RELATIONSHIP BETWEEN SIZE AT PLANTING AND GROWTH OF WHITE SPRUCE TUBED SEEDLINGS

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Frontispiece. View of planting site in July 1968. The area was clear felled in 1958 and scarified in 1966 using spiked chains.

ABSTRACT

White spruce tubed seedlings, 6, 8, 10, 12, 14 and 16 weeks old (from sowing) grown by methods duplicating operational practices, were planted in mid-July on a lightly scarified river terrace of coarse silts in northern Ontario. Seedlings excavated after two growing seasons clearly demonstrated the critical nature of small differences in size/age at planting in determining subsequent field performance. Seedlings less than 10 weeks of age when planted were inferior in all respects to seedlings in the four older age classes, and in many instances, after 2 years in the field, exhibited typical symptoms of planting check. Best results were obtained with seedlings 12 weeks old or older when planted. Although the use of seedlings older than 12 weeks did not improve growth significantly, seedling quality showed a continuing improvement in the older age classes.

TABLE OF CONTENTS

INTRODUCTION

Although container planting is by no means new to forestry, there has been growing interest over the past decade, particularly in Canada, in the development of container-planting systems aimed at achieving large-scale forestation rapidly and at reasonable cost. Two factors which have played a major part in promoting this interest are the increasing rate at which forests are being harvested and the rising cost of manual labor required to reforest the resultant large areas of cutover land. Conventional planting practices using bare-rooted nursery stock depend heavily upon manual labor and offer little scope for either major cost reductions or increased labor productivity. Containerized seedlings, on the other hand, offer a number of potentially important advantages over bare-root stock, which, if realized, could reduce the cost of reforestation and at the same time increase planting capability:

(1) A shorter production period, permitting a greater degree of flexibility in nursery and planting operation. Through intensive production techniques, it may also be possible to reduce the cost of planting stock.

(2) A uniform package, favoring an increased rate and lower cost of hand planting and facilitating mechanization of the production and planting operations.

(3) Reduced transplanting shock and improved seedling survival as a result of "ball" planting seedlings with an undisturbed root system.

(4) An extended planting season, permitting summer planting on many sites.

The Ontario Ministry of Natural Resources (formerly the Ontario Department of Lands and Forests) initiated an operational container-planting program in 1966 based on the use of small seedlings raised and planted in plastic tubes. The open-ended tubes are composed of high-impact styrene, 3 inches long and 9/16 inch in diameter, slit longitudinally. This is a considerably smaller container than those used in forestry applications in the past. Seedlings are usually planted when only a few weeks old; in early operational plantings the period recommended to produce a plantable seedling was 50 days for spruce (Anon 1967b). The reasons for this approach are economic rather than biological, being determined by such factors as nursery production and transportation costs, and ease of planting.

In the first 4 years of operation (1966-69), planting of tubed seedlings in Ontario averaged 17 million per year, increasing to a planned 20 million in 1971 (MacKinnon 1970). Survival of seedlings from

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the first year of operational planting (1966) varied from district to district, but in many cases was extremely poor, with much of the mortality being directly or indirectly attributable to the small size of stock or to planting too late in the season. Although the quality of seedlings planted improved somewhat in the following year, their field performance again showed extreme variability, indicating the need for studies aimed at evaluating the importance of factors influencing seedling survival and establishment.

In 1968 a series of studies was established by the Forestry Branch of the Department of Fisheries and Forestry (now the Canadian Forestry Service, Department of the Environment) in the White River District to evaluate the relationships between seedling age, size, planting date, and tubed seedling growth/survival over a wide range of site conditions. Included in the studies were three species--white spruce [*Picea glauca* (Moench) Voss], black spruce [*P. mariana* (Mill.) B.S.P.], and jack pine [*Pinus banksiana* Lamb. (= *P. divaricata* (Ait.) Dumont)]--which ranged in age from 6 to 12 weeks. The supplementary study reported here was established in the same year to provide some interim indication of the comparative performance, after two growing seasons, of a wider range of seedling age classes (white spruce only--6 to 16 weeks old at planting).

The use of seedling age at planting as a treatment variable may be criticized on the grounds that the size of seedling which can be grown within a given period depends on the cultural techniques adopted. The nutrient regime is obviously one of the most important factors. One of the aims of this and related studies, however, was to evaluate the efficacy of prescribed techniques. The results reported here are, therefore, relevant to a specific cultural situation, representative of operational practice, in which the principal factor determining seedling size at planting was the length of the production period, i.e., seedling age. Throughout this report seedling age is therefore used as a simple identifier to describe a batch of seedlings of a given average size at planting (see Table 2 p. 9) grown, for the stated production period, by the methods specified. It is important to recognize that these seedlings were raised on a rather conservative nutrient regime. No inference is made that seedlings of similar age grown under different cultural regimes would perform similarly.

DESCRIPTION OF THE AREA

The study area is located approximately 28 miles north of White River, Ontario, on the boundary between Welsh and Matthews Townships (lat. 48° 59'N, long. 85° 12'W) in the Central Plateau Section (B8) of the Boreal Forest Region (Rowe 1959). It is situated on a flat river terrace of glacio-fluvial origin consisting of moderately acid, coarse silts of indeterminate depth, but certainly greater than 20 feet as indicated by adjacent exposed river banks. The soil moisture regime is fresh to somewhat dry.

The original tree cover on the area consisted of black spruce with an admixture of jack pine and trembling aspen [*Populus tremuloides* Michx.]. This was clear felled in 1958 and a sparse cover of pine and black spruce regeneration subsequently developed. However, the area was lightly scarified with spiked chains in 1966, and much of the regeneration was destroyed. White spruce tubed seedlings were planted in the late summer of 1966, but were a total failure.

Ground cover is relatively sparse, and has been slow to recover since scarification (frontispiece). At the time of planting, undecomposed litter or mineral soil exposed by the scarification predominated over a fairly high proportion of the area. Logging debris was light to moderate, but well-decomposed.

The climate is characterized by cold winters and moderately warm summers. At White River, July is usually the warmest month, with a mean daily maximum temperature of 75°F (Anon 1967a). The average frost-free period is only 31 days (June 22 to July 22), and the average length of the growing season[1] 144 days (May 11 to October 2) (Boughner 1964). The mean annual precipitation is 32 inches, with approximately 15 inches falling during the period May to September (Anon 1967a). Weather data for the period of this study are summarized in Appendix A.

MATERIALS AND METHODS

Seedling Culture

The "Ontario" split-plastic tube (9/16 inch in diameter) was used in this study. White spruce seedlings of six age classes (6, 8, 10, 12, 14 and 16 weeks from sowing) were grown at White River by using methods recommended in the Ontario Department of Lands and Forests' manual "Provisional Instructions for Growing and Planting Tubed Seedlings" (Anon 1967b).

The growing medium, collected in the vicinity of White River, was a well-decomposed peaty muck from which the larger fragments of woody material had been removed. Potassium sulphate (2 g/ft^3) and finely ground superphosphate (35 g/ft^3) were added during soil preparation. Tubes were filled with growing medium to within 1/4 inch of the tube lip.

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[1] Mean daily temperature above 42°F.

Before seeding, white spruce seed[2] was soaked in tap water at 36°F for 48 hours to promote more rapid and uniform germination. Subsequently, one seed was sown per tube, the seeds then being covered with a shallow layer of fine sand. After seeding and sanding, the trays of tubes were covered with plastic sheet and burlap to help maintain a high humidity during the germination period. These were removed when the germinating seedlings began to touch the plastic. Greenhouse temperatures were maintained at 70 to 80°F during the germination period, but once this was completed, night temperatures were allowed to drop to 60 to 65°F.

Seedlings were watered as required. As a precaution against "damping off", a water suspension of Captan 50W was applied immediately after seeding, again when germination started, and thereafter at weekly intervals until the risk of infection was past. From the 21st day after sowing, the seedlings were fertilized at 2-week intervals, by substituting a proprietary nutrient solution (RX-15) for a routine watering. As a result the 6-week-old seedlings received only two applications of fertilizer compared with seven applications to the 16-week-old seedlings (Fig. 1).

Seedlings were moved outdoors to harden off 10 to 12 days before planting. The hardening-off racks were close to the planting site. Light shade was provided for the first 3 days, after which the seedlings were fully exposed. Seedlings were watered heavily on the 2 days before planting. The hardening-off period was 2 weeks longer for the 14- and 16-week-old stock since the bulk of these seedlings had slowed down their shoot growth activity and were in danger of resuming growth during the hardening-off period if they had been retained longer in the greenhouse. This course was subsequently justified because these seedlings resumed shoot growth activity shortly after outplanting.

The sowing, fertilizing, and hardening-off schedule is given in Figure 1. Size and form of seedlings at time of planting are illustrated in Figure 2. The 6-week-old seedlings were particularly small, with little secondary needle development, and all those sampled had poorly developed root systems, barely reaching the bottom of the tube. Size data, for a sample of 25 seedlings taken from each age class at the time of planting, are given in Table 2 (see p. 11).

Planting

All seedlings were planted on July 16, 1968, by using a fire hoe with a steel dibble welded onto the eye of the blade. Twenty-five seedlings from each age class were planted in rows at 6-foot spacing, in a random layout with two replications. Each seedling was planted in a

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[2] Ontario Ministry of Natural Resources seedlot 64-115 (seed zone 4E).

12-inch diameter patch from which all vegetation and most of the organic layer had been removed. Planters were instructed to ensure that at least half of the tube length was inserted into mineral soil, leaving about 1/2 inch of tube above ground.

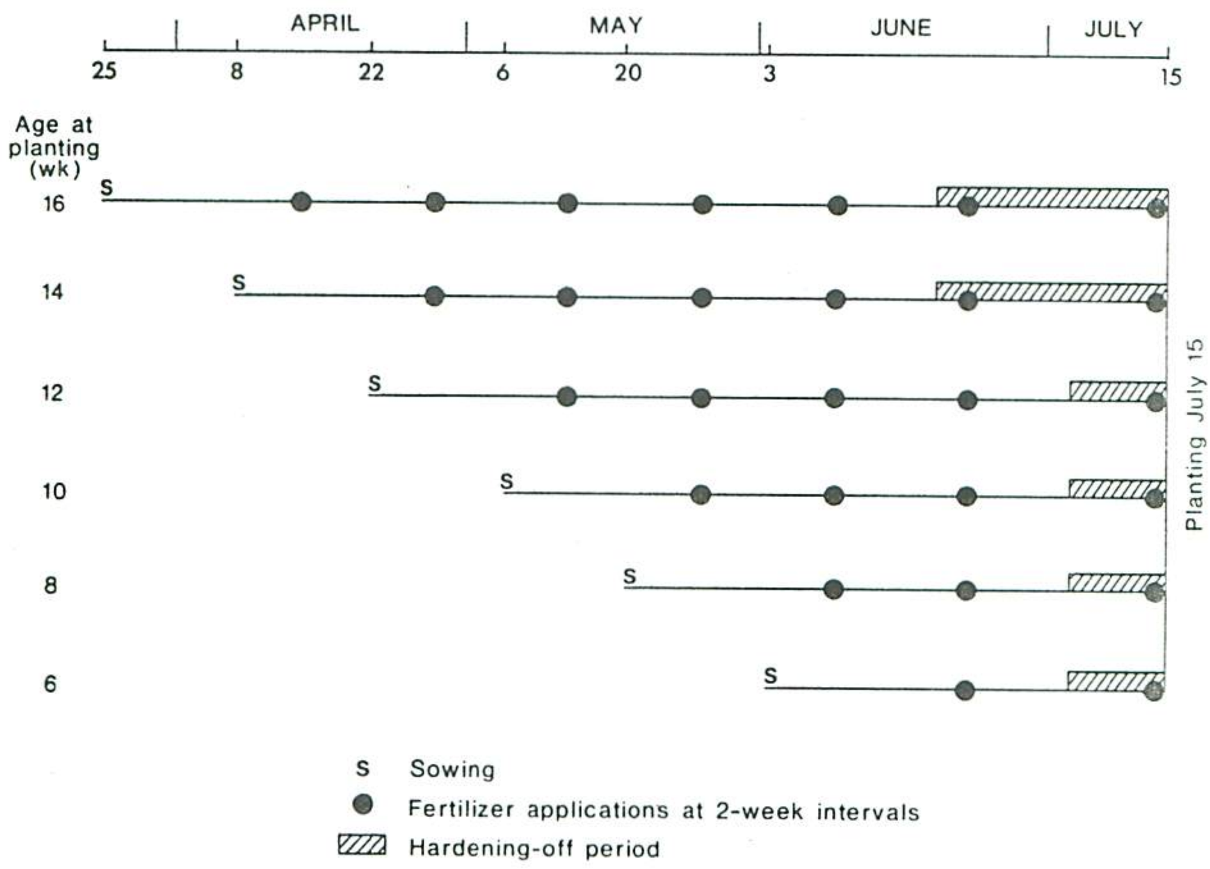

Figure 1. Treatment schedule used for raising six age classes of white spruce tubed seedlings.

Although the trays were copper-painted to prevent root growth from the bottom of the tubes during the nursery phase (Saul 1968), this was not entirely successful in the older age classes (Fig. 2). Recognizing the possibility of abnormal root development, the longest protruding roots were removed before planting.

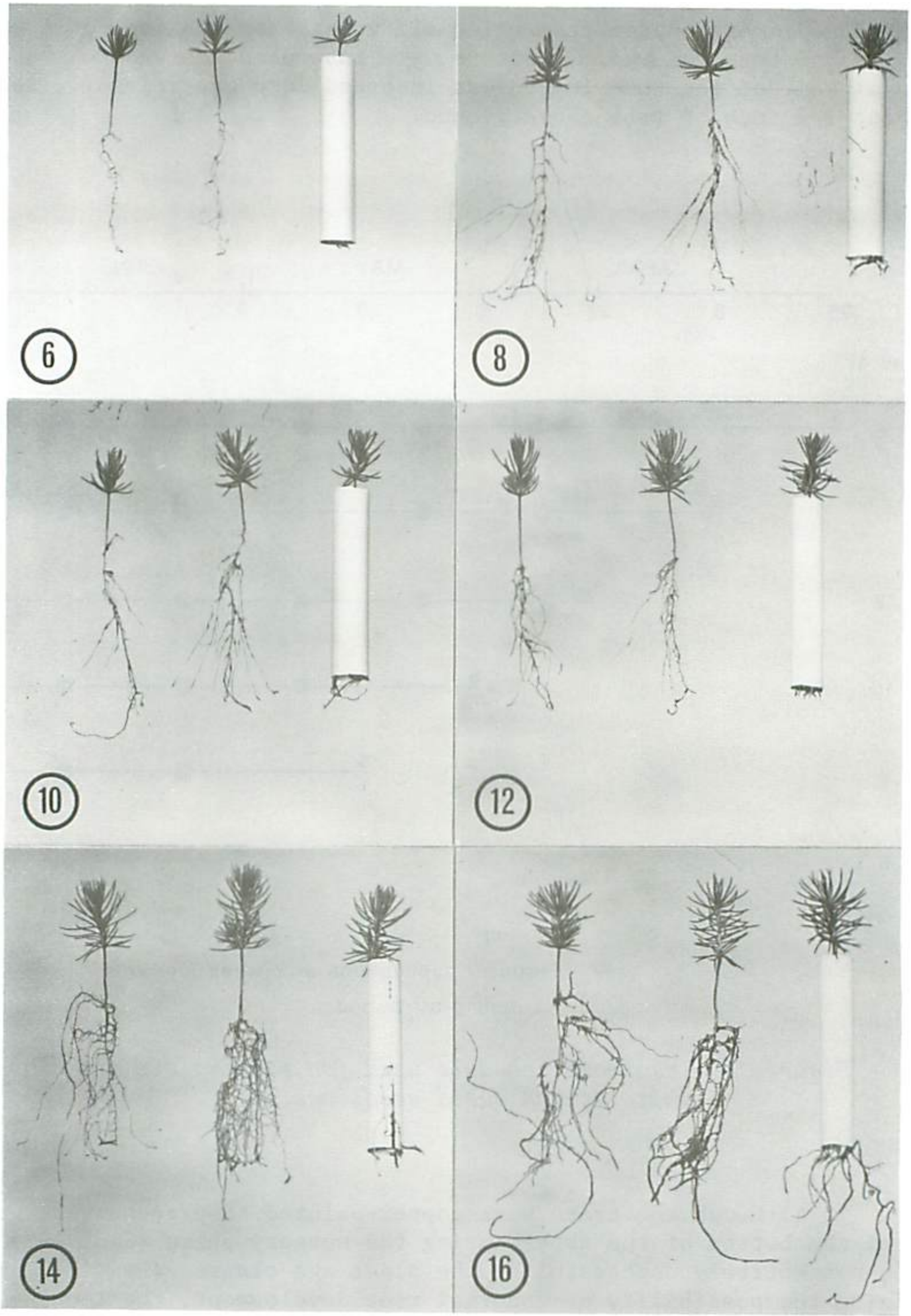

Figure 2. Representative white spruce seedlings at time of planting: two removed from tube, showing root development. Numbers refer to age of seedlings (in weeks) at time of planting. [scale - tube length is 3 inches (76 mm)]

Seedling Excavation and Measurement

Five surviving seedlings from each replicate were selected at random for careful excavation and detailed measurement at the end of the second growing season. To support the tubed seedling during excavation a thick rubber band was tied around the tube and stretched between two metal stakes outside the immediate area of excavation (Fig. 3). This supported the seedling adequately while the soil was gently washed away with a fire pump.

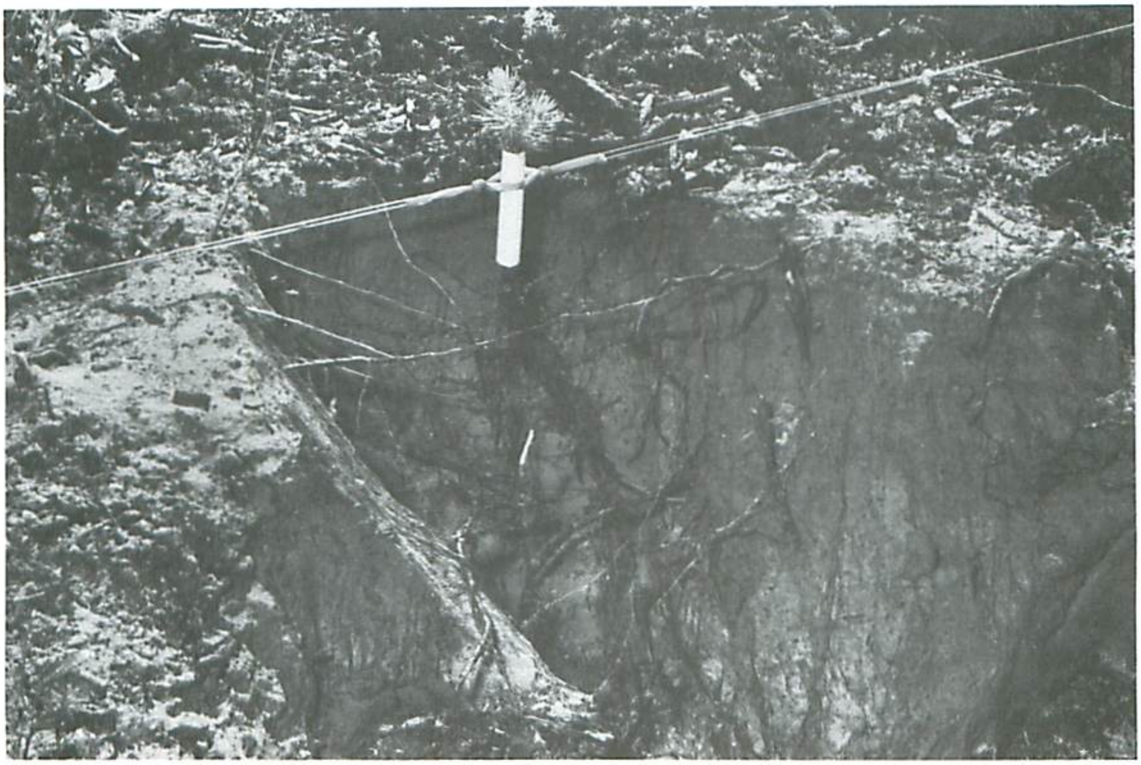

Figure 3. Method used to support tubed seedling during root excavation, showing rubber band stretched tightly around tube.

Measurements on excavated seedlings included shoot length, root-collar diameter, side shoot number, maximum root length (length of longest root), mean root length (average of two longest roots), and dry weights (48 hours at 70°C (158°F). Assessments of seedling condition and survival were made in September 1969, before excavation.

RESULTS AND DISCUSSION

Weather conditions immediately after planting were very favorable for survival, rainfall during the period from June to September being well above average, with day temperatures somewhat cooler than normal (Appendix A). This provided good conditions for initial establishment and as a result, seedling mortality during the first growing season was very low. In the second growing season, a moderately wet spring was followed by a warm, relatively dry summer. In general, therefore, climatic conditions may be considered to have been favorable for growth and survival in both seasons.

Although it is based upon a relatively small population, Table 1 indicates a strong relationship between seedling age at planting and the morphological condition of tubed seedlings after two growing seasons. There was a distinct reduction in seedling quality in the 6- and 8-week age classes, with a fairly large proportion having made very little additional height growth since planting and exhibiting typical symptoms of growth check, i.e., stunted growth; short needles, often yellowish or brownish; no distinct terminal growth; small buds (Fig. 4). In general and despite excellent survival in all age classes, only those seedlings of 10 weeks and older at planting could be considered a potential establishment success at the end of the second growing season.

Table 1. Condition of white spruce tubed seedlings after two growing seasons

Seedling condition	Age at planting (wk)					
	6	8	10	12	14	16
	Percent of total planted[a]					
1st class, vigorous and healthy	30	30	40	30	70	60
2nd class, slightly less vigorous or healthy	20	40	45	50	25	40
3rd class, poor or checked growth	30	20	10	10	5	0
Dead	20	5	5	10	0	0

[a] Based on 50 seedlings per age class.

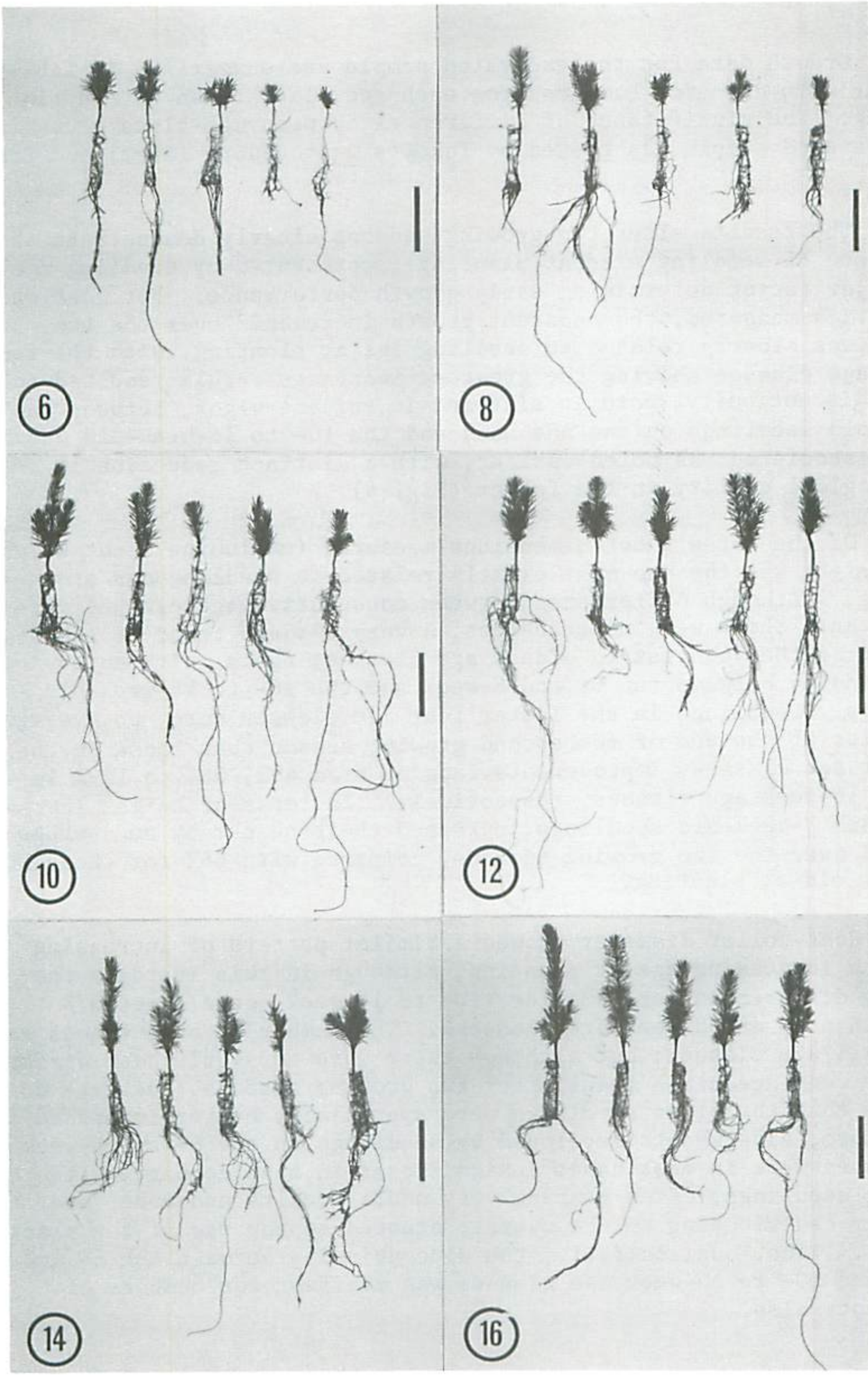

Figure 4. Size and form of excavated white spruce tubed seedlings after two growing seasons. Numbers refer to age of seedlings (in weeks) at time of planting.
[length of bar beside each photograph represents a 3-inch (76 mm) tube]

Growth data for the excavated sample are summarized in Table 2, together with data for samples from each age class taken at the time of planting. The significance of differences between age-class means in the excavated sample was tested by Tukey's w procedure (Steel and Torrie 1960).

The results after two growing seasons clearly demonstrate the importance of seedling size at planting (represented by seedling age) as a major factor determining early growth performance. For most characteristics measured, the apparent growth increment[3] over the two seasons was closely related to seedling age at planting, with the four oldest age classes showing the greatest increases. This resulted in a marked discontinuity, both in size and in evident vigor, between the 6- and 8-week-old seedlings on the one hand and the 10- to 16-week-old on the other, associated, as noted earlier, with a distinct reduction in morphological quality in the former (Fig. 4).

Of the three shoot dimensions measured (excluding shoot weight), total height was the one most clearly related to seedling age at planting. Although differences between consecutive age classes were not significant, there was, nevertheless, a very evident trend of increasing height from the youngest to oldest age classes, again, with an obvious discontinuity between the 6- and 8-week and the 10- to 16-week-old seedlings. Seedlings in the latter four age classes were, on average, 76% taller at the end of the second growing season than those in the two youngest age classes, improvements ranging from 49%, 68% to 129% in the 10-, 12- and 16-week age classes, respectively. In terms of height increment, the 6- and 8-week-old seedlings increased their height by an average of only 22% over the two growing seasons, compared with 66% for those 10-16 weeks old at planting.

Root-collar diameter showed a similar pattern of increasing size with increasing age at planting, although in this instance the relative differences were smaller (10- to 16-week age classes 37% larger than 6- and 8-week age classes). The number of side shoots was low in all age classes; but although there were no significant differences between age-class means after two growing seasons, the data do indicate that the older seedlings were appreciably better furnished. Furthermore, side shoots developed by seedlings in the 6- and 8-week age classes were in most cases insignificant in size compared with those of older seedlings, often bearing very small needles and buds, and generally contributing to the overall stunted appearance of the plants (Fig. 4). Thus, qualitatively, the discontinuity between the 6- and 8-week and 10- to 16-week age classes was manifest for numbers of side shoots also.

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[3] "Apparent" increment since each comparison is based upon two different samples with the same treatment history (A and B in Table 2).

Table 2. White spruce: mean values[a] of nine morphological characters at time of planting (A)[b] and after two growing seasons (B)[c] for tubed seedlings of different ages at time of planting

	Sample	Seedling age at planting (wk)					
		6	8	10	12	14	16
Total height (mm)	A	29.1	32.2	31.6	34.6	42.6	51.4
	B	34.2a	40.6ab	55.6bc	62.8cd	62.5cd	83.0d
Root collar diameter (mm)	A	0.50	0.54	0.59	0.63	0.77	0.91
	B	1.17a	1.32ab	1.64bc	1.70bc	1.82c	1.67bc
Side-shoot number	A	0.2	1.3	1.2	1.1	0.8	1.6
	B	2.4a	2.7a	2.7a	3.2a	3.9a	4.0a
Maximum root length (mm)	A	- - - - - - - - - - - - Not measured - - - - - - - - - - - -					
	B	179.3a	197.5a	279.2a	269.9a	265.4a	263.5a
Mean root length (mm)	A	75.3	76.2	78.9	82.7	86.4	80.1
	B	148.1a	144.8a	230.1b	207.0ab	228.9b	202.0ab
Total weight (mg)	A	10.5	20.7	30.2	32.6	77.3	115.9
	B	179.6a	232.6a	385.2ab	448.8b	493.3b	521.8b
Shoot weight (mg)	A	8.7	16.4	22.6	23.5	49.6	77.7
	B	112.2a	148.1ab	248.1abc	289.7bc	326.7c	353.0c
Root weight (mg)	A	1.8	4.3	7.6	9.1	27.7	38.1
	B	67.3a	84.5ab	137.1bc	159.1c	166.6c	168.9c
Root/shoot ratio	A	0.21	0.26	0.34	0.39	0.56	0.49
	B	0.63a	0.63a	0.60a	0.58a	0.53a	0.50a

[a] Means not followed by a common letter within a row are significantly different at the 5% level.

[b] Based on 25 random seedlings from each age class.

[c] Based on 10 excavated seedlings in each age class.

The effect of seedling age/size at planting upon subsequent seedling performance was most clearly demonstrated by dry matter production. Once again, for all three dry weight measurements, seedlings in the 12- to 16-week age classes were distinctly, and significantly, superior to those in the two youngest age classes. In this instance, however, emphasizing the tendency evident with other growth parameters, seedlings in the 10-week age class fell into an intermediate position. Nevertheless, the improvements in dry matter production achieved with this and older age classes of seedling were large, and of a much greater magnitude than the improvements seen in height growth (Table 3). However, as in the case of seedling height, differences in dry weight between the 12- to 16-week age classes were not significant, although there were improvements in seedling quality in the older classes.

Table 3. Performance, after two growing seasons, of 10- to 16-week age classes of white spruce tubed seedlings compared with the mean for 6- and 8-week age classes (percent improvement)

	Seedling age at planting (wk)				
	10-16 (mean)	10	12	14	16
Total height (mm)	76	49	68	67	122
Shoot weight (mg)	134	91	123	151	171
Root weight (mg)	108	81	110	119	123
Total weight (mg)	124	87	118	139	153

Root/shoot ratios at the time of planting were closely related to seedling age, with reasonably good, but somewhat constricted, root development in the two oldest age classes. By contrast, the 6- and 8-week-old seedlings had very sparse root development at this time, with minimal exploitation of the soil volume within the tube in the younger of the two age classes. After two growing seasons, however, differences in root/shoot ratios between the six age classes had largely disappeared. While the root/shoot ratios in the 14- and 16-week age classes remained fairly constant after planting, those in other age classes increased to the level achieved by the two oldest age classes before planting (Table 2). In the 14- and 16-week-old seedlings, root and shoot weights increased at comparable rates, but in the 6- and 8-week-old age classes, despite the low quality of seedlings, root weight increased some 2 1/2 times more than shoot weight (percentage basis). A small number of seedlings excavated at the end of the first growing season showed that the differences in root/shoot ratio between age classes were apparently eliminated shortly after planting. Comparison of Figures 3 and 4 indicates that much of the additional root growth which occurred in 6- and 8-week-old seedlings after outplanting was confined within the plastic tube.

Almost all external root development in excavated seedlings originated from the bottom of the tube, few roots growing from the slit in the tube wall even in older age classes. Most roots radiated outwards and upwards from their point of exit from the tube, and feeding roots were growing almost exclusively at the interface of the F and A horizons. There were few descending roots. Generally speaking, both the number and length of roots emerging from the tubes were highest in the older age classes. Once again, seedlings in the 6- and 8-week age classes were distinctly inferior to older seedlings, particularly in terms of mean root length.

Excavated seedlings showed little evidence of serious root deformation and roots growing from the tubes appeared to develop a perfectly normal rooting habit. Within the tube, however, roots formed a compact mass, with lateral roots producing sharp bends on contact with the enveloping tube wall and much interlaced branching. Much of this root mass was already present in the older age classes at the time of planting, but evidently it also continued to develop after planting, particularly in the younger age classes (compare Fig. 3 and 4).

SUMMARY AND CONCLUSIONS

Within the limitations of this interim study (small sample, better than average growing conditions), the results demonstrate the critical nature of differences in size/age at planting for the subsequent field performance of white spruce tubed seedlings. Both seedling quality and size after two growing seasons were closely related to age at planting, with a clear demarcation, for most characters measured, between seedlings in the 6- and 8-week age classes and those in the 10- to 16-week age classes. Many seedlings in the 6- and 8-week age classes exhibited typical symptoms of growth check and, despite a relatively high level of survival, these two groups of seedlings could be considered a regeneration failure. Differences in size among the 10- to 16-week age classes were generally not significant at the end of the second growing season, although there were fairly substantial increases in height and weight associated with increasing age at planting. The latter was accompanied by a distinct improvement in seedling quality in the older age classes, with the result that, within the 10- to 16-week age-class range, older seedlings did appear to have a greater potential for successful establishment.

In general, seedlings 12 weeks of age and older at planting appeared to offer the best establishment and growth potential, although in terms of total dry matter production little additional benefit accrued from using seedlings older than 12 weeks. However, because height increment is often important (as in situations of heavy vegetation competition) use of the older planting stock may increase the chance of success.

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APPENDIX

APPENDIX A

Precipitation and temperature at White River, Ontario

Month	Precipitation (in)			Mean daily temp (°F)			Mean daily max temp (°F)		
	30-yr mean[a]	1968[b]	1969[b]	30-yr mean[a]	1968[b]	1969[b]	30-yr mean[a]	1968[b]	1969[b]
Jan	2.43	0.71	2.10	1.7	0	1.0	15.0	13.8	16.8
Feb	1.98	1.35	0.57	4.6	1.0	6.1	18.7	15.0	24.4
Mar	2.06	2.73	0.82	14.9	18.6	11.0	29.1	34.0	27.7
Apr	2.48	3.52	1.35	32.0	35.0	33.2	44.2	47.3	46.0
May	2.61	0.51	3.61	46.2	47.0	45.5	59.3	61.0	57.0
June	3.11	6.90	3.00	56.6	54.0	50.5	70.1	64.7	62.3
July	2.82	9.82	2.27	61.1	59.6	60.6	75.3	70.1	74.3
Aug	2.88	1.90	2.07	58.9	57.5	62.2	72.6	69.8	75.9
Sept	3.71	6.46	2.05	49.9	54.9	48.9	61.0	65.1	60.0
Oct	2.76	3.33	3.90	39.3	43.3	36.2	49.0	50.5	43.4
Nov	3.24	1.82	2.45	23.2	23.1	25.7	31.2	30.6	36.0
Dec	2.26	2.91	2.00	8.2	7.5	11.5	19.6	17.7	22.6
Total	32.34	41.96	26.19						
May-Sept total	15.13	25.59	13.00						

[a] From Anon. 1967A.

[b] Courtesy White River Air Services Ltd., Weather Office.