CONTAINERIZED CONIFER SEEDLING FIELD PERFORMANCE

IN ALBERTA AND THE NORTHWEST TERRITORIES

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ABSTRACT

Container-reared conifer seedling field performance trials were carried out in five forest districts of Alberta and one area in the Northwest Territories. Seedlings from two types of 40-cm^3 plug-style containers, the BC/CFS styroblock and the ARC sausage, and bare-root controls were outplanted between 1971 and 1974. With proper rearing techniques large, healthy seedlings were produced in the containers. Three- and 5-year field results indicate that container-reared seedlings have superior survival rates, good growth rates, and successful extended mid-summer planting seasons without loss of performance.

RESUME

Des essais ont été menés en cinq districts forestiers de l'Alberta et un autre des Territoires du Nord-Ouest, relativement au rendement des semis de conifères cultivés en récipients. Des semis cultivés dans deux types de récipients de 40 cm^3, genre mottes, le styroblock BC/CFS et le saucisson ARC, ainsi que des témoins à racines nues ont été transplantés entre 1971 et 1974. Au moyen de techniques de culture appropriées, des semis de bonne grosseur et sains ont été produits dans les récipients. Les résultats obtenus après 3 à 5 ans à l'extérieur indiquent que les semis cultivés en récipients ont un taux de survie supérieur, une bonne croissance et peuvent être plantés avec succès jusqu'à la mi-saison d'été sans perte de rendement.

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NOTE

The exclusion of certain manufactured products does not imply rejection nor does the mention of other products imply endorsement by the Canadian Forestry Service.

INTRODUCTION

The concept of reforestation with container-reared seedlings planted in a plug form that permits free root egress was introduced to Alberta in 1970 with the British Columbia/Canadian Forestry Service (BC/CFS) styroblock (Kinghorn 1970). A pilot study with this container was carried out the same year that demonstrated a successful greenhouse culturing technique and good field performance of the seedlings (Johnson and Walker 1976). In 1971 a 4-year large-scale trial was initiated to evaluate the field performance of seedlings reared in the BC/CFS styroblock and in the Alberta Research Council (ARC) sausage container (Mitchell et al. 1972).

DESCRIPTION OF CONTAINERS

The styroblock container is formed by injection molding of expandable polystyrene and consists of 192 tapered cavities 40 cm^3 in volume. Each cavity is 11.4 cm in length, with a top diameter of 2.5 cm and a bottom opening of 9.5 mm. Two molded slats at the bottom allow drainage and air circulation. In 1971 and 1972 the styroblocks were manufactured with smooth-walled cavities that allowed spiralling of the root system. In 1973 half of the tray cavities had four raised ridges to prevent spiralling, and in 1974 all cavities in the tray were ridged.

The ARC sausage container is formed by forcing a semifluid peat paste of about 80% moisture content through a nozzle into tubular polyethylene casings 2.5 cm in diameter and 4-6 m long. The casings are then cut into 7.6-cm lengths and placed into wooden-walled trays with screened bottoms. Each tray can hold 98 sausages. A small depression for seeding is made with compressed air at the top of each sausage. The rooting volume of each sausage is 40 cm^3, with bulk densities of 0.16 to 0.29 g/cm^3 (dry weight per wet volume) (Mitchell et al. 1972). Hand-filled cavities, such as those in the styroblocks, normally have bulk densities of 0.09 to 0.12 g/cm^3.

GREENHOUSE REARING

All container seedlings used in the study were reared at the Northern Forest Research Centre (NFRC) in Edmonton. The styroblocks were hand filled at NFRC, and the sausages were obtained prepackaged from the Alberta Research Council. A pure peat medium was used in each. Seed of local origin was used for each planting location except the Northwest Territories, for which seed was collected in the Athabasca district of Alberta.

Seeds first were surface sterilized by being soaked in a 3% hydrogen peroxide solution for 30 minutes; then they were air dried. The containers were hand seeded at a rate of three or four seeds per cavity and were covered with No. 2 granite grit, which serves to direct the emerging radicle into the growing medium, maintain surface moisture, and prevent growth of moss on the plug surface. After a thorough wetting the trays were covered with polyethylene and allowed to germinate. Greenhouse temperatures were maintained at 21°C during the day and 16°C at night. A 20-hour continuous photoperiod, from 0400 to 2400 h, was provided by fluorescent lamps producing 7535 lux. The polyethylene was kept in place until germination was 75-80% complete, about 5 to 7 days for pine and 8 to 10 days for spruce; at this time the stock was considered to be age 0. During the following 21 days the plugs were subsequently thinned to one seedling in each.

Watering was as required, with two or three thorough soakings per week usually being sufficient. Fertilization was initiated at 2 to 3 weeks of age and was carried out weekly in the greenhouse; one or more applications were applied in the cold frame (Table 1). All watering and fertilization was performed manually. The greenhouse rearing period varied from 10 weeks in 1971 to 15 weeks in 1974. The cold frame period varied from 3 to 9 weeks as the individual areas were planted (Table 2).

During the first 3 years of rearing, the peat used in the styroblocks was steam sterilized for 1.5 h at 85°C, but no special treat-

Table 1. Seedling rearing schedule for the four years

Year	Week	Fertilizer	Frequency of application	Fertilizer concentration (ppm) N	P	K	S	Fe
1971	2-10	Hocking's solution[1]	Weekly	112	31	156	150	0.56
	10	To cold frame						
	11-14	Hocking's solution	Weekly	112	31	156	150	0.56
	16	Planting						
1972	2-11	Hocking's solution	Weekly	112	31	156	150	0.56
	11.5	To cold frame						
	11-13	Hocking's solution	Weekly	112	31	156	150	0.56
	16	Planting						
1973	3-13	20-5-30	Weekly	133	15	166	0	0.20
	13	To cold frame						
	13-14	20-5-30	Weekly	133	15	166	0	0.20
	18	Planting						
1974	3-4	20-5-30	Weekly	133	15	166	0	0.20
	5-12	20-20-20	Weekly	133	58	110	0	0.20
	13-15	10-52-17	Twice in 3 weeks	66	151	93	0	0
	15	To cold frame						
	16-18	10-52-17	Once in 3 weeks	66	151	93	0	0
	18	Planting						

[1] Hocking (1971).

Table 2. Rearing time, planting date, and site preparation by planting areas

District	Year of planting	Rearing time (wk)		Planting date	Site preparation	Soil texture[1]	Elevation (m)	Moisture at planting
		greenhouse	coldframe					
Bow	1971	10	7	July 28–30	Scarified cutover	Loam	1 555	Dry
Whitecourt	1971	10	6	July 20–23	Bulldozed strips	Silt loam to clay	884	Fresh
Lac La Biche	1971	10	7	July 28–30	Bulldozed strips	Loam	617	Dry
Footner Lake	1971	10	9	August 11–12	Bulldozed strips	Silty clay loam to clay	427	Dry
Crowsnest	1972	11.5	4	June 13–16	Bulldozed strips	Loam	1 433	Moist
Bow	1972	11.5	5	June 20–23	Scarified cutover	Loam	1 585	Fresh
Whitecourt	1972	11.5	8	July 11–14	Bulldozed strips	Clay loam to clay	838	Fresh
Lac La Biche	1972	11.5	6	June 28–July 4	Bulldozed strips	Loam	617	Moist
Grande Prairie	1972	11.5	4	June 14–21	Bladed	Sandy loam to loam	655	Fresh
Footner Lake	1972	11.5	5	June 22–23	Bulldozed strips	Clay	427	Fresh
Wood Buffalo Nat. Park (jP)[2]	1972	11.5	6	June 30	Bladed	Sand	274	Dry
Wood Buffalo Nat. Park (wS)[3]	1972	11.5	6	June 30	Bladed	Loam to clay loam	244	Fresh
Fort Smith	1972	11.5	6	June 29	Cutover	Loamy sand to sandy loam	183	Fresh
Crowsnest	1973	13	6	June 27–July 2	Bladed	Sandy loam to loam	1 585	Fresh
Bow	1973	13	7	July 5– 7	Scarified cutover	Loam to clay loam	1 555	Fresh
Whitecourt	1973	13	5	June 19–21	Bulldozed strips	Silt loam to clay	838	Moist
Lac La Biche	1973	13	6	June 26–28	Bulldozed strips	Sandy loam to loam	617	Moist
Grande Prairie	1973	13	7	July 5– 9	Bladed	Silt loam to clay	655	Very dry
Footner Lake	1973	13	8	July 11–12	Bladed	Sandy loam	335	Moist
Fort Smith	1973	13	9	July 16–17	Cutover	Loamy sand to sandy loam	183	Fresh
Crowsnest	1974	15	4	June 18–25	Bladed	Silt loam to clay loam	1 753	Fresh
Grande Prairie	1974	15	3	June 8–13	Bulldozed strips	Clay loam	1 021	Moist
Fort Smith	1974	15	7	July 11–12	Cutover	Loamy sand to sandy loam	183	Moist

[1] Upper 15 cm.
[2] jP = jack pine.
[3] wS = white spruce.

ment was applied to the prepackaged sausages. The granite grit was washed before being sprinkled over the plugs. In the last year of rearing, both steps were eliminated without any noticeable effect on germination or seedling establishment. In addition, subsequent rearing of pine and spruce for other studies showed that the 20-h continuous photoperiod could be reduced to take advantage of natural daylight without any noticeable effect on the seedlings.

Terminal bud development and cessation of top growth were noted on individual pine seedlings as early as the 9th week in the greenhouse. With the longer greenhouse rearing period in 1973 and 1974, terminal bud development was common on the majority of pine seedlings before they were placed into the cold frame. Terminal growth on the spruce seedlings remained active right up to removal from the greenhouse and ceased only with the reduction of fertilizer applications and the cooling period in the cold frame. Prior to transportation to the field, top growth, root, and shoot weights were taken on 20 randomly selected seedlings.

In 1973 the sausages produced decidedly smaller seedlings than the styroblocks because no extra time was given to watering and fertilizing. With a higher bulk density and a small top depression, the sausages required more time for adequate soaking of the plug. In 1974 a different fertilizer mix was used than had been applied in the 3 previous years (Table 1). Seedlings were taller and appeared more slender due to the use of 20-20-20 fertilizer; the fertilizer was switched to 10-52-17 during the latter rearing stage to slow down top growth by reducing the nitrogen supply.

FIELD PROCEDURES

Six locations—Crowsnest, Bow, Whitecourt, Lac La Biche, Grande Prairie, and Footner Lake—representative of common sites found in five forest districts of Alberta and one area near Fort Smith in the Northwest Territories were planted over a 4-year period, from 1971 to 1974 (Table 2, Fig. 1). Each location was planted 3 consecutive years.

In the Crowsnest area, lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) and Engelmann spruce (*Picea engelmannii* Parry) were planted. The other five locations in Alberta were planted to lodgepole pine and/or white spruce (*Picea glauca* [Moench] Voss). Jack pine (*Pinus banksiana* Lamb.) was used at Fort Smith, and single years of jack pine and white spruce were planted in 1972 in two different locations in Wood Buffalo National Park in the Northwest Territories. Approximately 2000 seedlings per species and container were planted each year, and 1000 were marked with wire pins to provide a permanent sample. To permit comparisons, each area in Alberta was also planted with about 200 conventional bare-root (3-0) local origin seedlings reared in the provincial tree nursery at Oliver.

Container seedlings were maintained in the cold frame, and individual area lots were removed just prior to planting. The seedlings were stored on site in the field or at the local provincial forest service field headquarters; they were watered as required if the planting operation was spread over several days (Table 2). Noncoring dibbles were used to plant the container-reared seedlings, and planting bars were used to plant the conventional seedlings. For the ARC stock the entire polyethylene sausage casing was removed before planting.

Soil moisture conditions during planting are given in Table 2. General moisture ratings were as follows: dry for Wood Buffalo National Park; fresh for the Bow, Crowsnest, and Fort Smith; moist for Lac La Biche, Grande Prairie, and Footner Lake; and moist to wet for Whitecourt. Shallow topsoil over sandstone and shale in the Bow area throughout 1971 to 1973 and loose shale covering much of the 1973 Crowsnest area made planting difficult. Dibble planting on the 1973 Grande Prairie area was very difficult in the very dry soil conditions that prevailed at that time.

Survival and height measurements were made 1, 3, and 5 years after planting. The condition of each seedling and apparent damage were recorded. Cause of mortality, when apparent, was also noted. Five to 10

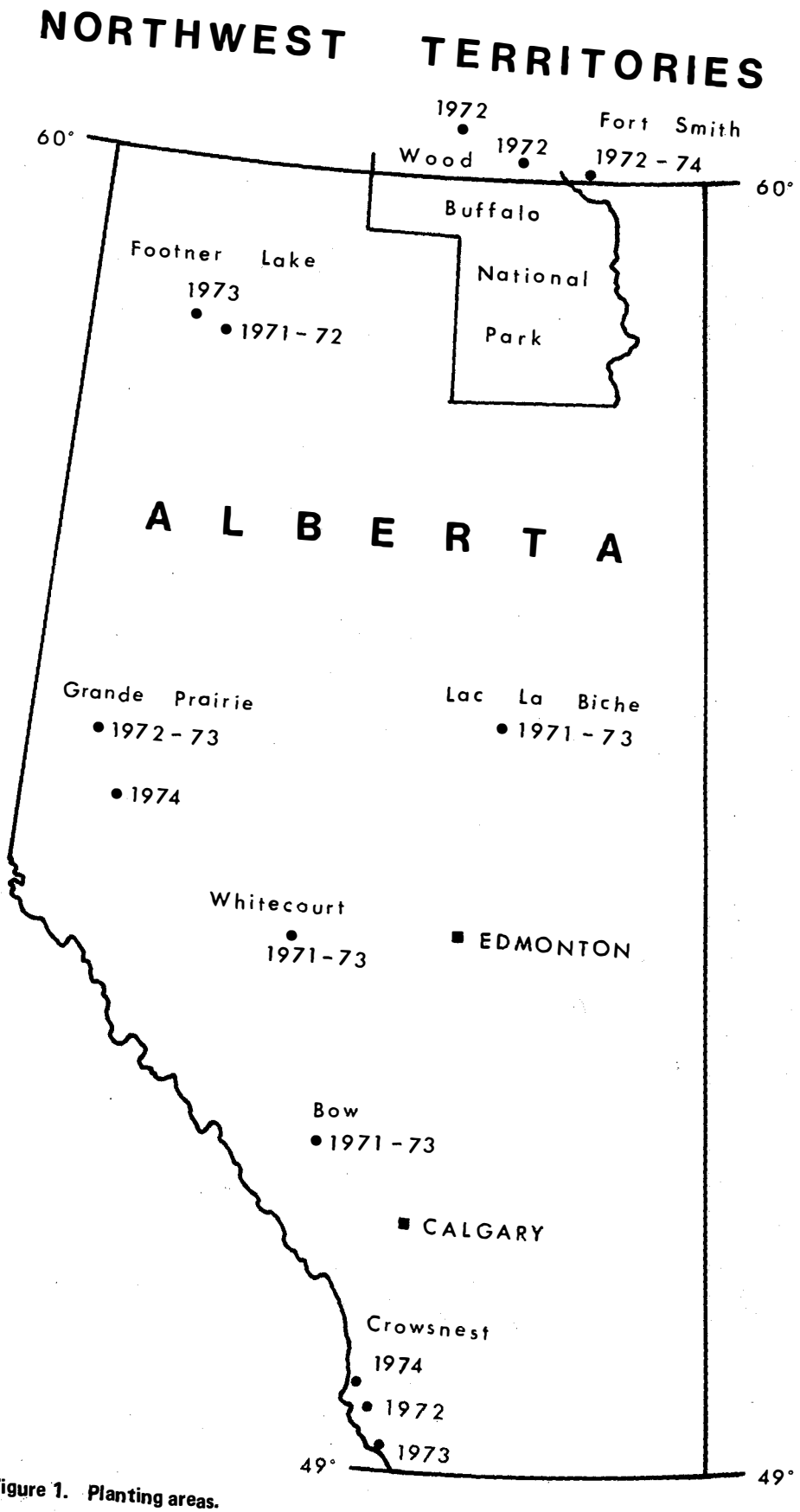

Figure 1. Planting areas.

representative seedlings were excavated during each measurement to observe root development and to obtain total seedling weight. Seedlings were excavated with a spade by cutting the ground vertically in a circle about 30 cm from the seedling. The soil clod, also about 30 cm in depth, was lifted to the surface, and the soil particles were broken away from the roots by hand. Although this procedure cut off the lateral roots beyond 30 cm, the bulk of the root system was obtained, and root configuration was readily apparent. Dry weights were obtained after oven drying at 105°C for 48 h.

RESULTS

Survival

For each year of planting, white spruce and lodgepole pine container seedling survival rates were consistently higher than those of the conventional seedlings (Fig. 2). Only in the 1972 Engelmann spruce plantation did conventional seedlings have a higher survival rate than the sausage seedlings. Overall survival after three growing seasons was 81% or better in 68% of the container plantations; only 20% of the conventional plantations were in this category (Table 3). The month of planting did not significantly affect survival of the container seedlings, but it was a critical factor for the conventional plantations. Of the container seedling plantations planted during July or August, 67% had a survival rate of 80% or more; none of the conventional plantations that were planted at the same time was within this range (Table 4). When planted in June, 68% of the container plantations and only 36% of the conventional plantations had survival rates of 80% or more.

Where flooding or browsing was not a factor, 5th-year survival of lodgepole pine was highest in the Grande Prairie and Whitecourt districts (Tables 5-8). Styroplug and ARC sausage seedling survival rates in the 1972 Grande Prairie area were 99% and 96%, respectively; conventional seedling survival was comparable at 97%. In the 1972 Whitecourt area, styroplug and ARC sausage seedling survival rates were 91% and 92%, but conventional survival was only 7%. The poor bare-root survival rate is attributed to the late planting dates of July 11-14 (Table 2). Earlier planting dates during June, as in the 1972 Grande Prairie area, usually assured good survival rates, and seedling type—container or conventional—was not important. Styroplug jack pine survival at Fort Smith was 85% 5 years after planting for the 1972 plantation and 96% 4 and 3 years after planting for the 1973 and 1974 plantations. Third-year survival of the pine container plantations in the 1974 Crowsnest and Grande Prairie areas ranged from 91% to 98%.

Fifth-year survival of white spruce was highest in the 1972 and 1973 Lac La Biche, Grande Prairie, and Footner Lake areas. The 1972 Grande Prairie area had styroplug and ARC sausage seedling survival rates of 96% and 92%. Survival rates of the 1973 Lac La Biche container seedlings were 98% and 95% for the styroblock and ARC sausage plugs. The 1973 Footner Lake area had survival rates of 88% and 96%, respectively, for styroblock and ARC sausage seedlings. Conventional seedling survival was comparable at 96% in 1972 and 98% in 1973 in only the Lac La Biche district. Individual survival rates of the 12 container plantations within these three districts ranged from 72% to 98%, and only two of these plantations were less than 88%.

Growth

The average yearly height was greater in conventional plantations than in container plantations in 9 of 11 cases (Fig. 3). The 1973 pine styroblock seedlings had better 5th-year heights than the conventional. Conventional pine plantations were established only in the Crowsnest, Bow, and Grande Prairie areas (Table 7), and all planting took place in late June and during July (Table 2). The 1974 lodgepole pine seedlings in both containers also had better 3rd-year heights than the conventional seedlings. Severe winter drying and leader dieback affected 68% of the conventional seedlings in the Crowsnest area (Table 8). At Grande Prairie the conventional stock was the smallest used for any plantation; seedlings averaged only 8.4 cm in height and 1108 mg in weight when planted.

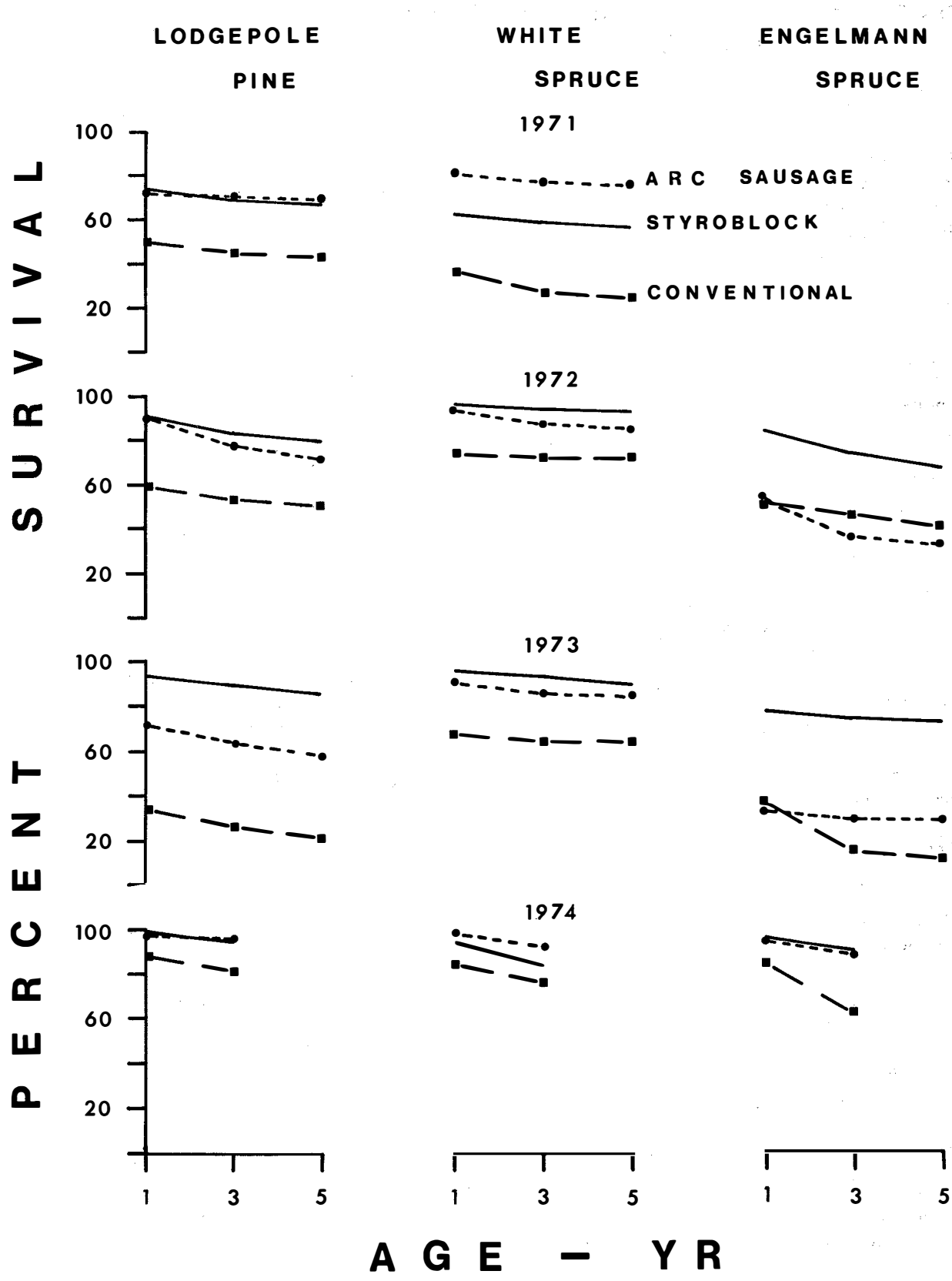

Figure 2. Average yearly survival by seedling type and year of planting.

Table 3. Distribution of 3rd-year percentage survival by class for pine and spruce planted 1971 to 1974

Species and container	Plot distribution by percentage survival class				
	0-20	21-40	41-60	61-80	81-100
Pine, styroblock	0	0	1	1	14
Pine, sausage	0	1	2	3	6
Spruce, styroblock	0	0	2	3	11
Spruce, sausage	0	2	1	3	9
Total	0	3	6	10	40
Percent	0	5	10	17	68
Pine, conventional	2	4	0	2	3
Spruce, conventional	3	0	5	4	2
Total	5	4	5	6	5
Percent	20	16	20	24	20

Table 4. Distribution of 3rd-year survival by month of planting, for container and conventional seedlings

Species and container	Number of plots by month of planting		
	June	July	August
Pine, container	16	12	0
Spruce, container	19	10	2
Total	35	22	2
Number of plots with survival > 80%	24	15	1
Percent	68	68	50
Pine, conventional	6	5	0
Spruce, conventional	8	5	1
Total	14	10	1
Number of plots with survival > 80%	5	0	0
Percent	36	0	0

Table 5. Seedling performance after 1, 3, and 5 years of the 1971 plantations

District	Container	Species	Number of seedlings	Percentage survival			Average height (cm)			Average height (cm)		Percentage heaved		
				1 yr	3 yr	5 yr	1 yr	3 yr	5 yr	dominant and codominant number	5 yr	1 yr[1]	3 yr	5 yr
Bow	Styroblock	1P[2]	1 002	59	52	50	6	14	31(15)[3]	100	54(10)[3]	2	11	8
	Sausage	1P	1 000	47	42	42	9	19	41(16)	100	52(10)	54	21	7
	Conventional	1P	172	28	22	20	10	20	45(23)	-[4]	-	0	0	0
Whitecourt	Styroblock	1P	980	90	86	84	9	29	65(24)	100	106(12)	15	27	26
	Sausage	1P	1 000	97	95	94	14	32	66(21)	100	104(11)	43	51	36
	Styroblock	wS	962	61[5]	54	52	8	18	30(13)	100	50(7)	8	11	10
	Sausage	wS	1 000	86[6]	84	82	9	21	37(17)	100	67(10)	30	27	23
	Conventional	1P	175	72	68	66	24	57	104(37)	25	152(15)	0	0	0
	Conventional	wS	178	58	51	48	21	28	40(18)	25	61(20)	0	3	0
Lac La Biche	Styroblock	wS	999	44[7]	41	41	7	16	27(11)	100	42(7)	1	5	5
	Sausage	wS	1.000	57[8]	56	55	8	18	32(13)	100	50(6)	23	15	11
	Conventional	wS	177	10[9]	7	7	5	12	21(10)	-	-	0	0	0
Footner Lake	Styroblock	wS	990	82	77	74	8	17	26(11)	-	-	18	8	4
	Sausage	wS	990	96	91	89	9	17	25(12)	-	-	48	24	29
	Conventional	wS	117	38	20	19	10	16	24(10)	-	-	0	0	0

[1] 0.5 cm or more at 1 yr; 1.5 cm or more at 3 and 5 yrs (based on 1 and 3 yr survival).
[2] 1P = lodgepole pine.
[3] Standard deviation.
[4] Not sampled due to limited survival, severe competition, or flooding.
[5, 6] 8 and 3% flooding mortality during the 1st yr.
[7, 8, 9] 4, 14, and 8% browsed during the 1st yr.

Table 6. Seedling performance after 1, 3, and 5 years of the 1972 plantations

District	Container	Species	Number of seedlings	Percentage survival			Average height (cm)				Average height (cm)		Percentage heaved		
				1 yr	3 yr	5 yr	at planting	1 yr	3 yr	5 yr	dominant and codominant number	5 yr	1 yr[1]	3 yr	5 yr
Crowsnest	Styroblock	lP	1 000	78	62	[2]	5	11	22	-[2]	-	-	0	0	-
	Sausage	lP	998	70	41	[2]	4	9	17	-	-	-	0	0	-
	Styroblock	eS[3]	998	84	74	68	7	10	17	25(8)[4]	-	-	0	0	0
	Sausage	eS	1 000	53	36	33	5	7	12	20(9)	-	-	<1	0	0
	Conventional	lP	190	85	81	74[5]	18	29	52	80(33)	-	-	0	0	0
	Conventional	eS	181	52	46	41	16	19	31	44(13)	-	-	0	0	0
Bow	Styroblock	lP	1 000	93	82	77	5	9	20	44(18)	100	74(12)[4]	<1	1	1
	Sausage	lP	1 000	94	77	73	4	7	13	29(12)	100	50(9)	1	4	4
	Conventional	lP	170	32	25	22	17	16	32	64(25)	-	-	0	0	0
Whitecourt	Styroblock	lP	1 000	95	93	91	7	10	30	58(28)	100	114(13)	1	1	2
	Sausage	lP	999	96	94	92	5	8	28	58(24)	100	104(15)	23	8	6
	Styroblock	wS	999	92	89	87	7	10	22	32(13)	100	57(8)	4	2	3
	Sausage	wS	1 000	88	84	82	6	8	18	27(11)	100	47(7)	19	7	11
	Conventional	lP	165	12	7	7	15	12	30	64(25)	-	-	0	0	0
	Conventional	wS	165	45	42	40	27	24	30	42(21)	25	62(22)	0	3	0
Lac La Biche	Styroblock	wS	1 000	97	95	94	8	13	29	46(17)	100	74(6)	2	2	2
	Sausage	wS	1 000	92	89[6]	88	5	8	22	39(15)	100	64(5)	6	3	2
	Conventional	wS	176	97	96	96	17	21	43	71(20)	25	101(9)	0	0	0
Grande Prairie	Styroblock	lP	999	99	99	99	6	13	40	100(24)	100	137(9)	<1	<1	<1
	Sausage	lP	1 001	99	98	96	4	9	31	86(26)	100	129(10)	1	2	2
	Styroblock	wS	1 000	97	97	96	7	12	24	45(11)	100	63(5)	<1	0	0
	Sausage	wS	1 000	96	92	92	5	9	20	40(11)	100	58(5)	1	1	<1
	Conventional	lP	183	98	98	97	18	30	80	168(31)	25	212(11)	0	0	0
	Conventional	wS	184	78	77	76	18	23	36	65(16)	25	87(6)	0	0	0
Footner Lake	Styroblock	wS	998	98	95	94	8	12	24	30(10)	-	-	2	1	1
	Sausage	wS	1 000	92	79	75[7]	6	6	13	19(9)	-	-	17	5	2
Wood Buffalo Nat. Park	Styroblock	jP	850	93	90	89	6	7	16	33(20)	-	-	<1	1	1
	Styroblock	wS	1 000	93	92	90	8	9	18	26(10)	-	-	1	6	6
Fort Smith	Styroblock	jP	1 000	89	86	85	6	10	32	63(27)	100	113(16)	<1	<1	<1

[1] 0.5 cm or more at 1 yr; 1.5 cm or more at 3 and 5 yr (based on 1 and 3 yr survival).
[2] Not sampled due to severe browsing by cattle (Crowsnest district), limited survival, severe competition, or flooding.
[3] eS = Engelmann spruce.
[4] Standard deviation.
[5] 38% browsed by cattle.
[6,7] 6 and 14% accumulative flooding mortality.

Table 7. Seedling performance after 1, 3, and 5 years of the 1973 plantations

District	Container	Species	Number of seedlings	Percentage survival			Average height (cm)				Average height (cm)		Percentage heaved		
				1 yr	3 yr	5 yr	at planting	1 yr	3 yr	5 yr	dominant and codominant number	5 yr	1 yr[1]	3 yr	5 yr
Crowsnest	Styroblock	1P	1 000	90	88[2]	87	8	12	36	81(28)[3]	100	124(9)[3]	<1	<1	0
	Sausage	1P	1 002	27	24	24[4]	4	5	19	50(27)	25	95(6)	1	0	0
	Styroblock	eS	1 000	78	75	73	8	10	21	36(12)	100	57(7)	1	<1	<1
	Sausage	eS	998	33	29	29	4	5	14	28(11)	70	43(5)	<1	0	0
	Conventional	1P	187	19	12	10	17	13	29	60(26)	-[5]	-	0	0	0
	Conventional	eS	179	37	14	11	17	16	28	46(12)	-	-	0	0	0
Bow	Styroblock	1P	1 000	94	91	88	7	10	25	49(18)	100	80(8)	2	1	<1
	Sausage	1P	998	84	76	73	4	6	15	32(14)	100	55(7)	2	<1	<1
	Conventional	1P	191	43	36	32	17	13	24	41(18)	25	58(12)	0	0	0
Whitecourt	Styroblock	1P	992	96	83	75	9	16	32	48(16)	-	-	1	1	1
	Sausage	1P	997	85	70[6]	54	5	8	16	29(12)	-	-	8	2	2
	Styroblock	wS	996	92	88	84	9	14	25	42(14)	100	67(8)	2	1	<1
	Sausage	wS	995	86	79	73	5	7	14	25(10)	100	43(8)	5	2	1
	Conventional	wS	170	72	72	72	28	28	40	62(19)	25	89(10)	0	0	0
Lac La Biche	Styroblock	wS	989	99	99	98	10	15	27	46(15)	100	75(9)	0	0	0
	Sausage	wS	992	97	95	95	4	7	18	36(12)	100	56(7)	1	1	<1
	Conventional	wS	194	98	98	98	17	21	33	56(15)	25	81(6)	0	0	0
Grande Prairie	Styroblock	1P	992	98	97[7]	94[8]	11	14	33	-	100	50(5)[9]	0	<1	0
	Sausage	1P	997	91	84[10]	80[11]	4	6	18	-	100	29(3)[9]	<1	<1	0
	Styroblock	wS	995	94	93	92	11	12	24	41(10)	100	57(5)	1	1	<1
	Sausage	wS	999	78	73	72	4	5	14	27(9)	100	42(5)	1	<1	0
	Conventional	1P	193	38	32	31[12]	19	14	35	-	25	49(9)[9]	0	0	0
	Conventional	wS	195	55	49	45	15	14	21	34(11)	25	47(8)	0	0	0
Footner Lake	Styroblock	wS	998	99	96	88	8	9	17	28(10)	100	46(6)	0	0	<1
	Sausage	wS	998	99	98	96	4	5	10	17(8)	100	34(4)	4	1	1
	Conventional	wS	195	48	44	39	28	18	20	30(10)	25	42(5)	0	0	0
Fort Smith	Styroblock	jP	1 000	99	96[13]		8	14	42(15)[13]		100	72(7)[13]	0	0[13]	

[1] 0.5 cm or more at 1 yr; 1.5 cm or more at 3 and 5 yr (based on 1 and 3 yr survival).
[2, 4] 16 and 10% browsed.
[3] Standard deviation.
[5] Not sampled due to limited survival, severe competition, or flooding.
[6] 4% mortality from animal trampling.
[7, 8, 10, 11, 12] 9, 85, 4, 63, and 81% browsed by snowshoe hares.
[9] 3 yr after planting.
[13] 4 yr after planting.

Table 8. Seedling performance after 1 and 3 years of the 1974 plantations

District	Container	Species	Number of seedlings	Percentage survival		Average height (cm)			Average height (cm)		Percentage heaved	
				1 yr	3 yr	at planting	1 yr	3 yr	dominant and codominant number	3 yr	1 yr[1]	3 yr
Crowsnest	Styroblock	lP	998	99	98[2]	11	12	33(11)[3]	100	54(6)[3]	0	1
	Sausage	lP	1 000	98	97[4]	9	11	28(10)	100	49(6)	0	0
	Stryoblock	eS	998	96	91[5]	10	10	20(6)	100	30(3)	0	1
	Sausage	eS	1 000	95	89[6]	10	10	21(6)	100	32(3)	<1	2
	Conventional	lP	207	93	86[7]	15	10	23(10)	-[8]	-	0	0
	Conventional	eS	234	85	62[9, 10]	18	13	23(7)	25	33(4)	0	0
Grande Prairie	Styroblock	lP	993	98	91	10	17	46(14)	100	69(7)	0	1
	Sausage	lP	1 003	98	95	11	14	43(15)	100	68(6)	0	<1
	Styroblock	wS	998	94	84	10	14	31(11)	100	50(6)	0	0
	Sausage	wS	1 003	98	92	11	14	32(10)	100	51(5)	0	0
	Conventional	lP	187	83	79	8	9	24(11)	25	41(7)	0	0
	Conventional	wS	202	84	76	20	19	38(13)	25	59(6)	0	0
Fort Smith	Styroblock	jP	998	99	96	9	15	37(11)	100	56(6)	0	0

[1] 0.5 cm or more at 1 yr; 1.5 cm or more at 3 yr (based on 1 yr survival).
[2, 4, 5, 6, 7, 9] 27, 6, 14, 7, 68, and 11% of seedlings had dead tops due to winter drying.
[3] Standard deviation.
[8] Top kill from winter drying.
[10] 12% accumulative flooding mortality.

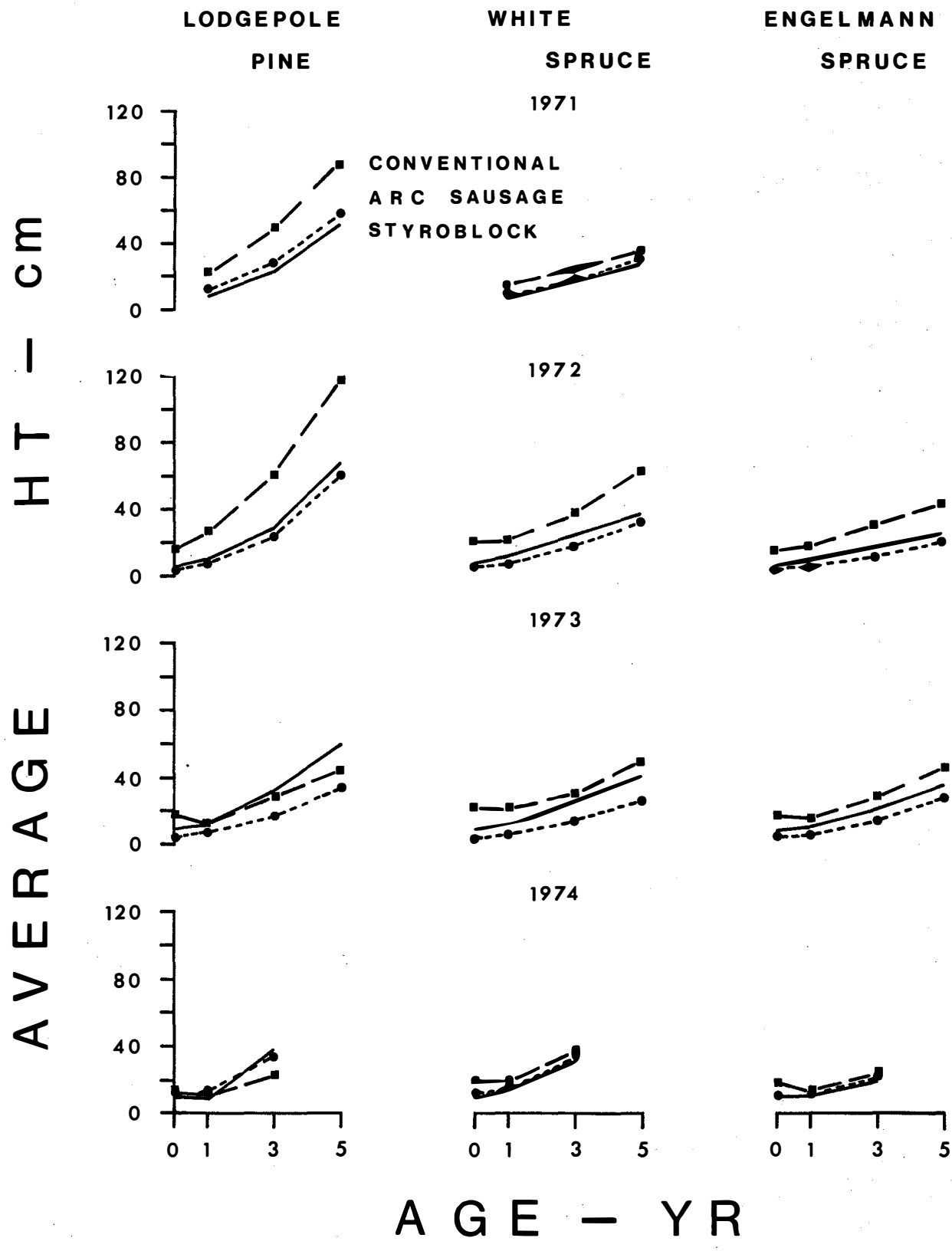

Figure 3. Average yearly height by seedling type and year of planting.

Height growth of lodgepole pine in individual areas 5 years after planting was best in the 1972 Grande Prairie area (Table 9). Dominant styroplug and ARC sausage seedlings averaged 149 cm and 141 cm, respectively, while conventional seedlings averaged 201 cm. The 1972 Whitecourt area had average 5th-year heights of 131 cm and 124 cm for styroblock and sausage plugs. The best seedling growth was in the 3rd and 4th years in the 1974 Grande Prairie and Crowsnest areas. Jack pine also showed good growth at the Fort Smith location; dominant 5th-year heights averaged 137 cm. White spruce growth to the 6th year was greatest in the 1972 Lac La Biche, Grande Prairie, and Whitecourt districts. At Lac La Biche, styroplug and ARC sausage seedlings averaged 108 cm and 95 cm, respectively; the conventional averaged 129 cm. Average 3rd-year growth of the container seedlings, however, again was best in the 1974 Grande Prairie area.

Effect of Seedling Size and Shoot/Root Ratio

Original seedling size was the most important factor in subsequent field performance. Initial 1971 preplanting weights for both species were greater for sausage than for styroblock seedlings; during 1972-74, however, the styroblocks produced larger seedlings (Tables 10-13, Fig. 4). The initially larger 1971 sausage seedlings had better survival and greater average plantation heights in four of the five comparable plantings (Table 5). In the 1972 plantings, the styroblock seedlings had better survival and greater heights in seven of eight plantings (Table 6), and in the 1973 plantings the styroblocks had better survival in eight of the nine plantations and greater heights in all cases (Table 7).

The weights of all seedlings excavated from the 1971, 1972, and 1974 plantations were averaged by species and year of excavation to compare the effect of the container type (Tables 14-16). Weights from the 1973 plantations were not included due to rearing problems experienced with the sausages. When comparable seedlings were reared, the styroblocks produced larger seedlings for each species, and they showed superior performance on a dry weight basis for lodgepole pine and white spruce during each remeasurement. Engelmann spruce sausage seedlings showed better performance in the 5th year, but this species was represented by only a single plantation each year in the Crowsnest district.

The substantially greater weight differential between the 1973 seedlings reared in the containers was still apparent 5 years after planting (Table 12, Figs. 4 and 5). The average 1973 outplanting weights of all lodgepole pine styroblock and sausage seedlings were 0.86 g and 0.29 g, respectively; 5 years after planting these seedlings averaged 102.4 g and 38.6 g, an advantage of 2.65:1 in favor of the initially larger seedling. A 0.57-g larger seedling at planting weighed an extra 63.8 g at 5 years; i.e., for each additional mg in outplanting weight there was an increase of 112 mg in the seedling weight. White spruce seedlings initially averaged 0.671 g and 0.158 g from the styroblocks and sausages, respectively; 5 years after planting these seedlings averaged 23.0 g and 9.3 g, an advantage of 2.48:1 in favor of the initially larger seedling. A 0.513-g larger seedling at planting weighed an extra 13.7 g at 5 years; i.e., for each additional mg in outplanting weight there was an increase of 26 mg in the seedling weight. Similarly, Engelmann spruce seedlings initially averaged 0.68 g and 0.149 g from the styroblocks and sausages, respectively; 5 years after planting these seedlings averaged 90.5 g and 23.7 g, an advantage of 3.82:1 in favor of the initially larger seedling. A 0.531-g larger seedling at planting weighed an extra 66.8 g at 5 years; i.e., for each additional mg in outplanting weight there was an increase of 125 mg in the seedling weight.

The larger seedlings produced by the styroblocks in 1972 and 1974 may be explained in part by the larger surface area and the reduced aerial competition within the styroblocks. The inside area of the 192-cavity styroblock was 1592 cm^2, providing 8.29 cm^2 of aerial growing space per seedling, whereas the 98-plug ARC container occupied only 682 cm^2, providing 6.96 cm^2 per seedling. Scarratt (1972) reared white spruce for 16 weeks in 9/16, 3/4, and 1 1/4 inch (1.4, 1.9, and 3.2 cm) in diameter plastic tubes and found significant improvement in seedling growth in the 1 1/4-inch size. He also noted,

Table 9. Height growth of dominant seedlings (All species not planted in each district.)

District	Year	Container	Average height of 25 seedlings (cm)													
			Species	1 yr	3 yr	4 yr	5 yr	6 yr	7 yr	Species	1 yr	3 yr	4 yr	5 yr	6 yr	7 yr
Crowsnest	1973	Styroblock	1P	16	57	-[1]	136			eS	13	33	-	66		
		Sausage	1P	6	35	-	95			eS	6	21	-	48		
	1974	Styroblock	1P	17	60	89				eS	12	32	46			
		Sausage	1P	15	60	93				eS	14	33	48			
Bow	1971	Styroblock	1P	7	26	-	60	-	117							
		Sausage	1P	9	26	-	60	-	116							
	1972	Styroblock	1P	15	40	-	88	118								
		Sausage	1P	9	26	-	57	81								
	1973	Styroblock	1P	13	42	-	90									
		Sausage	1P	7	27	-	65									
		Conventional	1P	16	32	-	58									
Whitecourt	1971	Styroblock	1P[2]	13	50	-	122			wS	12	29	-	55	-	108
		Sausage	1P[2]	16	50	-	119			wS	15	36	-	68	-	119
	1972	Styroblock	1P[2]	12	54	-	131			wS	12	31	-	59	79	
		Sausage	1P[2]	9	44	-	124			wS	9	25	-	46	62	
	1973	Styroblock	1P[3]							wS	17	37	-	70		
		Sausage	1P[3]							wS	8	22	-	49		
		Conventional								wS	32	52	-	89		
Lac La Biche	1971	Styroblock								wS	9	25	-	47	-	84
		Sausage								wS	10	29	-	57	-	100
	1972	Styroblock								wS	16	43	-	81	108	
		Sausage								wS	13	37	-	71	95	
		Conventional								wS	25	56	-	99	129	
	1973	Styroblock								wS	19	46	-	89		
		Sausage								wS	10	30	-	66		
		Conventional								wS	24	45	-	81		
Grande Prairie	1972	Styroblock	1P	15	58	-	149	214		wS	13	31	-	65	90	
		Sausage	1P	12	52	-	141	205		wS	12	30	-	64	90	
		Conventional	1P	36	99	-	201	268		wS	23	44	-	84	116	
	1973	Styroblock	1P[4]							wS	14	33	-	65		
		Sausage	1P[4]							wS	7	21	-	49		
	1974	Styroblock	1P	21	71	102				wS	20	57	77			
		Sausage	1P	19	70	110				wS	19	59	80			
		Conventional								wS	26	56	75			
Footner Lake	1973	Styroblock								wS	11	28	-	53		
		Sausage								wS	6	19	-	40		
Fort Smith[5]	1972	Styroblock	jP	14	67	-	137									
	1973	Styroblock	jP	18	-	81										
	1974	Styroblock	jP	20	64											

[1] Samples not taken for that year.
[2] Lodgepole pine not sampled in 6th and 7th yr because of browsing.
[3] Lodgepole pine not sampled due to suppression.
[4] Lodgepole pine not sampled because of severe browsing.
[5] Samples discontinued after 1977.

Table 10. Oven dry weights and shoot/root ratios of the 1971 container-reared and conventional seedlings at planting and 1, 3, and 5 years after planting

District	Container	Species	Oven dry wt (mg)		Ratio shoot/root	Oven dry wt (mg)						Total dry wt (mg)						
						shoot	root	shoot	root	shoot	root	at planting		% increment		% increment		% increment
			shoot	root		1 yr		3 yr		5 yr			1 yr		3 yr		5 yr	
Bow	Stryoblock	lP	195	198	0.98	366	318	6 578	1 480	46 383	7 264	393	684	74	8 058	1 078	53 647	566
	Sausage	lP	331	104	3.18	633	259	7 532	1 866	36 684	6 790	435	892	105	9 398	954	43 474	362
	Conventional 3-0	lP	4 610	990	4.66	3 043	1 346	12 011	2 226	116 876	18 064	5 600	4 389	-22	14 237	224	134 940	848
Whitecourt	Styroblock	lP	193	206	0.94	1 216	563	18 442	3 584	75 782	12 210	399	1 779	346	22 026	1 138	87 992	299
	Sausage	lP	392	110	3.56	1 479	530	13 540	2 704	55 430	6 790	502	2 009	300	16 244	708	62 220	283
	Styroblock	wS	160	81	1.98	463	238	1 730	532	11 403	1 259	241	701	191	2 262	223	12 662	460
	Sausage	wS	229	63	3.63	733	361	6 300	1 044	10 707	1 352	292	1 094	274	7 344	571	12 059	64
	Conventional 3-0	lP	8 370	1 840	4.55	14 219	4 406	33 124	7 218	157 514	19 196	10 210	18 625	82	40 342	117	176 710	338
	Conventional 3-0	wS	2 630	490	5.37	2 921	731	5 572	1 254	10 080	1 276	3 120	3 652	17	6 826	87	11 356	66
Lac La Biche	Styroblock	wS	107	63	1.70	306	158	1 653	399	11 427	1 131	170	464	173	2 052	342	12 558	512
	Sausage	wS	140	47	2.98	537	203	1 999	419	14 746	1 520	187	740	296	2 418	227	16 266	573
	Conventional 3-0	wS	5 020	990	5.07	- [1]	-	-	-	8 435	1 088	6 010	-	-	-	-	9 523	-
Footner Lake	Styroblock	wS	167	111	1.50	532	341	1 752	435	5 924	876	278	873	214	2 187	150	6 800	211
	Sausage	wS	297	84	3.54	743	343	2 208	507	12 231	2 223	381	1 086	185	2 715	150	14 454	432
	Conventional 3-0	wS	3 410	710	4.80	2 026	674	-	-	4 472	924	4 120	2 700	-34	-	-	5 396	-

[1] Not sampled due to limited survival.

Table 11. Oven dry weights and shoot/root ratios of the 1972 container-reared and conventional seedlings at planting and 1, 3, and 5 years after planting

District	Container	Species	Shoot length (cm)	Oven dry wt (mg)		Ratio shoot/root	Oven dry wt (mg)						Total dry wt (mg)						
							shoot	root	shoot	root	shoot	root							
				shoot	root		1 yr		3 yr		5 yr		at planting	1 yr	% increment	3 yr	% increment	5 yr	% increment
Crowsnest	Styroblock	1P	4.6	214	172	1.24	714	523	2 120	654	-[1]	-	386	1 237	220	2 774	124	-	-
	Sausage	1P	4.1	194	110	1.76	461	221	2 528	540	-	-	304	682	124	3 068	350	-	-
	Styroblock	eS	6.6	188	98	1.92	498	402	1 870	482	9 926	1 464	286	900	215	2 352	161	11 390	384
	Sausage	eS	4.6	131	75	1.75	472	232	1 672	424	11 644	1 923	206	704	242	2 096	198	13 567	547
	Conventional 3-0	1P	17.5	5 300	1 260	4.21	4 992	1 756	21 850	3 765	104 842	16 196	6 560	6 748	3	25 615	280	121 038	372
	Conventional 3-0	eS	16.5	3 730	1 280	2.91	4 236	1 500	13 000	2 832	30 422	4 578	5 010	5 736	14	15 832	176	35 000	121
Bow	Styroblock	1P	5.1	297	239	1.24	569	521	3 848	1 688	43 645	9 762	536	1 090	103	5 536	408	53 407	865
	Sausage	1P	4.1	172	95	1.81	381	181	2 190	894	18 842	2 746	267	562	110	3 084	449	21 588	600
	Conventional 3-0	1P	17.0	5 840	1 110	5.26	7 240	2 050	22 233	7 540	56 574	9 122	6 950	9 290	34	29 773	220	65 696	121
Whitecourt	Styroblock	1P	6.6	324	280	1.16	844	516	12 524	1 934	121 919	20 696	604	1 360	125	14 458	963	142 615	886
	Sausage	1P	5.3	210	149	1.41	520	248	4 690	1 090	48 801	6 379	359	768	114	5 780	653	55 180	855
	Styroblock	wS	7.4	294	149	1.97	609	349	4 718	1 118	22 087	3 806	443	958	116	5 836	509	25 893	344
	Sausage	wS	5.8	181	75	2.41	588	214	5 574	976	15 100	1 769	256	802	213	6 550	717	16 869	158
	Conventional 3-0	1P	15.2	4 360	1 160	3.76	3 858	1 836	-	-	70 227	9 273	5 520	5 694	3	-	-	79 500	-
	Conventional 3-0	wS	27.2	6 840	1 730	3.95	7 424	2 064	13 532	3 475	31 744	3 470	8 570	9 488	11	17 007	79	35 214	107
Lac La Biche	Styroblock	wS	7.6	342	145	2.36	1 044	520	8 242	1 340	29 770	3 765	487	1 564	221	9 582	513	33 535	250
	Sausage	wS	4.8	121	61	1.98	540	250	5 394	844	30 047	2 673	182	790	334	6 238	690	32 720	424
	Conventional 3-0	wS	16.8	2 050	470	4.36	5 250	1 506	17 884	3 244	70 450	8 210	2 520	6 756	168	21 128	213	78 660	272
Grande Prairie	Styroblock	1P	6.1	235	181	1.30	1 666	713	36 064	5 406	190 649	33 654	416	2 379	472	41 470	1 643	224 303	441
	Sausage	1P	4.3	160	97	1.65	900	324	17 240	3 040	159 224	22 164	257	1 224	376	20 280	1 557	181 388	794
	Styroblock	wS	6.6	231	90	2.57	731	312	6 947	1 014	32 916	4 070	321	1 043	225	7 961	663	36 986	364
	Sausage	wS	5.1	112	43	2.60	458	193	4 046	730	22 288	2 491	155	651	320	4 776	634	24 779	419
	Conventional 3-0	1P	17.8	6 280	1 470	4.27	12 014	4 264	86 612	15 710	347 672	56 200	7 750	16 278	110	102 322	528	403 872	295
	Conventional 3-0	wS	17.5	2 680	650	4.12	5 124	1 142	19 448	3 112	63 596	9 804	3 330	6 266	88	22 560	260	73 400	225
Footner Lake	Styroblock	wS	8.1	292	121	2.41	982	305	9 568	2 072	22 909	4 235	413	1 287	212	11 640	804	27 144	133
	Sausage	wS	5.6	122	52	2.35	428	151	3 557	860	14 080	2 099	174	579	233	4 417	663	16 179	266
Wood Buffalo Nat. Park	Styroblock	jP	6.1	235	196	1.20	561	503	1 821	653	17 372	2 376	431	1 064	147	2 474	132	19 748	698
	Styroblock	wS	7.9	270	125	2.16	485	321	6 145	1 897	24 119	4 336	395	806	104	8 042	898	28 455	254
Fort Smith	Styroblock	jP	5.8	266	234	1.14	559	411	7 868	1 626	48 809	7 042	500	970	94	9 494	879	55 851	488

[1] Not sampled due to severe browsing by cattle (Crowsnest district) or limited survival (Whitecourt district).

Table 12. Oven dry weights and shoot/root ratios of the 1973 container-reared and conventional seedlings at planting and 1, 3, and 5 years after planting

District	Container	Species	Shoot length (cm)	Oven dry wt (mg)		Ratio shoot/root	Oven dry wt (mg)						Total dry wt (mg)						
							shoot	root	shoot	root	shoot	root							
				shoot	root		1 yr		3 yr		5 yr		at planting	1 yr	% increment	3 yr	% increment	5 yr	% increment
Crowsnest	Styroblock	1P	7.6	526	289	1.82	2 413	1 038	13 394	2 598	219 389	39 960	815	3 451	323	15 992	363	259 349	1 522
	Sausage	1P	3.6	197	107	1.84	677	224	4 646	748	82 915	12 742	304	901	196	5 394	499	95 657	1 673
	Styroblock	eS	7.9	436	244	1.78	1 738	834	6 768	1 537	75 539	14 980	680	2 572	278	8 305	223	90 519	990
	Sausage	eS	3.6	89	60	1.48	458	284	1 519	331	20 199	3 468	149	742	398	1 850	149	23 667	1 179
	Conventional 3-0	1P	16.8	2 960	620	4.90	3 637	1 240	6 898	1 335	120 630	15 532	3 580	4 877	36	8 233	69	136 162	1 554
	Conventional 3-0	eS	17.5	2 815	820	3.43	6 320	2 180	9 968	2 118	36 195	6 628	3 635	8.500	134	12 086	42	42 823	254
Bow	Styroblock	1P	6.6	610	321	1.90	1 185	593	8 819	1 484	42 159	7 700	931	1 778	91	10 303	479	49 859	384
	Sausage	1P	4.3	186	124	1.50	358	186	6 786	1 174	10 295	2 042	310	544	75	7 960	1 363	12 337	55
	Conventional 3-0	1P	17.3	4 660	1 080	4.31	5 166	2 022	13 420	3 802	34 542	5 028	5 740	7 188	25	17 222	140	39 570	130
Whitecourt	Styroblock	1P	8.6	522	210	2.49	1 420	624	7 910	1 156	13 493	2 033	732	2 044	179	9 066	344	15 526	71
	Sausage	1P	5.1	183	84	2.16	460	188	1 135	194	9 427	1 291	267	648	143	1 329	105	10 718	706
	Styroblock	wS	9.1	418	117	3.57	1 050	425	2 412	364	22 594	2 232	535	1 475	176	2 776	88	24 826	794
	Sausage	wS	5.1	125	39	3.21	290	120	671	110	4 586	529	164	410	150	781	90	5 115	555
	Conventional 3-0	wS	27.7	6 789	1 926	3.52	7 828	2 034	10 138	2 106	29 038	4 204	8 715	9 862	13	12 244	24	33 242	171
Lac La Biche	Styroblock	wS	9.9	544	175	3.10	1 352	500	8 559	1 041	34 331	3 252	719	1 852	158	9 600	418	37 583	291
	Sausage	wS	4.3	108	41	2.61	366	119	2 807	439	18 610	1 690	149	485	226	3 246	569	20 300	525
	Conventional 3-0	wS	16.8	3 030	900	3.64	4 488	1 360	13 196	2 452	66 996	6 294	3 930	5 848	49	15 648	168	73 290	368
Grande Prairie	Styroblock	1P	10.7	631	331	1.90	1 147	693	13 674	2 220	-- [1]	8 492	962	1 840	91	15 894	764	--	--
	Sausage	1P	3.8	169	108	1.56	280	150	3 589	609	--	2 981	277	430	55	4 198	876	--	--
	Styroblock	wS	10.7	553	189	2.93	939	458	4 125	811	15 654	1 920	742	1 397	88	4 936	253	17 574	256
	Sausage	wS	4.3	125	48	2.58	226	96	1 008	154	5 297	926	173	322	86	1 162	261	6 223	436
	Conventional 3-0	1P	19.3	3 610	720	4.98	4 442	1 626	21 220	3 354	--	7 850	4 330	6 068	40	24 574	305	--	--
	Conventional 3-0	wS	14.7	1 490	370	4.42	2 912	1 032	4 714	886	23 178	3 164	1 860	3 944	112	5 600	42	26 342	370
Footner Lake	Styroblock	wS	8.1	477	216	2.20	936	504	2 193	602	10 555	1 677	693	1 440	108	2 795	94	12 232	338
	Sausage	wS	4.3	100	46	2.15	199	98	1 241	317	6 010	737	146	297	103	1 558	424	6 747	333
	Conventional 3-0	wS	27.9	5 085	875	5.81	4 694	1 212	4 117	675	27 516	3 892	5 960	5 906	-1	4 792	-19	31 408	555
Fort Smith	Styroblock	jP	7.6	497	307	1.62	864	564	28 137[2]	3 282[2]			804	1 428	78	31 419[2]	2 100		

[1] Severely browsed by snowshoe hares.
[2] 4 yr after outplanting.

Table 13. Oven dry weights and shoot/root ratios of the 1974 container-reared and conventional seedlings at planting and 1 and 3 years after planting

District	Container	Species	Shoot length (cm)	Oven dry wt (mg)		Ratio shoot/root	Oven dry wt (mg)				Total dry wt (mg)				
				shoot	root		shoot	root	shoot	root					
							1 yr		3 yr		at planting	1 yr	% increment	3 yr	% increment
Crowsnest	Styroblock	1P	10.7	562	159	3.53	1 339	449	32 188	4 140	721	1 788	148	36 328	1 932
	Sausage	1P	8.6	497	174	2.85	1 284	317	23 611	3 229	671	1 601	138	26 840	1 576
	Styroblock	eS	9.6	336	117	2.87	868	303	8 721	1 966	453	1 171	158	10 687	813
	Sausage	eS	9.9	320	124	2.59	782	270	8 352	1 609	444	1 052	137	9 961	847
	Conventional 3-0	1P	15.2	2 909	496	5.87	2 338	688	23 576	3 626	3 405	3 026	-11	27 202	799
	Conventional 3-0	eS	17.5	2 410	469	5.14	1 756	546	15 100	2 054	2 879	2 302	-20	17 154	645
Grande Prairie	Styroblock	1P	10.4	565	127	4.45	2 070	770	21 156	3 160	692	2 840	310	24 316	756
	Sausage	1P	11.2	515	130	3.98	2 198	626	25 596	3 399	645	2 824	338	28 995	927
	Styroblock	wS	9.6	332	50	6.71	1 890	400	11 830	1 467	382	2 290	499	13 297	481
	Sausage	wS	10.9	304	41	7.40	1 295	300	8 760	1 140	345	1 595	362	9 900	521
	Conventional 3-0	1P	8.4	882	226	3.91	2 200	730	10 928	1 493	1 108	2 930	164	12 422	324
	Conventional 3-0	wS	20.3	2 267	362	6.26	3 542	868	9 870	1 582	2 629	4 410	68	11 452	160
Fort Smith	Styroblock	jP	8.6	732	257	2.85	1 336	608	12 927	1 872	989	1 944	96	14 799	661

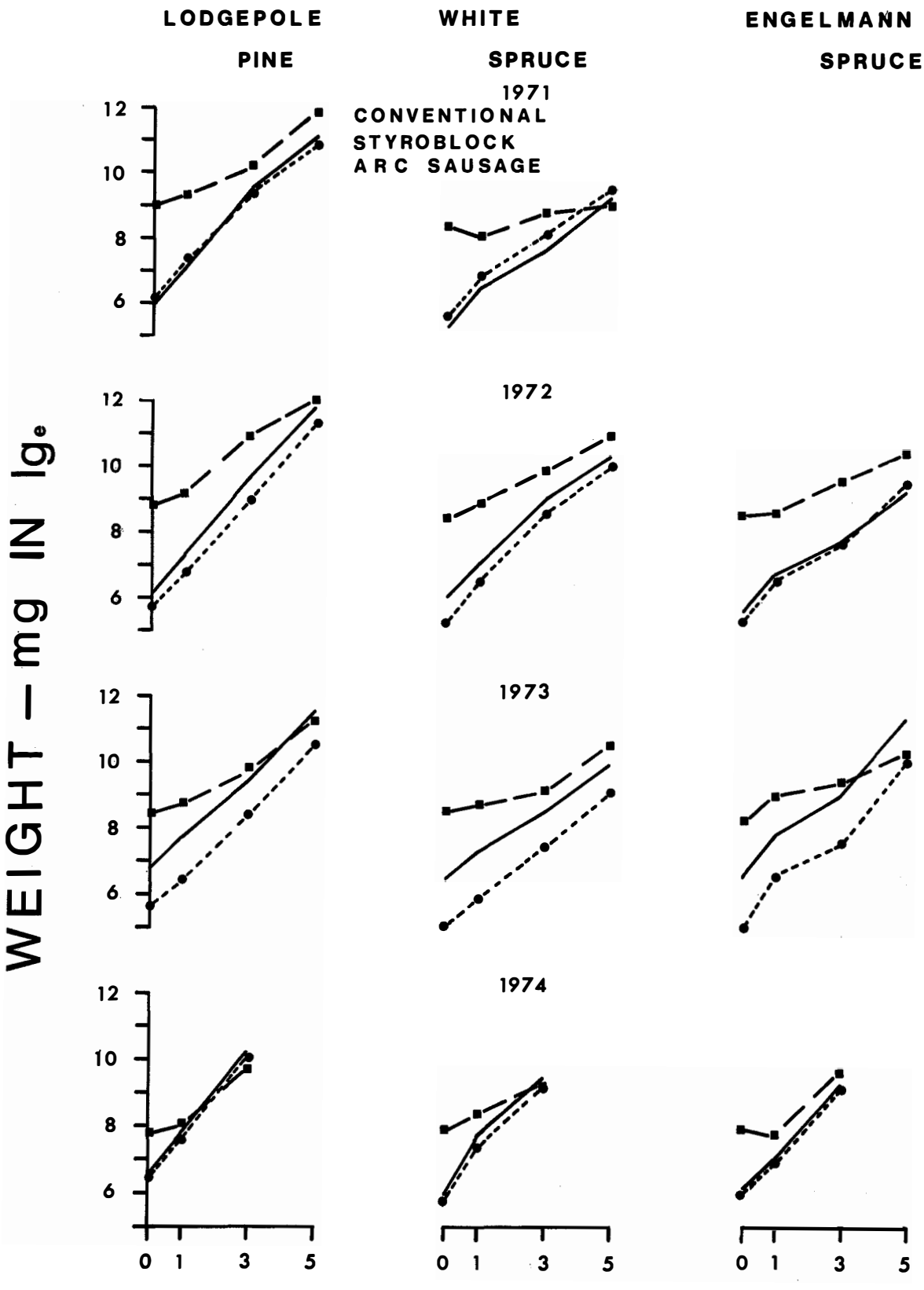

Figure 4. Average yearly total seedling dry weight by seedling type and year of planting.

Table 14. Container seedling dry weight as a percentage of the conventional

Species	Container	At planting	1st year	3rd year	5th year
lP	Styroblock	9	20	60	66
lP	Sausage	7	16	48	42
wS	Styroblock	8	20	43	59
wS	Sausage	6	16	34	51
eS	Styroblock	9	26	48	32
eS	Sausage	8	22	44	39

Table 15. Styroblock container seedling dry weight as a percentage of the sausage seedling dry weight

Species	Container	At planting	1st year	3rd year	5th year
lP	Styroblock	120	124	124	157
wS	Styroblock	134	124	125	114
eS	Styroblock	114	118	108	84

Table 16. Average dry weight of conventional and container seedlings after 5 years (g)

Species	Conventional	Styroblock	Sausage
lP	170	112	72
wS	36	21	19
eS	35	11	14

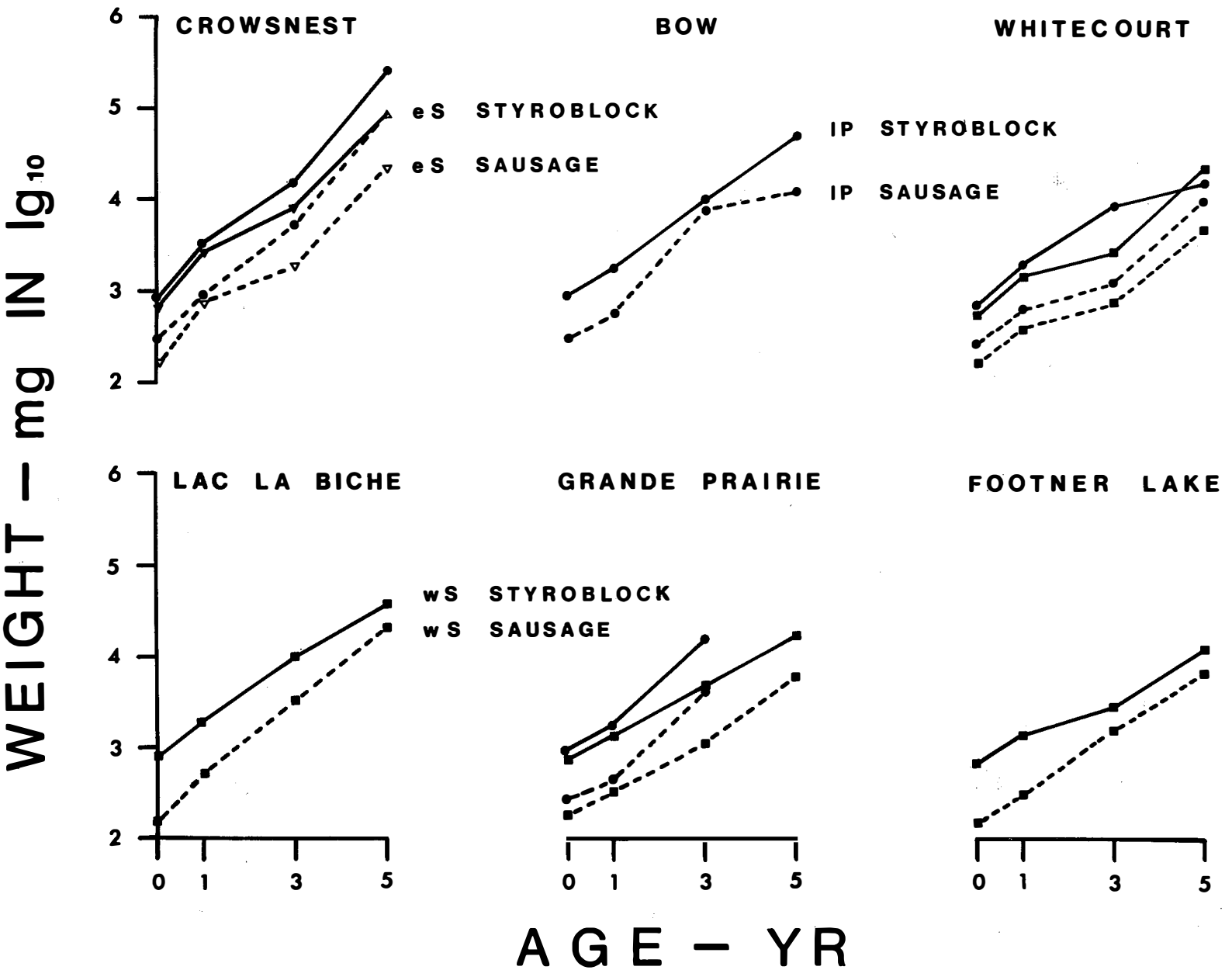

Figure 5. Average yearly total seedling dry weight of 1973 plantations.

however, that "growth in the closely packed tubes may fall short of the full growth potential of the larger rooting volume as a result of aerial competition between seedlings."

Container seedlings usually have been reared with the view that a well-balanced seedling with a shoot/root ratio between 1 and 2 would perform better after planting (Ferdinand 1972). However, the 1971 spruce and pine sausage seedlings with shoot/root ratios ranging from 2.98 to 3.63 outperformed the styroblocks that had shoot/root ratios ranging from 0.94 to 1.98 (Tables 5 and 10, Figs. 2 and 3). The 1974 Grande Prairie container seedlings had shoot/root ratios ranging from 3.98 to 7.40 for both species (Table 13), the highest of any previously produced, yet growth in this location was best to the 3rd year (Table 9). Simple linear regressions showing the influence of initial seedling weight and shoot/root ratios on the weight of white spruce container seedlings 1 year after planting are given in Fig. 6. These regressions show that the weight obtained 1 year after planting is proportional to initial seedling weight and the shoot/root ratio; larger seedlings with larger shoot/root ratios of up to 7.40 had significantly greater weight increases than smaller seedlings with smaller shoot/root ratios of around 2.00. Lodgepole pine and jack pine container seedlings showed a similar relationship.

Average shoot/root ratios at planting and during each excavation are given in Table 17 for the 1971, 1972, and 1974 plantations. Shoot/root ratios of lodgepole pine container seedlings increased each year after planting. Lower shoot/root ratios 1 year after planting for the white spruce container seedlings, the Engelmann spruce styroblock seedlings, and all the conventional seedlings occurred primarily through top loss from winter drying and frost damage. During the 3rd- and 5th-year excavations, shoot/root ratios ranged from 4.38 to 8.42 for container seedlings and from 5.24 to 7.62 for conventional. These high shoot/root ratios as early as the 3rd year after planting indicate that this is a normal situation, comparable to what occurs with naturally grown seedlings, and that this range of shoot/root ratios may be desirable for container seedlings at planting.

Frost Heaving

Frost heaving was extensive in the 1971 plantations and affected more ARC seedlings than styroplugs, but it occurred less frequently in the following 3 years. It was not considered a problem in the 1973 or 1974 plantings. The greatest amount of heaving took place during the 1st year in the 1971 Bow area; 54% of the sausage seedlings were heaved (Table 5). This area was characterized by shallow topsoil over shale, and the planters at the time had remarked on the difficulty of planting. Shallow planting with a dibble, which may not have been suitable for this particular site, might have contributed to the high rate of heaving. Moist clay soils in the 1971 Whitecourt and Footner Lake areas also had high heaving rates. Heaving need not be a factor in container planting if proper care is taken to ensure that the plug is set just below the ground surface and that a small amount of soil is pressed over the top. This can be accomplished by stepping on the top edge of the planted plug, just as in planting conventional seedlings.

Injuries and Damages

The 1971 plantings were affected by drought in the Bow and flooding at Footner Lake, Lac La Biche, and Whitecourt (in the styroblock white spruce). The Lac La Biche area was also browsed by snowshoe hare (*Lepus americanus*). The 1972 Crowsnest area was seriously browsed and trampled by cattle, and the Footner Lake area was flooded for an extended period. A moderate amount of snowshoe hare browsing took place on the 1973 Grande Prairie pine container seedlings prior to the 3rd-year remeasurement; after four growing seasons both container and conventional seedlings were severely damaged by browsing. Interestingly, no browsing occurred on white spruce seedlings. Leaders on the 1971 and 1972 pine plantations at Whitecourt were extensively browsed by big game animals in 1978, 7 and 6 years, respectively, after planting. Moderate to severe browsing also took place in 1978 on the 1974 Grande Prairie pine plantations. The 1973 Whitecourt area was considered to be an off-site area for pine. It was scarified in 1971, and at the time

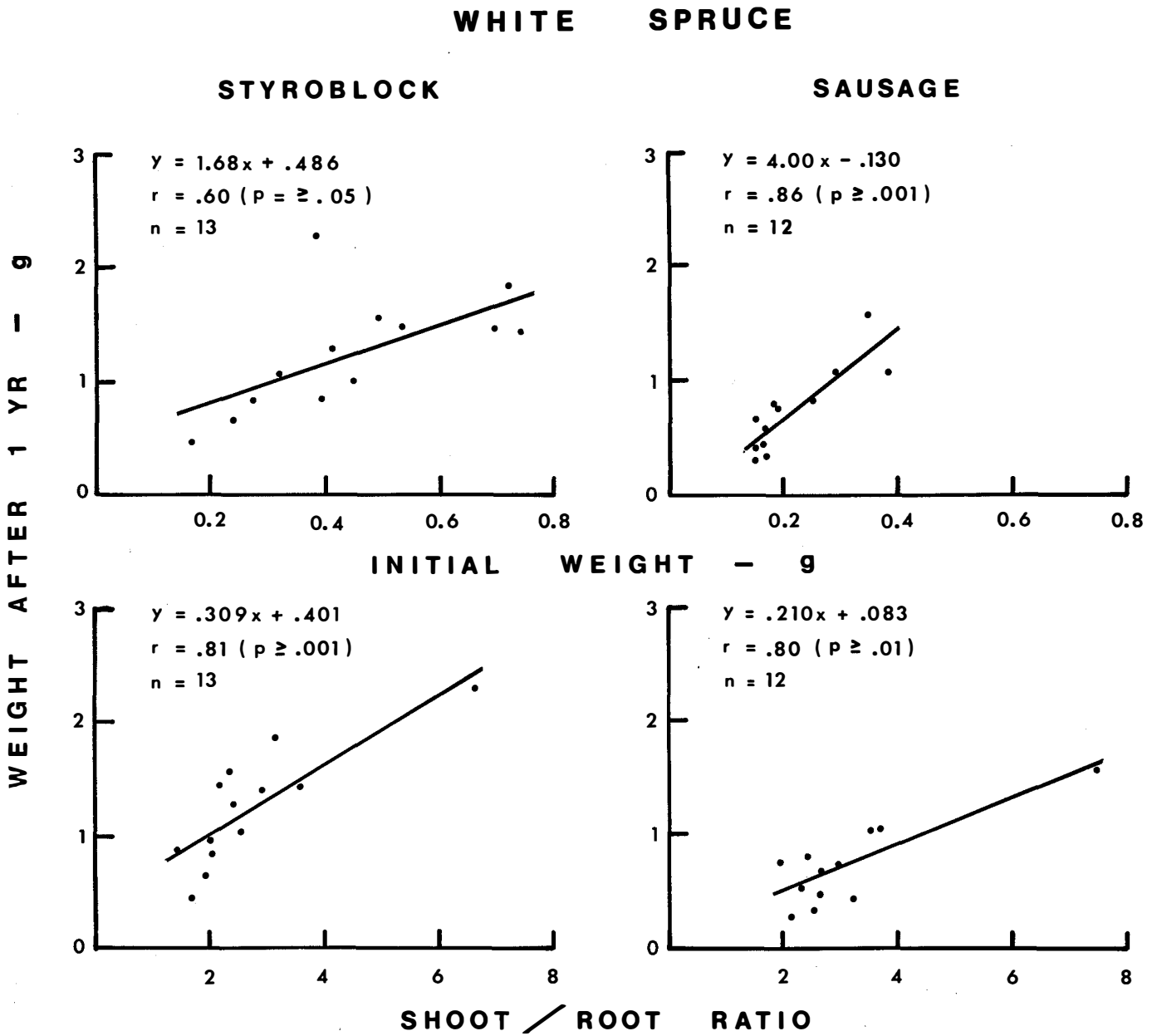

Figure 6. Relationships between seedling weight after 1 year and initial weight or shoot/root ratio.

Table 17. Average shoot/root ratios by species and seedling type

Species	Container	At planting	1st year	3rd year	5th year
lP	Styroblock	1.66	2.01	6.31	5.72
lP	Sausage	2.55	2.90	6.25	7.12
wS	Styroblock	2.71	2.50	5.77	7.20
wS	Sausage	3.22	2.63	5.88	8.42
eS	Styroblock	2.44	1.94	4.38	6.78
eS	Sausage	2.27	2.50	5.04	6.06
lP	Conventional	4.51	2.92	5.24	6.64
wS	Conventional	4.61	3.76	5.31	7.62
eS	Conventional	3.53	2.93	5.90	6.64

of planting in 1973 competition was already severe. Grass and alder (*Alnus rugosa* [Du Roi] Spreng.) subsequently overtopped most seedlings. Lodgepole pine was most affected by this competition; numerous seedlings were noted to be weak, with small diameter growth. White spruce seedlings were generally healthy and better able to withstand the competition.

A visit to the Lac La Biche area in August 1979 revealed extensive browsing by snowshoe hare on the white spruce terminals. Browsing was probably 80% or greater on each of the 1971-73 plantations, and most of these seedlings had twin or multiple leaders at this time. It appeared that browsing took place above the snow cover at about the 50-70 cm height and that only a limited number of seedlings that were 1 m or more in height or protected by the snow or vegetation escaped browsing.

DISCUSSION

Container seedlings planted in late summer had good subsequent survival and growth rates, but conventional seedlings planted after June resulted in plantation failures (Tables 2 and 4). Similar results have been reported by Carlson (1972); conventional jack pine in southeastern Manitoba had increasing mortality as the planting season progressed. Ackerman and Johnson (1962) also reported increasing mortality and decreasing growth of conventional white spruce in Alberta with a continuous weekly planting period from May to October. In Ontario, conventional jack pine seedlings planted at 2-week intervals from May to October had good spring and fall survival rates after the first growing season, but height growth of the May-planted seedlings after 15 years was significantly greater than that of the later plantings (Bunting and Mullin 1967). The spring planting period may be more successful for conventional seedlings than a later summer planting period because of a better moisture supply; in addition, as the season progresses, storage problems become a factor.

The importance of using large, good quality planting stock is shown in the performance of the 1973 plantations. Survival was better for styroblock seedlings than for sausage seedlings in eight of the nine comparable plantings, and average heights of the styroplugs exceeded the sausages in all plantations (Table 7). The larger weights of the styroblock seedlings were maintained during each remeasurement (Table 12, Figs. 4 and 5).

Pollard (1978) also found that the effects of 1st-year differences in initial heights of white spruce seedlings were amplified 3 years after planting. An additional 3-week rearing period in the greenhouse, from 8 to 11 weeks, produced a larger seedling that to the 3rd year grew 50% more in height than a seedling reared only 8 weeks.

Where seedlings similar in size and weight were planted, whether from styroblock or sausage containers, field performance in terms of growth and survival was about equal (Tables 8 and 13). In greenhouse rearing, more time and attention were required for the sausages. When planted, the entire polyethylene sausage casing must be removed. This is a time-consuming operation and involves one more handling of the sausages, but it is imperative in order to prevent heaving and to allow free root egress (Walker and Johnson 1974, Johnson and Walker 1976). With its tapered plug configuration, the styroplug proved to be easier to plant. Problems of root deformities within the styroblock have been alleviated with the introduction of raised ridges, and Burdett (1978) suggests an alternative method of controlling deformities that makes the use of this container even more attractive. Burdett painted the container walls with cupric carbonate to inhibit lateral root growth. When planted, however, the seedling roots quickly resumed growth from the plug, and root form resembled that of a natural seedling. Mitchell and Kay (1972) cited initial costs in material, exclusive of media and labor, of $2.60 and $6.98 per 1000 seedlings for the sausages and the styroblock, respectively. The cost advantage of the sausage container must be balanced, however, against the extra time required for rearing and the additional handling needed to remove the polyethylene casing, with the resultant risk of plug and seedling damage. Dibbles conforming to the size of the plugs were found to be the easiest and quickest means of planting; planting bars, spades, and the Pottiputki planting tool were used on a trial basis.

Seedlings grown in smooth-walled styroblock cavities developed spiralling root systems that were still apparent on seedlings excavated 5 years after planting. The introduction of raised ridges stopped the spiralling by directing root growth to the bottom opening, where the roots were air pruned (Fig. 7). A number of sausage plugs were excavated that had a root with a loop that was directed upward before growing down once more. This kink may have occurred in the greenhouse from improper air pruning, by peat accumulation between the plug and the screened bottom, or by a supporting crosspiece that redirected the emerging root upward into the plug. Live roots projecting from the bottom of the plug also can be deformed when the plug is placed into the ground. Removing any loose peat and ensuring that the trays are supported only on the edges would eliminate this problem. Outplanted lodgepole pine sausage seedlings generally had several well-spread lateral roots. Holes too shallow to accommodate the roots of conventional seedlings caused deformities such as a bunched root system and development directed to only one side of the seedling. Typical root systems and seedlings 3 and 5 years after outplanting are shown in Figs. 8-20.

The practice in British Columbia is to remove the seedlings from the styroblocks before they are shipped to the field (Vyse and Ketcheson 1974). Culling at the nursery, space economy in transit and storage, cold storage, and reuse of the styroblocks are cited as advantages. There are, however, also decided advantages in retaining the seedlings in the original container right up to planting time. Once a healthy seedling has been reared, the most important step that remains is proper planting. Container trays are the easiest means of carrying seedlings in the field, and ease of transport is an essential step in reducing the work load of the planter. In addition, the original plug form is retained, which ensures that dibbles can be used for planting. With styroblock tray capacities of up to 240 seedlings and seedling establishment of 80-90%, each tray would have 200 or more seedlings. A planter would then be handling only 5 to 10 trays on an average planting day. Some tray breakage would occur, but the majority of trays could be reused two or three times before being discarded. Transportation and storage in the original container would reduce mechanical damage to individual plugs and seedlings through handling, and if planting operations

Figure 7. Pine plugs 13 weeks after seeding in unribbed (left) and ribbed (right) styroblock containers.

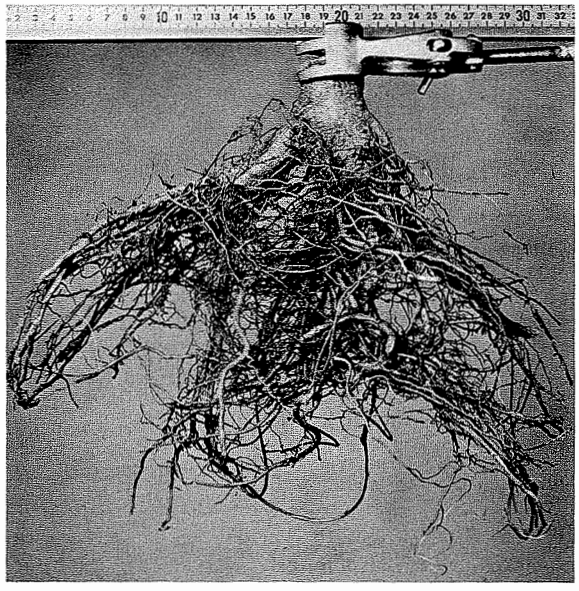

Figure 8. Root system of lodgepole pine conventional seedling 5 years after planting.

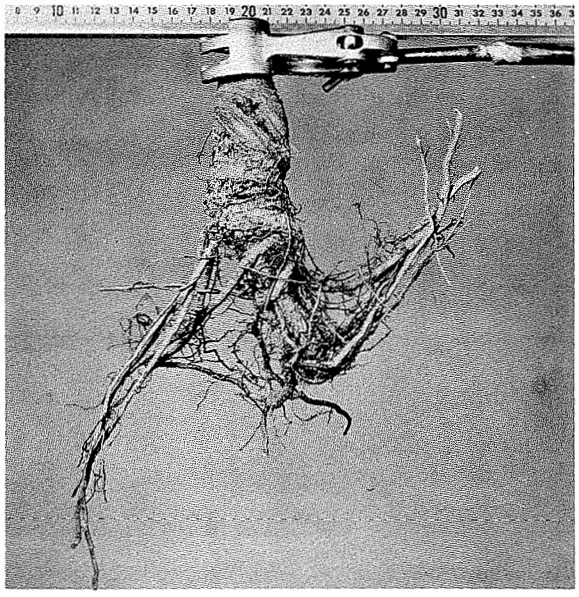

Figure 9. Root system of lodgepole pine unribbed styroblock seedling 5 years after planting.

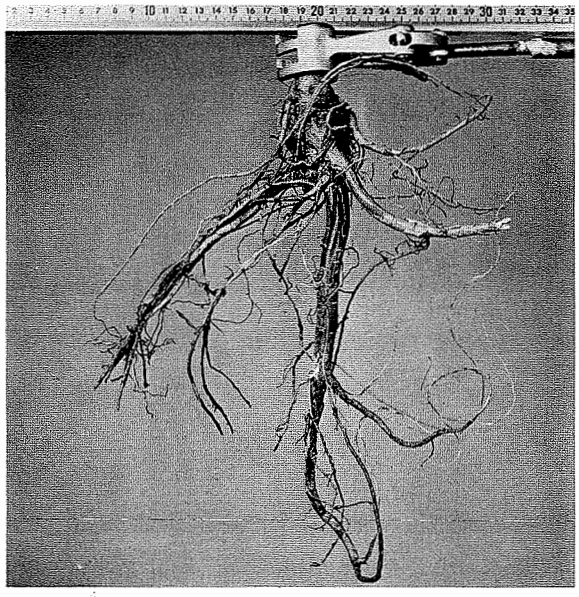

Figure 10. Root system of lodgepole pine sausage seedling 5 years after planting.

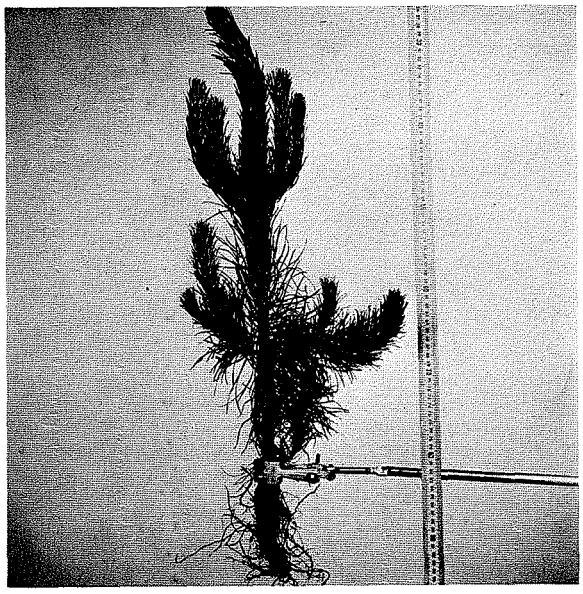

Figure 11. Lodgepole pine ribbed styroblock seedling 3 years after planting.

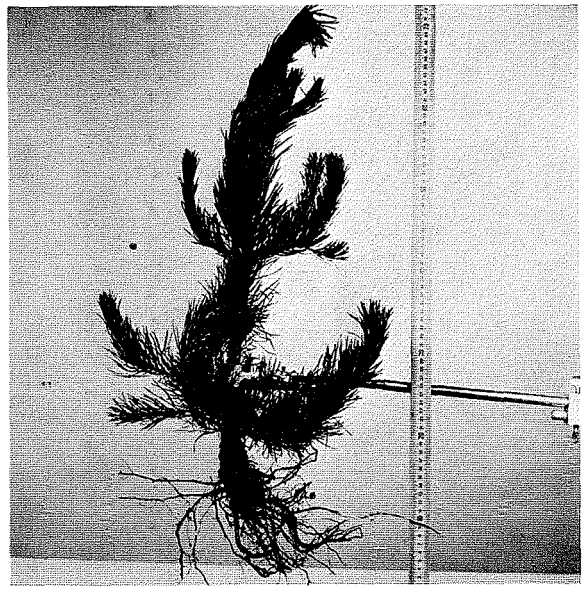

Figure 12. Lodgepole pine sausage seedling 3 years after planting.

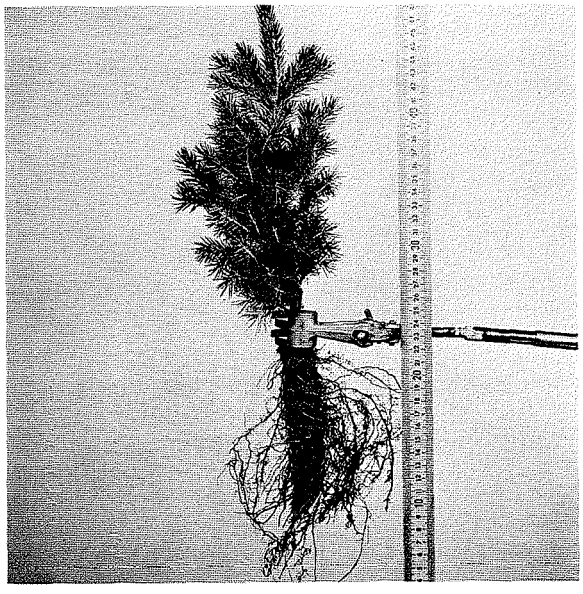

Figure 13. Engelmann spruce ribbed styroblock seedling 3 years after planting.

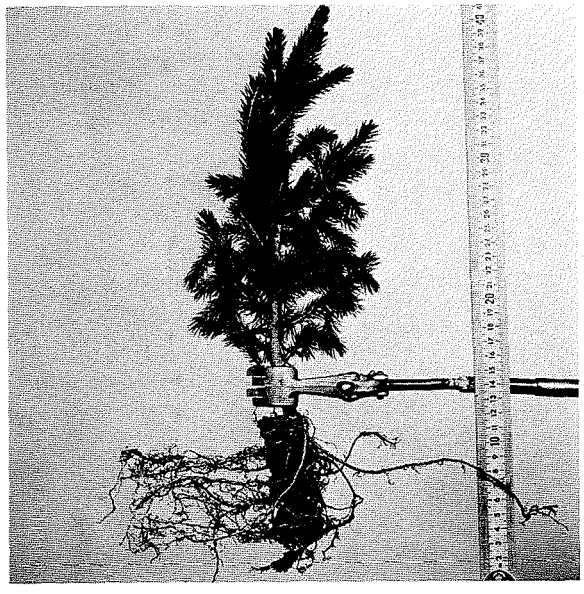

Figure 14. Engelmann spruce sausage seedling 3 years after planting.

Figure 15. Lodgepole pine conventional seedling 5 years after planting.

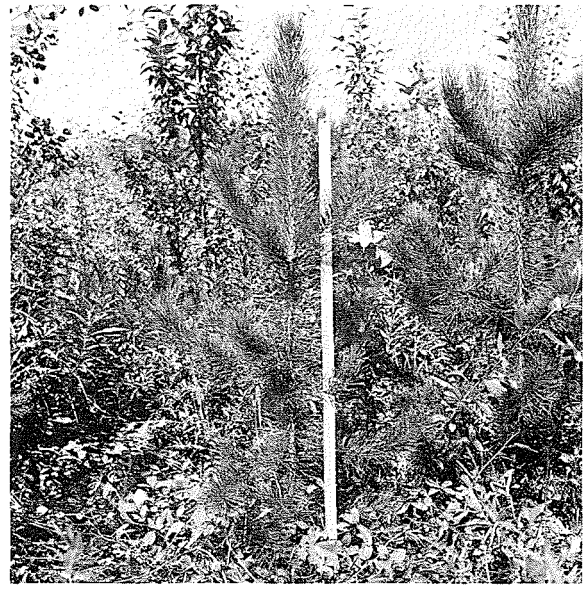

Figure 16. Lodgepole pine unribbed styroblock seedling 5 years after planting.

Figure 17. Lodgepole pine sausage seedling 5 years after planting.

Figure 18. White spruce conventional seedling 5 years after planting.

Figure 19. White spruce unribbed styroblock seedling 5 years after planting.

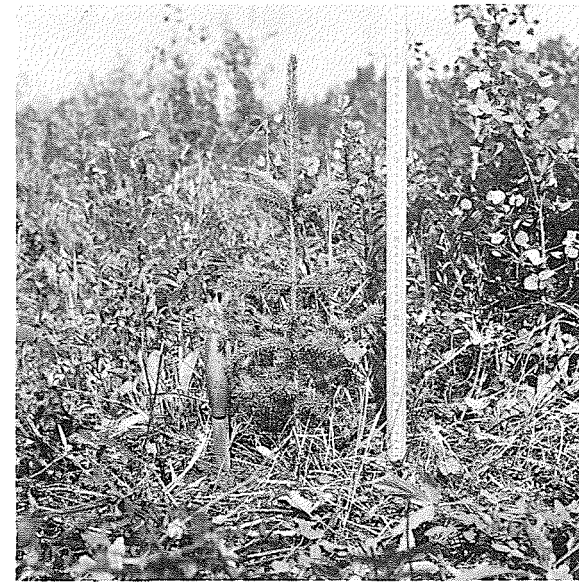

Figure 20. White spruce sausage seedling 5 years after planting.

are delayed in the field, the original container facilitates watering for seedling maintenance.

Bulldozed strips were used to prepare 10 of the 23 planting areas (Table 2). In the Whitecourt district, large overmature trembling aspen (*Populus tremuloides* Michx.) were left standing between the bulldozed rows, and these aspen are now being windthrown and are causing further mortality in the planted seedlings. This method of site preparation also resulted in numerous dips or depressions up to 10 m or more in length. Mortality due to flooding occurred almost exclusively in these depressions. The heaviest grass competition occurred here, subsequently overtopping and smothering a large proportion of the seedlings. Game animals used these bulldozed strips for travel purposes, which resulted in added mortality from trampling and browsing. With the exception of the 1974 plantations, most seedlings were planted at 60 X 60 cm spacing. This close spacing within a depression that was subsequently flooded affected a significant number of seedlings, which is reflected in the overall survival and growth rates. On bladed areas or bulldozed strips, varying amounts of topsoil were stripped away, and only the B horizon remained. Seedlings planted on these stripped locations were noticeably smaller in height than those just a few metres away where less soil disturbance had taken place. With microsite planting and irregular spacing, better survival and growth rates can be expected.

CONCLUSIONS AND RECOMMENDATIONS

1. Container-reared seedlings were successfully planted during June, July, and August; conventional plantations established after June were failures.

2. Initial preplanting weight is a very important characteristic; larger, heavier seedlings had better survival and growth rates. Longer rearing periods to maximize seedling size to the full capability of the container may be desirable. Larger containers, producing larger seedlings, should also be considered for good quality sites with severe competition.

3. A shoot/root ratio of between 1 and 2 for container seedlings was not necessarily optimum; larger seedlings with higher shoot/root ratios performed better after outplanting.

4. Both the styroblocks and the ARC sausages produced large, healthy stock with good field performance. Larger seedlings were produced in the styroblocks in 3 of the 4 years; rearing the sausage seedlings required more time and attention.

5. Dibbles proved to be the easiest and quickest method of planting container seedlings.

6. The entire polyethylene casing must be removed from the ARC sausage plugs before planting.

7. ARC lodgepole pine container seedlings usually had several well-spread lateral roots.

8. Frost heaving of container seedlings to a large extent can be eliminated by setting the plug approximately 1 cm below the ground surface and pressing a small amount of soil over the top.

9. Shallow topsoils underlain with shale or containing a large number of stones should be planted with bars or spades, as dibbles fail to make adequate holes for container plugs. Dibble planting on dry to very dry, fine soils is extremely difficult, and the planting operation should be delayed until there is adequate moisture to ensure a reasonable planting rate and to avoid the possibilities of shallow planting.

10. To minimize soil disturbance and to prevent continuous bulldozed strips with their resultant problems of animal traffic and water channeling, increased use should be made of a scarifier such as the Bräcke cultivator where forest conditions permit.

11. The establishment of plantations within prime snowshoe hare habitat should be considered carefully during the approaching peak of the snowshoe hare population cycle. Four-year-old lodgepole pine at Grande Prairie and 5- to 7-year-old white spruce at Lac La Biche less than 1 m in height were badly damaged by browsing. Keith (1972) reported that within 3-4 years from planting there was extensive snowshoe hare browsing on conventional 3-0 and 3-2 white spruce underplanted in aspen stands, and he suggests that seedlings may have to be at least 2 m in height to escape further damage. Aspen conversion attempts should be discouraged due to inherent hare and other problems associated with converting a pioneer species. In the rehabilitation of better sites supporting a sparse tree cover, planting should be discontinued prior to and during the peak of the snowshoe hare population cycle. Only good quality conventional and large container seedlings reared in larger containers should be planted, so that seedlings would be 1-2 m in height before the next snowshoe hare population peak occurred. Because bulldozed strips provide easy access, use of the Bräcke cultivator could reduce browsing by making the seedlings less accessible.

12. Where snowshoe hare browsing is not anticipated, attention should be given to the choice of species for reforestation on bulldozed strips, which permit and even encourage access by game animals. In the Whitecourt district, lodgepole pine 2 m or more in height were badly damaged by browsing of big game animals 6 and 7 years after planting, but no browsing occurred on the white spruce seedlings.

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