MULTIPLE-LEADERED TREES COMPARE FAVORABLY WITH SINGLE-LEADERED TREES IN FIELD PERFORMANCE TESTS OF NURSERY STOCK

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ABSTRACT

Coniferous trees produced at Ontario Ministry of Natural Resources tree Nurseries have generally been considered unacceptable for planting if more than one terminal shoot is present. Field performance tests of several pine and spruce species showed that multiple-leadered trees grew and survived as well as single-leadered trees, but that if trees remained multiple-leadered there were some adverse effects. A considerable proportion of the trees that were single-leadered when planted became multiple-leadered thereafter, and vice versa. The destiny after planting was not apparent when trees were graded prior to planting. Revision of acceptance standards to allow more than one terminal shoot is recommended.

RÉSUMÉ

Les conifères produits dans les pépinières du ministère des Richesses naturelles de l'Ontario sont généralement considérés comme inacceptables pour la plantation quand ils ont plus d'une pousse apicale. Des tests de performance sur le terrain avec plusieurs espèces de pin et d'épinette ont indiqué que les arbres à pousse apicale multiple avaient une croissance et une survie égales à celles des arbres à pousse apicale unique, mais que s'ils conservaient une pousse apicale multiple, il y avait des effets défavorables. Une proportion considérable des arbres à pousse apicale unique au moment de la plantation sont devenus à pousse apicale multiple par la suite, et vice versa. Le devenir après la plantation ne pouvait être prévu quand les arbres étaient classés avant d'être plantés. Une révision des normes d'acceptabilité pour permettre la présence de plus d'une pousse apicale est recommandée.

ACKNOWLEDGMENTS

The assistance and cooperation of K.H. Reese, Supervisor of the Stock Production Unit, Forest Resources Branch, and nursery superintendents C.R. Groves, L.J. Forcier and A. Wynia, all of the Ontario Ministry of Natural Resources, are gratefully acknowledged. My colleagues at the Great Lakes Forest Research Centre, particularly Dr. D.P. Webb, are thanked for their assistance and counsel.

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Cover Photo: White spruce outplanting test at Midhurst Nursery in 1982.

INTRODUCTION

Coniferous trees produced at Ontario Ministry of Natural Resources (OMNR) nurseries are normally discarded as unacceptable for planting if they have more than one terminal shoot. Diagnostic studies (Gross 1983) conducted at three OMNR nurseries showed that the multiple-leadered (ML) condition followed injuries to shoot terminals, and led to reduced apical dominance. A large portion of the trees that are multiple-leadered are discarded simply because they do not achieve acceptable size for planting. The poor form of those that did meet acceptable size standards was assumed to lead to poor field performance. This study was initiated to compare the performance of these otherwise acceptable ML trees to that of single-leadered (SL) trees, and to determine if ML trees recover to the SL form after planting.

METHODS

ML trees were compared with SL trees in seven plantings that included the following test stock[1]: (1½ + 1½) white spruce (WS) *(Picea glauca* [Moench] Voss); (3 + 0) black spruce (BS) *(Picea mariana* [Mill.] B.S.P.); (1½ + 1½) white pine (WP) *(Pinus strobus* L.); (2 + 0) jack pine (JP) *(Pinus banksiana* Lamb.). The trees planted were graded to normal acceptance standards (unpublished) except that the number of terminals was ignored. The planting stock was selected from nursery compartments known to have considerable ML; otherwise, selection was random. OMNR field crews planted the test stock in May 1978 as part of larger regeneration projects. Each test contained ten 20-tree plots randomly located in the plantings. The tests at the Midhurst Nursery were conducted on cultivated fields at the nursery, and the other plantings were on scarified forest sites. Site preparation by cultivation, as applied at Midhurst, is not unusual in southern Ontario; hence, all tests were on normal planting sites.

The trees were rated just after planting and at the end of each growing season from 1978 to 1980. The Midhurst tests were also inspected at the end of the 1982 season. Data recorded were: total height, stem diameter at 1 cm above ground, number of terminal shoots, terminal bud size, and presence of terminal injuries. Terminal shoots were defined as shoots with an upright habit and extending into the upper 20% of the tree. Through an oversight, the tests of stock from the Thunder Bay Nursery were rated only for the SL or ML character at planting time. Voids in tabular data reflect this problem. The planting stock was further characterized by random samples of 50 ML and 50 SL trees each taken at the time of planting for destructive sampling. Parameters measured on these were total height, stem diameter at 1 cm above the root collar, root area index defined by Morrison and Armson (1968) as the silhouette root area measured photometrically in cm^2, shoot oven-dry weight (70°C for 24 hr), and root oven-dry weight.

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[1]Nursery seedling designations usually show the number of years in seedbed culture (X_1) and as transplants (X_2) as follows: ($X_1 + X_2$).

RESULTS AND DISCUSSION

ML trees that met acceptable height standards (Fig. 1) tended to have greater bulk and a higher root area index in comparison with acceptable SL trees (Table 1). SL trees, especially in the BS Swastika test, and in the JP, WP tests, were taller initially, but the magnitude of the height difference was relatively small (Table 2, Fig. 2). Terminal injuries and the ML state had an adverse effect on height growth. While growth charts (Fig. 2) and data (Tables 2 and 3) seem to indicate that there is not much difference in height or diameter growth in ML and SL trees, these data are influenced by an abundance of trees that changed status after planting. The final height of SL trees that remained SL was consistently superior to the height of SL trees that changed status (Table 4). Conversely, heights of ML seedlings that remained ML were less than heights for those that changed status. Similarly, the average number of terminals on a tree was consistently negatively correlated ($\alpha > .05$, r) with height growth for the 3-year period and with final height for all except the WS Midhurst test, in which ML trees outperformed SL trees. The magnitude of the advantage of remaining SL or recovering to the SL state was impressive (Table 4). For all tests, the average height of the SL trees that remained SL was greater than the height of those that changed status at least once, and the average height of ML trees that stayed ML was less than the height of those that became SL at least once.

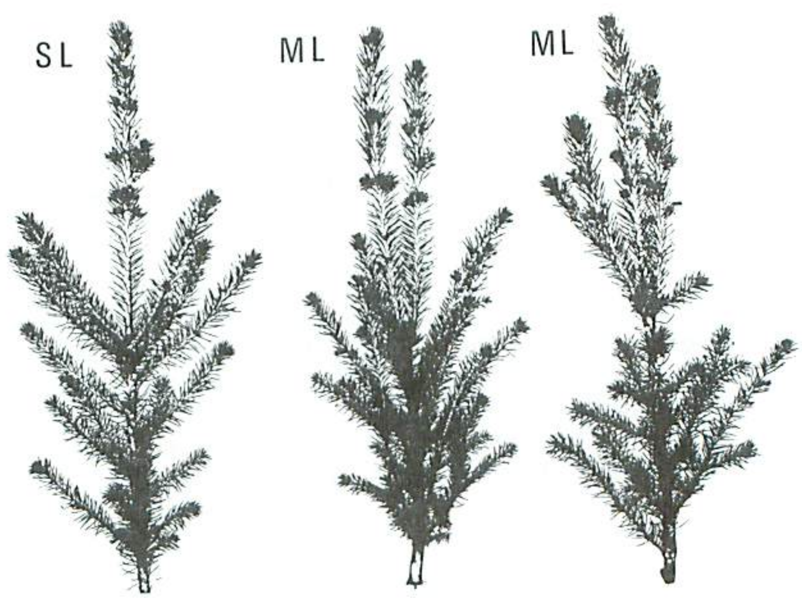

Figure 1. Examples of single-leadered (SL) and multiple-leadered (ML) white spruce with with two and three or more terminal shoots.

Table 1. Characteristics[a] of planting stock taken from provincial nurseries to compare performance of single-leadered (SL) and multiple-leadered (ML) bare-root trees.

Test	Root area index (cm)		Seedling weight (g ODW)		Shoot to root ratio	
	SL	ML	SL	ML	SL	ML
WS Midhurst	48.1	58.0[b]	7.9	9.5	2.9	2.5
WS Swastika	39.6	55.1	5.4	7.0	2.2	2.3
WS Thunder Bay	49.2	67.2	6.9	10.8	2.7	2.7
BS Swastika	32.4	32.8	3.4	5.6	3.6	4.8
BS Thunder Bay	38.1	51.0	6.8	10.9	4.0	4.3
JP Swastika	34.4	44.9	3.9	5.3	4.6	4.3
WP Midhurst	61.2	76.3	Data not recorded		Data not recorded	

[a]Data for seedling height and diameter are not presented as they are virtually the same as the heights and diameters of planted trees (Tables 2 and 3).

[b]Root area index values that differ at the $\alpha = .05$ level, t test, are underlined.

Table 2. The initial and final height of single-leadered (SL) and multiple-leadered (ML) seedlings 3 years after planting.

Test	Initial height (cm in 1978)		Final height (cm in 1980)	
	Single-leadered (SL)	Multiple-leadered (ML)	Single-leadered (SL)	Multiple-leadered (ML)
WS Midhurst	22.2	21.8	56.7	61.4
WS Swastika	26.9	28.3	43.3	46.7
WS Thunder Bay	Data not recorded		34.4	34.4
BS Swastika	25.3[a]	21.6	51.3	44.7
BS Thunder Bay	Data not recorded		44.7	44.0
JP Swastika	23.4	20.3	93.9	87.1
WP Midhurst	16.1	13.9	40.1	39.5

[a]Data for single-leadered (SL) seedlings that are significantly greater than data for multiple-leadered (ML) seedlings at the $\alpha = .01$ and .05 levels are underlined by one or two lines, respectively (t test).

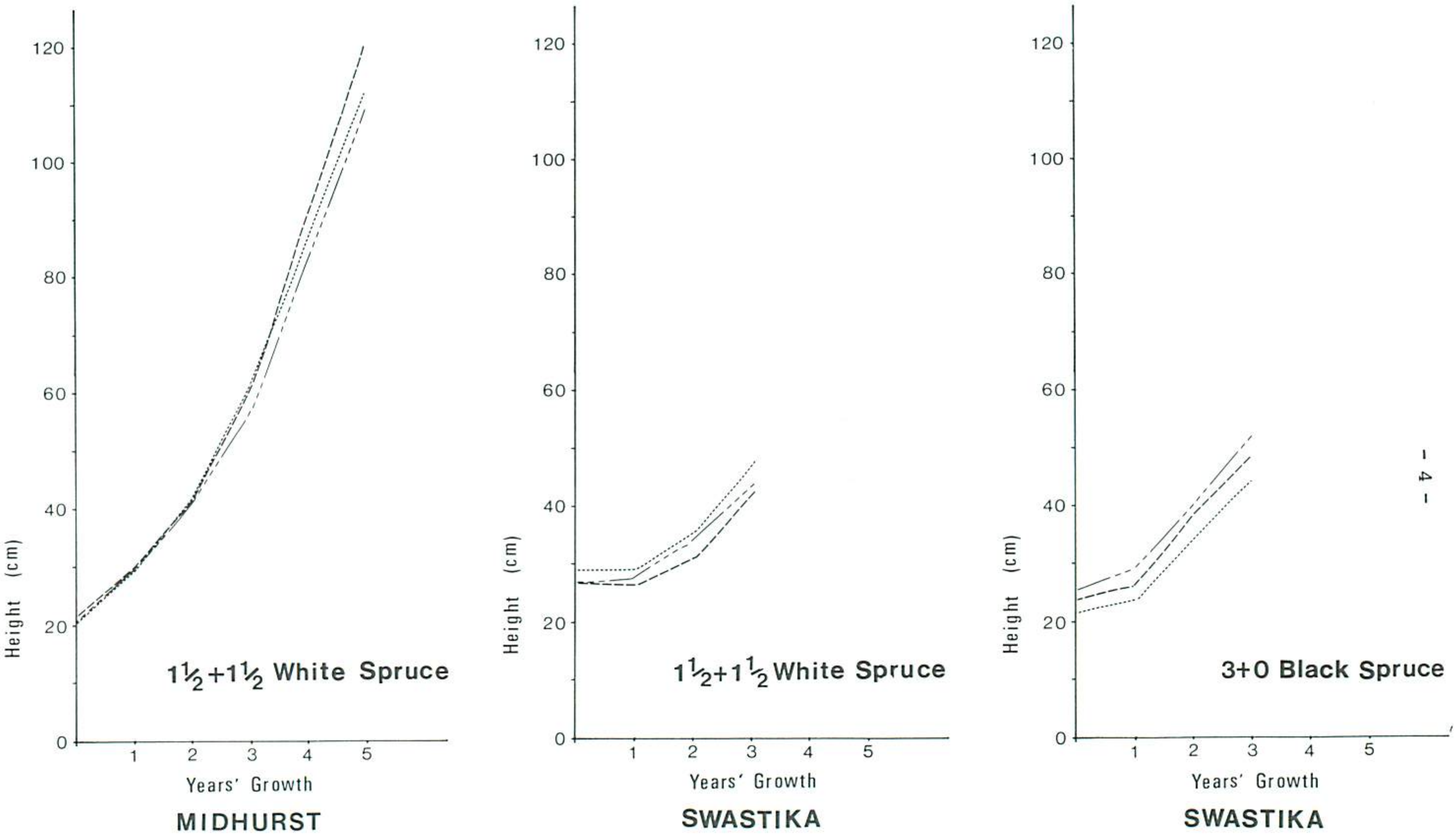

Figure 2. Height growth progressions for single-leadered seedlings (———) and multiple-leadered seedlings with two (– – – –) and three or more (·········) terminal shoots (continued).

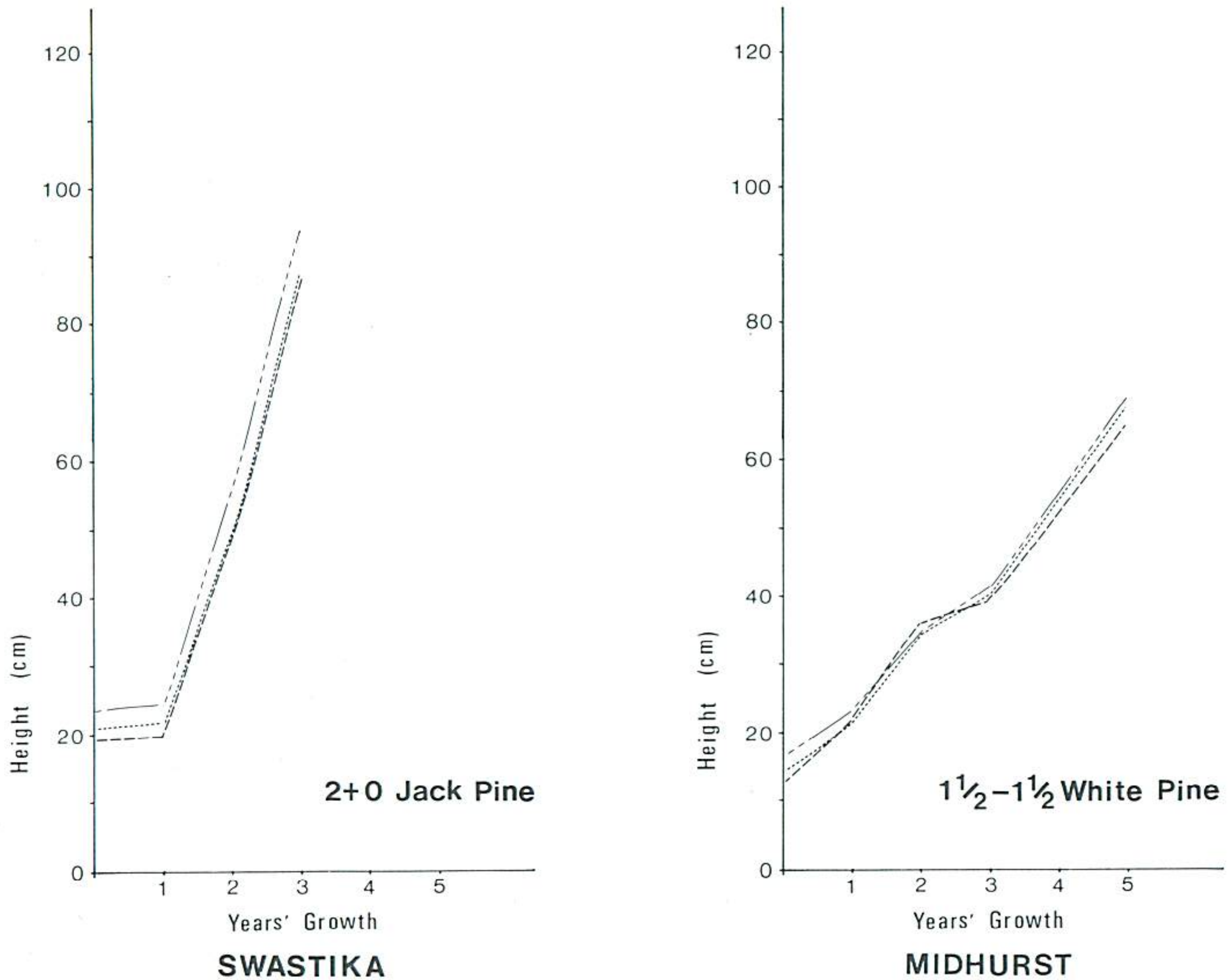

Figure 2. Height growth progressions for single-leadered seedlings (———) and multiple-leadered seedlings with two (– – – –) and three or more (---------) terminal shoots (concluded).

Table 3. The initial and final diameter at 1 cm height of single-leadered (SL) and multiple-leadered (ML) seedlings 3 years after planting.

Test	Initial diameter (cm in 1978)		Final diameter (cm in 1980)	
	Single-leadered (SL)	Multiple-leadered (ML)	Single-leadered (SL)	Multiple-leadered (ML)
WS Midhurst	.53	.55	1.70	1.82
WS Swastika	.50	.48	1.02	1.03
WS Thunder Bay	Data not recorded		.80	.81
BS Swastika	.40	.39	.89[a]	.78
BS Thunder Bay	Data not recorded		.74	.87
JP Swastika	.50	.42	1.84	1.76
WP Midhurst	.51	.48	1.38	1.40

[a]Data for single-leadered (SL) seedlings that are significantly greater than data for multiple-leadered (ML) seedlings at the α = .01 and .05 levels are underlined by one or two lines, respectively (t test).

Table 4. Heights of single-leadered (SL) and multiple-leadered (ML) seedlings 3 years after planting comparing heights of seedlings that remain SL or ML with those that change status at least once from SL to ML or ML to SL, respectively.

Test	Single-leadered seedlings (SL)					Multiple-leadered seedlings (ML)				
	Remain single-leadered		Status changes		Difference	Remain multiple-leadered		Status changes		Difference
	(avg)	(n)	(avg)	(n)	(%)	(avg)	(n)	(avg)	(n)	(%)
WS Midhurst	58.6	23	55.4	55	6	58.2	8	62.5	114	7
WS Swastika	46.9	69	41.8	29	12	41.6	30	48.3	68	14
WS Thunder Bay	38.0	47	32.4	84	17	34.0	34	34.8	22	2
BS Swastika	53.1	34	50.2	60	6	43.9	15	45.1	32	3
BS Thunder Bay	46.9	54	41.6	39	13	39.8	22	47.0	31	15
JP Swastika	97.0	72	89.4	49	8	68.4	5	88.4	72	23
WP Midhurst	44.0	81	36.4	85	21	30.0	2	40.2	24	25

Both white and black spruce seem to experience slow terminal growth for several years after planting, and this may retard recovery to the SL state. The form of ML trees in all of the WS and BS tests was poor in 1980 when most tests were terminated. However, tree form for most SL and ML trees in the WS Midhurst test was good in 1982, and most trees then had a single straight dominant stem. These trees experienced vigorous growth (Fig. 2) in 1981 and 1982, and this seems necessary before spruce can be expected to show good recovery from multiple-leadering. Only eight trees remained ML throughout the 1978-1982 period and these continued to have poor form.

Jack pine exhibited the greatest recovery to the SL state (Fig. 3). The apical dominance of jack pine is superior to that of spruce, and most jack pine that were initially ML became SL by the end of the test. Trees that experienced ML generally had straight stems and good form. Five trees remained ML throughout the test, and these had poor form caused by several twisted stems of about the same size and dominance.

The WP Midhurst test site was too dry for good white pine culture. The soil was a fine sand, ground cover was sparse, and foliar color of the pines was indicative of low soil fertility. Overall poor site character was reflected by the poor growth (Fig. 2) of the trees. The trees that were ML increased from 13.5% in 1978 to 17.7% in 1980 (Fig. 3) and 27.4% in 1982. These data seem to indicate that white pine is prone to ML. However, white pine has good apical dominance and probably would exhibit better recovery on a more favorable site.

Survival of both ML and SL trees was good in most tests. Only three of the test plantings experienced more than 5% mortality over the 3-year period and survival after the initial year was good for all tests. For the WS and BS Thunder Bay tests, mortality over the test period was 5.5 and 15.0%, respectively. More than 60% of this mortality occurred in the season of planting. Mortality seemed to be a function of initial tree size for both tests ($\alpha = .01$, t test). The average height at the end of the 1978 season for all the trees that died in the WS test was 9.2 cm in comparison with 19.2 cm for survivors, and for the BS test it was 21.7 cm in comparison with 28.7 cm for survivors. Nine of the 30 black spruce that died were ML and these averaged only 12.7 cm in height. Consequently, many of the trees that died in the Thunder Bay tests should have been excluded from the test as grading standards specify that spruce seedlings should be at least 14 cm tall. Mortality for the BS Swastika test seemed to be related to a storage or a handling problem during planting as 79% of the mortality occurred in the season of planting, and many of the trees appeared faded green and were probably dead soon after planting. A number of trees with faded green foliage in this test were examined just after planting in June, 1978 in areas near the sample plots. Most of the roots of these trees were dead and the cambial area of the stem was dry in comparison with that of "normal" trees. Mortality over the 3-year period was 28% for all trees and 45.3% for ML seedlings. Since entire rows of ML trees were interspersed with rows of SL trees in this test, the difference in mortality rate for ML trees could have been the result of additional handling necessary to segregate ML trees.

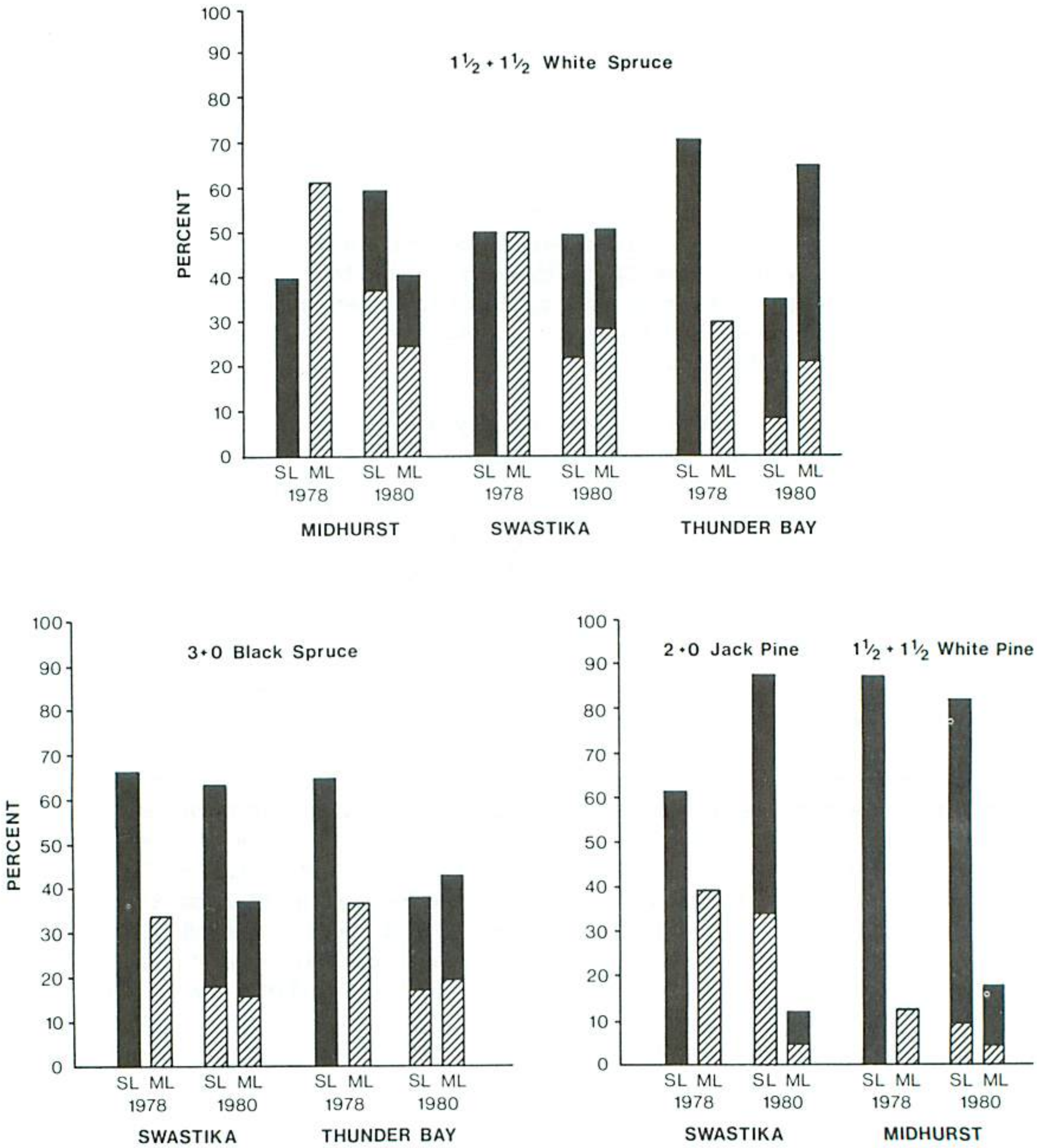

Figure 3. The fate of seedlings planted as single-leadered (SL) or multiple-leadered (ML) seedlings in May 1978. Total bar height illustrates the percentage of seedlings that were SL or ML initially and at the end of the 1980 growing season. A large portion of both the SL and ML seedlings changed status during the test. The magnitude of this change is shown by the proportion of the bars for 1980 that are illustrated with the 1978 hatching codes to show the ultimate destiny of the SL and ML seedlings.

Performance, rated as height and diameter at the end of the test, was about the same for trees planted as either ML or SL (Tables 2 and 3, Fig. 2). There were significant size differences between trees planted as SL and those planted as ML, but these were usually related to differences also present when the trees were planted. Height and diameter at planting were positively correlated (α = .01, r) with final height for the combined SL and ML samples for the WS Midhurst test and for the WS, BS, and JP Swastika tests. This is illustrated by the height growth charts (Fig. 2), in which the magnitude of difference in average height changes very little over time among groups with one, two, or three and more terminals when planted. Not many test trees had four or more terminals.

Hypotheses were formulated to test if ML trees were inferior to SL trees; hence, the superior performance by ML trees seems out of character. However, ML trees actually outperformed SL trees in the WS Midhurst, WS Swastika and WP Midhurst tests (Table 2). Initial heights in the two white spruce tests were about the same, but final height was greater (α = .05, t test) for the trees that were ML when planted. For the white pine (WP) Midhurst test, initial height was less (α = .01, t test) for ML trees but final heights were about the same. Diameter at 1 cm above ground was about the same for ML and SL trees when planted and at the end of most tests (Table 3). Diameter was greater for SL trees at the start of the JP Swastika test and at the end of the BS Swastika test (α = .01, t test). In the BS Swastika test, this superior diameter size probably was related to greater tree heights in SL trees. The height of SL trees in the JP Swastika test was also significantly greater (α = .05) than that of ML trees. ML jack pine nursery trees are generally smaller than SL trees (Tables 1, 2 and 3), and probably the ML test trees included only the upper part of the range in size represented in the nursery beds. Except for the ML trees that remained ML throughout the JP Swastika test (n = 5, Table 3), ML jack pine grew well.

The percentage of SL and ML trees that changed status to either ML or SL, respectively, was high for all the species tested (Fig. 3). This aspect of the tests was very impressive, and at least partially explains the comparable performance based on initial SL or ML form. Many of the initially ML trees did recover to the SL state, but a large portion of the trees that were SL when planted became ML during the test. Only the JP Swastika and the WS Midhurst tests showed good improvement in the overall percentage of trees that were SL. The WS Swastika test showed only a minor increase in the percentage of ML trees. The remaining tests showed at least a 10% increase in the overall percentage of trees that were ML after three seasons.

Terminal injuries that result in ML continued to occur after planting. Frost damage was prevalent in 1979 in the WS and BS trees of the Thunder Bay and Swastika tests. Also, dead resinous buds were often present on a small percentage (<3%) of the spruce terminals in all tests. Usually, recovery to the SL state was the result of superior growth by a single terminal; however, injuries also contributed to recovery as injured terminals frequently dropped out of competition.

CONCLUSIONS

The initial SL or ML form of the trees tested did not seem to be important, provided that other acceptance standards are met. Field performance of ML trees compared favorably with that of SL seedlings on the basis of height growth, diameter growth, and survival after planting. The greater mass of ML in comparison with SL trees at planting time may have offset the adverse influence of the ML form demonstrated by other comparisons. Most spruce trees changed status at least once during the test. The ML state did have an adverse effect on height growth; however, the ML or SL destiny of trees was not apparent when the trees were graded at the nursery. Therefore, the ML form does not appear to be justification for rejecting trees when they are graded at the nursery. Trees with four or more terminals probably should be rejected, but most of these fail to meet other acceptance standards, as is evidenced by the small number of these that were encountered in the tests.

Jack pine has good apical dominance and most ML trees can be expected to recover to the SL state. Spruce seems to need a period of vigorous growth free from terminal injuries before recovery to the SL state is satisfactory. The WS Midhurst test that was extended for two additional years demonstrated this recovery. Also, ML trees are rare in the spruce plantations over 10 years of age that I have observed throughout Ontario.

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