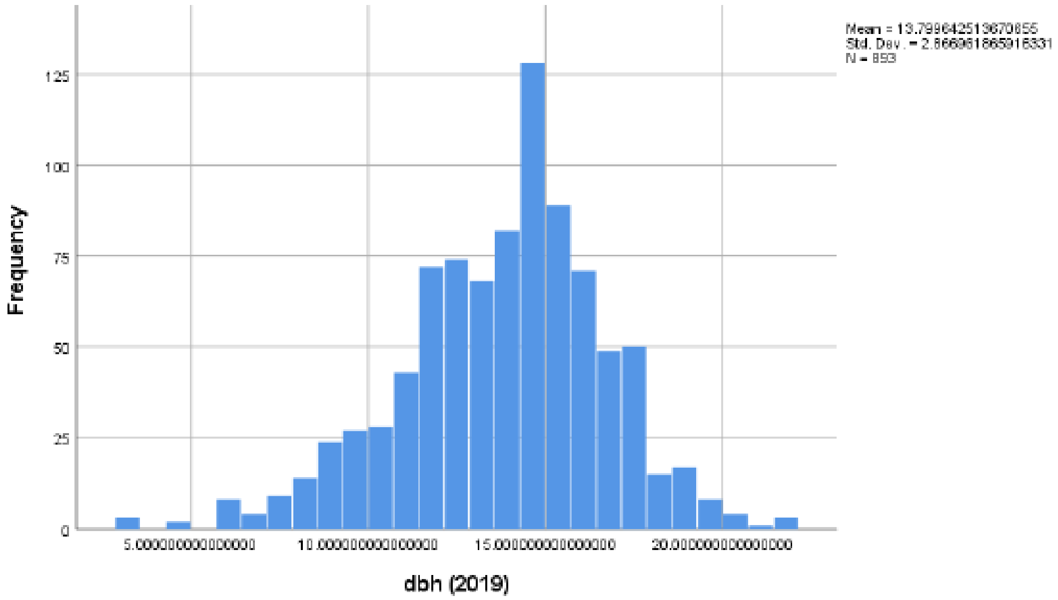

Figure 5. Histogram distribution for dbh (cm) measurements.

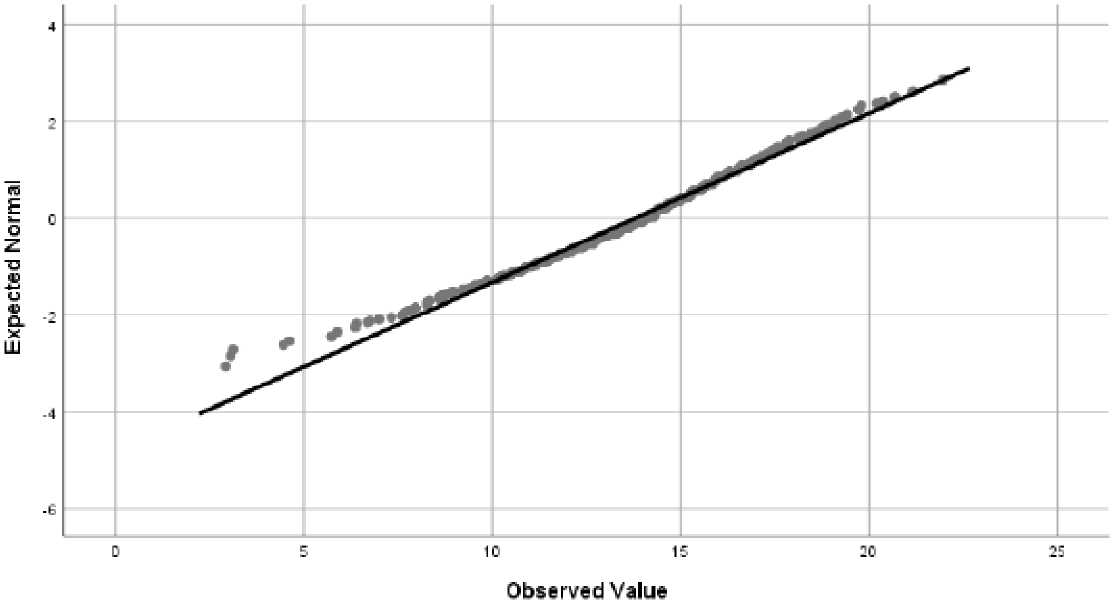

Figure 6. Normal Q-Q plot of dbh (cm) measurements.