EARLY GROWTH OF BARE-ROOT AND PAPERPOT PLANTATIONS AT VARIOUS LOCATIONS IN NEW BRUNSWICK

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Abstract.--Jack pine *(Pinus banksiana* Lamb.) and black spruce *(Picea mariana* [Mill.] B.S.P.) planting stock were graded and their growth was monitored during the first few years after planting. Bare-root (2-0) jack pine has shown faster height development and biomass accretion than paperpot jack pine on similar sites, but paperpot black spruce was superior to bare-root (3-0 and 2-0) black spruce.

Résumé.--Des semis de pin gris *(Pinus banksiana* Lamb.) et d'épinette noire *(Picea mariana* [Mill.] B.S.P.) ont été classés, puis leur croissance a été contrôlée au cours des premières années après le plantage. Chez le pin gris planté à racines nues (2-0), la croissance verticale et celle de la biomasse ont été plus rapides que chez les sujets de même essence cultivés en tubes de papier et plantés dans des endroits semblables; cependant, c'est l'inverse qui s'est produit pour l'épinette noire (3-0 et 2-0).

INTRODUCTION

During the 1977 and 1978 planting seasons samples of different planting stock types were obtained at the planting site or as the stock was shipped from the provincial forest nursery at Kingsclear, New Brunswick for field planting. The samples included bare-root and containerized (2-0) jack pine *(Pinus banksiana* Lamb.) and bare-root and containerized (2-0 and 3-0) black spruce *(Picea mariana* [Mill.] B.S.P.) seedlings. Containers were FH 408 Japanese paperpots. The planting stock was evaluated according to morphological criteria and status of mineral nutrition.

The planted seedlings were sampled and subjected to similar measurements in the spring of 1978, 1979 and 1981 in an attempt to determine the effects of type and quality of planting stock on early plantation growth. Although the observations have shown striking differences in rates and patterns of early growth, the results do not lend themselves to rigorous mathematical analysis since the study was a survey rather than a controlled experiment.

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METHODS

Selection of Planting Stock Samples

In 1977, with the assistance of personnel from the New Brunswick Department of Natural Resources (DNR), principal planting areas in the province were selected and stock in the process of being planted was sampled. The samples were taken without undue delay to the Forest Soils Laboratory of the University of New Brunswick. In 1978, samples were obtained directly from the provincial nursery at Kingsclear, as the stock was being prepared for shipment to known planting sites.

Each sample contained a minimum of 32 plants. Shoot lengths and root collar diameters were measured and total and component dry weights were determined. On the basis of mean shoot:root and height:root collar ratios, and seedling dry weight, a quality index (Dickson et al. 1960) was calculated. Each batch of planting stock was then rated according to provisional standards defined on the basis of published information (Scarratt and Reese 1976, Roller 1977, Armson and Sadreika 1979) and experience gained in the province (Table 1).

The needles of seedlings were analyzed to determine macro-nutrient contents. Planting stock types used and stock evaluation results are summarized in Table 2. The jack pine paperpot stock was small to intermediate in size, and identified as grades 1 and 2. Bare-root jack pine was of a low grade in 1977, but a top grade was produced in 1978. Poor morphological balance was the reason for the low rating in 1977.

The quality of black spruce stock was extremely variable. A morphologically imbalanced, low-grade bare-root stock was produced in both years. In contrast, top and intermediate grade paperpot stock was shipped to the field in 1977 and 1978, respectively.

Sampling of Plantations

The plantations (Table 3) were sampled as early as possible in the spring of each growing season except 1980. Eight of the numerous plots established earlier by DNR to determine survival were randomly chosen for sampling in each plantation. In the peripheral zone of each plot, four trees were randomly selected, 32 trees from each plantation.

Growth Measurements

The trees were taken to the laboratory for determination of height, root collar diameter and component dry weights.

Height and biomass data for the average tree from plantations of different ages were extrapolated to a common age by use of polynomial equations with the following general form:

$$y = a + bx + cx^2$$

where "y" is either the height or total biomass of the tree and "x" the number of completed growing seasons since planting; the intercept "a" gives the height or biomass of the tree at time of planting, and the coefficients "b" and "c" are reflections of site and type of planting stock.

Intercepts and coefficients for all but the bare-root black spruce plantations are given in Table 4. The listed standard errors indicate a moderately high accuracy for estimates of height in most plantations, but estimates of tree biomass were less reliable.

Table 1. Provisional standards for the evaluation of planting stock.

Type of stock	Grade	Shoot length (cm)	Root collar diam (mm)	Dry weight Top (g)	Dry weight Root (g)	Dry weight Total (g)	Ratios Shoot/diam	Ratios Shoot/root	Quality index (QI)[a]
Jack pine bare-root	1	< 6	< 0.9	< 0.150	< 0.075	< 0.225	< 6.7	< 2.0	< 0.026
	2 lower	6	0.9	0.150	0.075	0.225	6.7	2.0	0.026
	upper	12	1.8	0.414	0.136	0.550		3.99	0.057
	3	> 12	> 1.8	> 0.414	> 1.36	> 0.550	> 6.7	3.0 – > 3.5	> 0.057
paperpot	1	< 12	< 2.5	< 1.2	< 0.6	< 1.8	< 4.8	< 2.0	< 0.264
	2 lower	12	2.5	1.2	0.6	1.8	4.8	2.0	0.264
	upper	20	4.0	1.95	0.65	2.6	5.0	3.0	0.325
	3	> 20	> 4.0	> 1.95	> 0.65	> 2.6	> 5.0	> 3.5	> 0.325
Black spruce bare-root	1	< 7.5	< 1.0	< 0.233	< 0.117	< 0.35	< 7.5	< 2.0	< 0.036
	2 lower	7.5	1.0	0.233	0.117	0.35	7.5	2.0	0.036
	upper	15	2.0	0.526	0.174	0.70		3.0	0.078
	3	> 15	> 2.0	> 0.526	> 0.174	> 0.70	> 7.5	3.0 – > 3.5	> 0.078
paperpot	1	< 15	< 3.5	< 2.14	< 0.86	< 3.0	< 4.3	< 2.5	< 0.441
	2 lower	15	3.5	2.14	0.86	3.0	4.3	2.5	0.441
	upper	25	5.5	5.83	1.67	7.5	4.5	3.5	0.937
	3	> 25	> 5.5	> 5.83	> 1.67	> 7.5	> 4.5	3.5 – > 4.5	> 0.937

[a] $QI = \text{Mean seedling dry weight (g)} / \left(\dfrac{\text{shoot(g)}}{\text{root (g)}} + \dfrac{\text{shoot (cm)}}{\text{diam (mm)}} \right)$

Table 2. Type, morphological characteristics and grade of jack pine and black spruce planting stock used.

No. of sample	Species and type	Age	Shoot length (cm)	Root collar diam (mm)	Mean seedling dry weight (g)	Ratios Shoot/diam	Ratios Shoot/root	Quality index	Grade
1	jP[a], br[b]	2-0	18.8	2.4	1.90	7.7	5.5	0.142	1
2	" , "	"	21.8	3.3	2.50	6.6	6.0	0.191	1
3	" , "	"	16.0	2.4	1.60	6.7	5.1	0.136	1
4	" , "	"	19.3	3.7	4.50	5.2	4.1	0.459	3
5	" , "	"	18.0	5.2	5.02	3.5	3.8	0.690	3
6	jP, pp[b]	8 weeks[c]	5.7	1.1	0.226	5.2	3.1	0.026	2
7	" , "	9 "	4.3	1.0	0.159	4.4	2.0	0.025	1
8	" , "	10 "	11.8	1.7	0.430	6.9	4.9	0.037	2
9	" , "	7 "	4.5	0.7	0.088	6.7	1.3	0.011	1
10	" , "	6 "	3.0	0.9	0.094	3.5	1.3	0.020	1
11	" , "	10 months	2.9	0.9	0.125	3.3	4.3	0.016	1
12	" , "	1 year	6.6	1.5	0.370	4.4	3.3	0.048	2
13	bS[a], "	28 weeks	19.2	2.6	1.264	7.4	3.1	0.119	3
14	" , "	30 "	22.1	2.6	1.362	8.5	3.3	0.114	3
15	" , "	23 "	22.8	2.1	1.130	10.0	5.1	0.071	2
16	" , "	20 "	20.4	2.0	0.700	10.1	4.2	0.052	2
17	" , br	2-0	13.9	2.0	0.67	7.7	4.8	0.053	1
18	" , "	3-0	33.8	3.5	3.30	9.7	5.7	0.212	1
19	" , "	3-0	45.1	4.2	5.74	10.6	6.9	0.328	1

[a]jP = jack pine, bS = black spruce
[b]br = bare-root, pp = paperpot
[c]Counted from germination

Table 3. Time of planting, first-year survival, site preparation and some site characteristics of monitored plantations.

Plantation No.	DNR designation	Time of planting	Survival[a] (%)	Type of site preparation	Soil Texture[b]	Soil Drainage class[c]	Competition Degree[d]	Competition Type
1	P-12-77	15-20/5/77	89	Disc trencher	sL/lS	2	1	Eric.-elderberry
2	P- 9-77	24/5-25/6/77	71	Wildfire	lS	2/1	2/3	Eric.
3	P-11-77	1-10/6/77	81	Sharkfin barrels	lS	2/1	2	Eric.-intol hardw.
4	P-16-78	17/5-7/6/78	97	Finnish plow	L	3	1	Eric.-grasses
5	P -3-78	6/5-16/6/78	91	Sharkfin barrels	sL	2	1/2	Eric.-brack. fern
6	TP-31-77	3-10/8/77	96	Disc trencher	lS	1/2	2/3	Eric.
7	TP-15-77	2/8-7/9/77	98	Sharkfin barrels	sL/lS	2	1/2	Eric.
8	TP-32-78	20/8-10/9/78	76	Crusher	sL	2	1/2	Eric.-brack. fern
9	TP-14-78	8-20/9/77	88	Sharkfin barrels	lS	2/3	2/3	" "
10	"	"/"/"	89	Bräcke	lS/sL	2/3	2/3	" "
11	TP- 1-77	20/5-15/6/77	82	Burned, Bräcke	sL	2	2/3	" "
12	TP-22-78	10-15/7/78	-	Finnish plow	lS/sL	1/2	2/3	Eric.
13	TP-11-77	20-30/6/77	96	Sharkfin barrels	lS	2	2	Eric.-sweetfern
14	TP-20-77	10-20/7/77	84	"	l/sL	2/3	2/3	Rasp.-grasses
15	TP-35-78	20/6-28/7/78	83	"	L	2	2/3	Rasp.-b. fir
16	TP- 1-78	10/7-14/8/78	85	Disc trencher	L/sL	2/3	2/3	" "

[a]Determined on DNR plots
[b]L(l) = loam (loamy)
S(s) = sand (sandy)
[c]As defined by Canada Soil Survey Committee
[d]1 = mild, 2 = moderate, 3 = strong

RESULTS

Jack Pine Bare-root Stock

The growth of 2-0 stock was monitored after outplanting at five different locations (Tables 2 and 3). Mean tree heights (measured or estimated annually) (Fig. 1) showed strongly divergent patterns of growth with the expected mean height at age 5 years differing by more than 100%. The difference in plantation performance is revealed more dramatically when biomass production is examined (Fig. 2). The estimated 5-year biomass gives plantation 1 a more than sevenfold lead over plantation 2.

Grade of planting stock may have affected survival, but there are no indications that it has contributed significantly to variation in early plantation growth. Site and method of site preparation appear to be of greater importance.

Plantation 1, which has performed best, was established on well drained sandy loam prepared for planting by a disc trencher. After one year, 89% of the planted trees had survived. Sparse growth of elderberry (*Sambucus* sp.), blueberry (*Vaccinium angustifolium* Ait.) and raspberry (*Rebus idaeus* L.) offered little competition to the planted trees. Foliar nitrogen was high after three growing seasons in the field (Table 5), and this indicates moderately high soil fertility.

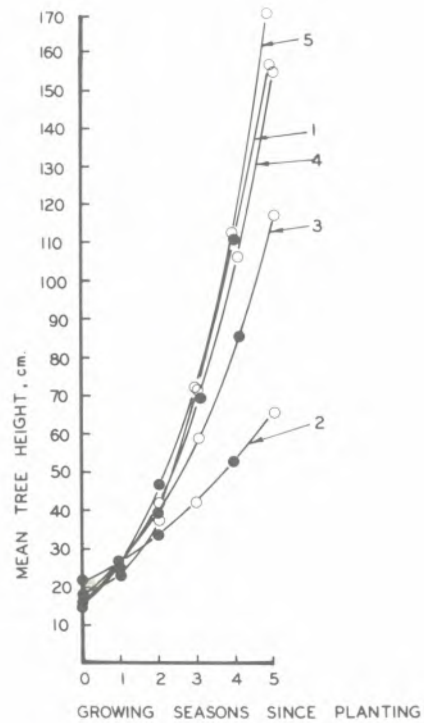

Figure 1. Height development of jack pine plantations established with 2-0 bare-root stock. (Dots and open circles represent measured and calculated mean heights, respectively.)

Table 4. Intercept a, coefficients b and c and standard error of the estimate (SE) of polynomial equations used to extrapolate heights and biomass to age 5 years. Also shown are projected height (Δh_5) and biomass (Δm_5) increments for the fifth year.

Plantation No.	Height growth a	b	c	SE (%)	h_5 (cm)	Biomass accretion a	b	c	SE (%)	m_5 (g)
1	18.1	4.03	4.78	± 2.9	43.8	7.85	-56.8	41.3	±16.6	356
2	21.7	3.76	1.01	± 0.7	13.9	2.69	- 1.7	4.1	± 3.2	39
3	16.1	5.87	2.88	± 0.6	34.7	3.31	-11.9	10.9	±15.1	97
4	19.8	-0.25	5.54	± 5.2	55.2	6.60	-17.8	18.4	±21.3	166
5	18.6	-3.81	6.85	± 7.2	64.7	7.78	-27.4	19.7	±34.8	170
6	5.9	-2.01	2.93	± 0.1	27.3	1.08	- 7.3	4.4	±26.1	37
7	4.8	-0.41	2.06	±11.3	21.0	0.82	- 5.1	3.3	±25.8	27
8	12.4	-7.17	4.85	±13.5	41.3	1.35	-11.0	7.5	±37.1	64
9	4.0	-4.96	3.89	±21.1	34.0	1.24	- 9.4	5.3	±35.2	43
10	4.9	-3.53	2.64	±11.3	22.9	0.49	- 3.3	2.0	±28.6	16
11	3.6	-1.97	2.16	±12.4	23.5	1.24	- 9.5	6.2	±22.8	53
12	6.7	-3.75	3.13	± 2.1	27.5	0.51	- 1.5	1.4	±20.6	12
13	18.8	3.77	0.43	± 5.5	8.1	1.77	- 4.0	3.8	±12.5	33
14	21.1	-0.52	2.21	±11.1	21.6	2.57	-12.3	8.1	±18.0	69
15	22.8	2.35	2.30	± 0.1	28.0	1.18	1.8	3.1	± 2.9	26
16	20.7	-6.12	4.76	± 4.4	41.5	0.90	- 3.2	3.7	± 8.3	34

Plantation 2, close to stagnation since the time of planting, was established on well to rapidly drained soil varying in texture from loamy sand to sandy loam. The site supported jack pine previously and was intensively burned by a wildfire, after which a dense ericaceous ground vegetation developed. Planting stock was morphologically similar to that used in plantation 1, but apparently had suffered while kept in storage for delayed planting in June. The use of the impaired plants may explain their high rate of mortality. Only 71% of the planted trees survived the first winter and 67% the second winter. The condition of the plants may also have contributed to their poor growth over the first two years, but is not believed to be responsible for continued unsatisfactory performance. More likely, this is the result of low native fertility of the soil, aggravated by the burn and severe competition from the ericaceous vegetation. The tree foliage sampled in the fall of 1979 contained only 1.51% nitrogen as compared with 1.91% in plantation 1.

Plantation 3, which grew at an intermediate rate (Fig. 1 and 2), was established in the first half of June with plants exhibiting morphological conditions similar to those used at the other two sites. Soil conditions were generally comparable with those of plantation 2, but the area had not been burnt. This may have helped to conserve the small nutrient reservoirs of this sandy site. The results of foliar analysis (Table 5) indicate noticeably better nitrogen nutrition than in trees of plantation 2.

The 1978 plantations showed rapid height development and intermediate rates of biomass accretion. They were established on moderately well drained to well drained medium-textured soils of intermediate fertility. Groundcover plants including bracken fern (*Pteridium aquilinum* L.), blueberry, lambkill (*Kalmia angustifolia* L.) and grasses offered light to moderate competition. The 1978 planting stock had received a more favorable rating than the 1977 stock (Table 2). The difference in stock quality is a possible reason for the strong first-year growth observed in 1978 but not in 1977. However, differences in weather, site preparation, and planting time prevent a direct comparison of 1977 and 1978 stock.

Jack Pine Paperpot Stock

At the time of this study the Kingsclear nursery was growing two crops of jack pine paperpot seedlings per year. The first crop was usually sown in late spring, retained in the greenhouses or nursery until midsummer and outplanted before the end of the summer.

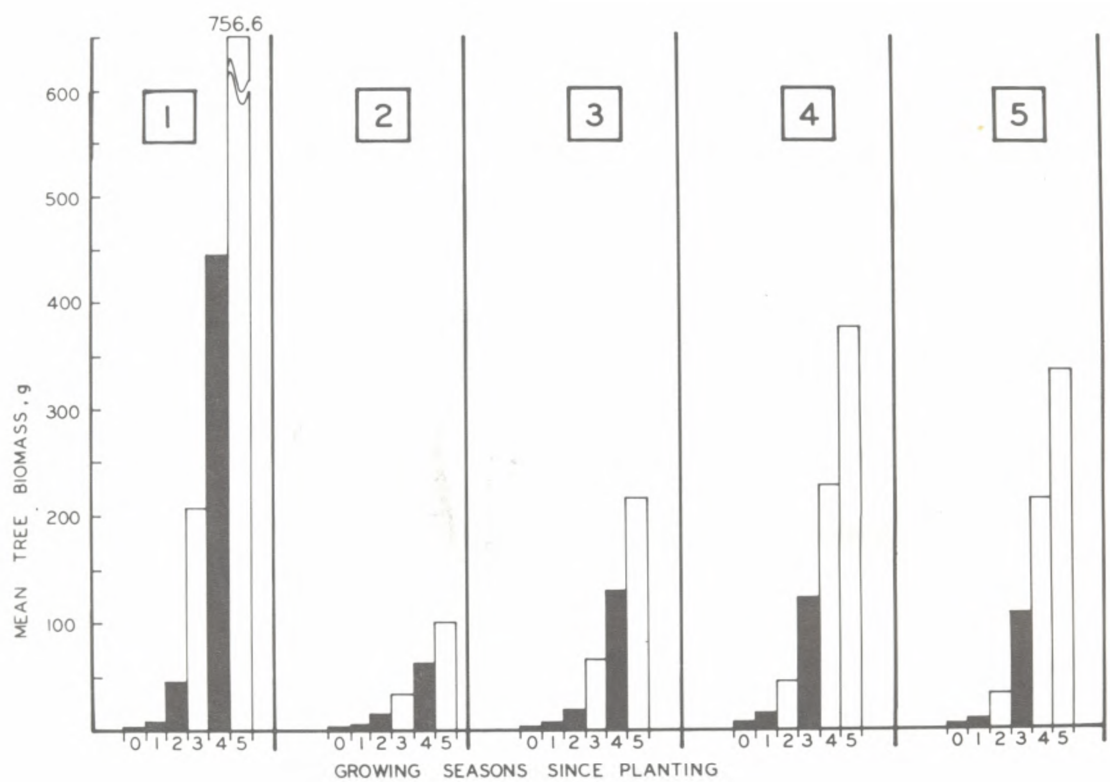

Figure 2. Biomass accretion in jack pine plantations established with 2-0 bare-root stock. (Solid and open bars represent measured and calculated mean biomass, respectively.)

Table 5. Macro-element concentrations in foliage of seedlings at the time of planting and after two or three growing seasons in the field.

Plantation No.	N	P	K	Ca	Mg
	(%)				
	Before planting				
1	2.02	0.20	0.59	0.60	0.13
2	1.82	0.18	0.64	0.56	0.15
3	1.76	0.19	0.79	0.59	0.13
4	1.86	0.19	0.67	0.35	0.13
5	1.80	0.20	0.59	0.41	0.13
6	3.08	0.40	1.39	0.11	0.15
7	2.17	0.39	1.30	0.15	0.19
8	2.62	0.39	1.20	0.23	0.16
9	1.81	0.34	1.07	0.12	0.22
10	1.98	0.34	0.99	0.12	0.16
11	2.68	0.26	0.75	0.16	0.11
12	1.35	0.13	0.57	0.20	0.12
13	2.10	0.25	0.95	0.26	0.11
14	2.97	0.33	1.01	0.44	0.15
15	1.95	0.25	0.98	0.12	0.14
16	1.93	0.23	1.08	0.25	0.15
	After two (three) growing seasons				
1	1.91	0.16	0.50	0.18	0.10
2	1.51	0.15	0.54	0.20	0.11
3	1.76	0.16	0.56	0.25	0.11
4	1.64	0.15	0.53	0.22	0.11
5	1.76	0.16	0.59	0.24	0.10
10	1.83	0.18	0.67	0.20	0.11
11	1.69	0.17	0.60	0.20	0.11
12	1.75	0.18	0.72	0.18	0.12
13	1.73	0.20	0.51	0.68	0.11
14	2.18	0.21	0.55	0.68	0.11
15	2.08	0.21	0.60	0.60	0.10
16	2.39	0.27	0.59	0.64	0.13

The second crop was sown in early summer or midsummer, shipped to the field for late summer planting or retained over winter in the nursery and planted in the spring or early summer of the following year.

Spring-sown, summer-planted

Three plantations, established with grades 1 and 2 stock (Table 2), were monitored.

The plants showed little height growth during the year of planting, but large relative increases in needle, stem, branch, and particularly root biomass. The high shoot: root ratio of the plants as they left the nursery had decreased to approximately 1.0 before the second growing season had begun.

The plants approximately doubled their heights and increased their dry weights by a factor of two or greater in the second year (Fig. 3a and 4). Despite these growth rates, height development and biomass accretion were considerably retarded in paperpot plantations in comparison with bare-root plantations. Mean tree heights, extrapolated to year 5, approached 1.0 m in the best paperpot plantation whereas three of the five bare-root plantations have projected 5-year heights in excess of 1.5 m under similar soil conditions (Fig. 1 and 3a). A similar relationship is revealed when plantations 3 (bare-root) and 6 or 7 (paperpot), all established on sandy soil with ericaceous growth, are compared. However, two of the paperpot plantations are expected to surpass in height the slowly developing bare-root plantation on the burned site and the best performing paperpot plantation (8) may equal in annual height growth the thrifty bare-root plantation 1 by the fifth year (Table 4).

Paperpot and bare-root plantations show even greater differences when biomass accretions are compared (Fig. 2 and 4). The mean tree biomass at five years is expected to vary between 57 and 133 g in paperpot plantations and between 100 and 757 g in bare-root plantations.

Although the somewhat variable quality of paperpot stock used in the above plantations may have influenced rates of survival, it is doubtful that the observed differences in growth are related to the condition of seedlings at the time of planting. Site, particularly soil and competing vegetation, and method of site preparation, are believed to be dominant factors as previously discussed for bare-root plantations.

The most rapidly growing paperpot plantation (8) had been established on a moderately fertile sandy loam after minimal site preparation by a tree crusher. In contrast, plantations 6 and 7 were located on coarser soil (loamy sand) with a heavy ericaceous vegetation. In one case (plantation 6), trees had been planted in infertile sand exposed by deep trenching. Lack of nutrients may explain the slow start of this plantation, although by the fourth year seedling roots had developed well into the ridges of organic matter turned up by the trencher, improving thereby the nutrient supply to the trees.

Plantation 7 was established after site preparation with sharkfin barrels which presumably created microsites richer in nutrients than those created by trenching. However, the plants in this plantation which were growing well initially fell behind those

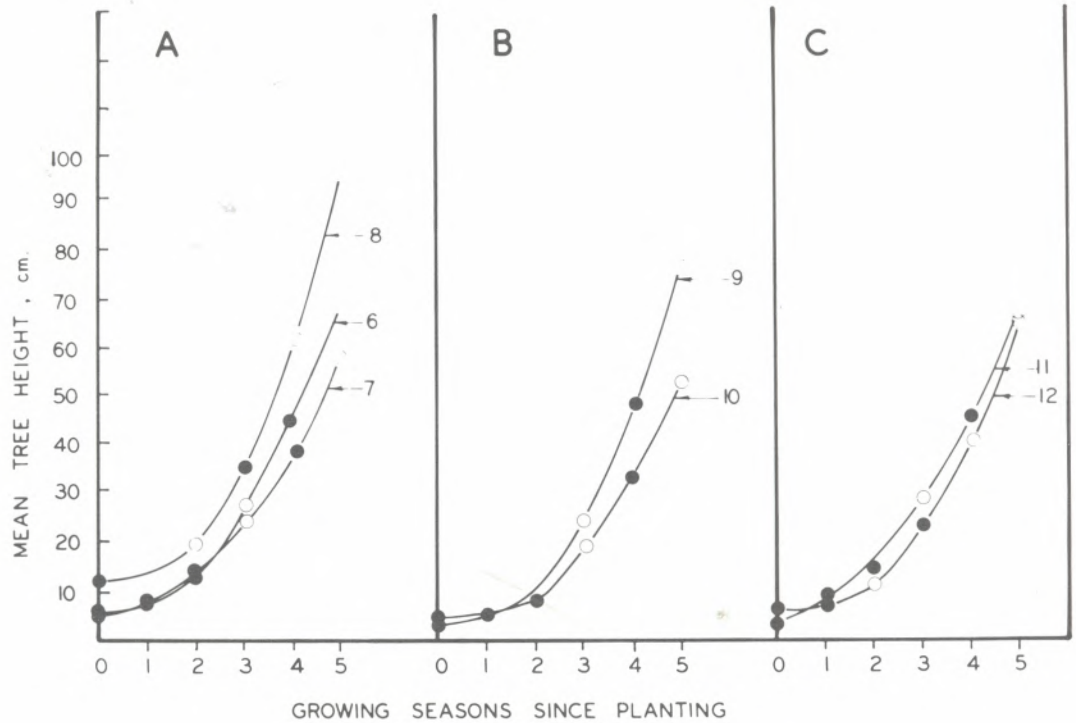

Figure 3. Height development of jack pine plantations established with paperpot stock A) sown in spring and planted in summer, B) sown in midsummer and planted in late summer, or C) sown and planted in the year following overwintering in the nursery. (Dots and open circles represent measured and calculated mean heights, respectively.)

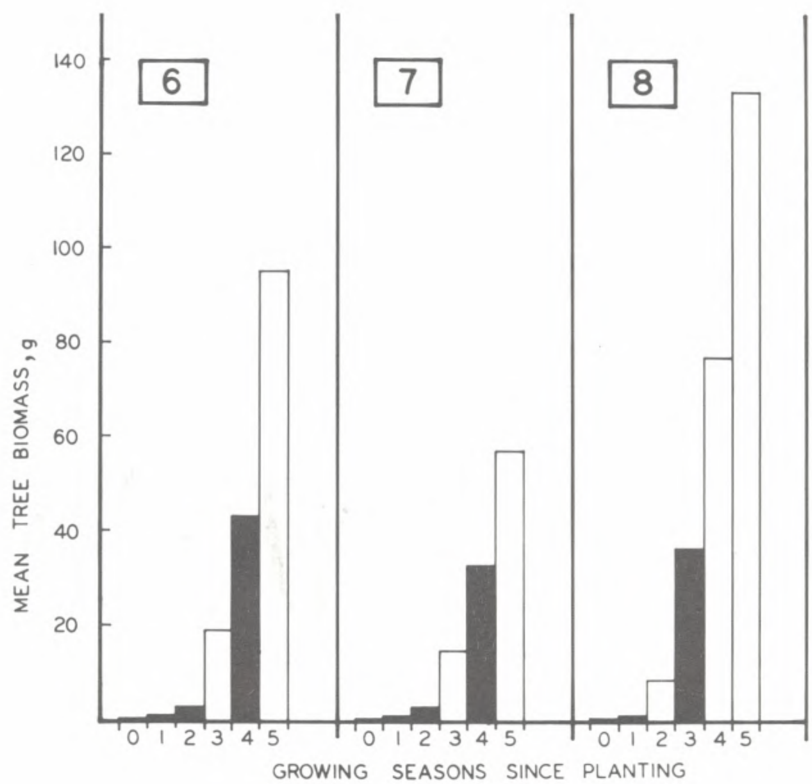

Figure 4. Biomass accretion in jack pine plantations established with paperpot stock sown in spring and planted in summer. (Solid and open bars represent measured and calculated mean biomass, respectively.)

of plantation 6, possibly because of increasing competition from the ericaceous growth.

Summer-sown, late summer-planted

Two plantations (9 and 10) were established with very small planting stock (Table 2) in mid-September.

Survival after the first winter was noticeably lower than in the plantations established during the same year with spring-sown stock (Table 3). The surviving plants showed some gain in biomass and shoot elongation between the time of planting and sampling the following spring. In contrast with summer-planted stock, which showed a strong root development during the first few months in the field, the late-planted seedlings exhibited some shoot development but little gain in roots.

In the second year, mean seedling dry weight was increased by factors of 6.7 (plantation 9) and 3.5 (plantation 10). This amounted to only minor absolute gains since the original weight of seedlings was very small. However, with continued high relative growth rates, plantation 9 may display, by the fifth year, a mean tree height and biomass comparable with what is expected in summer planted stock (Fig. 3, 4 and 5a).

Several factors are believed to be responsible for the slow development of plantation 10. It could be a consequence of very late planting, but the effects of improperly chosen microsites appear more likely to be responsible. Many of the trees had been planted in holes created by the Bracke cultivator rather than on prepared mounds. At the time of sampling in spring, the holes were usually filled with water. This problem did not exist in plantation 9 which had been established after site preparation with sharkfin barrels.

Overwintered, spring- or summer-planted

Two plantations were monitored, one that had been established towards the end of May, 1977 (11) and another established in mid-July, 1978 (12).

The two plantations showed similar patterns of height development, but differed dramatically with respect to biomass accretion. Among the possible causes of this difference, variability of planting stock and time of planting are probably the least important.

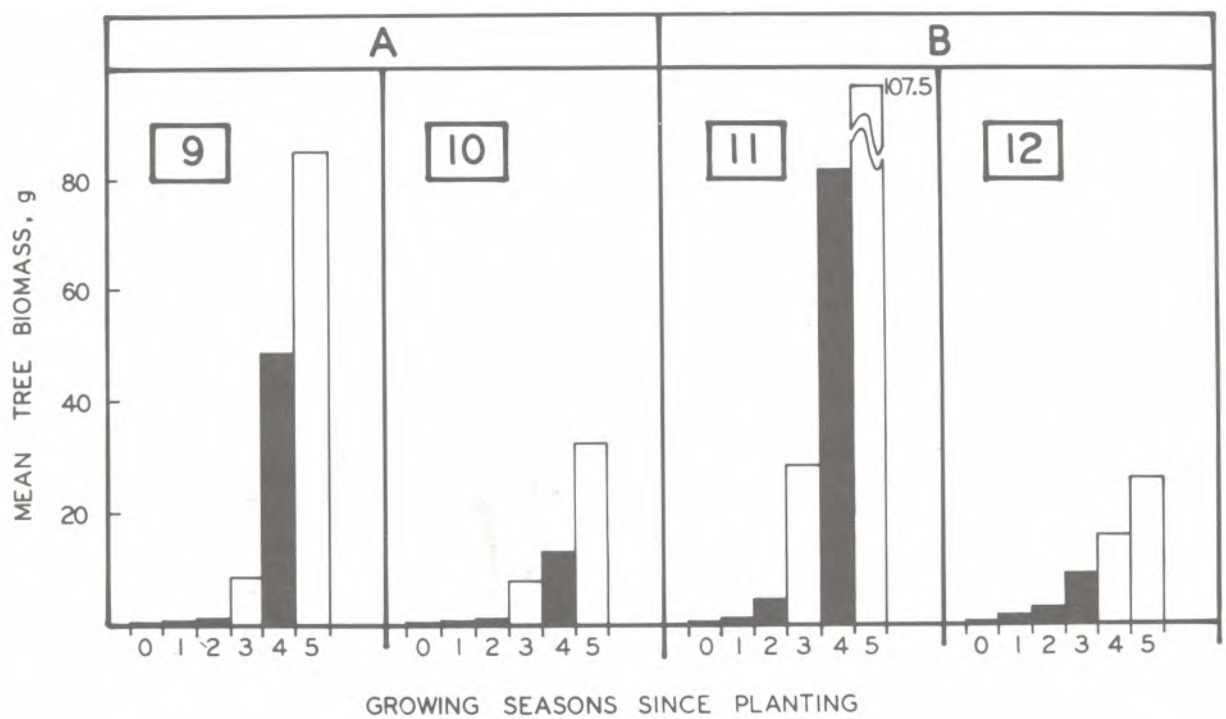

Figure 5. Biomass accretion in jack pine plantations established with paperpot stock A) sown in early or midsummer and planted in late summer, or B) sown and planted in the year following overwintering in the nursery. (Solid and open bars represent measured and calculated mean biomass, respectively.)

Plantation 11 was located on a sandy plain previously supporting jack pine. The area was burned and site-prepared with a Bräcke cultivator. The small plants (Table 2) suffered high mortality, but those that had survived exhibited an approximately six-fold increase in mean dry weight and a three-fold increase in height during the first growing season. This rapid rate of growth, presumably supported by a short-term improvement in nutrient supply after the fire, was not maintained through the following years.

The overwintered seedlings planted in 1978 were of a higher morphological grade than those used in the previous spring, but showed very little growth in the first two years (Fig. 3a and 5b). Most of the seedlings had been planted in infertile sandy soil exposed by a Finnish plow. Low nutrient availability in the rooting medium combined with a very low nitrogen content in the seedlings at the time of planting (Table 5) were probably reasons for the poor growth. Additional factors appear to have been shading and competition by volunteer hardwoods and larger jack pine of an unsuccessful earlier planting. Under these conditions, early planting of overwintered stock has not resulted in a more rapid development than was found in plantations established with the same type of stock in late summer or early fall.

Black Spruce Bare-root Stock

Three-year-old seedling stock used in the 1977 fall planting and the 1978 spring planting, as well as 2-0 seedlings planted in 1978, were evaluated.

The bare-root stock had received a low rating at time of planting (Table 2). Plantation survival was very low and the three areas have since been replanted with different stock. The surviving plants exhibited very little growth in the first year. Observations were discontinued thereafter.

Black Spruce Paperpot Stock

Four batches of paperpot stock were sampled, two in 1977 and two in 1978. The 1977 samples had received a top rating whereas those produced in 1978 were of intermediate grade (Table 2). This stock showed moderately high rates of survival (Table 3).

The plantations varied considerably in growth (Fig. 6 and 7), apparently because of differences in soil fertility and competing vegetation. Plantation 13, characterized by its sluggish height development, was established on an ericaceous site with predominantly coarse textured soil. Lack of fertility is suggested by the low foliar nitrogen content (Table 5).

Plantations 14, 15 and 16 were established on moderately rich sites with a vigorous competing vegetation dominated by raspberry. Plantation 14 showed little biomass accretion in the first year when rapidly overtopped by raspberry, but seems to have responded well to a herbicide spray in the second year. Plantation 16 has shown the fastest height development, but trails plantation 14 in biomass accretion. Rapid height growth with a less than normal gain in biomass may be a typical response to shading by faster growing, competing plants.

Black spruce paperpot plantations cover height and biomass ranges similar to those of paperpot jack pine plantations (Fig. 3, 4, 6, and 7).

There are no indications that the observed differences in grade of paperpot planting stock (Table 2) have had or will have a noticeable influence on the 5-year growth of black spruce plantations.

DISCUSSION

Height development in bare-root jack pine plantations followed patterns established by Hamilton (1979) with a larger number of plantations. That study also indicated that jack pine growth in New Brunswick plantations was comparable with, if not superior to, growth in parts of the Great Lakes region (Wilde et al. 1964).

Several studies with other species in various parts of North America have suggested faster juvenile growth in plantations established with containerized stock than in those established with bare-root stock (Aycock 1974, Mann 1977, Stein and Owston 1977). The jack pine paperpot plantations of this study have lagged one to two years behind bare-root plantations. A considerable time lag in the development of jack pine plantations from containerized stock was also evident in one of the early comparisons in Ontario (Scarratt 1974).

Black spruce paperpot stock was judged superior to bare-root stock because of the high mortality in the latter. Because of the heavy losses, it has not been possible to compare the different types of planting stock of this species with respect to early growth. When the results of a previous sur-

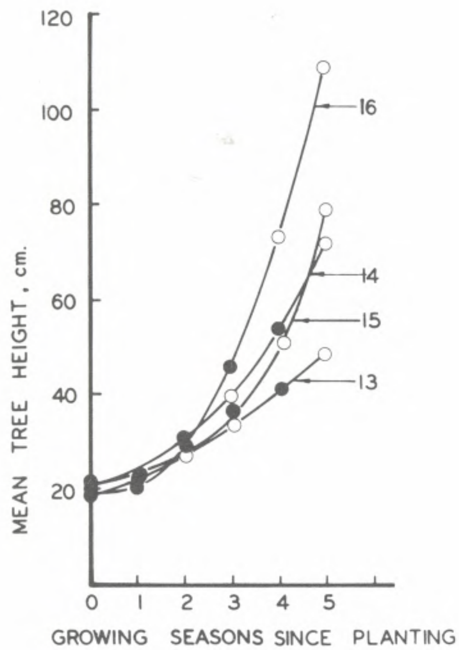

Figure 6. Height development in black spruce plantations established with paperpot stock. (Dots and open circles represent measured and calculated mean heights, respectively.)

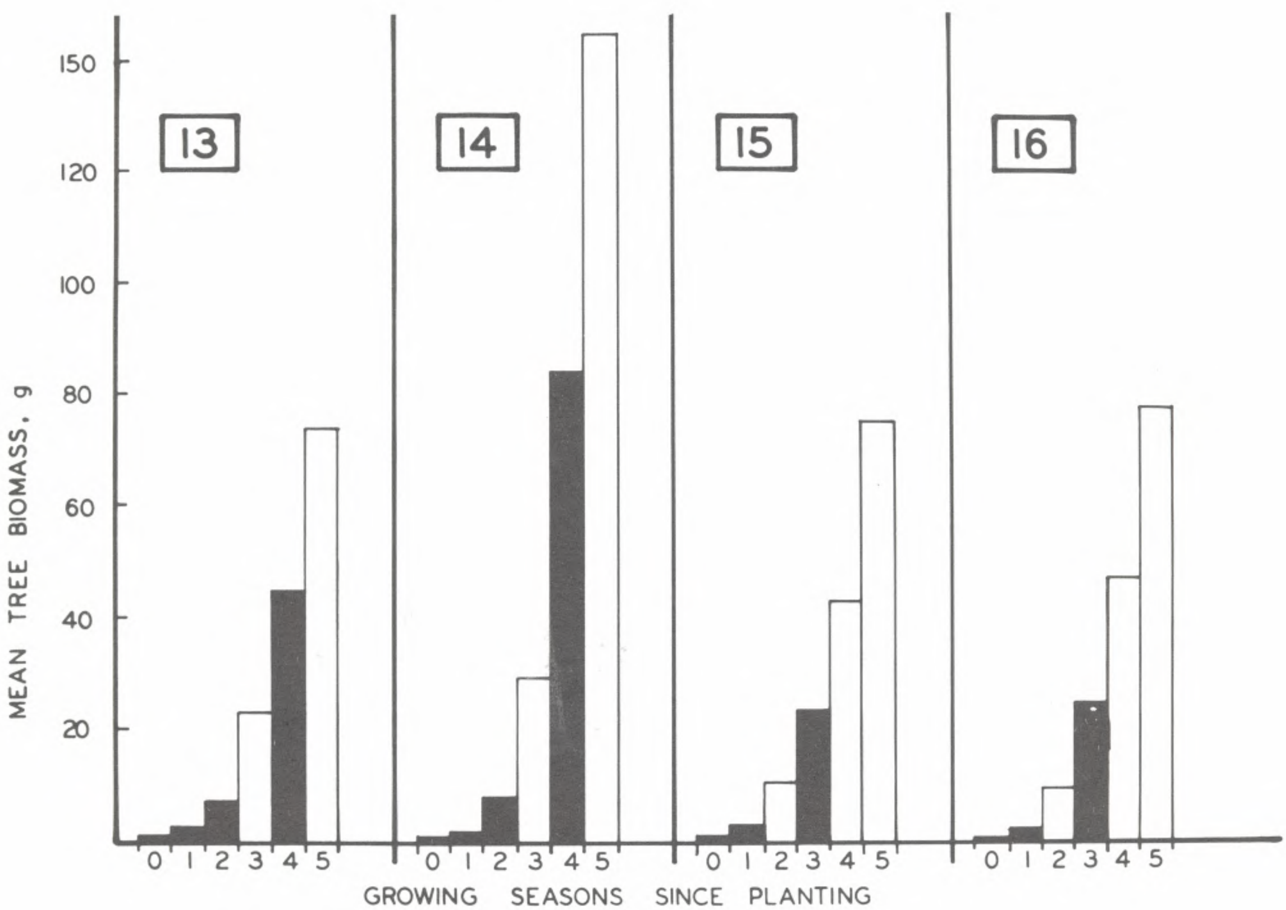

Figure 7. Biomass accretion in black spruce plantations established with paperpot stock. (Solid and open bars represent measured and calculated mean biomass, respectively.)

vey of black spruce plantations established in the province with 2-2 stock[2] are compared it becomes apparent that the development of black spruce paperpot plantations exhibits a time lag similar to that of jack pine paperpot plantations. For example, the expected height of 109 cm at age five years in the best growing paperpot plantation (Fig. 6) was reached by the average bare-root transplant plantation three years after planting, and the slowest growing paperpot plantation would just have surpassed the size of 2-2 planting stock in the fourth year after planting. The lag in paperpot stock plantations would be especially noticeable on sites with heavy shrub competition which require herbicide treatments earlier and more often than plantations established with large stock.

With the results of the present study, it would not be unreasonable to expect that the average paperpot plantation may require an additional one to two years in the rotation to produce a yield comparable with that of the average bare-root plantation. However, the advantage of a shortened juvenile period in bare-root plantations must be weighed against the advantages of the paperpot planting system, including extended planting season, reduced planting cost and improved survival. The problem of root deformation, which appears to be more severe in trees from bare-root than from container-grown stock, should also be mentioned. Scarratt (1974) and Scarratt and Reese (1976) have made a case for an integrated system of planting stock production and field planting in which containerized stock supplements conventional bare-root stock or vice versa.

While the use of different types of planting stock (bare-root vs. containerized) has had an obvious effect on the early growth of jack pine plantations, the influence of grade, as defined in Table 1, was not discernible. For example, bare-root plantations 4 and 5 were established with grades 1 and 2 stock, yet they exhibited comparable patterns of height development. Paperpot plantations 6 and 7 were established with stock that had received a much higher rating than stock used in plantation 9, but the cumulative height of the latter was equal to or greater than that of the former despite the fact that the seedlings were planted late in the season. Plantation 12 has been trailing plantation 11 (Fig. 3c and 5b) because of very slow growth in the former in the first two years. Stock used for plantation 12 was of a higher morphological grade than that of plantation 11, but was low in nitrogen at the time of planting.

[2]H.H. Krause, unpublished data.

The lack of a clear effect of morphological grade on the early growth of plantations used in this study is no justification for relaxing standards of planting stock quality. It has been shown repeatedly that rate of survival, the overriding criterion in judging early plantation performance, is related to those features of the plant that determine its morphological grade (Dobbs 1976, van den Driesche 1980, Mullin and Christie 1981).

Scarratt (1974) has shown that late season planting of tubed seedlings of several conifer species resulted in considerably reduced growth. In the present study, the time of planting of paperpot stock had no clear effect. Plantations 11 and 12, having been established early in the season, were expected to be the most advanced in growth. Instead, the late-summer planted stock of plantations 8 and 9 has shown faster height development than the early planted stock of plantations 11 and 12. However, it should be recalled that jack pine paperpot stock planted late in the season (September) had shown little root growth before the onset of winter. The lack of sufficient new roots to anchor the plant firmly in the ground is usually the reason for frost heaving and reduction in survival.

Observations from this study indicate a strong effect of site and microsite on early plantation development. Most prominent among site factors are type and vigor of competing vegetation and soil fertility. Typically unsuitable microsites were infertile soil and depressions exposed or created by implements used in site preparation. The high incidence of poor growth of planted trees on adverse site or microsite conditions underlines the importance of accurate matching of species and site, and proper choice of site preparation method.

SUMMARY AND CONCLUSIONS

1. Jack pine bare-root plantations have shown highly variable growth, with projected mean tree heights ranging from 0.65 to 1.70 m at the age of five years.

2. Jack pine paperpot plantations exhibited a time lag of one to two years over bareroot plantations on similar sites.

3. Black spruce bare-root seedlings suffered excessive mortality and showed very little growth after planting.

4. In comparison with bare-root seedlings, black spruce paperpot seedlings were highly successful; height development and biomass accretion followed patterns similar to those observed with jack pine paperpot plantations.

5. The results of this study have not shown a clear effect of morphological grade of planting stock or time of planting on the early growth of paperpot plantations.

6. Dominant factors determining the rate of growth of seedlings that have survived the first winter in the field appear to be site and microsite.

ACKNOWLEDGMENTS

This study was carried out under contract agreement between the New Brunswick Department of Natural Resources and the University of New Brunswick. Financial support was also received from the block grant of the Canadian Forestry Service to the Faculty of Forestry. I am grateful to Misses M.E. Guptill and L.J. Calder, and Messrs. J. Beyeler, W.N. Hamilton, S.D. Reilly, P.D. Archibald, S. Ramnarine and D.E. Swift for field sampling and work in the laboratory.

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