A red pine provenance test in northwestern Ontario: 48-year results

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ABSTRACT

Survival, total height and diameter at breast height (DBH) were measured in the fall of 2005 in a 48-year-old red pine (*Pinus resinosa* Ait.) provenance trial growing in northwestern Ontario. There was significant variation in both height and diameter among the 23 provenances. Generally, westerly provenances performed well while those from the Maritime Provinces exhibited relatively poor growth. Considering that the plantation is at the northern biological range of red pine, survival was high, averaging 96% after 48 years. Provenances with the best growth rates exceeded a volume of 420 m³ ha⁻¹. Some provenances from Minnesota and Wisconsin as well as Fort Frances, Ontario exhibited superior growth and should be considered as seed sources for future planting programs in northwestern Ontario.

Key words: red pine, provenance test, survival, diameter, height, volume, Northwestern Ontario

RÉSUMÉ

Le taux de survie, la hauteur totale et le diamètre à hauteur de poitrine (dhp) ont été mesurées à l'automne 2005 dans une plantation de pin rouge (*Pinus resinosa* Ait.) âgée de 48 ans destinée à faire l'essai de différentes provenances de semis et située dans le nord-ouest de l'Ontario. On a relevé une variation significative tant au niveau de la hauteur que du diamètre parmi les 23 provenances. De façon générale, les provenances occidentales ont bien performé tandis que celles issues des provinces de l'Atlantique ont démontré une croissance relativement décevante. En prenant en considération que la plantation est située à la limite nordique de l'aire de distribution biologique du pin rouge, le taux de survie s'est révélé être élevé, atteignant une moyenne de 96 % après 48 ans. Les provenances ayant les meilleurs taux de croissance ont atteint un volume supérieur à 420 m³ ha⁻¹. Certaines provenances du Minnesota et du Wisconsin ainsi que de la région de Fort Frances en Ontario ont démontré une croissance plus importante et devraient être retenues comme sources de semences pour les prochains programmes de plantation à être réalisés dans le nord-ouest de l'Ontario.

Mots clés : pin rouge, essai de provenance, survie, diamètre, hauteur, volume, nord-ouest de l'Ontario

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a limited seed supply, sensitivity to hard water and excessively large branches (especially at wider spacing) are drawbacks.

Despite growing on a wide range of sites, red pine is remarkably uniform in taxonomic and morphological characteristics, a rare feature amongst pines (Holst 1975, Boys *et al.* 2005). Studies on red pine populations from Quebec (Simon *et al.* 1986), Ontario, New Brunswick and Nova Scotia (Fowler and Morris

1977), and isolated populations in Newfoundland (Mosser *et al.* 1991, 1992) have shown no genetic diversity.

Recent studies, however, detected a low level of polymorphism among both individuals and populations of red pine (DeVerno and Mosseler 1997) while Boys *et al.* (2005) found that three northeastern populations from Newfoundland and New Brunswick were genetically distinct from others. Also,

Introduction

Red pine (*Pinus resinosa* Ait.) is commonly planted throughout the north-central United States and central and eastern Canada (Rudolph 1990, Boys *et al.* 2005) with growth rates exceeding 13 m³ ha⁻¹ yr⁻¹ in northwestern Ontario under ideal conditions (McClain *et al.* 1994). Its uniform growth rate and good form enhance thinning and pruning operations for value-added products (Fowler and Heimburger 1969) but

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Walter and Epperson (2005) found a remarkably narrow and sharply bounded band-shaped area of high genetic diversity centered at northeastern New England, which showed genetic diversity within the geographic distribution of red pine. Even though red pine may not be genetically diverse in isozyme and other molecular markers, it may show genetic variation in quantitative traits such as diameter and height. These traits are controlled by many minor genes and are subjected to strong natural selection by the environment (Morgenstern *et al.* 1975). In this study, we report on survival, height, diameter and volume growth among provenances in a 48-year-old trial planted in northwestern Ontario.

Materials and Methods

Study area

Between 1959 and 1964, 10 red pine provenance tests were established as the 216 series by Natural Resources Canada and various co-operators. Four of these tests are in Ontario, two in Quebec, one each in Prince Edward Island and Nova Scotia and two in Wisconsin. Results reported here are based on data collected from Experiment 216-C located in McIlraith Township, Ontario. In 1958, seeds from 23 provenances, spanning a significant portion of the natural range of red pine (Burns and Honkala 1990) (Fig. 1 and Table 1), were sown at the nursery of the former Petawawa Forest Experiment Station and grown as 2+2 transplant stock. The plantation was established in 1962 in co-operation with Dryden Paper Company and is located approximately 40 km southwest of Sioux Lookout at 49°28'N, 92°27'W close to the northern and western limit of the species' natural range (Fig. 1). The site is a gravelly sandy ablation till that commonly supports fire-

origin jack pine (*Pinus banksiana* Lamb.) stands under natural succession. Site quality is classified as Class 2 according to provincial yield tables (Plonski 1981) with an average jack pine height of approximately 15 m at 50 years.

After harvesting the natural jack pine stand, the planting site was bladed, which resulted in the removal of most of the forest floor and uppermost mineral soil horizon. Bareroot seedlings were planted in a randomized complete block design with three replications. Each plot consisted of 25 trees (5 × 5) planted at 1.8-m spacing. A single buffer row of red pine surrounds each plot and two buffer rows comprise the outside perimeter of the installation.

Measurements were carried out in the fall of 2005. To avoid possible bias in growth measurements as a result of openings due to mortality, trees that were completely surrounded by living neighbours were identified and five were randomly selected for height and diameter at breast height (DBH) measurements. Thus, a total of 345 trees (23 provenances × 3 reps × 5 trees per plot) were measured. Measurements were averaged by provenance at each plot giving one value per plot for each measured parameter.

Data analysis

Complete random block with random effect analysis of variance was carried out to test the hypothesis that red pine growth varies among provenances. All statistical analyses were conducted using SAS (1993). For survival, percentages were transformed by arcsin to meet the requirements of normal distribution. The homogeneity assumption was checked using Leven's test and a scatterplot of residuals versus predicted values was tested for normality assumption (Lorenzen and Anderson

Fig. 1. Natural range of red pine, showing approximate locations for the provenances, and the test site in northwestern Ontario.

Table 1. Seed lot number and origin (location, latitude [N] and longitude [W]) of red pine provenances planted in 1962 in McIlraith Township, northwestern Ontario

Seed lot no.	Location	Province or State	Latitude (°N)	Longitude (°W)
1713	Trout Lake	Wisconsin	46.0	89.7
2045	Stanley	Nova Scotia	45.1	63.9
2046	Grand Lake	New Brunswick	46.0	66.1
2132	Rawdon	Quebec	46.0	73.7
2356	Sturgeon Falls	Ontario	46.4	79.9
2530	Thistledew Lake	Minnesota	47.8	93.3
2531	Clubhouse Lake	Minnesota	47.5	93.5
2532	Itasca Park	Minnesota	47.3	95.3
2533	Cass Lake	Minnesota	47.4	94.7
2559	Dryden	Ontario	49.8	92.9
2560	Fort Frances	Ontario	48.6	93.4
2561	Douglas	Ontario	45.5	76.9
2567	Lake States	Wisconsin	45.6	91.0
2578	Schoolcraft Co.	Michigan	46.2	86.2
2579	Grand Traverse Co.	Michigan	44.7	85.5
2580	Presque Isle Co.	Michigan	45.4	84.2
2581	Superior Nat. For.	Minnesota	47.5	90.8
2582	Chippewa Nat. For.	Minnesota	47.3	94.0
3136	Boulder Jct.	Wisconsin	46.0	89.7
3137	Oneida Co.	Wisconsin	45.9	89.7
3138	Six Mile Lake	Minnesota	47.3	94.1
3139	Lake Thirteen	Minnesota	47.3	94.5
3140	Grand Bend	Ontario	43.3	81.8

1993). Simple Pearson correlation was used to evaluate relationships between geographic coordinates of seed sources and averages of tree height and DBH. Gross total tree volume was estimated using Honer's equation (Honer *et al.* 1983):

$$[1] V = \frac{0.0043891 \times (DBH)^2 \times (1 - 0.04365 \times x)^2}{c_1 + \left(0.3048 \times \frac{c_2}{ht}\right)}$$

where: V = volume ($m^3 \text{ tree}^{-1}$)

DBH = diameter at breast height (cm)

$x = 0.151$

$c_1 = 0.710$

$c_2 = 355.623$

ht = total tree height (m)

Volume per hectare, taking mortality into account, was calculated for each provenance. Data from measurements made in 1978 (21 years) (Maley and Bowling 1993) were analyzed in the same fashion as the 2005 (48 years) data to compare provenance performance at different ages.

Results

Means of parameters measured in 1978 and 2005 are presented in Table 2. Results from the analysis of variance for survival, height, DBH, and volume at age 48 are presented in Table 3. Correlation coefficients for measurements made at ages 21 and 48 years and for latitude and longitude are given in Table 4.

Survival

Survival at age 21 years averaged 98% and only decreased to 96% at age 48 (Table 2). Two provenances (1713, Trout Lake and 2578, Schoolcraft Co.) had 100% survival at 48 years

while provenance 2356, Sturgeon Falls had the poorest survival at 88%. There was no significant difference among provenances for survival (Table 3) and survival was only correlated with 21-year height (Table 4).

Height

Average height at age 21 was 6.2 m, ranging from 5.4 m (2045, Stanley and 2356 to 6.9 m (1713) (Table 2). At age 48, height averaged 15.3 m, ranging from 14.0 m (2045) to 16.2 m (1713) and was significantly different among provenances (Table 3). Height at age 21 was significantly correlated with longitude, and with height, DBH, volume and survival at 48 years. Height at age 48 was significantly correlated with DBH, volume and longitude, but no longer with survival (Table 4).

Diameter

Diameter at breast height at 48 years averaged 14.6 cm and ranged from 13.2 cm (2045) to 15.9 cm (2581, Superior National Forest) (Table 2) and was significantly different among provenances (Table 3). Diameter was significantly correlated with height at 21 years, height and volume at age 48 and longitude (Table 4).

Volume

Volume production at age 48 averaged 365.9 $m^3 \text{ ha}^{-1}$ and ranged from 249.5 $m^3 \text{ ha}^{-1}$ (2045) to 448.8 $m^3 \text{ ha}^{-1}$ (2581) (Table 2) and was significantly different among provenances (Table 3). Volume was significantly correlated with 21-year height, 48-year height and DBH, and longitude (Table 4).

Discussion

It has been generally believed that red pine is a relatively homogenous species; however, results from this study

Table 2. Provenance means for selected traits measured at two ages

Seed lot no.	Age 21		Age 48			
	Survival (%)	Height (m)	Survival (%)	Height (m)	DBH (cm)	Volume (m ³ ha ⁻¹)
1713	100	6.9	100	16.2	15.3	435.1
2045	95	5.4	89	14.0	13.2	249.5
2046	97	6.0	97	14.5	13.5	300.4
2132	99	5.9	96	14.4	13.9	316.3
2356	95	5.4	88	14.9	14.0	302.9
2530	99	6.0	95	15.4	14.5	363.7
2531	96	6.5	93	15.3	15.1	384.9
2532	92	6.3	92	15.5	15.4	389.1
2533	99	6.3	99	15.3	14.5	366.9
2559	99	6.3	97	15.5	14.5	348.0
2560	99	6.2	99	15.7	15.5	424.3
2561	99	6.1	93	15.0	14.4	342.0
2567	100	5.9	97	14.9	14.1	339.5
2578	100	6.3	100	15.1	14.6	386.5
2579	97	6.0	97	14.9	14.4	343.8
2580	96	6.3	92	15.5	15.4	386.4
2581	97	6.4	95	15.9	15.9	448.8
2582	100	6.4	99	15.4	14.9	389.5
3136	99	6.2	99	15.2	14.8	383.0
3137	97	6.1	96	15.3	14.0	344.6
3138	97	6.7	96	15.9	15.6	425.9
3139	96	6.7	96	15.7	15.3	402.8
3140	99	6.5	97	15.4	14.2	341.2
Mean	98	6.2	96	15.3	14.6	365.9

demonstrate that variation in growth exists. Here, we found that trees originating from eastern Canada (i.e., New Brunswick, Nova Scotia, and Quebec) performed poorly compared to those from the Lake States. The relationship between geographical origin and growth of red pine has been reported elsewhere. For example, Hough (1967) reported on a study consisting of 50 sources ranging from Maine to Minnesota and planted in northwestern Pennsylvania. He found that red pine sources from southern latitudes were significantly taller than sources from northern latitudes 10, 20 and 25 years after planting. In contrast, in an 11-year-old red pine provenance trial in Nebraska, significant differences in total height and height growth rate were found but no correlation between height and latitude or longitude was detected (Sprackling and Read 1975). Park and Fowler (1981) evaluated the same provenances as in our study, planted in Nova Scotia and Prince Edward Island, and found that at 17 years of age height was negatively correlated with latitude and trees from the central part of the range in the Lake States and Ontario grew faster than those from northern provenances while Maritime sources were average. Our results show strong correlations between growth parameters (height, DBH, and volume) and longitude. However, no correlations between latitude and any growth parameter were found that might be due to the narrow latitudinal range of the provenances.

We expected to observe higher mortality in provenances originating from southern latitudes due to a harsher climate at the more northern planting site. However, there was no relationship between survival at 48 years and latitude. Based on these data, we cannot dismiss the impact of genetic variation in terms of photoperiodic response (Vaartaja 1962) or other geographic acclimation that might exist among red pine populations. More data from other red pine plantation sites are needed to explore such possibilities.

Table 3. Mean squares (MS) and F-values (F) from an analysis of variance of red pine provenance data at age 48 years

Source	df	Survival (%)		Height (m)		DBH (cm)		Volume (m ³ ha ⁻¹)	
		MS	F	MS	F	MS	F	MS	F
Blocks	2	77.32	1.10	0.33	1.88	0.16	0.19	0.00006	0.16
Provenance	22	81.03	1.15	0.80	4.53	2.83	3.37	0.0012	3.52
Error	44	70.44	–	0.41	–	0.84	–	0.0003	–

Bold values are significant at $p < 0.001$.

Table 4. Pearson correlation coefficients for selected traits at ages 21 and 48 years, and for latitude and longitude of provenance location

	Surv ₄₈	Height ₂₁	Height ₄₈	DBH ₄₈	Vol ₄₈	Lat	Long
Survival ₄₈	1.00	0.38*	0.18	0.04	0.05	0.03	0.20
Height ₂₁	–	1.00	0.60**	0.33*	0.38*	0.21	0.55**
Height ₄₈	–	–	1.00	0.75**	0.82**	0.17	0.53**
DBH ₄₈	–	–	–	1.00	0.99**	0.05	0.28*
Volume ₄₈	–	–	–	–	1.00	0.07	0.32*
Latitude	–	–	–	–	–	1.00	0.57**
Longitude	–	–	–	–	–	–	1.00

* = significant at 5%; ** = significant at 1%

Fig. 2. Height (A) and DBH (B) growth over time of four red pine provenances. Trees were measured in 1967 (height only), 1972, 1978, 1991, 1998 and 2005. Note that the relative ranks did not change through to age 48.

Results of a 44-year-old white spruce provenance trial (Morgenstern *et al.* 2006) planted in Petawawa, Ontario showed that identification of the best provenances at an early age (15 years) was ineffective because of changes in rank and differential survival through to age 44. In contrast, performance was more consistent in our red pine trial with 21- and 48-year heights being strongly correlated (Table 4). Generally, provenances performing either well or poorly at a young age continued to perform in a consistent manner over time (Fig. 2).

In an attempt to evaluate potential climate change impacts on boreal tree growth and implications for tree seed management, a re-measurement of range-wide jack pine (Thomson and Parker 2008) and black spruce (Thomson *et al.* 2009) provenance trials has been undertaken. For both species they found that southern sources performed better in cooler environments. They concluded that moving southern seed sources north will result in trees achieving superior height growth in response to predicted future climate. If these findings can be extrapolated to our study, it suggests that the two “local” red pine provenances (Dryden (2559) and Fort Frances (2560)) may not be growing under their optimal climatic conditions whereas southern provenances may be responding better to the climatic conditions at our trial site. The Fort Frances and Dryden provenances ranked fourth and sixth for mean height but for volume production they ranked fourth and fourteenth, respectively. This rank difference is probably due to a combination of lower survival (97%) and mean DBH (14.5 cm) of the Dryden provenance compared to the Fort Frances provenance with 99% survival and mean DBH of 15.5 cm.

Conclusion

Results from this trial demonstrate that some non-local sources of red pine perform well in northwestern Ontario and attain more than 420 m³ ha⁻¹ by age 48 on medium quality sites. Mean annual increment for this trial of approximately 7.6 m³ h⁻¹ yr⁻¹ is impressive considering that the trial is located near the northern limit of red pine’s natural range on a somewhat droughty soil. Two provenances from Minnesota (2581 and 3138) and one from Wisconsin (1713) produced

from 425.9 m³ ha⁻¹ to 448.8 m³ ha⁻¹, more than the best local provenance from Fort Frances at 424.3 m³ ha⁻¹. With projected climate change, some southern provenances may continue to grow as well or better than local sources. From a management perspective, it appears that obtaining red pine seed from northern Michigan, Minnesota and Wisconsin may be a viable management option. In contrast, red pine provenances from the Maritime Provinces and Quebec performed relatively poorly, and should not be considered as seed sources for northwestern Ontario.

Acknowledgments

We thank Peter Copis, retired (Petawawa Research Forest) for supplying historical data, Eric Kahkonen for field work assistance and data entry and Gwen MacIsaac for creating Fig. 1. Sally Dunphy, USFS National Forest Service Library, Fort Collins, Colorado provided exemplary support to the authors. In addition, we thank two anonymous reviewers for their constructive suggestions for improvement to the original manuscript.

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