BLACK SPRUCE, WHITE SPRUCE, AND JACK PINE OUTPLANTINGS IN BOREAL ONTARIO: BARE-ROOT VS. PAPERPOT STOCK AND SPRING VS. SUMMER PLANTING

J.E. WOOD

and

S.W.J. DOMINY

GREAT LAKES FOREST RESEARCH CENTRE

CANADIAN FORESTRY SERVICE

GOVERNMENT OF CANADA

1985

INFORMATION REPORT O-X-368

Catalogue No. Fo46-14/368E
ISBN 0-662-13991-7
ISSN 0822-210X

Additional copies of this publication are available at no charge from:

*Communications Services
Great Lakes Forest Research Centre
Canadian Forestry Service
Government of Canada
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7*

ABSTRACT

This report presents five-year results of a study to evaluate the comparative field performance of spring- and summer-planted Japanese paperpot, transplant and/or seedling stock. From 1974 to 1981, 18 experimental plantations were established on a range of typical boreal forest sites in Ontario. Included in the experiments were one or more of the following species: black spruce (*Picea mariana* [Mill.] B.S.P.), white spruce (*P. glauca* [Moench] Voss), and jack pine (*Pinus banksiana* Lamb.).

Several trends were evident in most of the experiments. Spring-planted spruce transplants were superior to spring-planted paperpot and seedling stock. Black spruce paperpots planted in July generally had higher survival and were in better condition than was July-planted bare-root stock. Summer-planted white spruce paperpot and rising transplant stock demonstrated equivalent performance. The spring-planted jack pine paperpots frequently achieved survival and growth rates similar to those of spring-planted seedlings and substantially higher than those of July-planted rising seedlings. It appears that paperpot stock of the three species examined may be planted until the end of July provided that good care is taken of stock during transportation and handling.

RÉSUMÉ

Les auteurs présentent les résultats de cinq années d'évaluation et de comparaison du rendement sur le terrain de semis, de plants repiqués et de plants en pots de papier japonais, mis en terre au printemps ou à l'été. Entre 1974 et 1981, ils ont créé 18 plantations expérimentales dans une série d'emplacements types de la forêt boréale ontarienne. Les expériences ont porté sur une ou plusieurs espèces: l'épinette noire (*Picea mariana* [Mill.] B.S.P.), l'épinette blanche (*P. glauca* [Moench] Voss) et le pin gris (*Pinus banksiana* Lamb.).

Les expériences ont, pour la plupart, permis de dégager certaines constantes: les plants repiqués d'épinette mis en terre au printemps ont donné de meilleurs résultats que le matériel en pots de papier et les semis plantés en même temps. L'épinette noire en pots de papier plantée en juillet a eu un taux de survie généralement meilleur et était en meilleur état que le matériel à racines nues mis en terre en même temps. Le rendement s'est avéré le même, dans le cas de l'épinette blanche en pots de papier et des plants repiqués plantés en été. Les plants de pin gris en pots de papier plantés au printemps ont souvent eu des taux de survie et de croissance comparables aux semis plantés au printemps et notablement plus élevés que les semis de juillet. Il semble que, pour les troix espèces, le matériel en pots de papier peut se planter jusqu'à la fin de juillet, pourvu qu'il ait été transporté et manipulé adéquatement.

ACKNOWLEDGMENTS

Numerous individuals and organizations have made significant contributions to this study. C.R. Mattice, formerly of the Great Lakes Forest Research Centre (GLFRC), directed the work from 1974 to 1980 and consolidated much of the site information prior to the preparation of this report. J.B. Scarratt, of GLFRC, initiated the study and reared the paperpot stock. F.W. Curtis, of GLFRC, provided technical assistance from the outset. B.R. Canning and M. Laporte, of GLFRC, measured sample trees and assisted with the production of the paperpot stock. The Ontario Ministry of Natural Resources provided scarified cutovers and bare-root planting stock. In addition, they also contributed to the funding of this work from 1977 to 1979. Starting in 1980, funding was provided by the Canada-Ontario Forest Management Subsidiary Agreement. Various contractors (KBM Forestry Consultants Inc., Amik Forest Consultants, Matcam Forestry Consultants Inc., and Arbex Forest Development Company Ltd.) contributed by establishing and assessing field plantings.

The authors wish to express their appreciation to all of these individuals and organizations.

TABLE OF CONTENTS

(cont'd)

TABLE OF CONTENTS (cont'd)

(cont'd)

TABLE OF CONTENTS (concl.)

Cover photo: Operational tree planting in northern Ontario.

INTRODUCTION

One of the most important challenges facing foresters today is that of regenerating cutover lands adequately. What is needed is an efficient regeneration system that makes both biological and economic sense (Barber 1982). A containerized seedling production and planting program may provide such a system and at the same time augment the traditional bare-root planting programs.

Ontario has been producing and planting trees operationally in various containers since 1966. The first container to be used widely was the Ontario tube. However, the field performance of stock grown in this container (tubelings) proved unsatisfactory (Haig[1], Heeney 1982). Production of tubelings was phased out in the early 1970s. The Japanese paperpot, widely used in Finland (Haavisto and Jeglum 1984), was adopted as a replacement in the mid-1970s.

The current containerized reforestation program in Ontario has increased from a modest 2.9 million in 1973 (Heeney 1982) to 31.0 million shippable trees in 1982 (Scarratt 1985). Of the containerized trees produced in 1982, 69% were grown in Japanese paperpots (ibid.). In comparison, 61 million bare-root trees were produced in 1982 (ibid.).

The recent increase in size of the provincial paperpot planting program has intensified the debate about whether the performance of containerized outplants can match that of the bare-root product and whether containerized planting can be effectively extended into the summer months.

OBJECTIVES

In 1974, the Great Lakes Forest Research Centre in cooperation with the Ontario Ministry of Natural Resources initiated a research study to compare the outplant performance of paperpot and bare-root stock and spring (May-June) and summer (July) planting on a wide range of typical Boreal Forest Region (Rowe 1972) sites in Ontario.

This report summarizes by species the results obtained to date (1985) in 18 separate outplanting experiments located across northern Ontario (Fig. 1 and Table 1) and conducted during the period 1974 to 1981. In all, about 22,000 trees were planted and assessed for survival, condition, and growth.

SPECIES

Black spruce *(Picea mariana* [Mill.] B.S.P.), white spruce *(P. glauca* [Moench] Voss), and jack pine *(Pinus banksiana* Lamb.) are extremely important tree species as far as the provincial economy is concerned (Anon. 1979b). Because of their importance and regional occurrence, these three species were selected for investigation. Each experiment includes one or more of these species.

---

[1] Haig, R.A. 1972. Assessment of factors affecting the survival of tubed seedlings. Cupa Lake, Ontario, 1967-1970. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Intern. Rep. O-35. 20 p. + appendices.

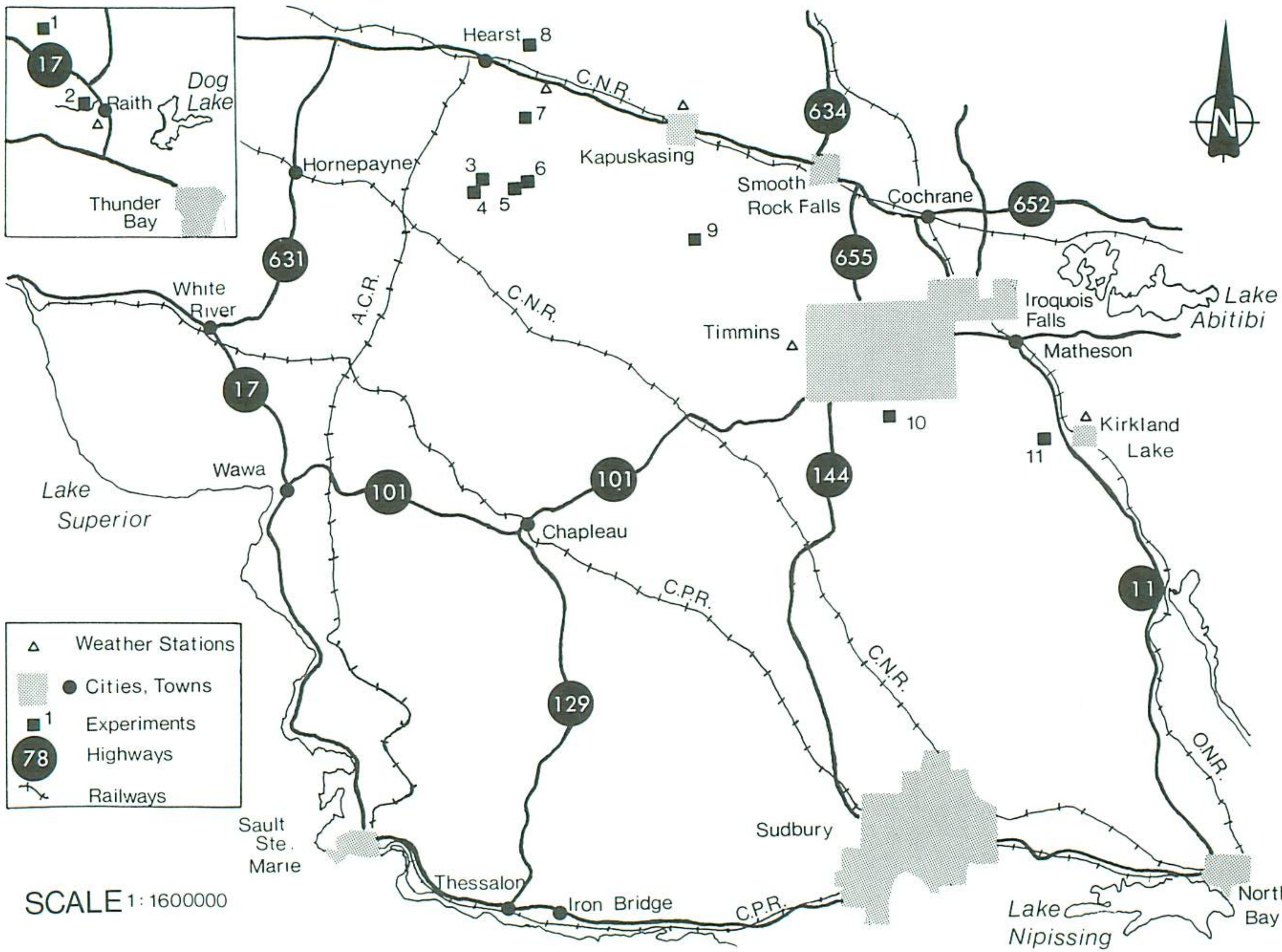


Figure 1. Location of experimental plantings and weather stations used to collect weather data, in relation to northern Ontario cities, towns, and transportation routes.

Table 1. Geographic location of outplant experimental areas.

Year of planting	Township	Map no.[a]	Experiment designation	Latitude N	Longitude W
1974	unsurveyed	1	P74-UN1	49° 12'	90° 12'
1976	Golding	2	P76-GL1	48° 50'	89° 58'
1976	Golding	2	P76-GL2	48° 50'	89° 58'
1976	Golding	2	P76-GL3	48° 50'	89° 58'
1976	Golding	2	P76-GL4	48° 50'	89° 58'
1977	Barker	7	P77-BR1	49° 28'	83° 13'
1977	Barker	7	P77-BR2	49° 28'	83° 13'
1977	Slack	9	P77-SL1	49° 03'	82° 23'
1977	Slack	9	P77-SL2	49° 03'	82° 23'
1977	Slack	9	P77-SL3	49° 03'	82° 23'
1978	Bompas	11	P78-BM1	48° 10'	80° 20'
1978	Opasatika	6	P78-OP1	49° 06'	83° 03'
1979	Abbott	5	P79-AB1	49° 08'	83° 22'
1979	Abbott	5	P79-AB2	49° 08'	83° 22'
1979	Adams	10	P79-AD1	48° 21'	81° 20'
1980	Pelletier	4	P80-PL1	49° 11'	83° 40'
1980	Scholfield	3	P80-SC1	49° 13'	83° 39'
1981	Shannon	8	P81-SH1	49° 48'	83° 28'

[a] Refer to Figure 1.

METHODS AND MATERIALS

Site Selection

Experimental sites were located within operational planting chances, thereby making the findings relevant to provincial forestry practice. Sites were harvested, site prepared, and tended to operational standards.

Location and Description of Experimental Sites

The experimental outplantings are located near the northern Ontario communities of Timmins and Kirkland Lake in the southeast, Kapuskasing and Hearst in the north, and Thunder Bay in the west, the total distance between them being approximately 730 km east-west and 190 km north-south (Fig. 1). The latitude and longitude of each experiment are listed in Table 1. For descriptions of the experimental sites see Tables 2 to 7.

Experiments 1, 2, 10, and 11 are within the Height of Land Climatic Region (Chapman and Thomas 1968). This Climatic Region is characterized by a mean annual precipitation of 762 mm, half of which falls from May to September. The growing season averages 162 days in length; mean annual temperature is 1.1°C (ibid.). The forest climate is classed as a dry-humid to mid-humid, mid-boreal type (Hills 1959).

The remaining experimental sites are in the Northern Clay Belt Climatic Region. This region is characterized by a mean annual precipitation of 787 mm, of which 406 mm falls from May to September. The growing season averages 160 days in length; mean annual temperature is 1.1°C (Chapman and Thomas 1968). The forest climate is a mid-humid, mid-boreal type (Hills 1959).

Experimental Design

Experiments were designated by year of planting (Sutton and Tinus 1983), township, and number (Table 1). For example, the third planting experiment in Golding Township in 1976 was designated P76-GL3.

Three different experimental designs were used: paired nonrandomized, blocked nonrandomized, and fully randomized.

In P74-UN1 a paired nonrandomized experimental design was used. In this experiment, for each species, stock type and time of planting, there were four plots, each plot containing five rows of 15 trees.

A blocked nonrandomized design was used to establish P79-AD1. Treatment rows (species, stock type, and planting season) contained 25 trees and were systematically replicated along a baseline.

A fully randomized design was used to establish the remainder of the experiments. Randomized treatment rows (plots) were arranged along baselines, with three to six replicates of each treatment. The number of trees per treatment row varied from 25 to 50. The species outplanted, by experiment and season, are listed in Table 8. The total number of trees planted for each species, by stock type and planting season, is presented in Tables 9, 10, and 11.

Table 2. Description of black spruce outplanting study areas.

Experiment designation	Boreal Forest Region Section[a]	Site District and Region[b]	Surficial geology[c]	Local relief and aspect	Soil texture and moisture regime[d]	Organic horizon description[d]
P74-UN1	Upper English River (B.11).	Savanne (3) of Lake Nipigon (3W).	Loess deposits over water-lain sand.	5%, generally to the west.	Very fine sand. Fresh.	Typical moder or raw moder.
P76-GL1 P76-GL2 P76-GL3 P76-GL4	Upper English River (B.11).	Savanne (3) of Lake Nipigon (3W).	Clayey glacial till with some loess deposits.	5-10%, generally to the south.	Sandy loam to medium sand. Moderately moist.	Fibrimor, 5-10 cm thick.
P77-BR1	Northern Clay (B.4).	Cochrane (3) of Lake Abitibi (3E).	Clayey glacial till plains.	2% to the west.	Silty to sandy clay. Very moist.	Humic Peaty-mor, 25-45 cm thick.
P77-BR2	Northern Clay (B.4).	Cochrane (3) of Lake Abitibi (3E).	Clayey glacial till plains.	2% to the west.	Clay loam to silty clay. Fresh.	Humi-fibrimor, 4-6 cm thick.
P77-SL2 P77-SL3	Northern Clay (B.4).	Cochrane (3) of Lake Abitibi (3E).	Clayey glacial till plains,	2-5% to the south.	Sandy clay-loam to silty clay. Fresh.	Humi-fibrimor.
P78-OP1	Northern Clay (B.4).	Cochrane (3) of Lake Abitibi (3E).	Clayey glacial till plains.	0-5% to the south-east.	Silt-loam. Fresh.	Humimor (patchy), 1 cm thick.
P79-AB2	Northern Clay (B.4).	Hornepayne (2) of Lake Abitibi (3E).	Clayey glacial till plains.	Level.	Loam. Moist.	Humimor, 35 cm thick.
P79-AD1	Missinaibi-Cabonga (B.7).	Foleyet (5) of Lake Abitibi (3E).	Glacial till plains.	Level.	Fine sand. Fresh.	Fibrimor, 6-20 cm thick.
P80-PL1	Northern Clay (B.4).	Hornepayne (2) of Lake Abitibi (3E).	Silty to sandy glacial till.	0-2% to the west.	Silt-loam. Very moist.	Humimor, 9 cm thick.
P80-SC1	Northern Clay (B.4).	Hornepayne (2) of Lake Abitibi (3E).	Silty to sandy glacial till.	2-5% to the south-east.	Loam. Fresh.	Fibrimor, 5 cm thick.
P81-SH1	Northern Clay (B.4).	Smokey Falls (1) of Lake Abitibi (3E).	Clayey glacial till plains.	0-5% to the south.	Silty clay-loam. Moderately moist.	Humi-fibrimor.

[a] After Rowe (1972).
[b] After Hills (1959).
[c] After Boissonneau (1966) and Zoltai (1965).
[d] After Bélisle (1980).

Table 3. Description of white spruce outplanting study areas.

Experiment designation	Boreal Forest Region[a]	Site District and Region[b]	Surficial geology[c]	Local relief and aspect	Soil texture and moisture regime[d]	Organic horizon description[d]
P74-UN1	Upper English River (B.11).	Savanne (3) of Lake Nipigon (3W).	Loess deposits over water-lain sand.	5%, generally to the west.	Very fine sand. Fresh.	Typical moder or raw moder.
P76-GL1 P76-GL2 P76-GL3 P76-GL4	Upper English River (B.11).	Savanne (3) of Lake Nipigon (3W).	Clayey glacial till with some loess deposits.	5-10%, generally to the south.	Sandy loam to medium sand. Moderately moist.	Fibrimor, 5-10 cm thick.
P77-SL1 P77-SL2 P77-SL3	Northern Clay (B.4).	Cochrane (3) of Lake Abitibi (3E).	Clayey glacial till plains.	2-5% to the south.	Sandy clay-loam to silty clay. Fresh.	Humi-fibrimor.
P79-AB1	Northern Clay (B.4).	Hornepayne(2) of Lake Abitibi (3E).	Clayey glacial till plains.	0-5% to the south-west.	Silty clay-loam. Fresh.	Humimor, 10 cm thick.
P79-AD1	Missinaibi-Cabonga (B.7).	Foleyet (5) of Lake Abitibi (3E).	Glacial till plains.	Level.	Fine sand. Fresh.	Fibrimor, 6-20 cm thick.
P80-PL1	Northern Clay (B.4).	Hornepayne(2) of Lake Abitibi (3E).	Silty to sandy glacial till.	0-2% to the west.	Silt-loam. Very moist.	Humimor, 9 cm thick.
P80-SC1	Northern Clay (B.4).	Hornepayne(2) of Lake Abitibi (3E).	Silty to sandy glacial till.	2-5% to the south-east.	Loam. Fresh.	Fibrimor, 5 cm thick.
P81-SH1	Northern Clay (B.4).	Smokey Falls (1) of Lake Abitibi (3E).	Clayey glacial till plains.	0-5% to the south.	Silty clay-loam. Moderately moist.	Humi-fibrimor.

[a] After Rowe (1972).
[b] After Hills (1959).
[c] After Boissonneau (1966) and Zoltai (1965).
[d] After Bélisle (1980).

Table 4. Description of jack pine outplanting study areas.

Experiment designation	Boreal Forest Region[a]	Site District and Region[b]	Surficial geology[c]	Local relief and aspect	Soil texture and moisture regime[d]	Organic horizon description[d]
P76-GL1 P76-GL2 P76-GL3 P76-GL4	Upper English River (B.11).	Savanne (3) of Lake Nipigon (3W).	Clayey glacial till with some loess deposits.	5-10%, generally to the south.	Sandy loam to medium sand. Moderately moist.	Fibrimor, 5-10 cm thick.
P78-BM1	Missinaibi-Cabonga (B.7).	Kirkland Lake (6) of Lake Abitibi (3E).	Glacial till plains.	10%, to the north.	Loamy sand. Moderately dry.	Fibrimor, 4 cm thick.
P79-AD1	Missinaibi-Cabonga (B.7).	Foleyet (5) of Lake Abitibi (3E).	Glacial till plains.	Level.	Fine sand. Fresh.	Fibrimor, 6-20 cm thick.
P81-SH1	Northern Clay (B.4).	Smokey Falls (1) of Lake Abitibi (3E).	Clayey glacial till plains.	0-5%, to the south.	Silty clay-loam. Moderately moist.	Humi-fibrimor.

[a] After Rowe (1972).
[b] After Hills (1959).
[c] After Boissonneau (1966) and Zoltai (1965).
[d] After Bélisle (1980).

Table 5. Summary of recent forestry practices on black spruce outplanting study areas; see Table 8 for information on plantings.

Experiment designation	Previous forest stand characteristics[a]	Harvesting dates and methods	Site preparation history	Post-planting treatments
P74-UN1	Jack pine (75%), poplar and white birch. 50-60 years old.	1971-1972: jack pine clearcut by cut and skid.	Summer 1973: Shark-finned barrels and Tractor Pads - Anchor Chains.	Hand releasing of crop trees in 1979.
P76-GL1 P76-GL2 P76-GL3 P76-GL4	Poplar (80%), jack pine (10%), and black spruce (10%). 75 years old.	1974-1975: clearcut by cut and skid.	July 1975: 2,4-D @ 5.6 kg a.i. (active ingredient) ha^{-1}. Aug. 1975: 50:50 2,4-D and 2,4,5-T @ 2.5 kg a.i.ha^{-1}. Sept. and Oct. 1975: Marden Brush Cutter (GL1, GL2, GL3).	None.
P77-BR1 P77-BR2	Black spruce (70%), balsam (20%), and poplar (10%). 160 years old.	1974-1975: spruce removed by cut and skid.	Jan. 1977: area was shearbladed.	1978: 50:50 2,4-D and 2,4,5-T @ 2.2 kg a.i. ha^{-1}. 1980: 2,4-D @ 2.2 kg a.i. ha^{-1}.
P77-SL2	Black spruce (60%), poplar (30%), white birch (10%). 110 years old.	June and July 1976: clearcut, leaving poplar, by cut and skid.	1976: prescribed burned.	1979: 2,4-D @ 2.2 kg a.i. ha^{-1}.
P77-SL3	Black spruce (90%), balsam (10%). 110 years old.	June and July 1976: clearcut, leaving the poplar, by cut and skid.	1976: prescribed burned.	None.
P78-OP1	White spruce and black spruce mixture (80%), poplar (20%).	1975-1976: clearcut, leaving poplar, by cut and skid.	1977: prescribed burned.	1980: 2,4-D @ 1.4 kg a.i. ha^{-1}.
P79-AB2	Black spruce (100%).	Autumn 1976: clearcut by cut and skid.	1978: prescribed burned.	1981: 2,4-D @ 2.2 kg a.i. ha^{-1}.
P79-AD1	Jack pine, black spruce, and poplar.	1977: clearcut by cut and skid.	1978: C&H scarification plow.	1981: 2,4-D @ 1.7 kg a.i. ha^{-1}.
P80-PL1	Black spruce (100%), overmature.	1977-1978: clearcut by cut and skid.	Feb. 1978: area was shearbladed.	None.
P80-SC1	Black spruce (60%), balsam (15%), white spruce (15%), and poplar (10%).	1977-1978: clearcut by cut and skid.	Late Autumn 1979: area was shearbladed.	1982: 2,4-D @ 3.4 kg a.i. ha^{-1}.
P81-SH1	Mixed black spruce, white birch and poplar.	1976-1977: cut and skid.	Winter 1980-1981: area was shearbladed.	None.

[a] Percentages by area of crown coverage.

Table 6. Summary of recent forestry practices on white spruce outplanting study areas; see Table 8 for information on plantings.

Experiment designation	Previous forest stand characteristics[a]	Harvesting dates and methods	Site preparation history	Post-planting treatments
P74-UN1	Jack pine, poplar, and white birch. 50-60 years old.	1971-1972: clearcut by cut and skid.	Summer 1973: Shark-finned barrels and Tractor Pads-Anchor Chains.	Hand releasing of crop trees in 1979.
P76-GL1 P76-GL2 P76-GL3 P76-GL4	Poplar (80%), jack pine (10%), and black spruce (10%). 75 years old.	1974-1975: clearcut by cut and skid.	July 1975: 2,4-D @ 5.6 kg a.i. ha^{-1}. Aug. 1975: 50:50 2,4-D and 2,4,5-T @ 2.5 kg a.i. ha^{-1}. Sept. and Oct. 1975: Marden Brush Cutter (GL1, GL2, GL3).	None.
P77-SL1 P77-SL2	Black spruce (60%), poplar (30%), white birch (10%). 110 years old.	June and July 1976: clearcut, leaving poplar, by cut and skid.	1976: prescribed burn.	1979: 2,4-D @ 2.2 kg a.i. ha^{-1}.
P77-SL3	Black spruce (90%), balsam (10%). 110 years old.	June and July 1976: clearcut, leaving poplar, by cut and skid.	1976: prescribed burn.	None.
P79-AB1	Black spruce and white spruce (70%), poplar (20%), and white birch (10%).	1975-1976: removal of spruce by cut and skid.	1978: prescribed burn.	1981: 2,4-D @ 2.2 kg a.i. ha^{-1}.
P79-AD1	Jack pine, black spruce, and poplar.	1977: clearcut by cut and skid.	1978: C&H scarification plow.	1981: 2,4-D @ 1.7 kg a.i. ha^{-1}.
P80-PL1	Black spruce (100%). Overmature.	1977-1978: clearcut by cut and skid.	Feb. 1978: area was shearbladed.	None.
P80-SC1	Black spruce (60%), balsam (15%), white spruce (15%), and poplar (10%).	1977-1978: clearcut by cut and skid.	Late Autumn 1979: area was shearbladed.	1982: 2,4-D @ 3.4 kg a.i. ha^{-1}.
P81-SH1	Mixed black spruce, white birch, and poplar.	1976-1977: cut and skid.	Winter 1980-1981: area was shearbladed.	None.

[a] Percentages by area of crown coverage.

Table 7. Summary of recent forestry practices on jack pine outplanting study areas; see Table 8 for information on plantings.

Experiment designation	Previous forest stand characteristics[a]	Harvesting dates and methods	Site preparation history	Post-planting treatments
P76-GL1 P76-GL2 P76-GL3 P76-GL4	Poplar (80%), jack pine (10%) and black spruce (10%). 75 years old.	1974-1975: clearcut by cut and skid.	July 1975: 2,4-D @ 5.6 kg a.i. ha^{-1}. Aug. 1975: 50:50 2,4-D and 2,4,5-T @ 2.5 kg a.i. ha^{-1}. Sept. and Oct. 1975: Marden Brush Cutter (GL1, GL2, GL3).	None.
P78-BM1	Poplar (30%), white birch (30%), jack pine (20%), black spruce (10%), balsam (10%).	Summer 1977: cut and skid.	Oct. 1977: Young's Teeth.	None.
P79-AD1	Jack pine, black spruce, and poplar.	1977: clearcut by cut and skid.	1978: C&H scarification plow.	1981: 2,4-D @ 1.7 kg a.i. ha^{-1}.
P81-SH1	Mixed black spruce, white birch, and poplar.	1976-1977: cut and skid.	Winter 1980-1981: area was shearbladed.	None.

[a] Percentages by area of crown coverage.

Table 8. Species outplanted by experiment and season.

Experiment designation	Spring-planted Bare-root			Spring-planted Paperpot			Summer-planted Bare-root			Summer-planted Paperpot		
	B[a]	W	J	B	W	J	B	W	J	B	W	J
P74-UN1	●	●		●	●		●	●		●	●	
P76-GL1 P76-GL2 P76-GL3 P76-GL4	●	●	●	●	●	●						
P77-BR1 P77-BR2	●			●			●			●		
P77-SL1		●			●			●			●	
P77-SL2 P77-SL3	●	●		●	●		●	●		●	●	
P78-BM1			●			●			●			●
P78-OP1	●			●			●			●		
P79-AB1		●			●			●			●	
P79-AB2	●			●			●			●		
P79-AD1	●	●	●	●	●	●	●	●	●	●	●	●
P80-PL1 P80-SC1	●	●		●	●		●	●		●	●	
P81-SH1	●		●	●	●	●	●	●	●	●	●	●

[a] B = black spruce; W = white spruce; J = jack pine.

Table 9. Black spruce planting stock types by outplant experiment.

Experiment designation	Planting stock type			
	Spring-planted		Summer-planted	
	Bare-root	Paperpot	Bare-root	Paperpot
P74-UN1	3+0 (300)[a]	73-2[b] FH 308 (300)	3+0r[c] (300)	74-1 FH 308 (300)
P76-GL1	1½+1½(160)	75-2 FH 308 (160)		
P76-GL2	1½+1½(160)	75-2 FH 308 (160)		
P76-GL3	1½+1½(160)	75-2 FH 308 (160)		
P76-GL4	1½+1½(160)	75-2 FH 308 (160)		
P77-BR1	2+0 (140)	76-2 FH 308 (140)	3+0r (140)	77-1 FH 408 (140)
P77-BR2	2+0 (140)	76-2 FH 308 (140)	3+0r (140)	77-1 FH 408 (140)
P77-SL2	2+0 (175)	76-2 FH 308 (105)	3+0r (140)	77-1 FH 408 (140)
P77-SL3	2+0 (175)	76-2 FH 308 (105)	3+0r (140)	77-1 FH 408 (140)
P78-OP1	1½+1½(175) 3+0 (105)	77-2 FH 408 (140)	1½+1½r(140)	78-1 FH 408 (140)
P79-AB2	1½+1½(150) 3+0 (150)	78-2 FH 408 (150)	1½+1½r(150) 3+0r (150)	78-2 FH 408 (150) 79-1 FH 408 (150) 79-2 FH 308 (150)
P79-AD1	1½+1½(150) 3+0 (150)	78-2 FH 408 (150) 78-2 FH 308 (150)	1½+1½r (75) 3+0r (75)	78-2 FH 408 (75) 79-2 FH 408 (75) 79-2 FH 308 (75)
P80-PL1 P80-SC1	1½+1½(150) 3+0 (150)	79-2 FH 408 (150)	1½+1½r(150)	80-1 FH 408 (150)
P81-SH1	1½+1½(250)	80-3 FH 408 (250)	1½+1½r(250)	81-1 FH 408 (250)

[a] Figures within parentheses are numbers of planted trees.

[b] Crop identification, e.g., crop 73-2 was the second crop sown in 1973.

[c] 'r' indicates that the summer-planted bare-root stock was rising (see **Planting Stock,** ***Bare-root)***.

Table 10. White spruce planting stock types by outplant experiment.

Experiment designation	Planting stock type			
	Spring-planted		Summer-planted	
	Bare-root	Paperpot	Bare-root	Paperpot
P74-UN1	3+0 (300)[a]	73-2[b] FH 308 (300)	3+0r[c](300)	74-1 FH 308 (300)
P76-GL1	3+0 (160)	FH 308 (160)		
P76-GL2	3+0 (160)	FH 308 (160)		
P76-GL3	3+0 (160)	FH 308 (160)		
P76-GL4	3+0 (160)	FH 308 (160)		
P77-SL1	2+0 (140)	76-2 FH 308 (140)	2+1r (140)	77-1 FH 408 (140)
P77-SL2	2+0 (140)	76-2 FH 308 (140)	2+1r (140)	77-1 FH 408 (140)
P77-SL3	2+0 (140)	76-2 FH 308 (140)	2+1r (140)	77-1 FH 408 (140)
P79-AB1	2+2 (150) 2+1 (150) 3+0 (150)	78-2 FH 408 (150)	2+2r (100) 2+1r (150) 3+0r (150)	78-2 FH 408 (150) 79-2 FH 408 (150)
P79-AD1	2+1 (150) 3+0 (150)	78-2 FH 408 (150) 78-2 FH 308 (150)	2+2r (75) 2+1r (75) 3+0r (75)	78-2 FH 408 (75) 79-2 FH 408 (75) 79-2 FH 308 (75)
P80-PL1 P80-SC1	2+2 (150) 2+1 (150)	79-2 FH 408 (150)	2+2r (150) 2+1r (150) 3+0r (150)	80-1 FH 408 (150)
P81-SH1		80-4 FH 408 (250)	2+2r (250) 2+1r (250)	81-1 FH 408 (250)

[a] Figures within parentheses are numbers of planted trees.
[b] Crop identification, e.g., crop 73-2 was the second crop sown in 1973.
[c] 'r' indicates that the summer-planted bare-root stock was rising (see **Planting Stock, *Bare-root***).

Table 11. Jack pine planting stock types by outplant experiment.

Experiment designation	Planting stock type: Spring-planted, Bare-root	Planting stock type: Spring-planted, Paperpot	Planting stock type: Summer-planted, Bare-root	Planting stock type: Summer-planted, Paperpot
P76-GL1	2+0 (160)[a]	75-2[b] FH 408 (160)		
P76-GL2	2+0 (160)	75-2 FH 408 (160)		
P76-GL3	2+0 (160)	75-2 FH 408 (160)		
P76-GL4	2+0 (160)	75-2 FH 408 (160)		
P78-BM1	2+0 (140)	77-2 FH 408 (140)	2+0r[c] (140)	78-1 FH 408 (140)
P79-AD1	2+0 (150)	78-2 FH 408 (150) 78-2 FH 308 (150)	2+0r (75)	78-2 FH 408 (50) 79-2 FH 408 (50) FH 308 (75)
P81-SH1	2+0 (250)	FH 308 (250)	2+0r (250)	81-1 FH 408 (250) 81-1 FH 308 (250)

[a] Figures within parentheses are numbers of planted trees.

[b] Crop identification, e.g., crop 75-2 was the second crop sown in 1975.

[c] 'r' indicates that the summer-planted bare-root stock was rising (see **Planting Stock, *Bare-root***).

Data Analysis

Within species, the effects of stock type and planting season on field performance were evaluated.

Survival data were analyzed by means of G^2-unplanned tests of the homogeneity of replicates tested for goodness of fit (Sokal and Rolph 1981). Tree condition data were averaged by plot means on the basis of the total number of trees planted. However, these data were not subjected to statistical analyses. Height data were subjected to analysis of variance, and significant differences were identified by means of Tukey's multiple range test (Steel and Torrie 1960). Analyses of growth data were based on plot means of survivors rather than on individual tree values.

Planting Stock

Paperpot

Virtually all of the paperpot trees planted in this study were grown at the Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario (47°N, 84°W). Paperpot trees grown at other production facilities are noted in **APPENDICES A, B,** and **C.**

The paperpot trees planted in the spring months (May-June) were sown in the greenhouse approximately one year earlier and were grown inside until mid- to late August when they were moved outdoors to overwinter under a snow cover. Generally, all of the paperpots planted during the summer (July) were current-year stock, having been seeded in the greenhouse 21 to 25 weeks prior to planting and moved outside about mid-May. In two experiments (P79-AB2 and P79-AD1), overwintered stock was held beyond its normal spring planting date and included in the later plant along with the current-year paperpot stock. Sowing dates and stock specifications for the paperpot stock are contained in **APPENDICES A, B,** and **C.**

Bare-root

The Swastika Forest Station, Swastika, Ontario (48°N, 80°W) provided the bulk of the bare-root stock for this investigation. The Thunder Bay Forest Station (48°N, 89°W) and the Chapleau Provincial Tree Nursery (48°N, 83°W) produced the remaining stock. All trees were lifted from regular nursery production beds.

The bare-root trees planted in the spring months were fresh-lifted and placed in cool storage (0°C-4°C) for a short period prior to shipping to the planting site. Only in P74-UN1 were spring-planted trees fall-lifted and overwintered (in frozen storage). In the P77 experiments fresh-lifted 2+0 rather than 3+0 black spruce and 2+0 rather than 2+1 white spruce were used (Tables 9 and 10).

At the outset of the study a decision was made to summer-plant only fresh-lifted bare-root trees that had not completed their final growing season in the nursery bed. Hence, the age classes of July-planted bare-root trees are given as the class the trees would have attained had they remained in the beds until the end of the growing season, but are modified by the term "rising".

Planting Season and Planting Methods

Fourteen of 18 experiments included both spring and summer plantings. In the Boreal Forest Region the conventional spring planting period as defined by Sutton (1982) extends from the time the nursery beds have thawed sufficiently that stock can be lifted to the time the spring planting program has been completed. Similarly, for container stock, the spring planting season can be defined as the period starting when the planting site has warmed sufficiently and ending when the planting of the overwintered crop has been completed. For both bare-root and container stock, it is highly desirable to plant trees before the succulent new growth becomes too far advanced. All spring plantings in this study were carried out in May and June.

The summer planting season for container stock may be defined as the period starting when the current-year crop is ready for outplanting and ending when the crop has been planted. Planting should not be extended past mid-August (Scarratt 1974). All summer planting in this study was carried out in July.

Both the paperpot and the bare-root stock were field-culled prior to planting to remove misshapen, broken, or excessively small or large trees. Trees were then hand planted, the paperpot stock with a Pottiputki planting tool and the bare-root stock with a spade.

Stock Handling

Paperpot and bare-root stock were transported to the experimental planting sites under a canvas-covered metal frame mounted on the deck of the transporting vehicle. Prior to 1977, bare-root trees were carried in bales or crates and heeled into trenches at the planting site. Starting in 1977, bare-root trees were placed in wooden stock boxes filled with moist peat, just prior to transporting to the field. Trees for the summer plant were fresh-lifted and cool-stored for one night or transported immediately to the planting site. All summer-planted bare-root trees were planted within four days of being lifted[2]. While being held at the experimental site the planting stock was watered as required. Control of storage, handling, and planting was at what might be termed "operational" levels.

---

[2] F.W. Curtis, 1984. Silvicultural Technician, Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario (personal communication).

Stock Characterization

Samples of planting stock (25 to 50 trees) were selected when convenient, prior to planting. Measurements were made of several morphological characteristics: 1) shoot and root dry weight; 2) root collar diameter; 3) root area index (R.A.I.) (Morrison and Armson 1968); 4) shoot:root ratio (based on dry weights); and 5) shoot length (see **APPENDICES A, B,** and **C**). To obtain dry weight measurements trees were dried at 70°C for approximately 72 hours.

A quality index (Q.I.) to assess seedling morphological condition at time of planting was developed by Dickson et al. (1960) for white spruce and white pine *(Pinus strobus* L.). The Q.I. (see **APPENDICES A, B,** and **C**) uses seedling dry weight, shoot length, root collar diameter and shoot:root ratio, as follows:

$$Q.I. = \frac{\text{Mean seedling total dry weight (g)}}{\dfrac{\text{shoot weight (g)}}{\text{root weight (g)}} + \dfrac{\text{shoot length (cm)}}{\text{root collar diam. (mm)}}}.$$

Field Assessments

Field performance was measured by assessing survival status, condition, total height, and current annual height growth at the end of the first, second, third, and fifth growing seasons. The fifth year assessment had not been completed in P81-SH1.

While the determination of survival and mortality may be a necessary component of assessing outplant performance, other factors such as tree condition and growth should also be taken into consideration (Scarratt 1982, McClain 1981). Therefore, as part of the assessment an ocular estimate of the physical condition of each living tree was made. The four condition classes used in this assessment were vigorous, healthy, mediocre, and moribund. Vigorous trees were healthy with good form, sturdy shoots and good height growth. Healthy trees had at least moderate vigor, and only minor defects in form. Trees in the mediocre or moribund condition classes lacked vigor and had abnormalities in color or form (Scarratt 1974). Percentages of trees in at least healthy condition are presented.

Measurements of current annual height growth were taken along the single leading shoot or the largest lateral shoot in cases of multiple leadering. Measurement of shoots was taken from the previous year's node to the base of the terminal bud. Total height was the length of the main shoot from its intersection with the ground surface to the base of the terminal bud. Where the main shoot was growing from a live ground cover (e.g., mosses), the measurement was made from the approximate location of the root collar. Bent main shoots were straightened to obtain a measure of total height.

RESULTS AND DISCUSSION

Black Spruce

Paperpot stock (both FH 308 and FH 408) was compared with transplant and seedling stock in spring and summer plantings (Table 9). In all there were 15 experimental black spruce outplantings.

Spring Plantings

Paperpot versus Transplant Stock

Refer to Figures 2 and 3, Graphs 2 to 5 and 10 to 15 (10 experiments) for this section. By the final assessment the survival and condition of the spring-planted paperpot stock were equivalent to or poorer than those of the transplant stock. In the second growing season the container stock was growing at the same rate as the 1.5+1.5 stock in seven plantings; in P78-OP1, P79-AB2, and P80-SC1 the paperpots were growing faster. By the fifth year the transplant stock had better height increment than the paperpot stock in all but the P80 and P79-AB2 experiments, in which growth was similar. In nine experiments the transplants were taller than the paperpots.

The height disparity between the paperpots and transplants after five growing seasons in the current study is not surprising in view of their initial height differential (see **APPENDIX A**) and the superior growth of the transplants by the last assessment. Armson (1975) observed that larger black spruce stock maintained its height advantage over smaller stock for at least 10 years after planting. In New Brunswick, Krause (1982) reported that it took 5 years for the best black spruce paperpot plantation to achieve the height of an average three-year-old 2+2 plantation.

Paperpot versus Seedling Stock

Refer to Figures 2 and 3, Graphs 1 and 6 to 14 (10 experiments) for this section. By the fifth year the paperpots had a survival rate equivalent to or greater than that of the seedlings in nine plantings, and were generally in better condition. The only exception was P79-AD1. Wood and Jeglum (1984), Alm (1983), and Krause (1982) have also found that seedling stock is subject to higher mortality than paperpot stock.

Roller (1977) used Q.I. to establish minimum specifications for FH 408 paperpot stock of black spruce, white spruce, and jack pine. He suggested culling container stock with a Q.I. of less than 0.09. Both Ontario and New Brunswick have published culling limits for several grades of planting stock (see **APPENDIX D**). Since these are minimum specifications only, the forest manager should select the physical size of stock best suited to the planting site (Forward 1982).

The FH 308-1 paperpots, when outplanted in P79-AD1, had poor performance potential on the basis of morphological characteristics, and a Q.I. of 0.03

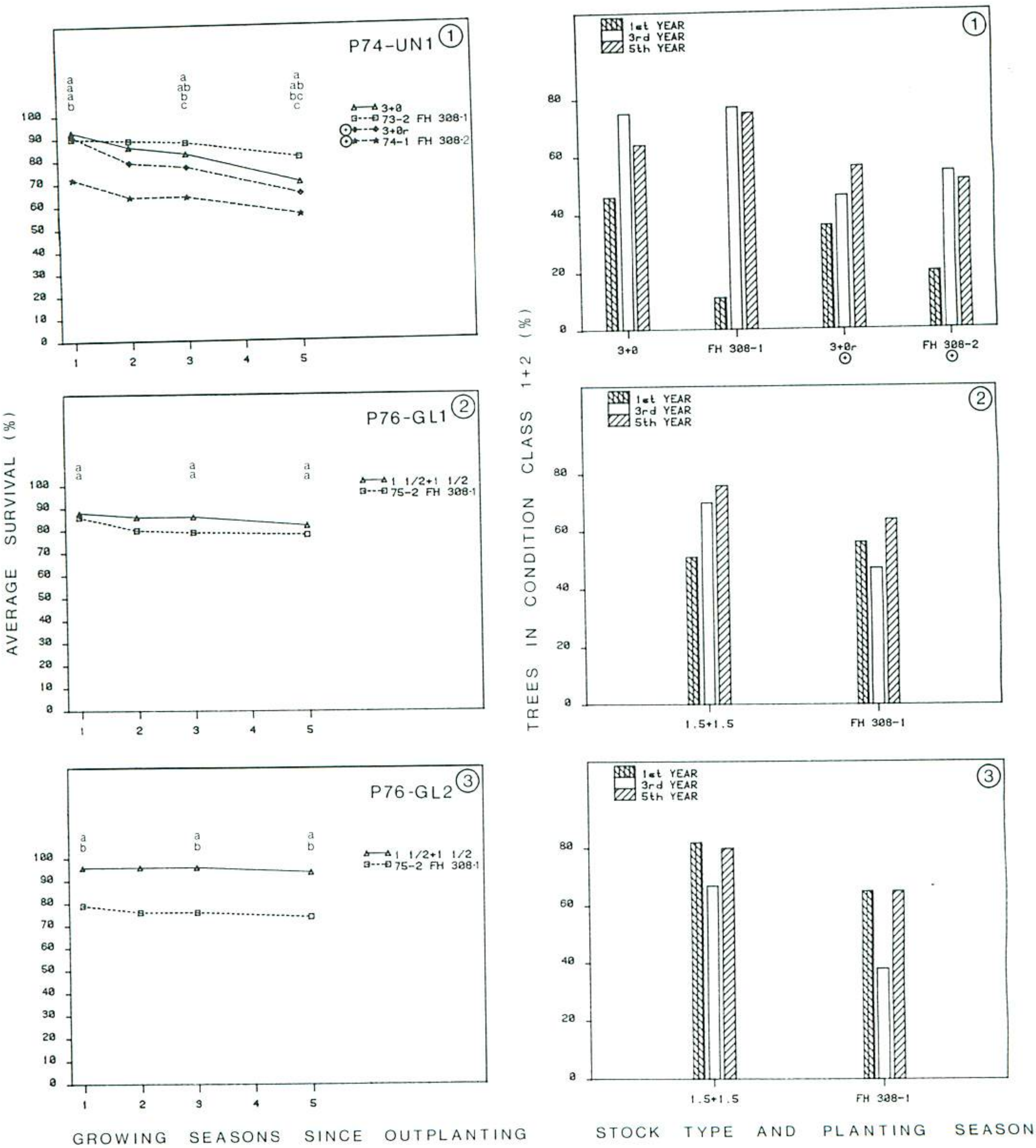


Figure 2. Black spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

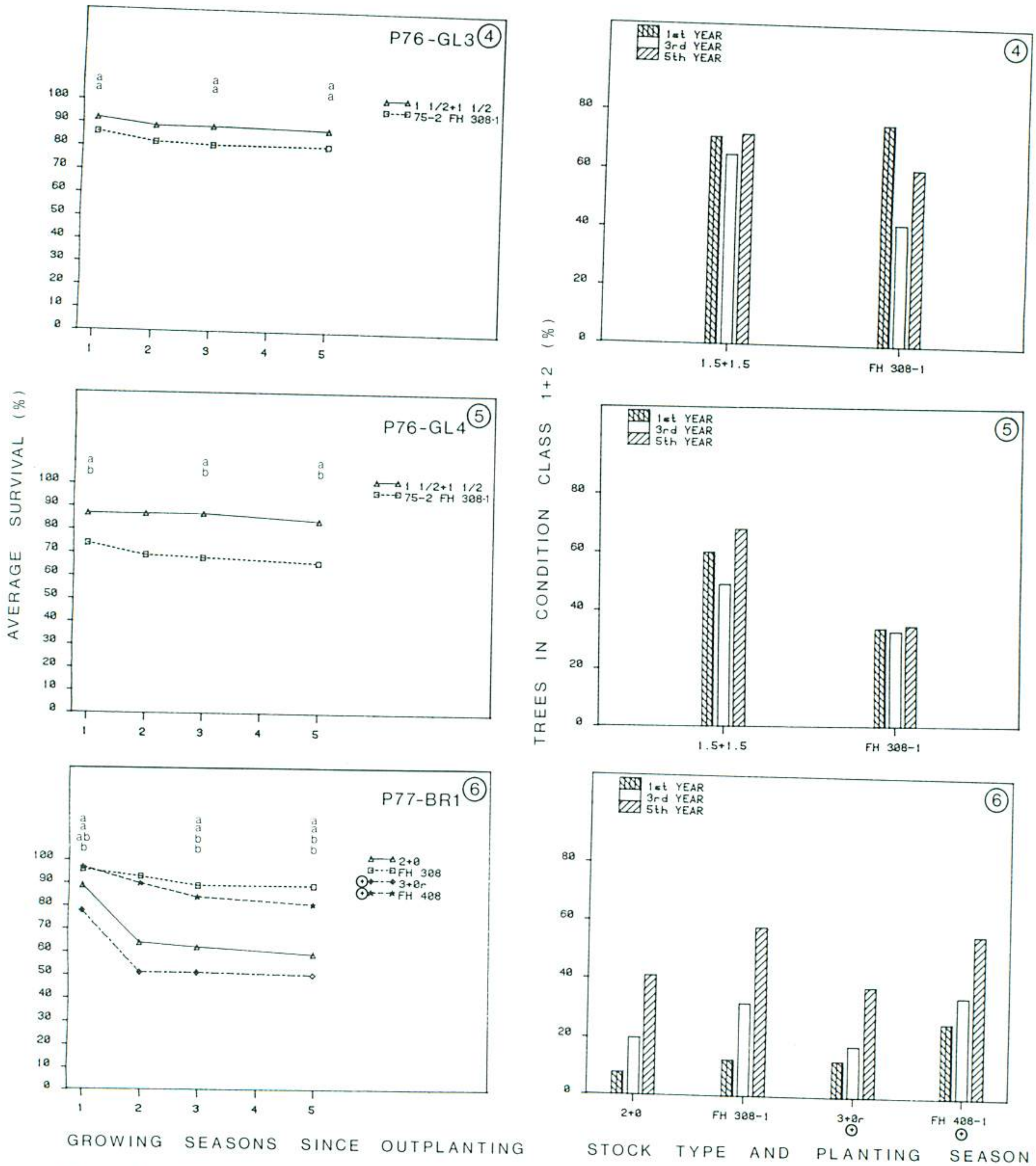


Figure 2. Black spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

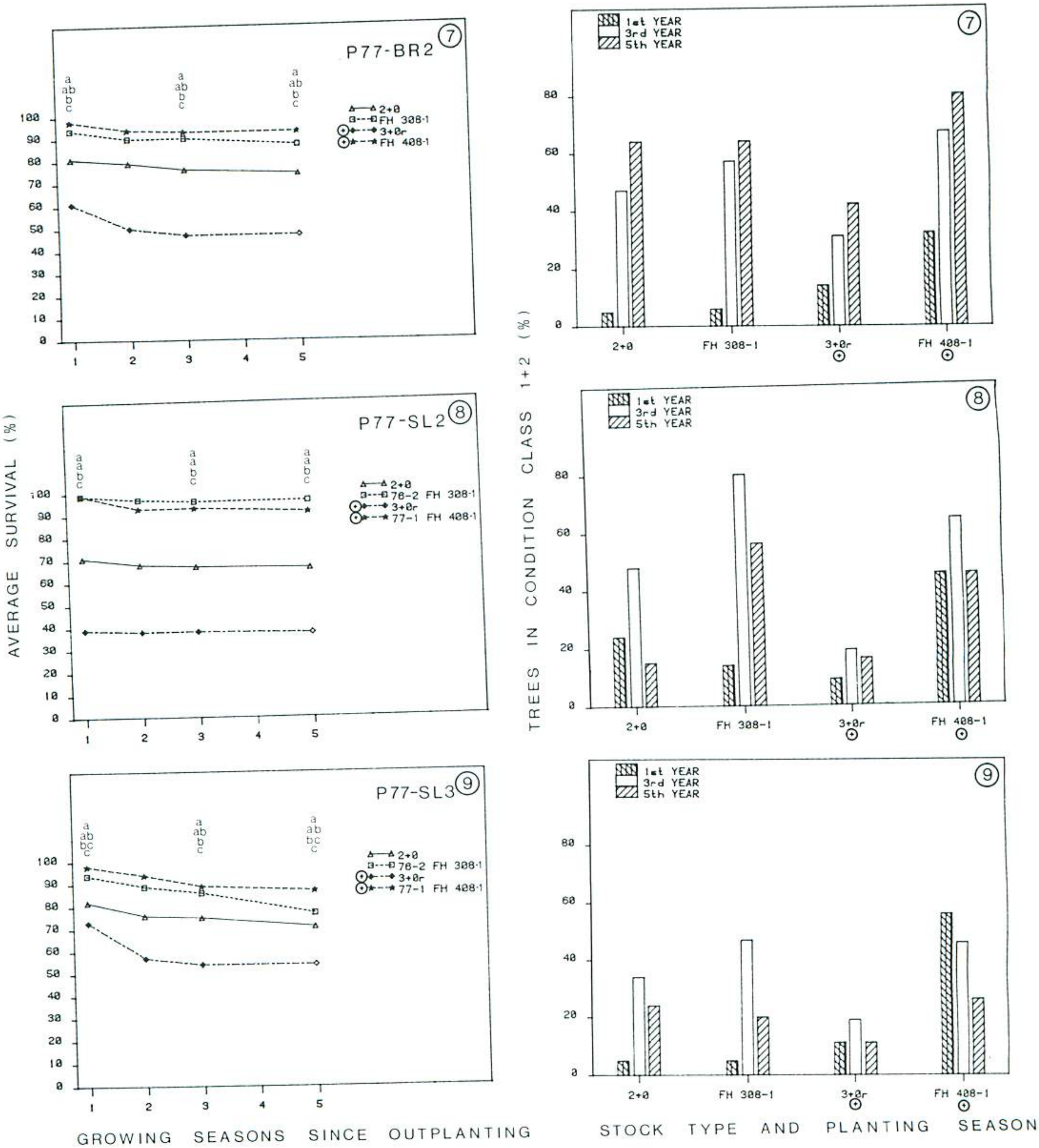


Figure 2. Black spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

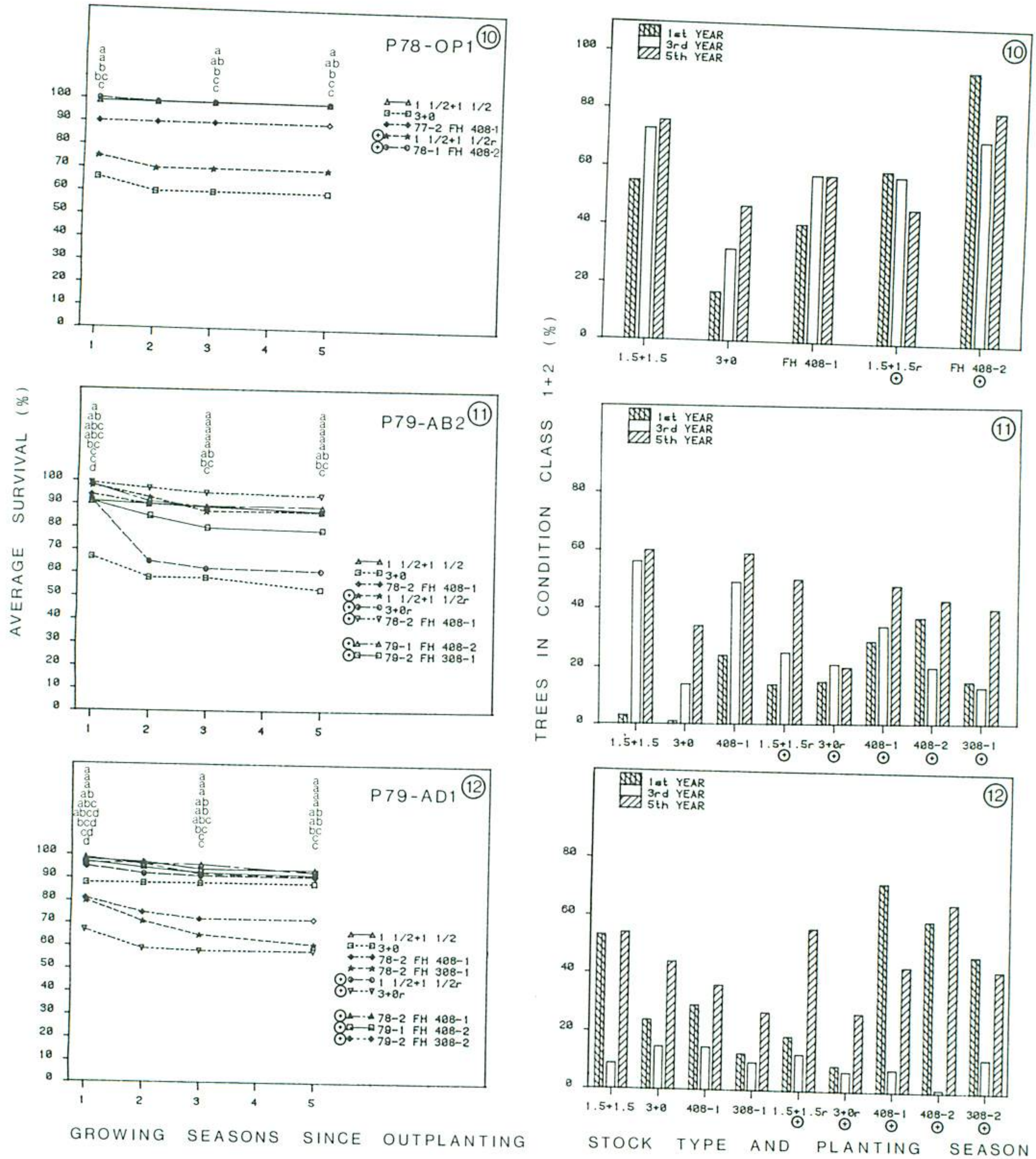


Figure 2. Black spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level: ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

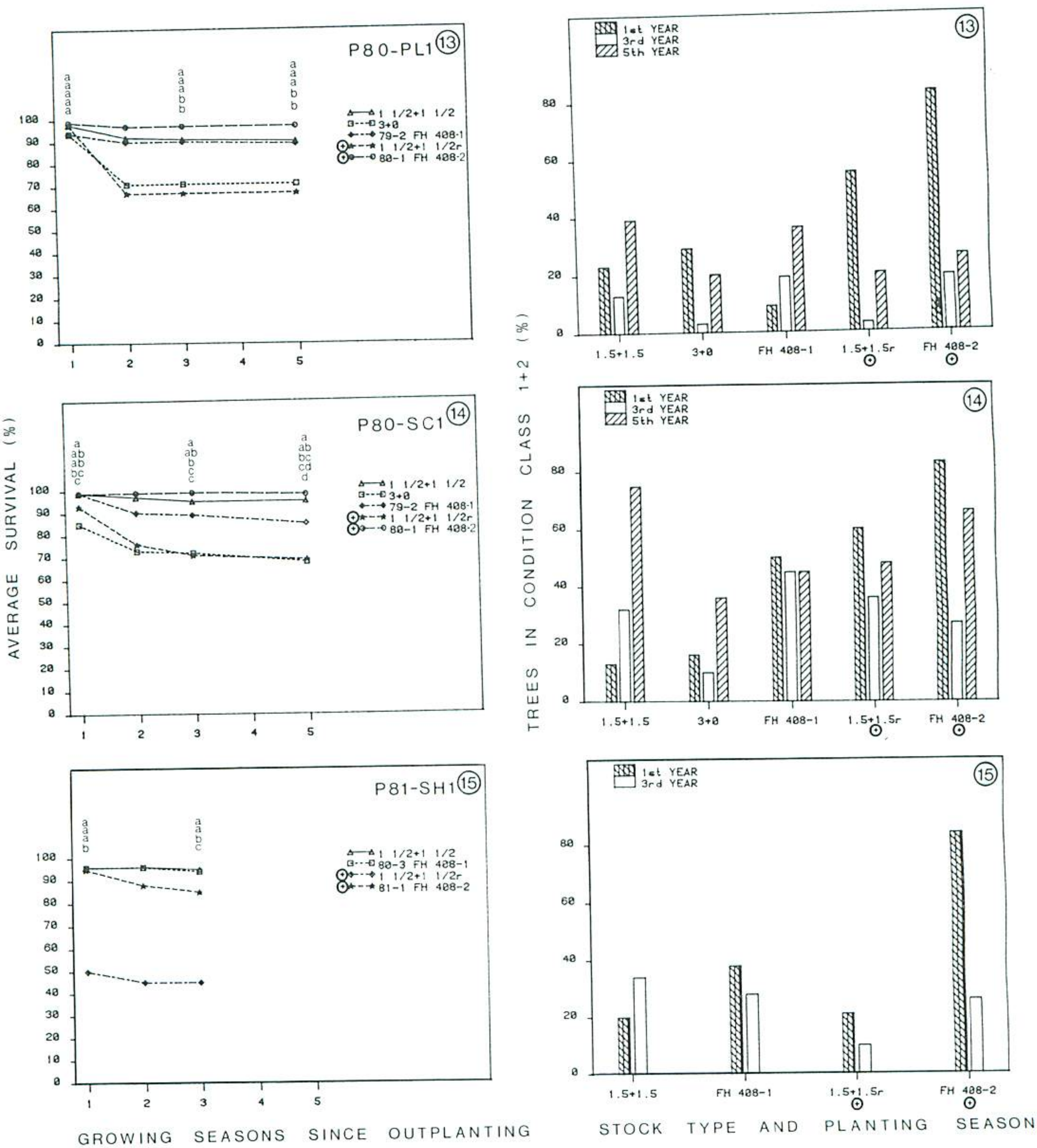


Figure 2. Black spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (concl.)

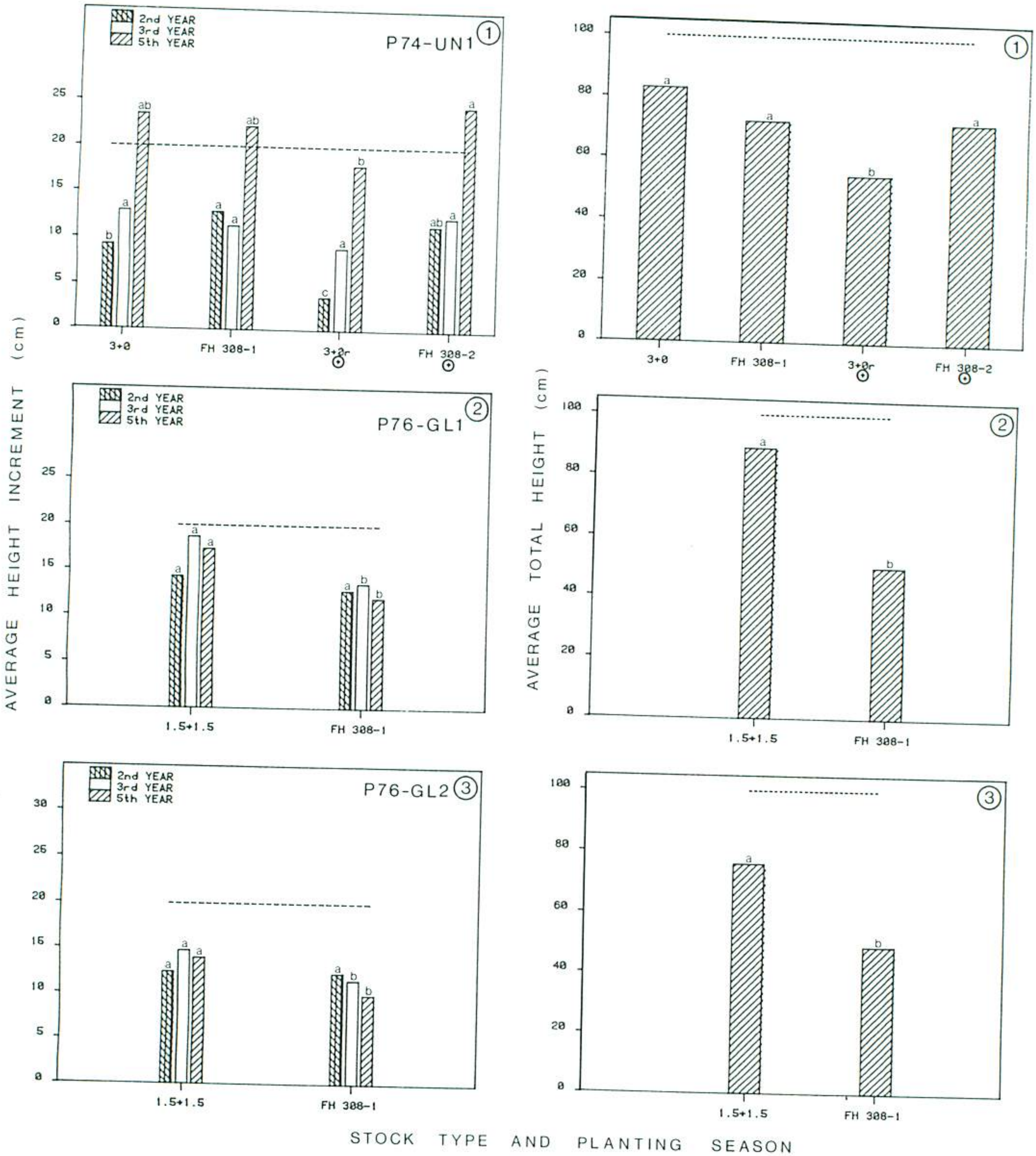


Figure 3. Black spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

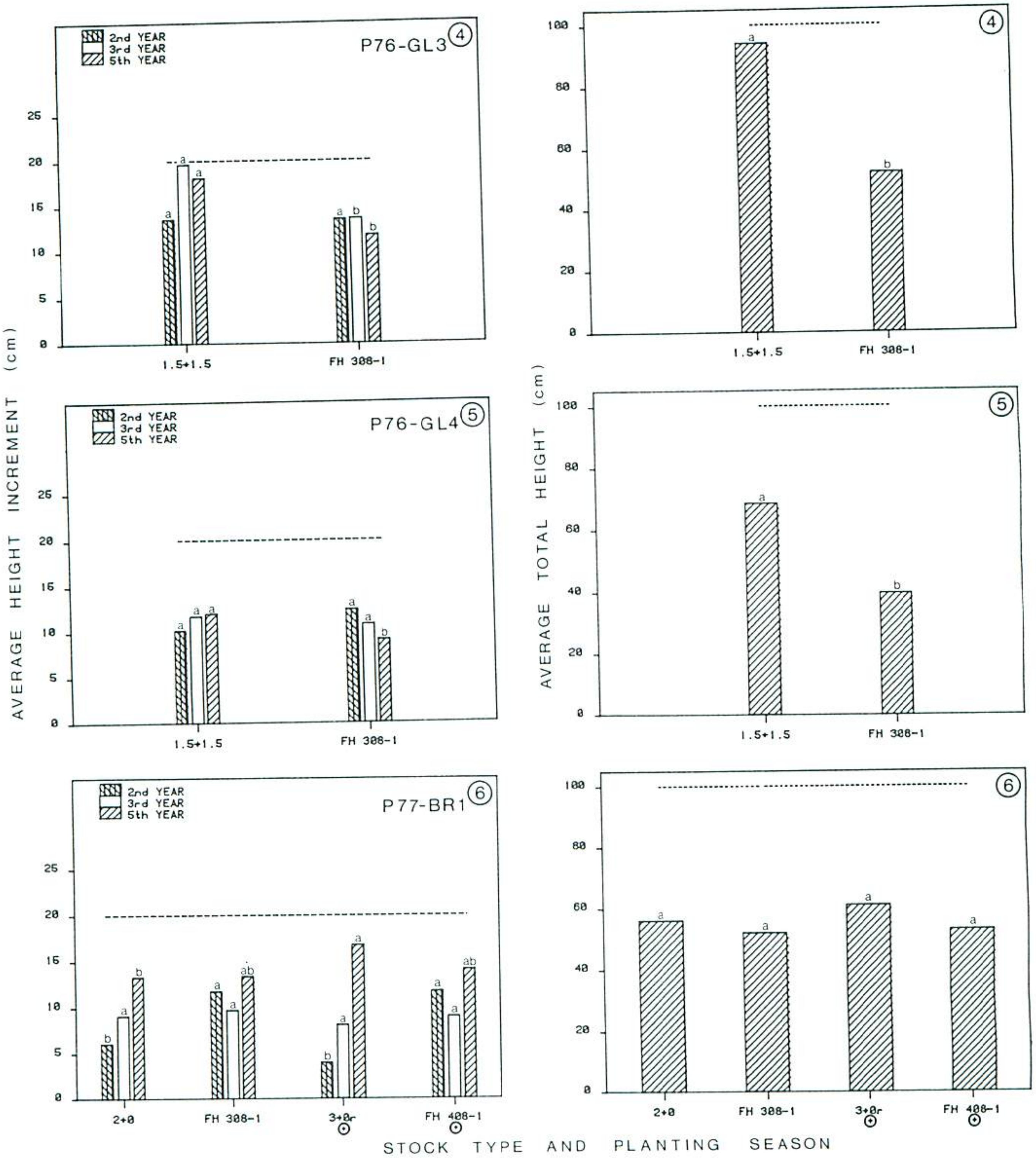


Figure 3. Black spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

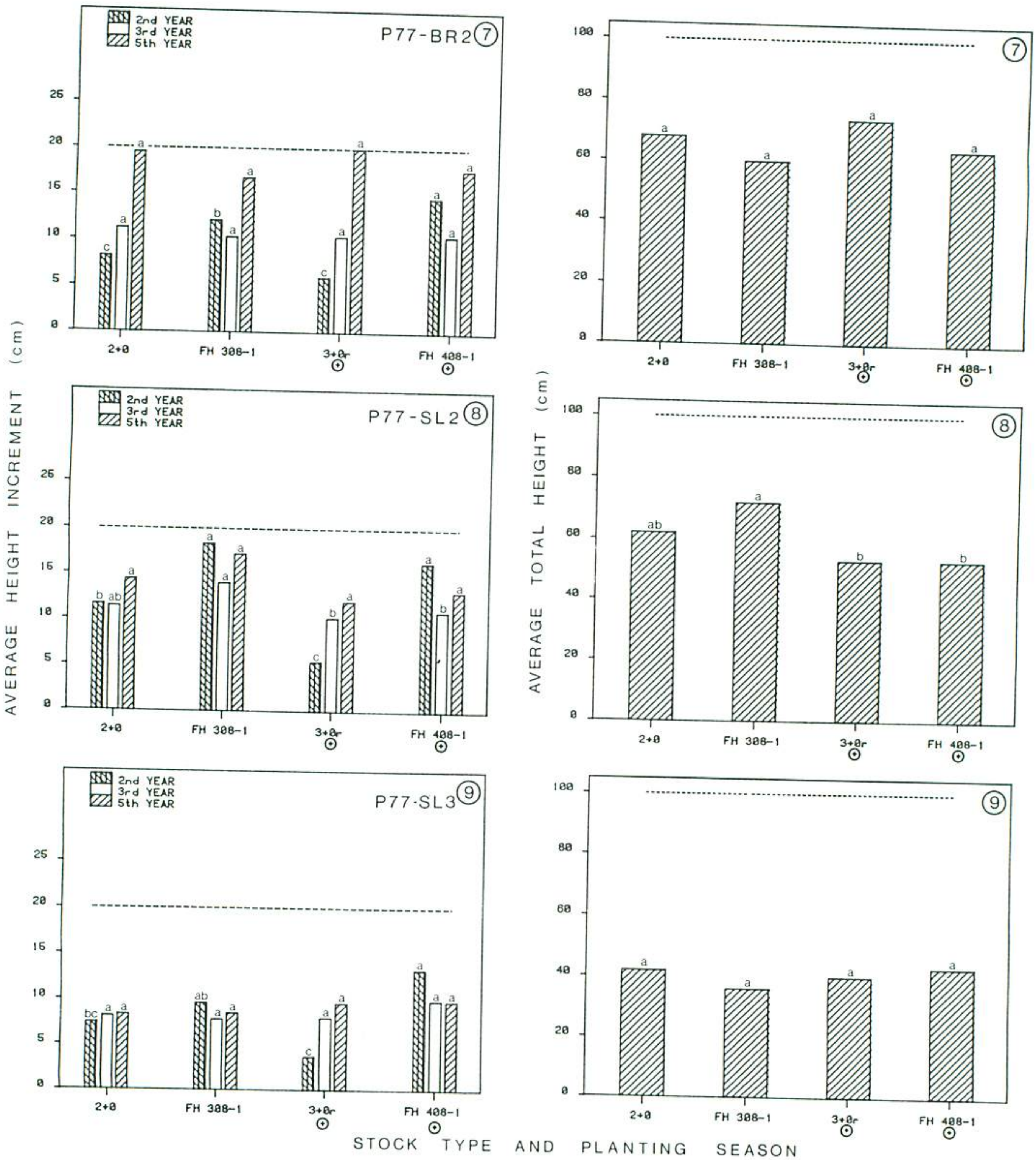


Figure 3. Black spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

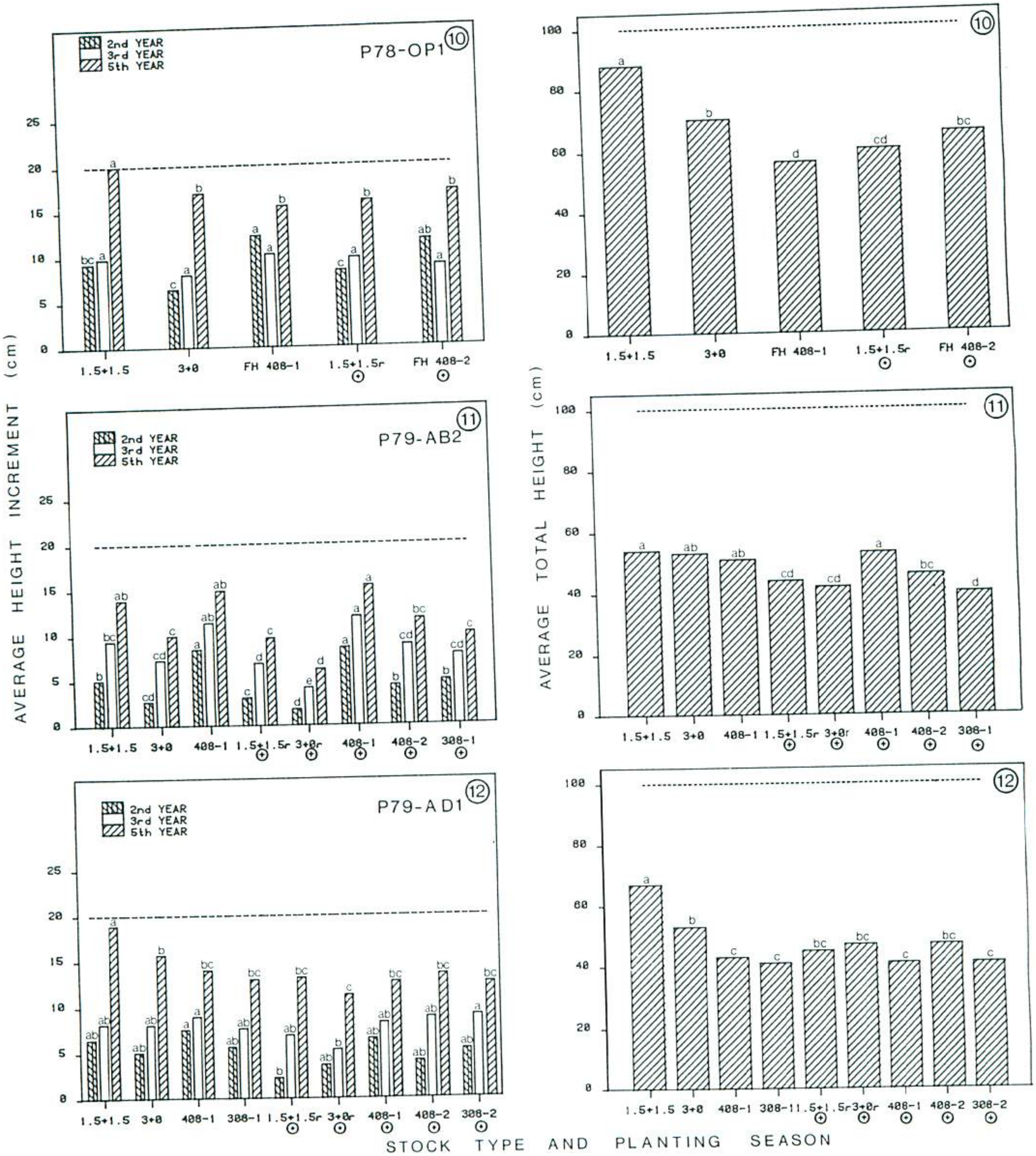


Figure 3. Black spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

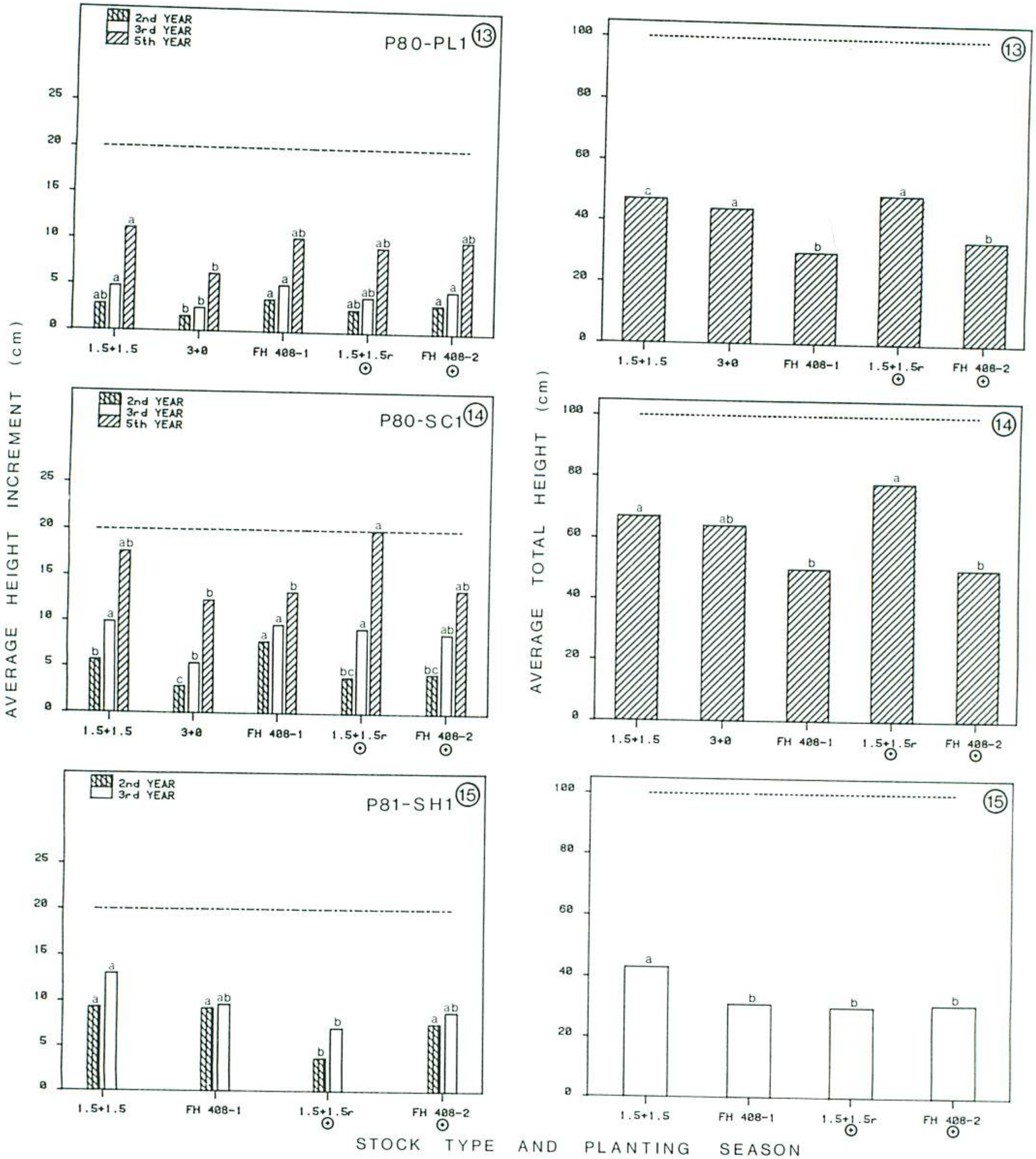


Figure 3. Black spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (concl.)

(see **Stock Characterization** and **APPENDIX A)**, much below the 0.09 minimum suggested by Roller (1977). The substandard stock and heavy graminoid competition on this fresh site (Table 2) undoubtedly reduced the survival of these trees.

In the second year the paperpots were growing faster than the seedling stock in eight experiments. In the third and fifth years the paperpots and seedlings were growing at a comparable rate in the majority of experiments. Similar results were noted by Alm (1983) in Minnesota where paperpots grew faster than seedlings until at least the fourth growing season. Scarratt (1982) found that large paperpot stock (minimum dry weight of 1.0 g and shoot height of 20 cm) had better height growth in the first two years after planting than transplant or seedling stock. He also observed that by the third growing season all stock types were growing at the same relative rate regardless of initial mass. In the current study, in only three of ten plantings (P79-AB2, P80-PL1 and -SC1) did the paperpot stock grow faster than the seedling stock beyond the second season. The average total dry weight of the spring-planted paperpots at the time of planting was 0.68 g, with an average shoot length of 10.6 cm (see **APPENDIX A)**. This indicates that black spruce stock smaller than that used by Scarratt (1982) can grow at a rate equivalent to either transplant or seedling stock in the first two years after planting.

After five growing seasons, the paperpots were equal in height to the seedling stock in seven experiments; in P78-OP1, P79-AD1, and P80-PL1 the seedling stock remained taller.

Transplant versus Seedling Stock

Refer to Figures 2 and 3, Graphs 10 to 14 (five experiments) for this section. In four experiments the transplants had a higher fifth-year survival and were in better condition than the seedlings. In P79-AD1 both stock types had similar survival and condition. By the fifth growing season the transplant stock was growing faster than the seedling stock on most sites, the only exception being P80-SC1 in which they were growing at the same rate. The faster growth of transplant compared to seedling stock has been well documented by Mullin (1980a), Armson (1975), and Fry (1975). However, only in P78-OP1 and P79-AD1 were the transplants taller than the seedlings.

Summer Plantings

All experiments, except the P76 series, contained summer-planted trees (Table 9).

Paperpot versus Rising Transplant Stock

Refer to Figures 2 and 3, Graphs 10 to 15 (six experiments) for this section. The paperpots had a higher fifth-year (third year for P81-SH1) survival and were in better condition than the rising transplants in four experiments. The only exceptions were the P79 experiments in which both stock types had equivalent survival rates.

The paperpots were growing at the same rate or faster than the rising transplants in the second year after outplanting. By the third and fifth growing seasons, both stock types were growing at the same relative rate, with the exception of the FH 408-1 stock in P79-AB2, which grew faster than both the transplant and other paperpot stock. The paperpots were as tall as or taller than the rising transplants, except in the P80 experiments in which the rising transplants were taller. The grade of the rising trees in the P80 plantings was comparable to that of the spring-planted transplants, and this may explain their better growth (see **APPENDIX A**). Because this stock had higher field performance potential, on the basis of morphological characteristics, than the rising transplants used in other experiments, for late planting, larger stock is perhaps needed to match the field performance of paperpots.

Paperpot versus Rising Seedling Stock

Refer to Figures 2 and 3, Graphs 1, 6 to 9, 11 and 12 (seven experiments) for this section. In the fifth year, the survival and condition of paperpots were superior to those of the rising seedlings in five experiments. In P74-UN1 and P79-AB2, survival was equivalent. Second-year height growth was generally better for the paperpot than for the rising seedling stock. By the fifth year both stock types were growing at the same rate and were equivalent in total height in all but two comparisons. In P74-UN1 the paperpots were faster-growing and taller. In P79-AB2 the paperpots were growing faster, but only the FH 408-1 stock was taller than the seedlings.

Rising Transplant versus Rising Seedling Stock

Refer to Figures 2 and 3, Graphs 11 and 12 (two experiments) for this section. The rising transplant stock had better fifth-year survival and were in better condition than the rising seedling stock. In P79-AD1 all rising stock grew at the same rate. In P79-AB2 the rising transplants grew faster than the seedlings. Both stock types had similar total height.

Planting Season: Spring versus Summer Planting

Paperpots

Refer to Figures 2 and 3, Graphs 1 and 6 to 15 (11 experiments) for the following section. Over the range of sites, the spring- and summer-planted paperpots frequently (i.e., in six experiments) had an equivalent fifth-year survival rate. In experiments P74-UN1 and P81-SH1 the spring-planted outplants had higher survival and were in better condition than their summer-planted counterparts, whereas in experiments P78-OP1, P79-AD1, and P80-SC1 the reverse was true. Height growth was generally the same for spring- and summer-planted trees. In eight plantings there was no difference in total height.

In large-scale planting trials in western Canada, Walker (1981) found that month of planting (June, July, and August) did not significantly affect survival of containerized spruce planting stock. Scarratt (1974) has presented data to show that containerized trees may be planted until mid-August, but beyond that time there is a marked decline in survival and height growth. In the current study the latest summer planting was 30 July (see **APPENDIX A**).

Transplants

Refer to Figures 2 and 3, Graphs 10 to 15 (six experiments) for this section. In four experiments the rising transplant stock had a lower survival rate and was in poorer condition than its spring-planted counterparts. The exceptions were the P79 experiments in which the survival of the rising stock was equivalent to that of the spring-planted stock. The high survival rates of the rising trees in the P79 experiments may in part be explained by the normal or above-normal precipitation in the Mattice and Timmins areas prior to the summer plant (see **APPENDIX E**). In the fifth year (third year for P81-SH1) the spring-planted trees were faster-growing and taller than the rising outplants in four experiments. The exceptions were the P80 experiments in which the rising trees were as tall and were growing at the same rate. Perhaps the large summer-planted stock in the P80 experiments, as discussed under ***Summer Plantings***, partially explains this result (see **APPENDIX A**).

The generally lower survival and slower growth of the rising transplants in comparison with the spring-planted transplants may have been caused by lifting the trees during an active growth period. McClain (1975) stated that this action may produce a physiological shock that is effected by root attrition, high internal moisture stress and planting site conditions. Also, the stock is very vulnerable to mechanical damage during this period. In an experiment near Thunder Bay, first-year survival above 90% was recorded for July-planted rising 1.5+1.5 stock (McClain 1981). In that study the stock was carefully handled and planted no later than one day after lifting (Sutton 1982). McClain (1981) noted that "[a]s the planting season progresses, handling procedures and planting become critical to survival and subsequent growth." Revel (personal communication *in* Sutton 1982) adds weight to this statement by stressing that "... summer planting requires local transplant nurseries (not more than two hours' drive to the planting site), careful handling, and "hot" planting (not more than three days between lifting and planting, and preferably the same day.)". In the current study, while the best care possible under operational conditions was taken with the bare-root stock it was nevertheless transported up to 430 km and planted up to four days after lifting. This may not have been adequate care to obtain good field performance when planting during the hot, dry summer months.

Seedlings

Refer to Figures 2 and 3, Graphs 1, 6 to 9, 11, and 12 (seven experiments) for this section. The spring-planted seedlings were better than or equivalent to the rising seedlings in fifth-year survival and condition. Walker (1981) found that month of planting was a critical factor in the survival of black spruce bare-root trees in western Canada, as mortality increased with later plantings.

In years three and five, seedlings from both plantings were growing at the same rate in four experiments. In the fifth year in P79 experiments the spring-planted stock was faster-growing, whereas in P77-BR1 the summer-planted stock was growing faster. In terms of total height, the spring-planted trees were as tall as or taller than the summer-planted trees.

In a three-year outplanting study in boreal Ontario, McClain (1975) reported that 3+0r black spruce had moderately high (>70%) fourth-year survival when planted from May until late July. He also found that the growth rate of the 3+0r stock was highest when the stock was planted in spring, but that it decreased in later plantings. In a similar comparison between 2+0 and 3+0r stock (P77 experiments), both spring- and summer-planted trees were growing at the same rate in the third year.

Outplant Performance Relative to Ontario Standards

After five growing seasons, only P74-UN1 had planting treatments with an average current height growth greater than the Ontario free-to-grow standard of 20 cm (Armson et al. 1980). The only stock type in this experiment that failed to meet the standard was the 3+0r (Fig. 3, Graph 1). In terms of average total height, none of the treatments achieved the 1-m standard within the study period. However, several experiments should have treatments with an average height above 1 m after six or seven growing seasons.

Site

Maximum growth rates of black spruce are often attained on moderately well drained loam and clay loam soils, where it frequently occurs as a minor component in a mixedwood site type (Fowells 1965). In this study the best crop tree growth was recorded in P74-UN1, P77-BR2, P78-OP1, P79-AD1, and P80-SC1 (Fig. 3, Graphs 1, 7, 10, 12, and 14). All of these experiments were established on sites with soil textures ranging from fine sand to silty clay, corresponding to a fresh moisture regime (Table 2). In comparing crop tree growth on fresh sites with that on very moist sites it was evident that trees planted on the fresh, well drained sites had better growth. For example, the growth of trees planted in P77-BR2 was superior to that of trees planted in P77-BR1 (Fig. 3, Graphs 6 and 7). Planting stock of the same lot was used in both experiments, all trees were planted at roughly the same time, and the plots had a similar local climate. Likewise, in another comparison between crop trees planted in P80-PL1 and P80-SC1, height growth on the fresh site (P80-SC1) was superior (Fig. 3, Graphs 13 and 14).

Numerous investigators (e.g., Krause 1982, Scarratt 1982, Scarratt and Wood 1982) have expressed the opinion that, on sites with a heavy competition potential, large black spruce container stock (perhaps 1.5 years old with total dry weight greater than 3.0 g) or transplant stock should be planted and then given routine weed control to avoid the possibility of suppression by weed species. In the current study, it was impossible to relate the percentage cover of weeds to stock performance because assessments of competing vegetation were inadequate.

On all sites, mortality after outplanting was highest in years one and two. The rate of mortality generally stabilized in years three and five, and this suggests that the first two years after outplanting are critical in the establishment of a plantation. In a tubed seedling study in Ontario, Scarratt (1974) noted that the highest mortality occurred during the first winter after planting. The three causes of winter mortality were identified as smothering by overtopping vegetation, frost damage, and burial by eroded soil materials (ibid.).

White Spruce

Paperpot stock (both FH 308 and FH 408) was compared with transplant and seedling stock in spring and summer plantings (Table 10). In all there were 13 experimental white spruce outplantings.

Spring Plantings

Paperpot versus Transplant Stock

Refer to Figures 4 and 5, Graphs 9 to 12 (four experiments) for this section. In the fifth year, survival of FH 408 paperpot stock was equivalent to that of transplant stock in three experiments. The paperpots were in poorer condition than the transplants in three experiments. In P80-SC1 the 2+2 stock had better survival and a higher percentage of planted trees in good condition than did the FH 408-1 stock. Generally, in the second and third growing seasons, the paperpot stock was growing at the same rate as the transplant stock. However, fifth-year height increment and total height of the transplants were greater than those of the paperpots in all but one planting.

Paperpot versus Seedling Stock

Refer to Figures 4 and 5, Graphs 1 to 10 (ten experiments) for this section. In the fifth year the paperpots generally had a survival rate equivalent to or lower than that of the seedlings in eight experiments. P74-UN1 and P79-AB1 were the two exceptions. Both stock types had roughly the same percentages of trees in good condition. The Q.I. of paperpot stock planted in most of the experiments was below Roller's (1977) proposed minimum limit (see **APPENDIX B)**. Both stock types were growing at the same rate in seven experiments in years two and three, and in nine experiments by year five.

In P74-UN1 the paperpots, in comparison with the seedlings, had higher survival, a similar percentage of trees in good condition, and a similar growth rate in the third and fifth growing seasons. The seedling stock in this experiment had been fall-lifted and frozen-stored (see **APPENDIX B)**. Factors such as lifting date, storage temperature, relative humidity, and method of packaging influence the outplant performance of fall-lifted, frozen-stored white spruce (Sutton 1982, Mullin and Laupert 1981, Mullin and Parker 1974). None of these factors was recorded in the current study. Therefore, it was impossible to relate field performance to treatment of stock.

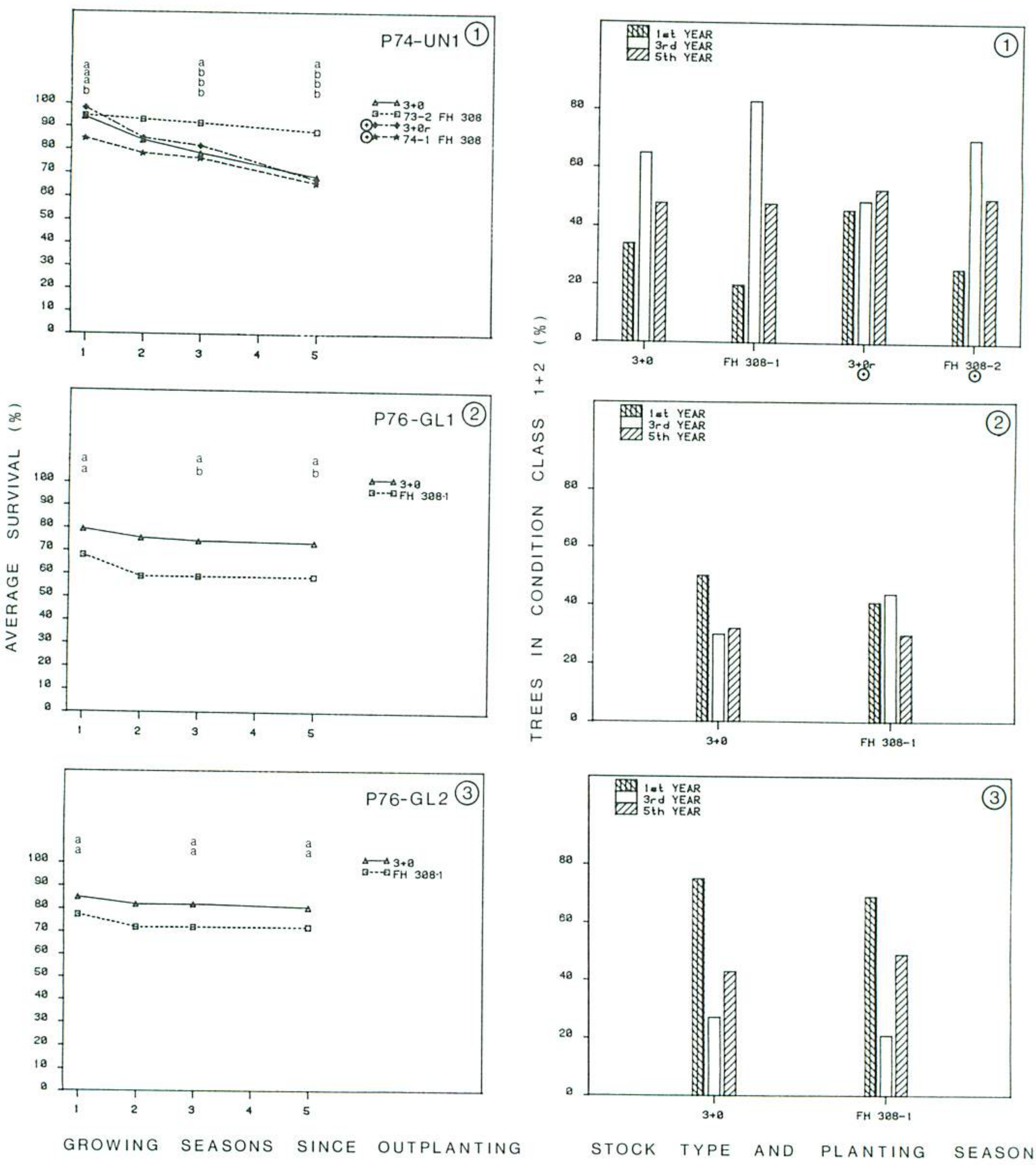


Figure 4. White spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

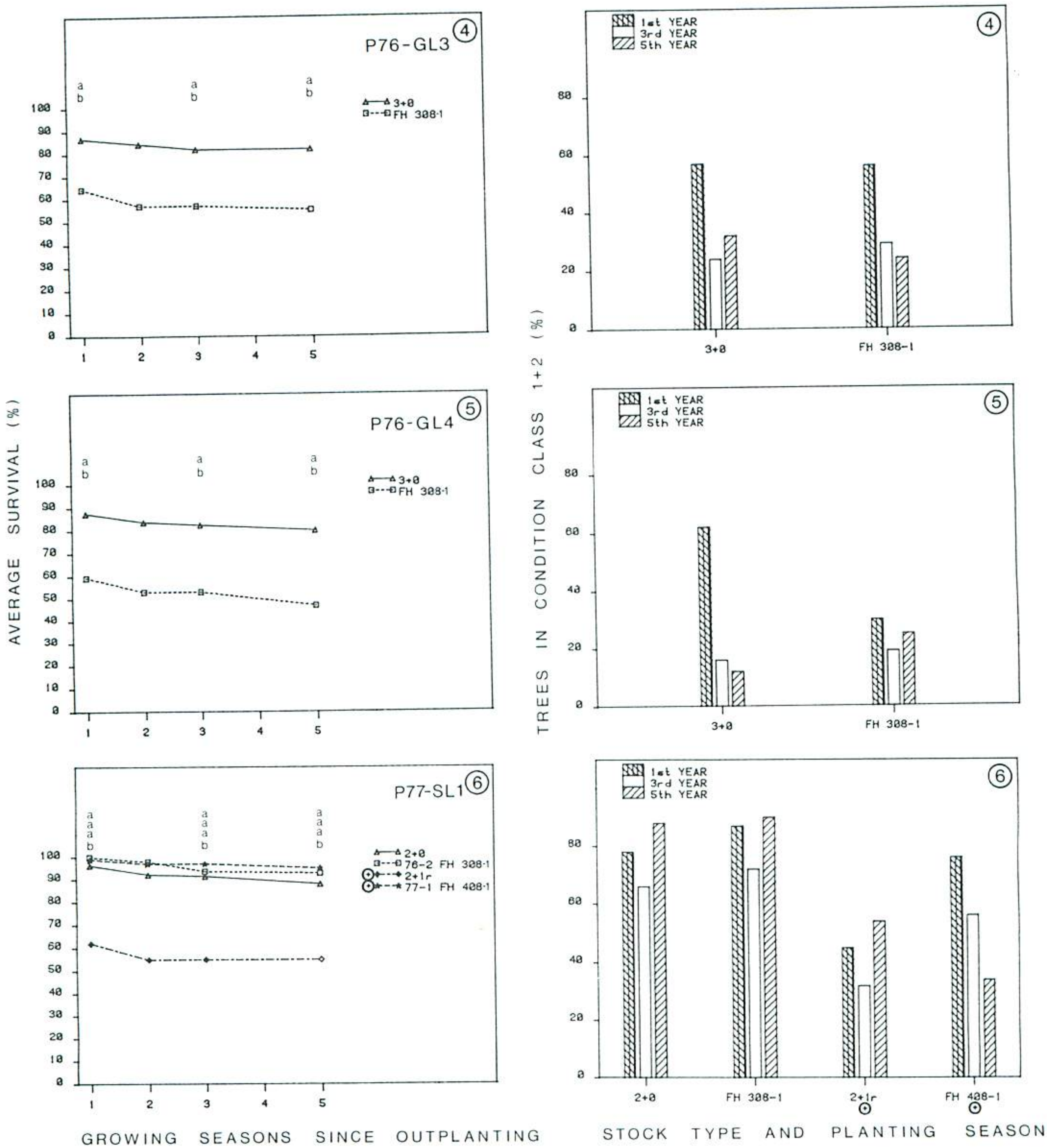


Figure 4. White spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

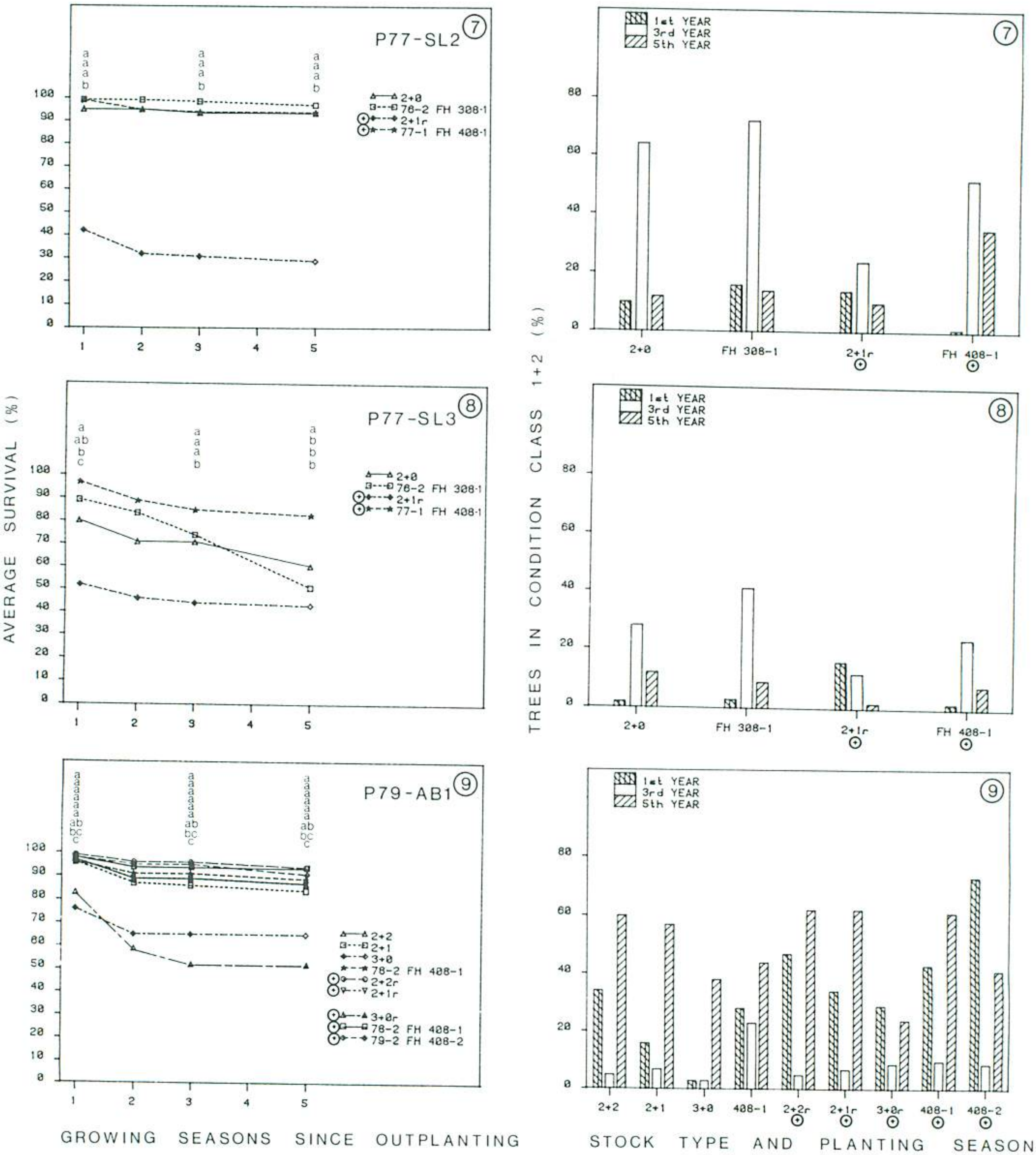


Figure 4. White spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

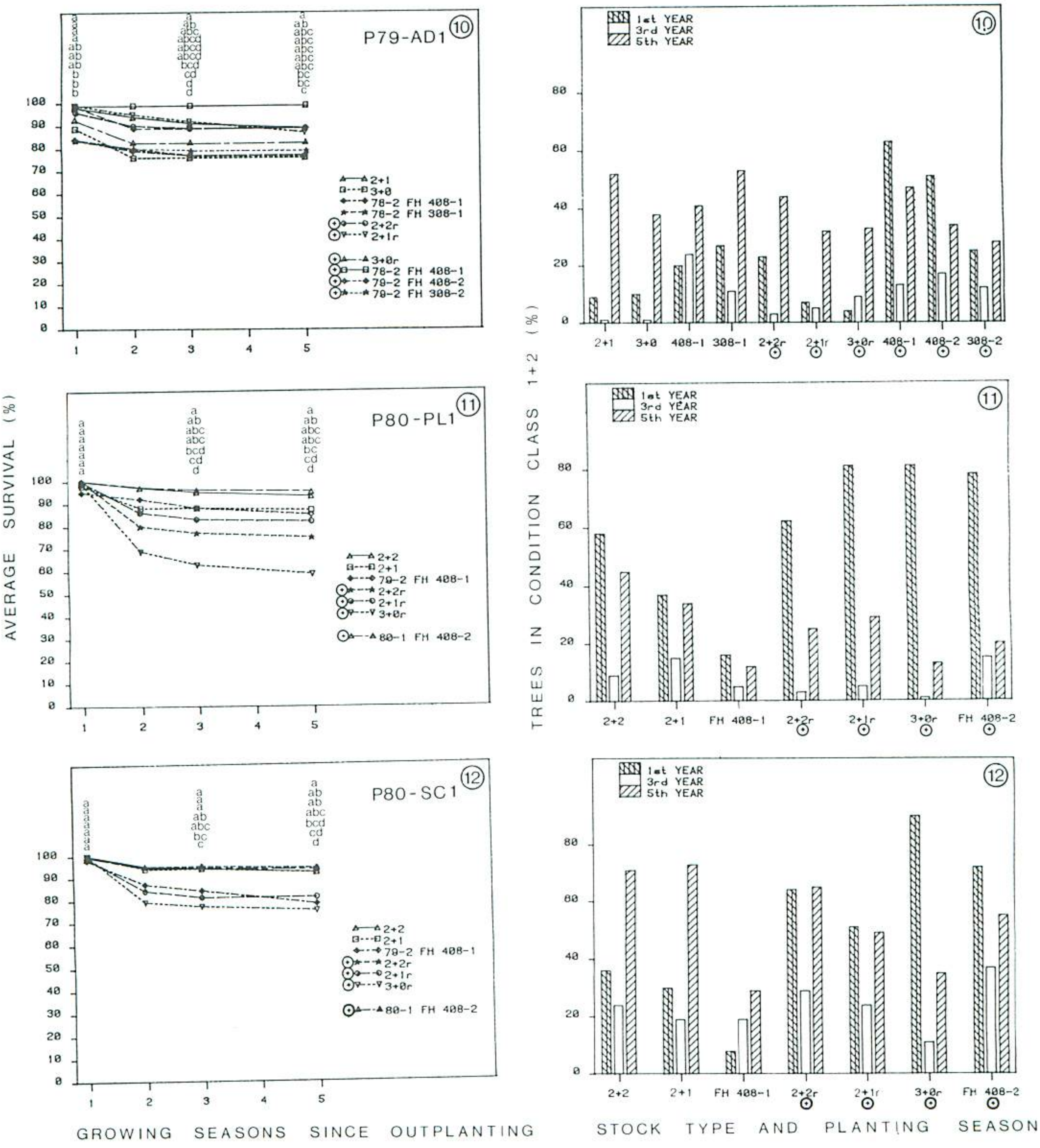


Figure 4. White spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

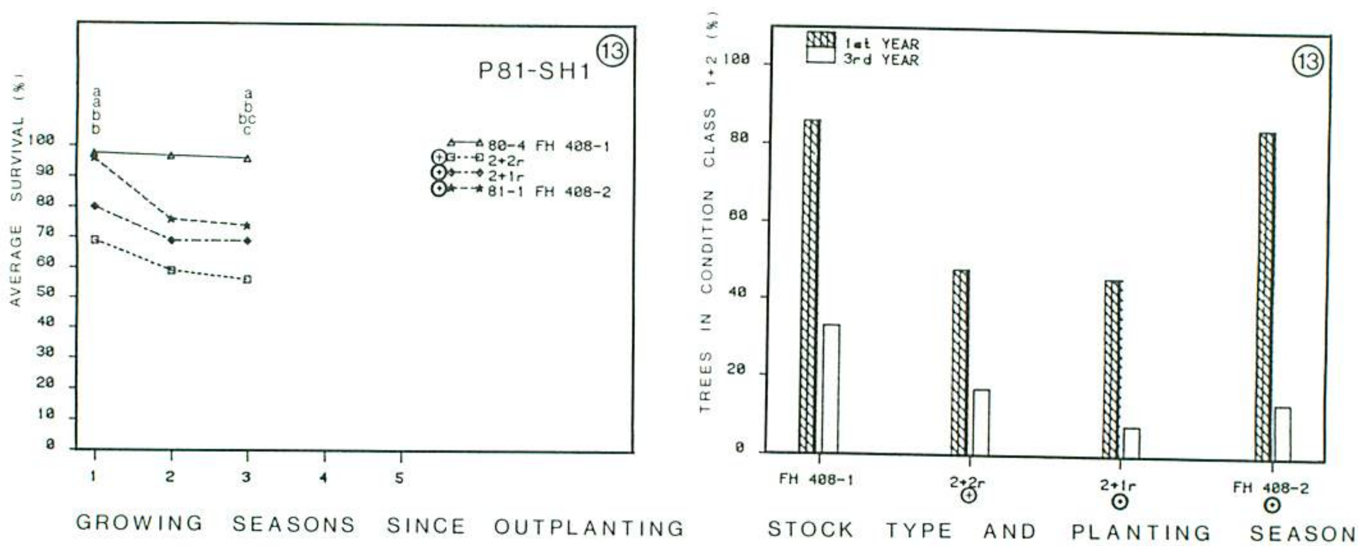


Figure 4. White spruce survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (concl.)

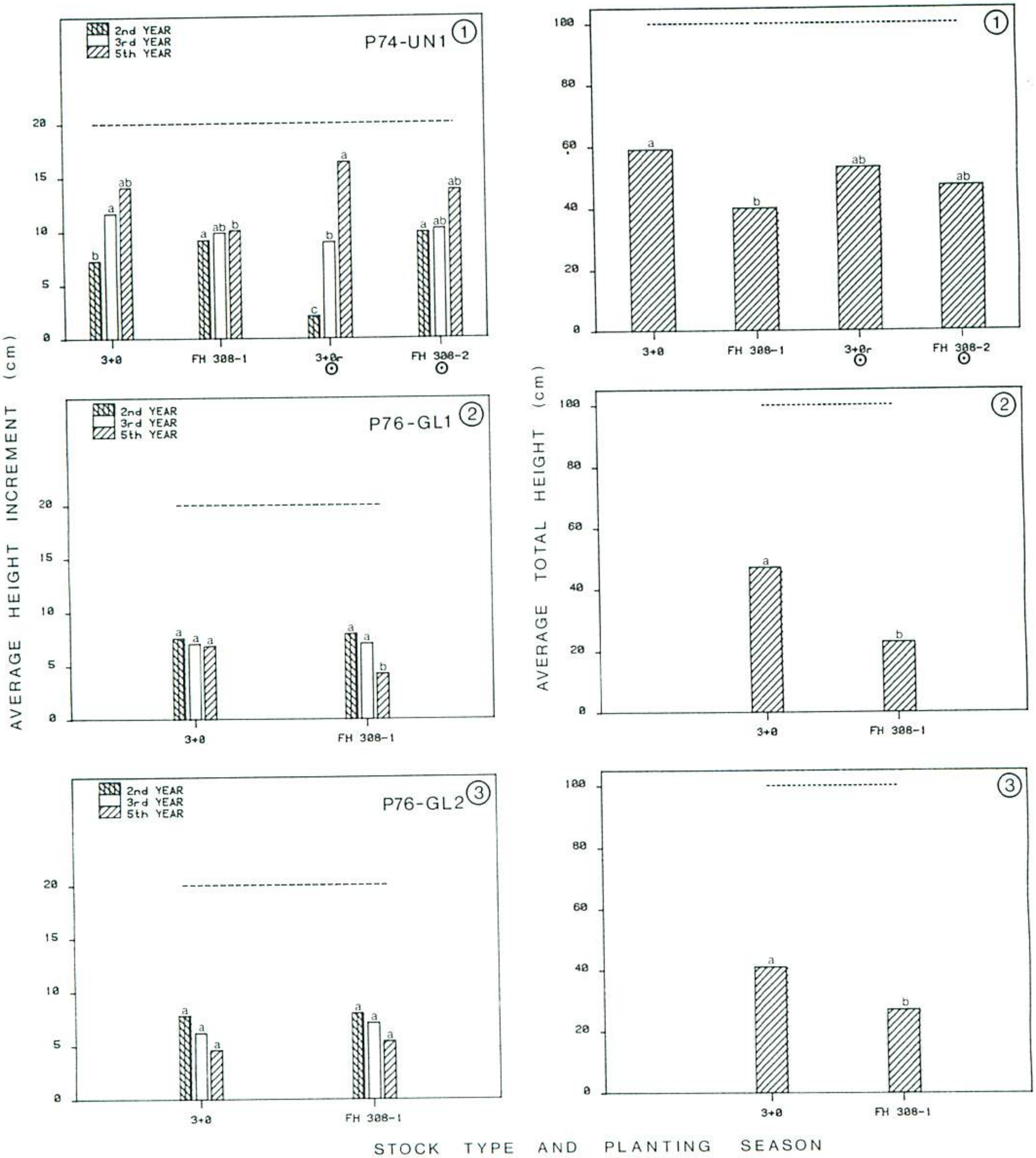


Figure 5. White spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

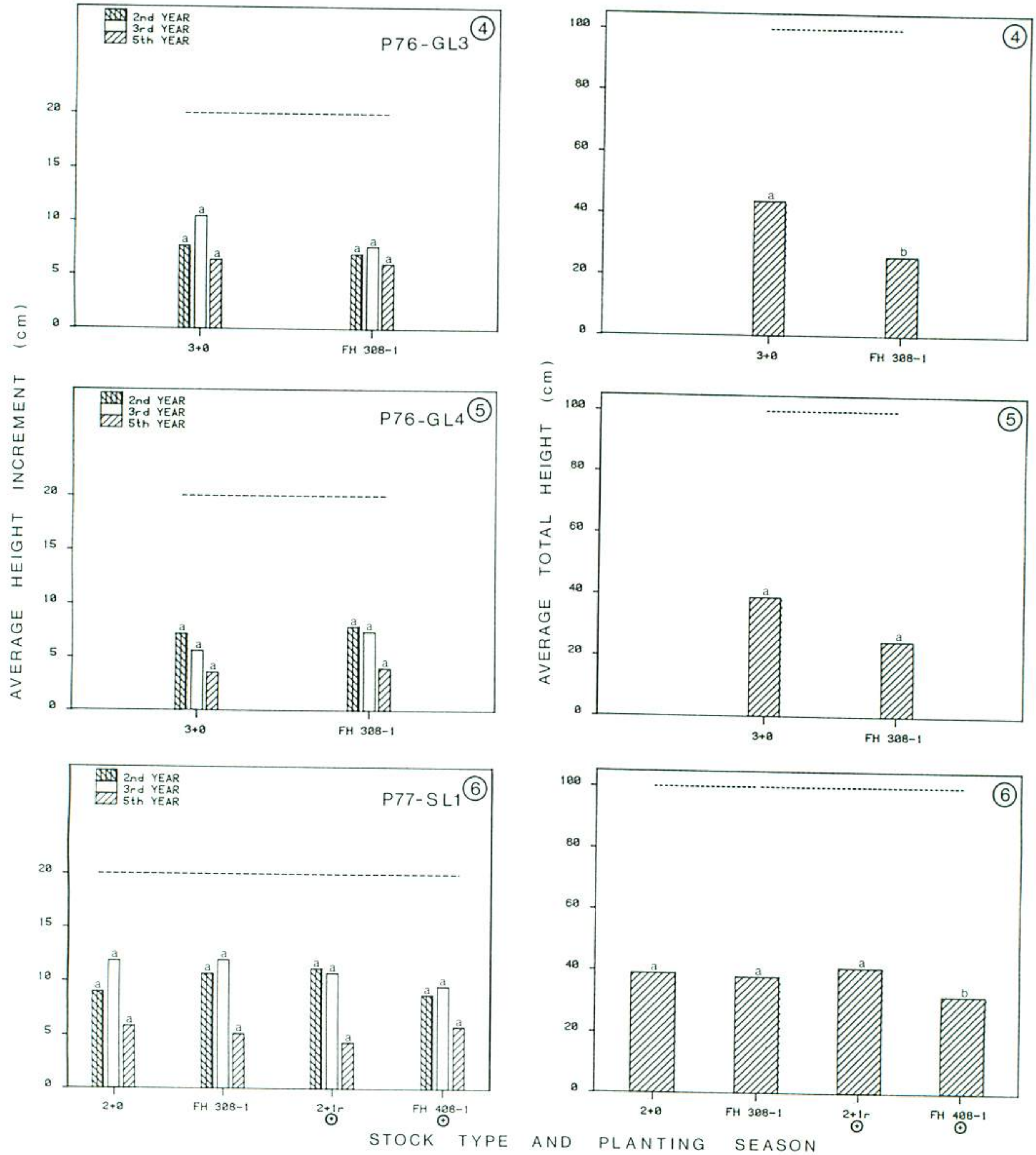


Figure 5. White spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

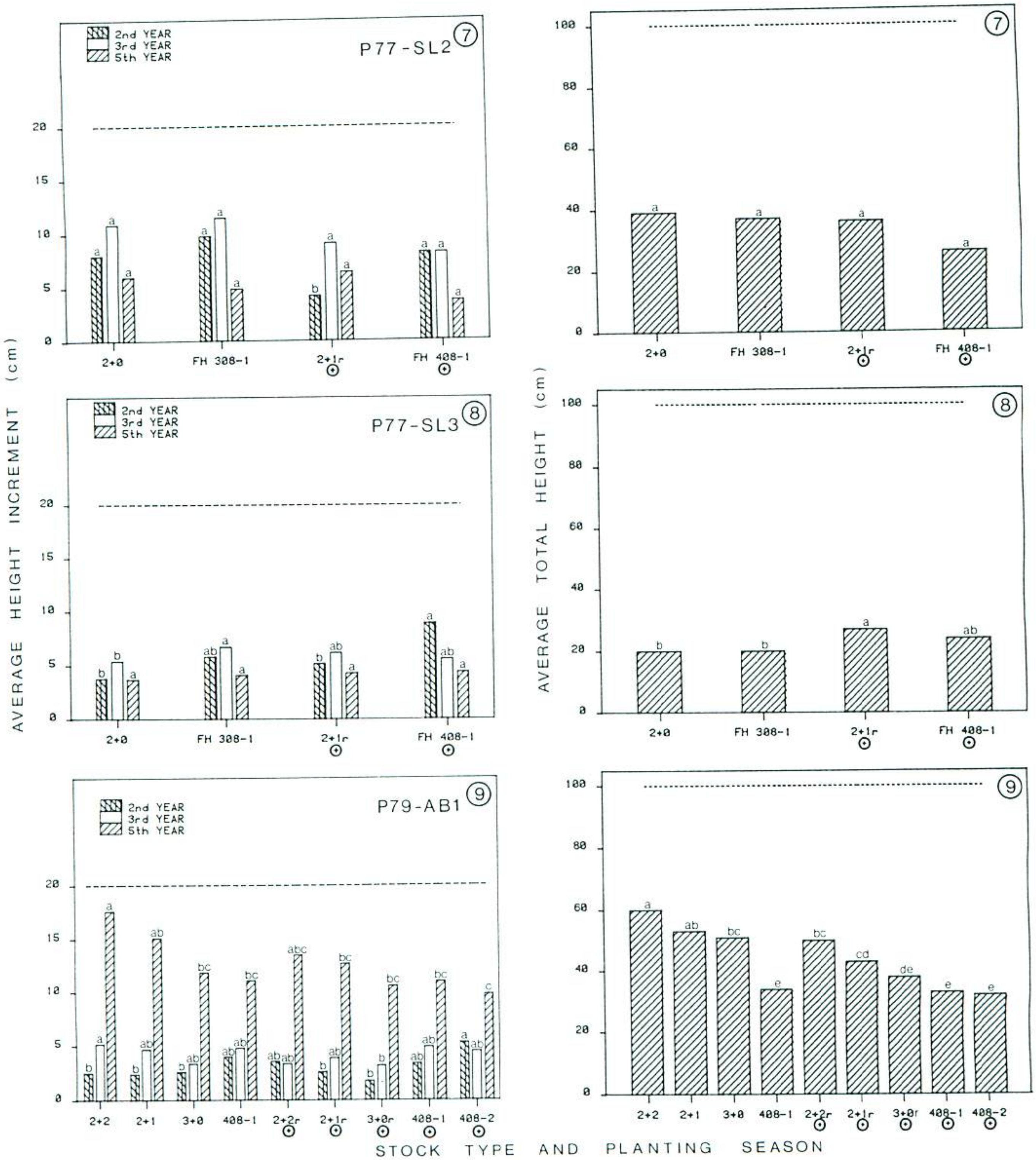


Figure 5. White spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

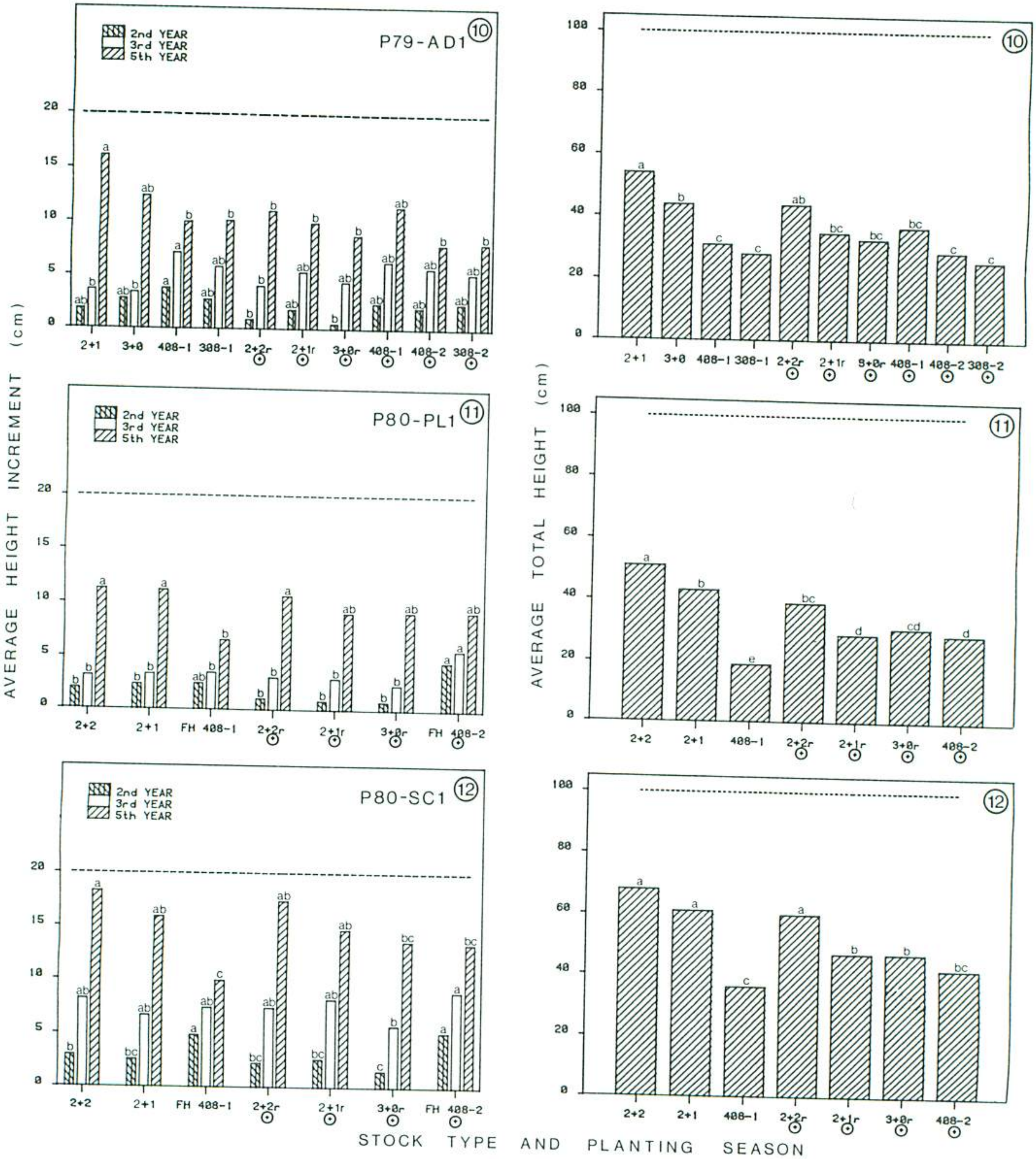


Figure 5. White spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

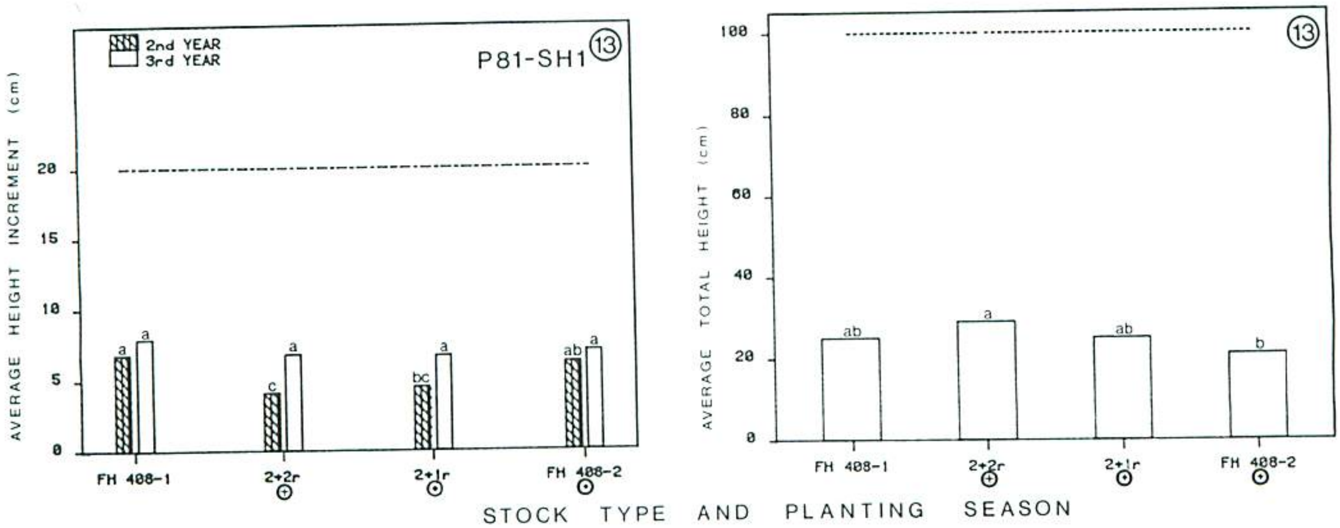


Figure 5. White spruce current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (concl.)

In the fifth year the paperpots, in comparison with the seedlings, in P79-AB1 had higher survival, a similar percentage of trees in good condition, and a similar growth rate. There was no apparent explanation for this result. In six experiments the seedlings were taller than the paperpots. In the P76-GL4 and P77 experiments the paperpots and seedlings were similar in total height.

In a study in Minnesota comparing 3+0 and 2+2 stock with paperpot stock, Alm (1983) reported that bare-root stock was significantly taller than paperpot stock after four years. Ball and Walker (1981) verified this relationship in a study in Alberta which showed that initial seedling mass was directly proportional to total seedling weight one year after outplanting. In another study, Walker and Ball (1981) showed that large white spruce seedlings raised in 164 cm^3 containers in greenhouses for 14 weeks had better fifth-year height growth under field conditions than did small container stock (i.e., stock grown in 40 cm^3 containers in greenhouses for 4 to 12 weeks). In Ontario, Scarratt (1972) found in experimental plantings with tubelings that seedling size was a major factor determining early growth performance.

The average dry weight of the spring-planted paperpots in the current study was 0.5 g (see **APPENDIX B**) and the volumes of the FH 408 and FH 308 paperpots were about 70 cm^3 and 44 cm^3, respectively. This suggests that within the Boreal Forest Region of Ontario, larger seedlings grown in larger containers may be needed if the growth of containerized white spruce is to match that of transplant stock and surpass seedling stock.

Transplant versus Seedling Stock

Refer to Figures 4 and 5, Graphs 9 and 10 (two experiments) for this section. In P79-AB1 the 2+2 stock had higher survival and was in better condition than the seedling stock, and in the fifth year was faster-growing and taller. This is in accordance with the findings of Alm (1983), Mullin (1980b), and Wang and Horton (1968), which show that white spruce transplant stock is less affected by planting check and therefore performs better than seedling stock. The result is less conclusive in the comparison between the 2+1 and 3+0 stock in the same experiment. Both stock types had similar survival and height growth, and were equal in total height. However, the transplant stock was in better condition.

In P79-AD1 the 2+1 stock, in comparison with the seedlings, had superior fifth-year survival, tree condition, and total height, but similar height growth throughout the five years. In a study in Newfoundland, Hall (1979) also showed that survival of 2+1 stock was superior to that of 3+0 stock.

Transplant Stock

<u>2+2 versus 2+1 stock</u>: Refer to Figures 4 and 5, Graphs 9, 11, and 12 (three experiments) for this section. The 2+2 and 2+1 stock had equivalent survival, condition, and height growth. Total height was equal in two experiments, but in P80-PL1 the 2+2 stock was taller. This

supports Hall's (1979) suggestion that 2+1 and 2+2 stock may be equally acceptable alternatives in plantation establishment.

Summer Plantings

All experiments, except the P76 series, contained summer-planted trees (Table 10).

Paperpot versus Rising Transplant Stock

Refer to Figures 4 and 5, Graphs 6 to 13 (eight experiments) for this section. Survival of the paperpot stock was equal to or better than that of the rising transplant stock. In the third and fifth years the paperpots and rising transplants were generally growing at the same rate. In six experiments the paperpots were as tall as the 2+1r stock; in P77-SL1 and P79-AB1 the transplants were taller. The 2+2r stock (Graphs 9 to 12) was taller than the paperpots except for the summer-planted FH 408-1 stock in P79-AD1, which was as tall as the transplant stock.

Paperpot versus Rising Seedling Stock

Refer to Figures 4 and 5, Graphs 1 and 9 to 12 (five experiments) for this section. In three experiments the paperpots had higher fifth-year survival than the rising seedlings and generally were in better condition. In P74-UN1 and P79-AD1 the two stock types had equivalent survival and were in the same condition. In the fifth growing season they were growing at the same rate. There were no differences in total height.

Rising Transplant versus Rising Seedling Stock

Refer to Figures 4 and 5, Graphs 9 to 12 (four experiments) for this section. Survival and condition of the transplants were equivalent to or better than those of the seedlings. Their growth over the five-year period was similar. At the time of the fifth-year assessment the transplants were as tall as or taller than the seedlings.

Rising Transplant Stock

<u>2+2r versus 2+1r stock</u>: Refer to Figures 4 and 5, Graphs 9 to 13 (five experiments) for this section. The 2+2r and 2+1r stock had a similar survival rate and a similar percentage of trees in good condition in four experiments. In P80-SC1, the 2+2r stock had higher survival and was in better condition. Growth rates were equivalent in all plantings. Total height was also similar, except in the P80 experiments in which the 2+2r was taller.

Planting Season: Spring versus Summer Planting

Paperpots

Refer to Figures 4 and 5, Graphs 1 and 6 to 13 (nine experiments) for this section. In five experiments, fifth-year survival of spring-planted paperpots was equivalent to that of summer-planted paperpots. The only exception in the five experiments was P79-AD1, in which the summer-planted FH 408-1 had higher survival than the spring-planted paperpots. In P74-UN1 and P81-SH1 the spring-planted trees had higher survival than the summer-planted trees. Conversely, in P77-SL3 and P80-SC1 the summer-planted stock had higher survival than the spring-planted stock. Similar trends were identified in the black spruce plantings (see page 30).

In the second and fifth years the spring- and summer-planted paperpots had equivalent height increment. In seven experiments all trees had comparable total height. In P77-SL1 the spring-planted FH 308 were taller than the summer-planted FH 408 paperpots, despite the fact that the Q.I. for the late-planted stock (0.15) was higher than for the spring-planted trees (0.05) (see **APPENDIX B**). In P80-PL1 the summer-planted paperpots were taller than their spring-planted counterparts.

Transplants

<u>2+2 versus 2+2r stock</u>: Refer to Figures 4 and 5, Graphs 9, 11, and 12 (three experiments) for this section. The 2+2 and 2+2r transplant stock in two experiments had similar rates of fifth-year survival and was in good condition. In P80-PL1 the 2+2 stock had a better survival rate. Trees planted in the spring and summer months had similar height increment. The 2+2 stock was taller than the 2+2r stock in two experiments, total heights being equivalent in P80-SC1.

<u>2+1 versus 2+1r stock</u>: Refer to Figures 4 and 5, Graphs 9 to 12 (four experiments) for this section. The 2+1 and 2+1r stock had similar rates of survival. In the fifth year in P79-AD1 and P80-SC1 the condition of the 2+1 stock was better. In the other two experiments, tree condition was similar for both plantings. Height growth in all plantings was similar for both spring- and summer-planted trees in years two and three. In year five, in three experiments, stock planted in both seasons had similar height growth. In P79-AD1 the 2+1 stock was growing faster. The 2+1 stock was taller than the 2+1r stock in all experiments.

Seedlings

Refer to Figures 4 and 5, Graphs 1, 9, and 10 (three experiments) for this section. In year five the spring- and summer-planted seedling stock had similar survival rates and a similar percentage of trees in good condition. In P79-AB1 and P79-AD1, seedlings planted in both seasons had similar growth rates. In P74-UN1 the 3+0 grew faster than the 3+0r in years two and three, but at an equivalent rate in year five. In two experiments the 3+0 and 3+0r stock was equally tall. In P79-AB1 the 3+0 was taller.

Outplant Performance Relative to Ontario Standards

By the fifth year none of the planting treatments had sufficient average height growth to meet the Ontario free-to-grow standard of 20 cm (Armson et al. 1980), although stock types in P79-AB1 and P80-SC1 had up to 18 cm of annual growth. In terms of average total height, the best treatment was 69 cm, well below the 1 m standard.

Site

On site-prepared, well drained loamy soils, white spruce has its best growth (Stiell 1976). In the current study, the best crop tree growth occurred in P79-AB1 and P80-SC1 (Fig. 4 and 5, Graphs 9 and 12), which are located on fresh, silty clay-loam or loam sites (Table 3). The growth of crop trees planted in P80-SC1, on a fresh site, was superior to trees planted in P80-PL1, on a very moist site. The same planting stock was used in both experiments, all trees were planted at roughly the same time, and both plots had a similar local climate.

In over 50% of the white spruce experiments, height increment in the fifth growing season was less than that in the second growing season. Neither black spruce nor jack pine experienced a similar decline in growth. Possible explanations for this loss of tree vigor are damage from late frosts, browsing, and weed competition. White spruce flushes from 5 to 10 days in advance of black spruce in northern Ontario (Sutton 1969) and as a result is more susceptible to late frosts. Stiell (1976) recommends that frost-prone areas be avoided when this species is being planted. He also noted that the seriousness of frost damage in white spruce has been observed mainly east of Manitoba.

Browsing by snowshoe hares *(Lepus americanus* Erxl.) may also have reduced the general crop tree vigor (Stiell 1976). In at least one other silvicultural study in northern Ontario (trees planted in 1978), hares caused considerable damage to white spruce outplants (Sutton 1984).

The decline in tree vigor may have been further exacerbated by weed competition during the third and subsequent growing seasons, as the benefits of scarification can be expected to last an average of only three years (Scarratt and Reese 1976). Competing vegetation can reduce the vigor of an outplant by lowering surrounding soil and air temperature, reducing light, and pressing the tree to the ground during the winter (McMinn 1981).

Jack Pine

Paperpot stock (FH 308 and FH 408) was compared with seedling 2+0 stock in spring and summer plantings (Table 11). There was a total of seven experimental jack pine outplantings.

Spring Plantings

Paperpot versus Seedling Stock

Refer to Figures 6 and 7, Graphs 1 to 7 (seven experiments) for this section. Paperpot and seedling stock had an equivalent survival rate and an equivalent percentage of trees in acceptable condition at the last assessment. After two growing seasons, the seedlings were growing at a faster rate than the paperpots in four experiments. In P76-GL1, P76-GL3, and P79-AD1 both stock types were growing at a similar rate. It has been documented in other studies (Scarratt 1982, Walker and Ball 1981) and shown to some degree in this study that the early growth of jack pine outplants is proportionate to initial mass. The mean dry weight at time of planting was 5.2 g for the 2+0 and 0.7 g for the spring-planted paperpots (see **APPENDIX C**). Nevertheless, by year five (year three for P81-SH1) both stock types were growing at the same rate in six experiments. In all experiments the seedling stock was taller than the paperpot stock by the final assessment year.

Summer Plantings

Paperpot versus Rising Seedling Stock

Refer to Figures 6 and 7, Graphs 5 to 7 (three experiments) for this section. The paperpots had higher survival and a higher percentage of trees in good condition than did the seedlings. The paperpots were growing at the same rate or faster than the seedlings in the second and third years. However, by the fifth year they were growing at the same rate. In terms of total height, the paperpots were as tall as or taller than the seedlings except in P81-SH1 where the rising seedlings were taller than the FH 308-2 stock.

Planting Season: Spring versus Summer Planting

Paperpots

Refer to Figures 6 and 7, Graphs 5 to 7 (three experiments) for this section. Paperpot stock planted in the spring and summer months in P78-BM1 had an equivalent rate of survival, although the percentage of summer-planted trees in good condition was lower. In P79-AD1, the summer-planted FH 408-1 and FH 408-2 stock had higher fifth-year survival and was in better condition than the spring-planted FH 308-1 stock. In the fifth year, the summer-planted FH 308-2 paperpots and spring-planted paperpots had similar survival rates and were in similar condition. In P81-SH1, the spring-planted FH 308-1 stock had higher third-year survival and was in better condition than the summer-planted FH 408-1 stock, but had a survival rate similar to that of the summer-planted FH 308-2 stock.

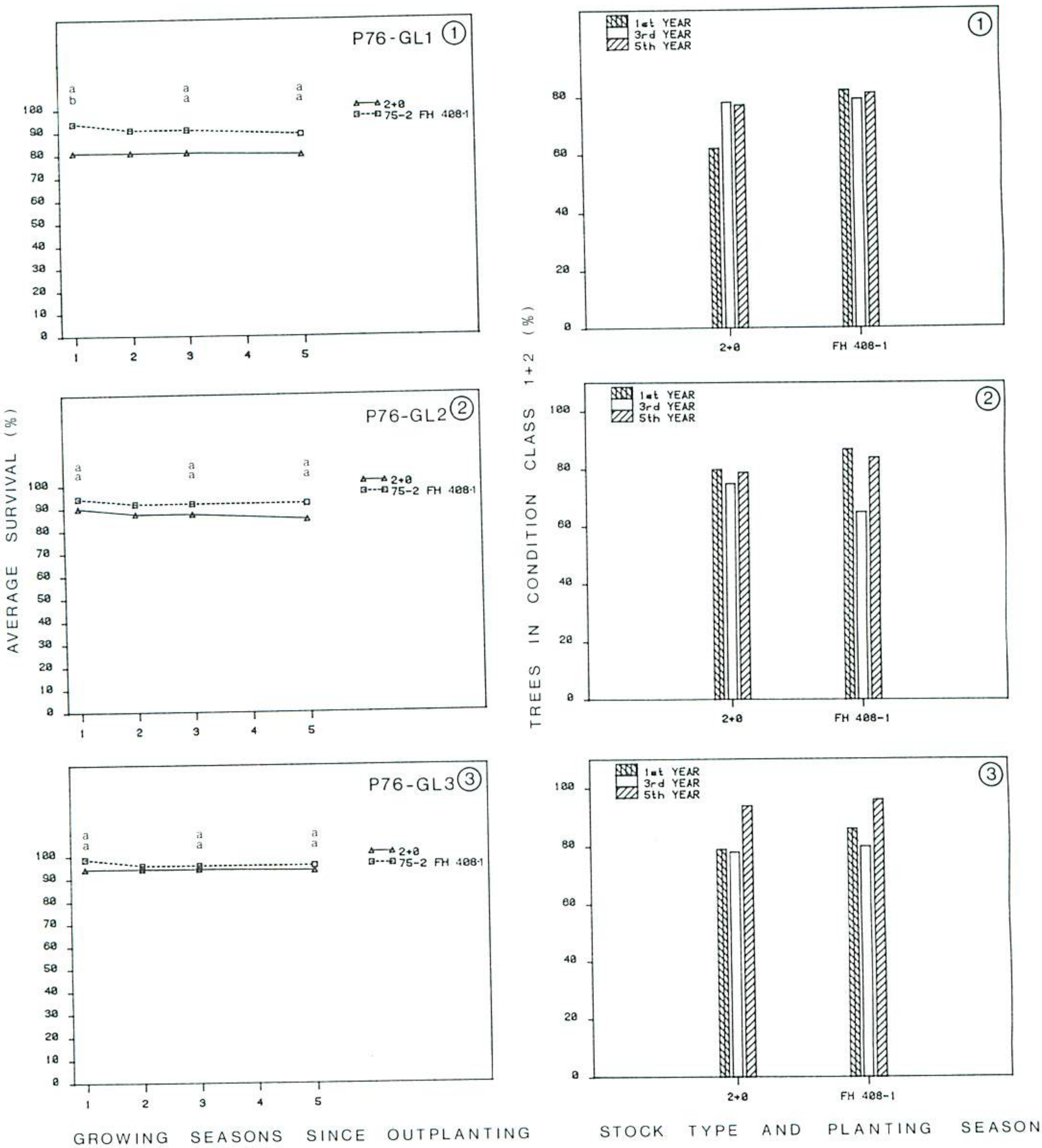


Figure 6. Jack pine survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

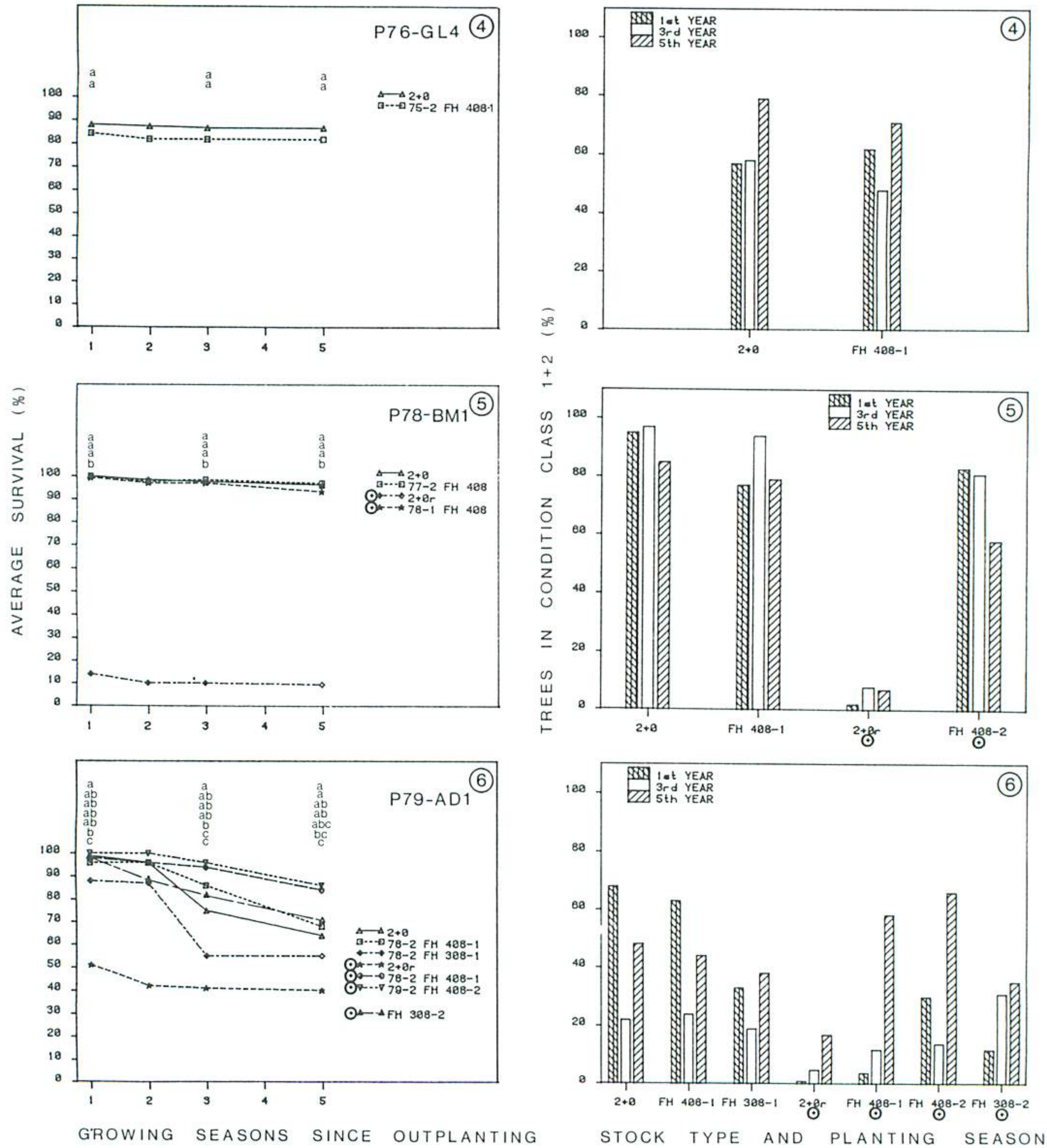


Figure 6. Jack pine survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (cont'd)

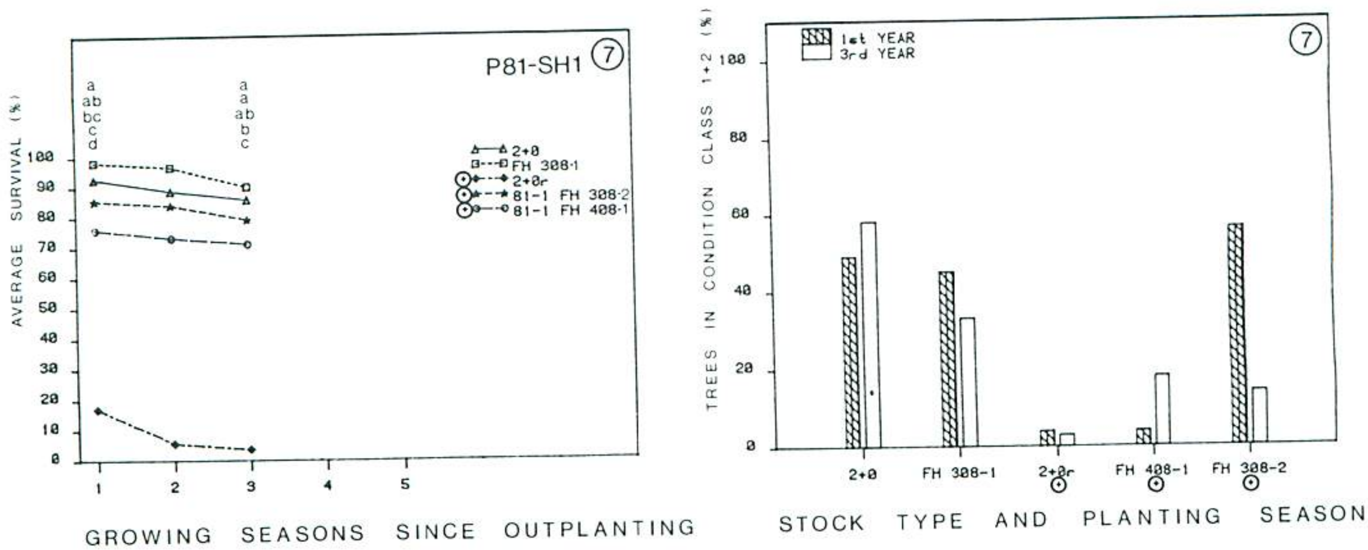


Figure 6. Jack pine survival 1, 2, 3, and 5 growing seasons after planting and trees in at least healthy condition 1, 3, and 5 growing seasons after planting. Differing letters within the same growing season indicate a significant difference at the P .01 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising. (concl.)

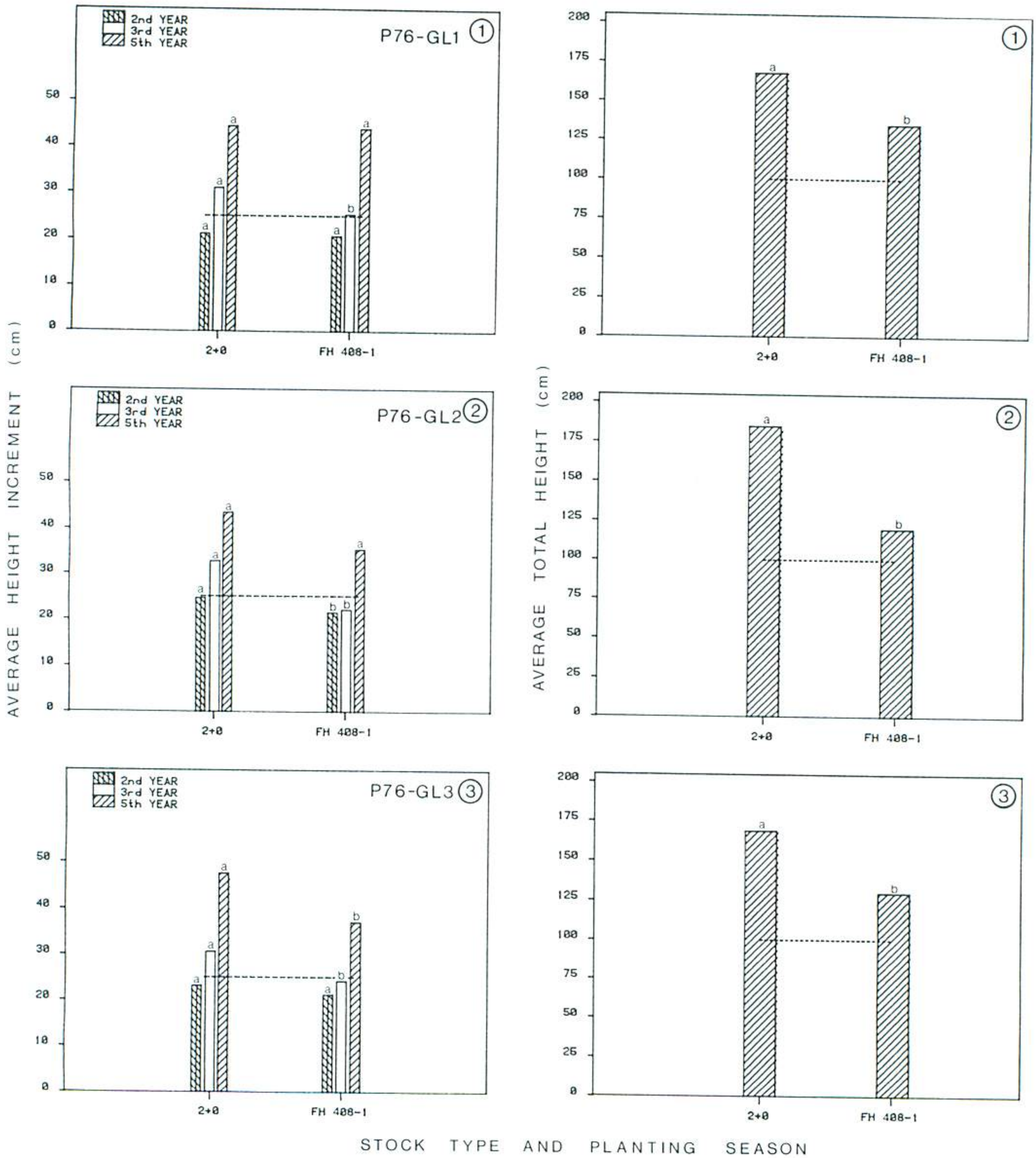


Figure 7. Jack pine current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

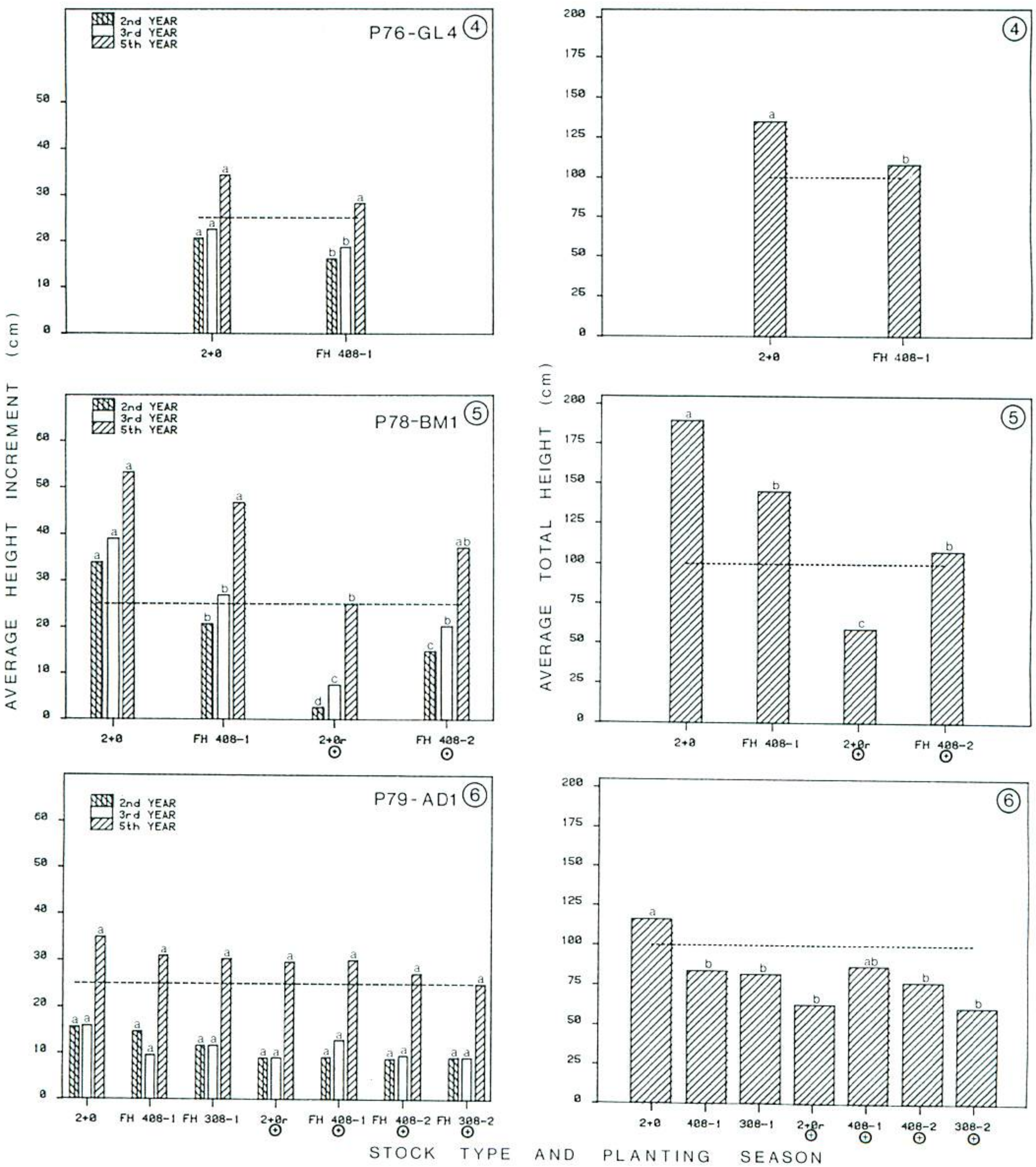


Figure 7. Jack pine current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (cont'd)

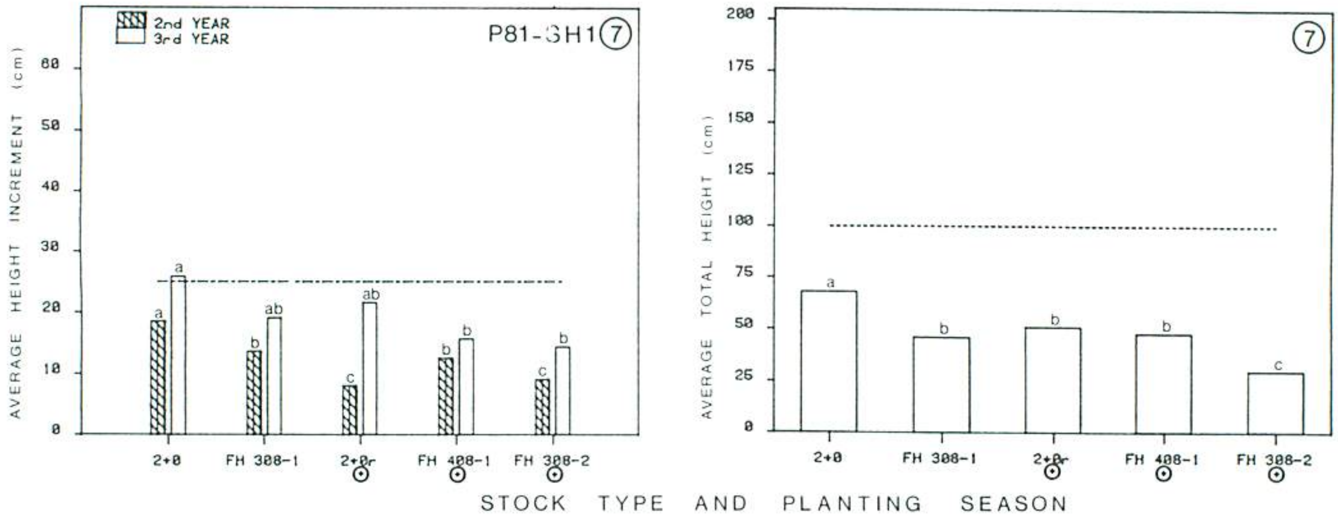


Figure 7. Jack pine current annual incremental height growth 2, 3, and 5 growing seasons after planting and total height 5 growing seasons after planting. Differing letters across the same growing season indicate a significant difference at the P .05 level; ⊕ signifies summer-planted stock; 'r' indicates that the summer-planted bare-root stock was rising; the broken line represents the minimum free-to-grow standard. (concl.)

Third-year height growth in P81-SH1 and third- and fifth-year growth in P78-BM1 and P79-AD1 was similar for trees planted in both the spring and summer months. The spring- and summer-planted trees had equivalent total height in all experiments except P81-SH1, in which the summer-planted FH 308-2 stock was shorter than the spring-planted FH 308-1 stock. The FH 308-2 stock had poor field performance potential on the basis of morphological characteristics, and a Q.I. of 0.02 (see **APPENDIX C**).

Seedlings

Refer to Figures 6 and 7, Graphs 5 to 7 (three experiments) for this section. The spring-planted seedlings had higher survival and were in better condition than the rising stock in two experiments. In P79-AD1, survival rates for spring- and summer-planted trees were similar, possibly owing to the high mortality in the 2+0 stock in comparison with other plantings, which may have been related to the heavy invasion of the site by graminoids. It has been well documented by Alm (1975, 1981) that weed competition increases mortality of jack pine. Alm (1981) found that fifth-year survival of pine tubelings planted on 1 August was 19% on control plots in comparison with 83% on plots that had the vegetative and duff layers removed prior to planting.

In the second growing season, the 2+0 stock was faster-growing than the 2+0r stock in two experiments. By the third and fifth years, the 2+0 seedlings were growing at the same rate as the 2+0r except in P78-BM1, in which the 2+0 continued to grow faster. The 2+0 stock was taller than the 2+0r stock in all experiments.

The poor early height growth of 2+0r may have been due to an inadequate root system. In P78-BM1 and P79-AD1, the root area index (R.A.I.) of the rising bare-root stock was below that of the summer-planted paperpots (see **APPENDIX C**). The 2+0 stock planted in P78-BM1 had a much higher Q.I. value (0.79) and greater R.A.I. (44.2 cm^2) than its summer-planted counterpart (0.23 and 5.9 cm^2, respectively) (see **APPENDIX C**). Bunting and Mullin (1967) found that 2+1 fresh-lifted stock planted in July had lower survival than May-planted stock and was shorter after 15 years. Mullin and Reffle (1980) recommended a cutoff date of about 25 May for planting fresh-lifted jack pine seedlings. The high survival of the fresh-lifted spring-planted (22 June) seedling stock in P78-BM1 was at least in part attributable to a wetter-than-normal first growing season (Kirkland Lake weather station) (see **APPENDIX E**).

Outplant Performance Relative to Ontario Standards

All planting treatments had equalled or surpassed the Ontario free-to-grow standard of 25 cm for average height increment (Armson et al. 1980). Most treatments had reached the free-to-grow requirement of 1 m for average total height by the fifth year except the 2+0r seedlings in P78-BM1 and 2+0r and spring- and summer-planted paperpots in P79-AD1.

Site

The best crop tree performance was in experiment P78-BM1, a well drained, loamy sand site. Fowells (1965) stated that the optimum performance of jack pine is attained on this soil type.

In all experiments except one, average height increment increased with successive assessments. In P79-AD1 the third-year growth rate was similar to or lower than the second-year growth rate. This may have been a result of vegetative competition and the fact that the months of July and August 1981 in the vicinity of P79-AD1 (Timmins weather station) were drier than normal (see **APPENDIX E**).

SUMMARY

Black Spruce

The field performance of the spring-planted transplants was superior to that of the spring-planted paperpots on the majority of sites (Table 12). The transplants were generally faster growing than the paperpots by the final assessment. The spring-planted paperpot stock was frequently superior to the spring-planted seedling stock in terms of survival and condition. In the second year, the paperpots on average were faster-growing than the seedling stock; however, in years three and five both stock types were growing at the same rate. The early-planted transplants usually had higher fifth-year survival, were in healthier condition, and were growing faster than the spring-planted seedlings.

Field performance of summer-planted paperpots was generally superior to that of rising bare-root stock (Table 12). In year two, the summer-planted paperpots were generally growing faster than the rising bare-root stock; however, in years three and five they were growing at the same relative rate.

Summer-planted paperpot stock generally had an equivalent or higher survival rate and its condition was similar to or better than that of spring-planted paperpot stock. In terms of height growth, spring- and summer-planted paperpots performed equally well. In the fifth year, on most sites, spring-planted transplants had higher survival, were in better condition, and were faster growing than rising transplants. Spring-planted seedling stock performed better than rising seedling stock in terms of survival and condition. In terms of height growth, spring-planted seedlings were generally growing at the same rate as, or faster than, the late-planted seedling stock. A fresh, very fine sandy soil was the only soil type to support planting treatments attaining the Ontario free-to-grow standards for height growth.

Table 12. Relative performance index for black spruce obtained by multiplying fifth-year survival by fifth growing season average height increment (cf. Mullin 1972 and Wang and Horton 1968). See Table 9 for details of planting stock grades.

	Planting stock type					
	Spring-planted			Summer-planted		
Experiment designation	Transplants	Seedlings	Paperpots	Transplants	Seedlings	Paperpots
P74-UN1		1652	1807		1172	1382
P76-GL1	1436		937			
P76-GL2	1322		737			
P76-GL3	1595		948			
P76-GL4	1013		601			
P77-BR1		787[a]	1195		840	1139
P77-BR2		1435[a]	1456		952	1643
P77-SL2		952[a]	1655		446	1197
P77-SL3		590[a]	656		521	854
P78-OP1	1976	1025	1357	1114		1676
P79-AB2	1205	533	1301	842	378	1080[b]
P79-AD1	1777	1380	895[b]	1197	656	1186[b]
P80-PL1	999	434	909	617		967
P80-SC1	1677	836	1126	1374		1323
P81-SH1[c]	--	--	--	--		--
Mean	1444	962	1113	1029	709	1245

[a] 2+0 rather than 3+0 seedling stock was outplanted.

[b] More than one grade of stock planted per stock type.

[c] Not included in calculations because only third-year data available.

White Spruce

The spring-planted paperpots were generally equivalent in survival to the spring-planted transplant stock. However, fifth-year height growth and condition of the transplants were generally superior to those of the paperpots. Over all, the field performance of spring-planted transplants was superior to that of paperpot stock (Table 13). Survival of spring-planted seedlings was equivalent to or better than that of spring-planted paperpots. In year five, the paperpots and seedlings were growing at the same rate. Transplant stock usually had an equivalent or better survival rate, and was in better condition than spring-planted seedlings. The 2+2 and 2+1 stock had equivalent survival, condition and height growth.

Survival of late-planted paperpot stock was equal to or better than that of rising transplant stock. In the third and fifth growing seasons both stock types were growing at the same rate. Survival and condition of summer-planted paperpots were similar to or better than those of rising seedlings. In the fifth growing season these two stock types were growing at the same rate. Survival rate and condition of rising transplants were equivalent to or better than those of rising seedlings. Summer-planted seedlings and transplants had similar rates of height growth. All summer-planted stock types had about the same field performance (Table 13).

Survival in over 50% of the plantings was equivalent for spring- and summer-planted paperpots. The spring- and summer-planted paperpots had comparable height growth. By the fifth year no experiments had achieved the Ontario free-to-grow standard for either height growth or total height. The best growth occurred on fresh, silty clay-loam or loam sites.

Table 13. Relative performance index for white spruce obtained by multiplying fifth-year survival by fifth growing season average height increment (cf. Mullin 1972 and Wang and Horton 1968). See Table 10 for details of planting stock grades.

	Planting stock type					
	Spring-planted			Summer-planted		
Experiment designation	Transplants	Seedlings	Paperpots	Transplants	Seedlings	Paperpots
P74-UN1		966	889		1104	908
P76-GL1		509	253			
P76-GL2		371	392			
P76-GL3		524	336			
P76-GL4		288	188			
P77-SL1		519[a]	482	242		560
P77-SL2		562[a]	476	187		346
P77-SL3		224[a]	208	184		365
P79-AB1	1404[b]	774	986	1184[b]	546	963[b]
P79-AD1	1438	941	767[b]	915[b]	719	807[b]
P80-PL1	1010[b]		562	775[b]	546	886
P80-SC1	1573[b]		769	1398[b]	1016	1260
P81-SH1[c]			--	--		--
Mean	1356	568	526	698	786	762

[a] 2+0 rather than 3+0 seedling stock was outplanted.

[b] More than one grade of stock planted per stock type.

[c] Not included in calculations because only third-year data available.

Jack Pine

The spring-planted paperpot and seedling stock had equivalent survival rates and percentages of trees in acceptable condition at the last assessment. Spring-planted seedlings were growing at a faster rate in the early years, but paperpots had achieved equivalent height growth by the final year of assessment.

In the summer-planted stock, field performance of paperpots was much superior to that of rising seedling stock (Table 14).

Height growth was similar for both spring- and summer-planted paperpots. The 2+0 stock and spring-planted paperpots were superior to the 2+0r stock in overall field performance (Table 14).

All treatments achieved the free-to-grow standard for height increment. Most treatments had reached the free-to-grow requirement for total height by the fifth year. The best jack pine crop tree growth occurred on a well drained loamy sand site.

Table 14. Relative performance index for jack pine obtained by multiplying fifth-year survival by fifth growing season average height increment (cf. Mullin 1972, and Wang and Horton 1968). See Table 11 for details of planting stock grades.

Experiment designation	Planting stock type			
	Spring-planted		Summer-planted	
	Seedlings	Paperpots	Seedlings	Paperpots
P76-GL1	3552	3898		
P76-GL2	3685	3246		
P76-GL3	4465	3547		
P76-GL4	2977	2296		
P78-BM1	5128	4535	240	3469
P79-AD1	2234	1873[a]	1173	2200[a]
P81-SH1[b]	--	--	--	--
Mean	3674	3232	706	2834

[a] More than one grade of stock planted per stock type.

[b] Not included in calculations because only third-year data were available.

CONCLUSIONS

Black Spruce

On sites similar to those tested, the best black spruce planting option would seem to be the spring-planting of transplant stock. The poorest treatment was the summer-planted rising seedling stock. The spring- and summer-planted paperpots performed better than the corresponding seedling stock. The FH 408 paperpots were the best summer-planted stock tested. The best black spruce crop tree growth occurred on fresh sites with fine sand to silty clay soils. Frequently, stock of poor morphological index did not perform as well as stock of higher morphological index (i.e., large, sturdy stock), this trend being more pronounced with later plantings.

White Spruce

Over the range of sites and stock types tested, the best spring planting treatment was transplant stock and the best summer planting treatments were fresh-lifted rising transplants and paperpots. Generally, the spring-planted seedling stock had better survival than the spring-planted paperpots and was growing at roughly the same rate in year five.

The best growth occurred on well drained loamy soils. In numerous experiments tree vigor declined over the five-year period possibly owing to frost, browsing, and/or competition from weeds.

Jack Pine

In this study, the spring-planted FH 408 paperpots and the 2+0 stock generally had equivalent survival and fifth-year height growth. The FH 408 paperpots were the best summer-planted stock. Over all, the poorest planting option was the summer-planted rising seedling stock. Stock of low morphological index did not appear to perform as well as stock of higher morphological index.

RECOMMENDATIONS

Black Spruce

1. On sites similar to those tested, black spruce paperpot stock may be planted until the end of July without its field performance being affected adversely, provided that proper transportation and handling procedures are followed.

2. Stock of low morphological index, including rising bare-root stock, should not be planted during the harsh summer months.

3. In the spring planting season on sites similar to those tested in this study, the forest manager should use either 1.5+1.5 or container stock.

4. On sites with a heavy competition potential, transplant stock or container stock of comparable grade should be used. Weed control may still be necessary.

White Spruce

1. On site types similar to those examined in this study, the planting season may be extended successfully with either paperpots or fresh-lifted transplant stock, although slightly better survival may be attained with the former.

2. Either 2+2 or 2+1 stock should be selected for spring planting on similar sites.

Jack Pine

1. On sites similar to those tested, the summer planting of rising seedling stock is not a feasible method of extending the planting season.

2. Reforestation with containerized jack pine through to the end of July is a practicable planting option.

LITERATURE CITED

Alm, A.A. 1975. Status of containerized forest seedling research in Minnesota. Minn. Acad. Sci. J. 41:18-21.

Alm, A.A. 1981. Pine tubeling survival varies with vegetative competition. Tree Plant. Notes 25:33-36.

Alm, A.A. 1983. Black and white spruce plantings in Minnesota: container vs bareroot stock and fall vs spring planting. For. Chron. 59:189-191.

Anon. 1974. Monthly record meteorological observations in Canada, April - October 1974. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont.

Anon. 1975. Monthly record meteorological observations in Canada, April - October 1975. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont.

Anon. 1976. Monthly record meteorological observations in Canada, April - October 1976. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont.

Anon. 1977. Monthly record meteorological observations in eastern Canada, April - October 1977. Dep. Fish. Environ., Atmospher. Environ. Serv., Downsview, Ont. 62:(4-10). Part 3.

Anon. 1978. Monthly record meteorological observations in eastern Canada, April - October 1978. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont. 63:(4-10). Part 3.

Anon. 1979a. Monthly record meteorological observations in eastern Canada, April - October 1979. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont. 64:(4-10). Part 3.

Anon. 1979b. Statistics. Ont. Min. Nat. Resour., Toronto, Ont. 120 p.

Anon. 1980. Monthly record meteorological observations in eastern Canada, April - October 1980. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont. 65:(4-10). Part 3.

Anon. 1981. Monthly record meteorological observations in eastern Canada, April - October 1981. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont. 66:(4-10). Part 3.

Anon. 1982. Monthly record meteorological observations in eastern Canada, April - October 1982. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont. 67:(4-10). Part 3.

Anon. 1983. Ontario climate summary, April - October 1983. Dep. Environ., Atmospher. Environ. Serv., Downsview, Ont.

Armson, K.A. 1975. Establishment and early development of black spruce. p. 45-56 *in* Black Spruce Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. O-P-4.

Armson, K.A., Robinson, F.C. and Osborn, J.E. 1980. Forest management manual for the province of Ontario. Ont. Min. Nat. Resour., For. Resour. Group, Toronto, Ont. 132 p.

Ball, W.J. and Walker, N.R. 1981. Increasing shoot-root ratio and seedling size improves 1st-year performance. p. 7 *in* Forestry Report No. 24. Fall 1981. Dep. Environ., Can. For. Serv., Edmonton, Alta.

Barber, J.C. 1982. Reforestation: key to southern forest productivity. p. 3-5 *in* R.W. Guldin and J.P. Barnett, *Ed*. Proc. Southern Containerized Forest Tree Seedling Conference. USDA For. Serv., New Orleans, La. Gen. Tech. Rep. SO-37.

Bélisle, J., *Ed*. 1980. Field manual for describing soils. Ont. Inst. Pedol., Guelph, Ont.

Boissonneau, A.N. 1966. Glacial history of northeastern Ontario. I. The Cochrane-Hearst area. Can. J. Earth Sci. 3:559-578.

Bunting, W.R. and Mullin, R.E. 1967. Summer and fall plantings of jack pine in Ontario suffer high mortality and slower height growth after 15 years. Tree Plant. Notes 18:22-24.

Chapman, L.J. and Thomas, M.K. 1968. The climate of northern Ontario. Dep. Transp., Meteorol. Br., Climatol. Stud. No. 6. 58 p.

Dickson, A., Leaf, A.L., and Hosner, J.F. 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. For. Chron. 36:10-13.

Forward, P.W. 1982. Stock production specifications - bareroot stock "state of the art". p. 260-272 *in* G.D. Mroz and J.F. Berner, *Comp.* Proc. Artificial Regeneration of Conifers in the Upper Great Lakes Region. Mich. Tech. Univ., Houghton, Mich.

Fowells, H.A., *Comp.* 1965. Silvics of forest trees of the United States. USDA Div. Timber Manage. Res., For. Serv., Washington, D.C. Agric. Handb. No. 271. 762 p.

Fry, R.D. 1975. Tree planting and stock quality--a view from the forest. p. 80-85 *in* Black Spruce Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. O-P-4.

Haavisto, V.F. and Jeglum, J.K. 1984. Forestry study tour of Finland. Can. For. Ind. 104(5):38-41.

Hall, J.P. 1979. Early survival and growth of four age classes of white spruce seedlings in western Newfoundland. Dep. Fish. Environ., Can. For. Serv., St. John's, Nfld. Inf. Rep. N-X-165. 8 p.

Heeney, C.J. 1982. The status of container planting programs in Canada: 5. Ontario. p. 35-39 *in* J.B. Scarratt, C. Glerum, and C.A. Plexman, *Ed.* Proc. Canadian Containerized Tree Seedling Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. COJFRC Symp. Proc. O-P-10.

Hills, G.A. 1959. A ready reference to the description of the land of Ontario and its productivity. Ont. Dep. Lands For., Div. Res., Maple, Ont. Prelim. Rep. 142 p.

Krause, H.H. 1982. Early growth of bare-root and paperpot plantations at various locations in New Brunswick. p. 355-366 *in* J.B. Scarratt, C. Glerum and C.A. Plexman, *Ed.* Proc. Canadian Containerized Tree Seedling Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. COJFRC Symp. Proc. O-P-10.

McClain, K.M. 1975. Continuous planting of seedling black spruce. p. 177-194 *in* Black Spruce Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. O-P-4.

McClain, K.M. 1981. Effects of continuous planting on black spruce survival and growth: an interim report. Ont. Min. Nat. Resour., For. Res. Note 28. 4 p.

McMinn, R.G. 1981. Ecology of site preparation to improve performance of planted white spruce in northern latitudes. Paper presented at Third Annual Workshop, International Committee on Regeneration of Northern Latitude Forest Lands, IUFRO W.P. S1 .05-.08 (Natural Stand Regeneration), Prince George, B.C. 30 August - 1 September 1981.

Morrison, I.K. and Armson, K.A. 1968. The rhizometer--a device for measuring roots of tree seedlings. For. Chron. 44:21-23.

Mullin, R.E. 1972. Machine planting of red pine. For. Chron. 48:37-38.

Mullin, R.E. 1980a. Comparison of seedling and transplant performance following 15 years growth. For. Chron. 56:231-232.

Mullin, R.E. 1980b. Recent tests of seedlings *versus* transplants. Ont. Min. Nat. Resour., For. Res. Note No. 26. 3 p.

Mullin, R.E. and Laupert, R.E. 1981. Cold and frozen overwinter storage of white pine at St. Williams nursery. Ont. Min. Nat. Resour., Nurs. Notes 70. 5 p.

Mullin, R.E. and Parker, J.D. 1974. Bales *versus* polybags in cold and frozen overwinter storage of nursery stock. Can. J. For. Res. 4:254-258.

Mullin, R.E. and Reffle, R.J. 1980. Effects of dates of lifting and planting on success of frozen spring storage at Swastika nursery. Ont. Min. Nat. Resour., Nurs. Notes 66. 5 p.

Reese, K.H. and Sadreika, V. 1979. Description of bareroot shipping stock and cull stock. Ont. Min. Nat. Resour., For. Resour. Br., Toronto, Ont. 39 p.

Roller, K.J. 1977. Suggested minimum standards for containerized seedlings in Nova Scotia. Dep. Fish. Environ., Can. For. Serv., Fredericton, N.B. Inf. Rep. M-X-69. 18 p.

Rowe, J.S. 1972. Forest regions of Canada. Dep. Environ., Can. For. Serv., Ottawa, Ont. Publ. 1300. 172 p.

Scarratt, J.B. 1972. Relationship between size at planting and growth of white spruce tubed seedlings. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-168. 15 p.

Scarratt, J.B. 1974. Performance of tubed seedlings in Ontario. p. 310-320 *in* R.W. Tinus, W.I. Stein and W.E. Balmer, *Ed.* Proc. North American Containerized Forest Tree Seedling Symposium. Great Plains Agric. Counc. Publ. No. 68.

Scarratt, J.B. 1982. Container stock specifications for northern Ontario. p. 343-354 *in* J.B. Scarratt, C. Glerum and C.A. Plexman, *Ed.* Proc. Canadian Containerized Tree Seedling Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. COJFRC Symp. Proc. O-P-10.

Scarratt, J.B., *Comp.* 1985. Containerized seedling production statistics for Ontario, 1982. A joint report of Great Lakes Forest Research Centre and Ontario Ministry of Natural Resources compiled under the auspices of the Container Stock Working Group of the Canada-Ontario Joint Forestry Research Committee. Can. For. Serv., Sault Ste. Marie, Ont. Joint Rep. 5. 16 p.

Scarratt, J.B. and Reese, K.H. 1976. Objectives and criteria for planting stock production in Ontario. Dep. Fish. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-253. 17 p.

Scarratt, J.B. and Wood, J.E. 1982. Development and evaluation of container planting methods. p. 6-8 *in* C.A. Plexman, *Ed.* Forestry Research Newsletter. Summer 1982. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont.

Sokal, R.R. and Rolph, F.J. 1981. Biometry. The principles and practice of statistics in biological research. 2nd ed. W.H. Freeman and Co., San Francisco. 859 p.

Steel, R.G.D. and Torrie, J.H. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill Book Co. Inc., New York. 481 p.

Stiell, W.M. 1976. White spruce: artificial regeneration in Canada. Dep. Environ., Can. For. Serv., Ottawa, Ont. Inf. Rep. FMR-X-85. 275 p.

Sutton, R.F. 1969. Silvics of white spruce *(Picea glauca* [Moench] Voss). Dep. Fish. For., For. Br. Publ. No. 1250. 57 p.

Sutton, R.F. 1982. Plantation establishment in the boreal forest: planting season extension. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. 0-X-344. 129 p.

Sutton, R.F. 1984. Plantation establishment in the boreal forest: glyphosate, hexazinone, and manual weed control. For. Chron. 60:283-287.

Sutton, R.F. and Tinus, R.W. 1983. Root and root system terminology. For. Sci. Monogr. 24. 137 p.

Walker, N.R. 1981. Container plug seedlings enhance survival and extend the planting season. p. 15 *in* Forestry Report No. 24. Fall 1981. Dep. Environ., Can. For. Serv., Edmonton, Alta.

Walker, N.R. and Ball, W.J. 1981. Larger cavity size and longer rearing time improve container seedling field performance. Dep. Environ., Can. For. Serv., Edmonton, Alta. For. Manage. Note 6. 2 p.

Wang, B.S.P. and Horton, K.W. 1968. An underplanting experiment with white pine and white spruce seedling and transplant stock. For. Chron. 44:36-39, 50-51.

Wood, J.E. and Jeglum, J.K. 1984. Black spruce regeneration trials near Nipigon, Ontario: planting *versus* seeding, lowlands *versus* uplands, clearcut *versus* strip cut. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-361. 19 p.

Zoltai, S.C. 1965. Glacial features of the Quetico-Nipigon area, Ontario. Can. J. Earth Sci. 2:247-269.

APPENDICES

APPENDIX A. Morphological characteristics of black spruce planting stock.

Experiment: P74-UN1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
73-2 FH 308-1	30 May- 1 June 1973	27-29 May	0.5	1.6	-	5.4	13.4	0.04
3+0[a]		27-29 May	3.9	4.0	-	1.5	25.3	0.50
74-1 FH 308-2	30 Jan. 1974	24-26 July	0.2	1.1	-	9.5	11.5	0.01
3+0r		24-26 July	3.2	3.8	-	3.0	24.4	0.34

Experiments: P76-GL1, P76-GL2, P76-GL3, P76-GL4

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
75-2 FH 308-1	12 May 1975	12-14 May	0.7	1.7	8.1	1.6	6.6	0.13
1½+1½		12-14 May	5.6	5.1	47.8	2.5	24.6	0.76

Experiments: P77-BR1, P77-BR2

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
76-2 FH 308-1	27-28 May 1976	31 May- 1 June	0.5	1.9	13.0	3.5	14.1	0.04
2+0		31 May- 1 June	2.0	2.5	15.2	4.7	23.4	0.21
77-1 FH 408-1	9 Feb. 1977	6-7 July	1.2	1.7	10.0	2.8	9.2	0.15
3+0r		6-7 July	2.7	3.4	20.0	5.9	26.8	0.20

Experiments: P77-SL2, P77-SL3

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
76-2 FH 308-1	27-28 May 1976	27 May[c] 30 May[d]	0.5	1.9	13.0	3.5	14.1	0.04
2+0		27 May[c] 30 May[d]	2.0	2.5	-	0.2	23.4	0.21
77-1 FH 408-1	9 Feb. 1977	5 July[c] 30 July[d]	1.2	1.7	10.0	2.8	9.2	0.15
3+0r		5 July[c] 30 July[d]	2.7	3.4	20.0	5.9	26.8	0.20

(cont'd)

APPENDIX A. Morphological characteristics of black spruce planting stock (cont'd).

Experiment: P78-OP1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
77-2 FH 408-1	25 May 1977	30-31 May	1.2	1.9	9.9	1.6	9.9	0.18
1½+1½		30-31 May	8.8	5.2	88.5	2.4	31.5	1.04
3+0		30-31 May	3.6	3.6	14.5	3.4	26.6	0.33
78-1 FH 408-2	15 Feb. 1978	7 July	1.1	1.6	8.0	2.1	10.4	0.13
1½+1½r		7 July	2.2	2.8	17.3	2.6	19.8	0.23

Experiment: P79-AB2

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
78-2 FH 408-2	16 June 1978	5 June	0.7	1.5	10.0	2.3	8.8	0.08
1½+1½		5 June	4.8	4.6	31.3	6.5	24.1	0.41
3+0		5 June	5.6	4.7	39.3	4.6	33.4	0.48
78-2 FH 408-1[e]	16 June 1978	21 July	0.8	2.0	16.8	2.0	10.4	0.11
79-1 FH 408-2	21 Feb. 1979	21 July	0.5	1.7	6.4	6.7	16.8	0.03
79-2 FH 308-1	26 Feb. 1979	21 July	0.4	1.5	4.3	10.7	14.2	0.02
1½+1½r		21 July	2.2	3.6	14.6	5.4	22.6	0.19
3+0r		21 July	2.6	3.5	8.9	6.3	37.0	0.15

Experiment: P79-AD1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
78-2 FH 408-1	16 June 1978	23-25 May	0.8	1.7	6.1	2.3	8.8	0.11
78-2 FH 308-1		23-25 May	0.3	1.2	3.2	3.2	7.9	0.03
1½+1½		23-25 May	4.3	3.9	44.3	2.6	16.7	0.62
3+0		23-25 May	4.6	4.3	27.6	17.5	25.7	0.20
78-2 FH 408-1	16 June 1978	18-20 July	0.8	2.0	16.8	2.0	10.4	0.11
79-2 FH 408-2	12 Dec. 1978	18-20 July	0.5	1.7	6.4	6.7	16.8	0.03
79-2 FH 308-2[f]		18-20 July	0.4	1.5	4.3	10.7	14.2	0.02
1½+1½r		18-20 July	2.2	3.6	14.6	5.4	22.6	0.19
3+0r		18-20 July	2.6	3.5	8.9	6.3	37.0	0.15

Experiments: P80-PL1, P80-SC1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
79-2 FH 408-1	26 Feb. 1979	9-10 June	0.4	1.5	7.0	3.4	9.6	0.04
1½+1½		9-10 June	6.7	4.7	71.2	1.9	24.1	0.95
3+0		9-10 June	6.4	4.2	16.7	4.8	42.4	0.43
80-1 FH 408-2	28 Nov. 1979	15 July	0.7	1.7	12.6	6.1	15.6	0.04
1½+1½r		15 July	8.4	5.0	31.2	7.8	40.7	0.53

(cont'd)

APPENDIX A. Morphological characteristics of black spruce planting stock (concl.).

Experiment: P81-SH1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
80-3 FH 408-1	28 Jan. 1980	28 May-2 June	1.2	1.5	8.1	2.2	12.4	0.11
1½+1½		28 May-2 June	7.5	5.4	54.3	2.6	26.7	0.99
81-1 FH 408-2	6 Feb. 1981	21-26 July	0.8	1.9	12.8	9.1	22.4	0.04
1½+1½r		21-26 July	2.8	3.5	26.4	5.4	25.0	0.22

[a] Bare-root stock for spring plant was fall-lifted, frozen-stored.

[b] Quality Index. After Dickson et al. (1960).

[c] Date P77-SL2 planted.

[d] Date P77-SL3 planted.

[e] Overwintered paperpot crop planted during July.

[f] FH 308 paperpots seeded and grown at the Swastika Forest Station (Swastika, Ontario).

APPENDIX B. Morphological characteristics of white spruce planting stock.

Experiment: P74-UN1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
73-2 FH 308-1	30 May- 1 June 1973	27-29 May	0.5	1.6	-	3.6	7.6	0.06
3+0[a]		27-29 May	6.5	5.7	-	3.0	22.7	0.93
74-1 FH 308-2	30 Jan. 1974	24-26 July	0.4	1.4	-	6.5	9.0	0.03
3+0r		24-26 July	5.1	4.8	-	3.6	22.6	0.61

Experiments: P76-GL1, P76-GL2, P76-GL3, P76-GL4

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
75-2 FH 308-1	12 May 1975	12-14 May	0.6	1.4	6.0	1.6	5.1	0.11
3+0		12-14 May	7.5	6.0	59.2	2.5	23.4	1.17

Experiments: P77-SL1, P77-SL2, P77-SL3

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
76-2 FH 308-1	27-28 May 1976	26-30 May	0.6	1.8	11.0	5.0	12.4	0.05
2+0		26-30 May	0.9	2.0	11.0	3.2	16.9	0.08
77-1 FH 408-1	9 Feb. 1977	4-5 July[c]	1.3	1.6	11.0	4.6	6.7	0.15
2+1r		4-5 July[c]	2.7	3.8	19.0	4.6	24.1	0.25

Experiment: P79-AB1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root: ratio	Shoot length (cm)	Q.I.[b]
78-2 FH 408-1	16 June 1978	5 June	0.6	1.4	6.1	2.2	5.5	0.10
2+1		5 June	8.9	4.1	50.6	3.9	28.2	0.82
2+2		5 June	11.6	6.3	62.4	3.3	30.6	1.42
3+0		5 June	4.8	4.4	28.8	4.1	25.3	0.49
78-2 FH 408-1[d]	16 June 1978	21 July	0.9	2.5	11.9	2.7	12.1	0.12
79-2 FH 408-2	21 Feb. 1979	21 July	0.6	1.8	5.3	2.2	11.5	0.07
2+1r		21 July	2.5	3.7	15.1	6.1	22.5	0.20
2+2r		21 July	4.8	4.4	22.8	4.3	25.2	0.48
3+0r		21 July	1.9	3.4	9.5	5.7	22.0	0.16

(cont'd)

APPENDIX B. Morphlogical characteristics of white spruce planting stock (concl.).

Experiment: P79-AD1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
78-2 FH 408-1	16 June 1978	23-25 May	0.5	1.3	4.0	2.0	4.9	0.09
78-2 FH 308-1	16 June 1978	23-25 May	0.5	1.2	3.1	1.9	4.5	0.09
2+1		23-25 May	8.9	5.2	50.6	3.9	28.2	0.95
3+0[e]		23-25 May	6.8	4.9	33.2	4.7	26.3	0.68
78-2 FH 408-1[d]	16 June 1978	18-20 July	0.9	2.5	11.9	2.7	12.1	0.12
79-2 FH 408-2	21 Feb. 1979	18-20 July	0.6	1.8	5.3	2.2	11.5	0.07
79-2 FH 308-2	12 Dec. 1978	18-20 July	0.2	1.4	4.1	2.8	7.4	0.02
2+1r		18-20 July	2.5	3.7	15.1	6.1	22.5	0.20
2+2r		18-20 July	4.8	4.4	22.8	4.3	25.2	0.48
3+0r		18-20 July	1.9	3.4	9.5	5.7	22.0	0.16

Experiments: P80-PL1, P80-SC1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
79-2 FH 408-1	26 Feb. 1979	9-10 June	0.4	1.5	5.2	3.0	8.1	0.05
2+2		9-10 June	10.2	5.7	53.5	2.5	27.3	1.40
2+1		9-10 June	8.1	5.5	54.4	2.9	25.8	1.07
80-1 FH 408-2	28 Nov. 1979	15 July	0.5	1.4	7.5	2.5	8.5	0.06
2+2r		15 July	5.5	4.6	27.4	5.3	26.3	0.50
2+1r		15 July	2.2	3.5	16.4	3.7	18.8	0.24
3+0r		9-10 June	6.4	4.2	16.7	4.8	42.4	0.43

Experiment: P81-SH1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
80-4 FH 408-1	28 Feb. 1980	9-10 June	0.5	1.5	7.5	5.1	10.9	0.04
81-1 FH 408-2	6 Feb. 1981	21-26 July	0.6	1.7	11.8	2.8	11.8	0.06
2+2r		21-26 July	3.8	4.0	25.9	5.7	24.6	0.32
2+1r		21-26 July	1.7	2.9	16.4	4.3	18.8	0.16

[a] Bare-root stock for spring plant was fall-lifted, frozen-stored.

[b] Quality Index. After Dickson et al. (1960).

[c] P77-SL3 planted 30 July.

[d] Overwintered paperpot crop planted during July.

[e] Stock reared at Chapleau Provincial Tree Nursery.

APPENDIX C. Morphological characteristics of jack pine planting stock.

Experiments: P76-GL1, P76-GL2, P76-GL3

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm²)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
75-2 FH 408-1[a]	26 June 1975	12-14 May	0.5	1.1	6.0	1.2	5.6	0.08
2+0		12-14 May	7.1	5.5	56.3	3.6	24.0	0.89

Experiment: P76-GL4

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm²)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
75-2 FH 408-1	26 June 1975	12-14 May	0.4	1.7	10.1	1.7	9.8	0.05
2+0		12-14 May	7.1	5.5	56.3	3.6	24.0	0.89

Experiment: P78-BM1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm²)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
77-2 FH 408-1	27 May 1977	22 June	0.8	2.1	9.1	3.4	16.6	0.07
2+0		22 June	4.8	4.8	44.2	2.8	15.7	0.79
78-1 FH 408-2	15 Feb. 1978	19 July	1.4	2.3	6.8	2.2	16.9	0.15
2+0r		19 July	1.8	3.4	5.9	3.1	16.2	0.23

Experiment: P79-AD1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm²)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
78-2 FH 408-1	16 June 1978	23-25 May	0.9	1.8	9.9	0.4	9.5	0.16
78-2 FH 308-1	16 June 1978	23-25 May	0.5	1.5	5.4	2.2	7.5	0.07
2+0		23-25 May	3.6	5.2	23.6	7.1	24.1	0.31
78-2 FH 408-1[c]	16 June 1978	18-20 July	1.3	2.7	15.7	4.6	21.4	0.10
79-2 FH 408-2	13 Dec. 1978	18-20 July	1.2	2.4	17.1	2.1	19.3	0.12
79-1 FH 308-2	13 Dec. 1978	18-20 July	0.5	1.8	9.4	1.6	9.7	0.07
2+0r		18-20 July	1.3	2.7	6.7	8.6	20.4	0.08

(cont'd)

APPENDIX C. Morphological characteristics of jack pine planting stock (concl.).

Experiment: P81-SH1

Stock type	Paperpot sowing date	Planting date	Total dry weight (g)	Root collar diameter (mm)	Root area index (cm^2)	Shoot: root ratio	Shoot length (cm)	Q.I.[b]
FH 308-1[d]	3 Feb. 1980	28 May- 2 June	1.0	1.5	8.0	1.7	12.4	0.10
2+0		28 May- 2 June	5.4	4.3	27.0	4.8	32.3	0.44
81-1 FH 308-2[e]	4 Jan. 1981	21-26 July	0.3	1.2	4.5	3.6	10.8	0.02
81-1 FH 408-1	16 March 1981	21-26 July	0.9	1.9	10.9	5.4	28.5	0.04
2+0r		21-26 July	2.8	3.2	12.4	12.2	31.6	0.13

[a] Paperpot trees sown at Great Lakes Forest Research Centre and grown at Abitibi's tree production centre in Thunder Bay, Ontario.

[b] Quality Index. After Dickson et al. 1960.

[c] Overwintered paperpot crop held and planted during July.

[d] Crop number not available.

[e] FH 308 paperpots seeded and grown at the Swastika Forest Station (Swastika, Ontario).

APPENDIX D. Bare-root and container planting stock minimum morphological specifications.

Black Spruce

	Stock type			
	1+2[a]	3+0[a]	2+0[a]	FH 408[b]
Shoot length (cm)	14.1	14.1	6.1	13
Root collar diameter (mm)	3.6	3.6	1.9	1.5
Shoot:root ratio	1.6	1.6	1.8	
Total dry weight (g)	5.0	4.1	0.8	0.5
Root area index (cm^2)	31	31	15	

White Spruce
(Container Specifications Unavailable)

	Stock type			
	2+2[a]	1+2[a]	3+0[a]	2+0[a]
Shoot length (cm)	14.1	14.1	14.1	6.1
Root collar diameter (mm)	3.6	3.6	3.6	1.7
Shoot:root ratio	2.0	1.5	1.5	2.0
Total dry weight (g)	5.0	5.0	3.3	0.8
Root area index (cm^2)	36	36	21	10

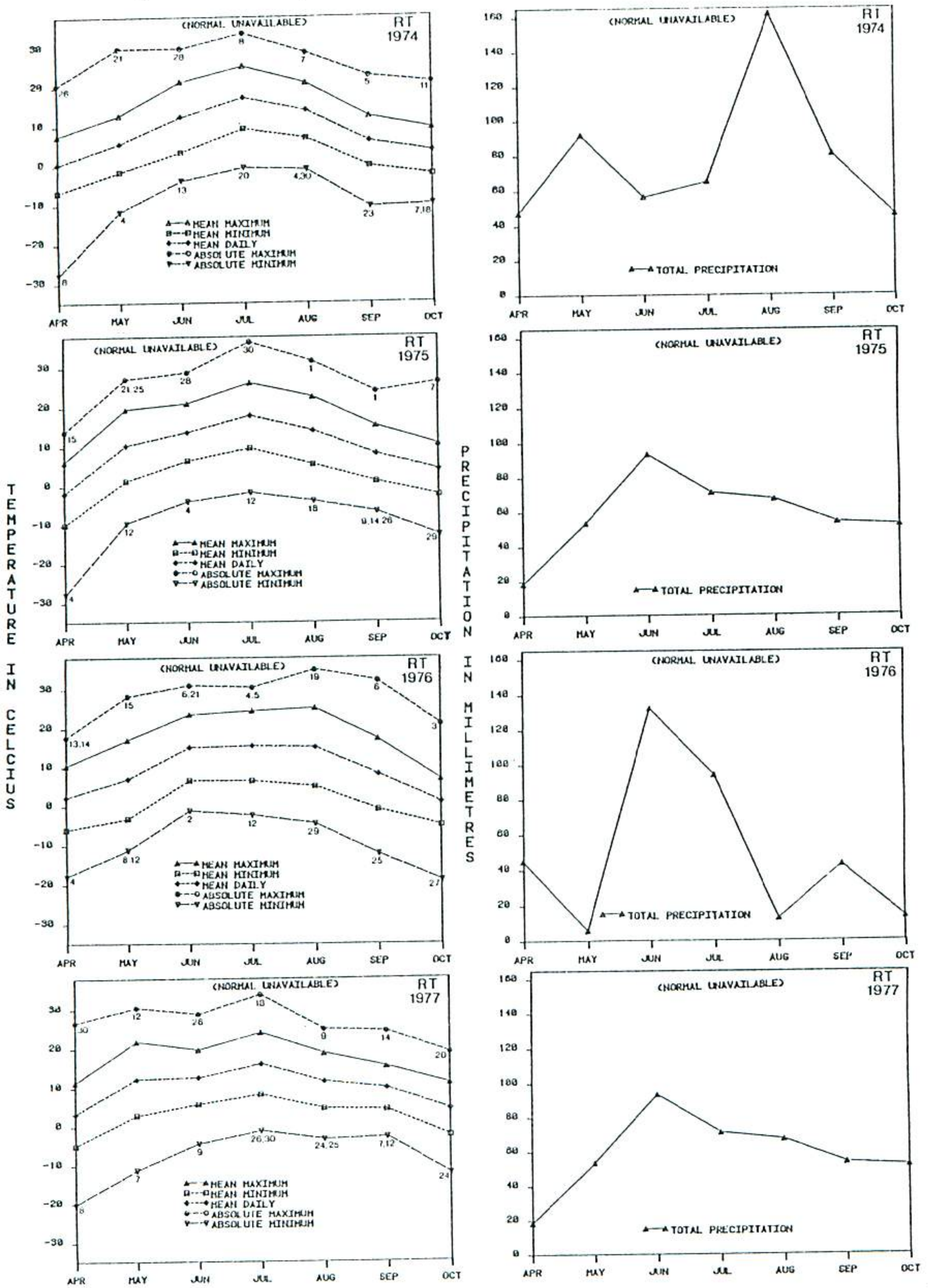
Jack Pine

	Stock type	
	2+0[a]	FH 408[b]
Shoot length (cm)	14.1	10
Root collar diameter (mm)	3.6	1
Shoot:root ratio	2.0	
Total dry weight (g)	3.0	0.4
Root area index (cm^2)	26	

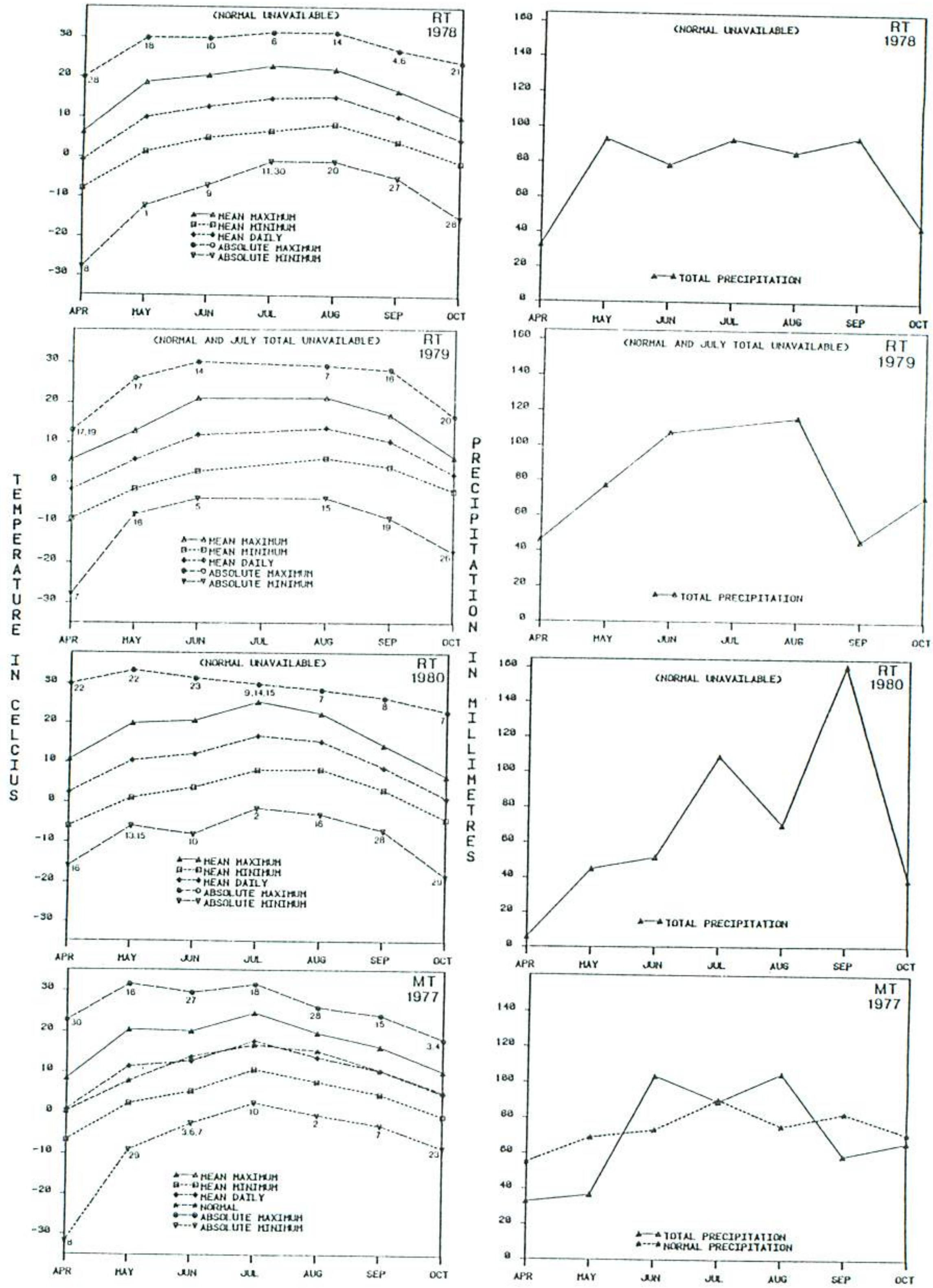
[a] Reese and Sadreika 1979.

[b] Anon. 1982. Forest management manual for crown lands. New Brunswick Dep. Nat. Resour., Fredericton, N.B., 176 p. (unpubl.).

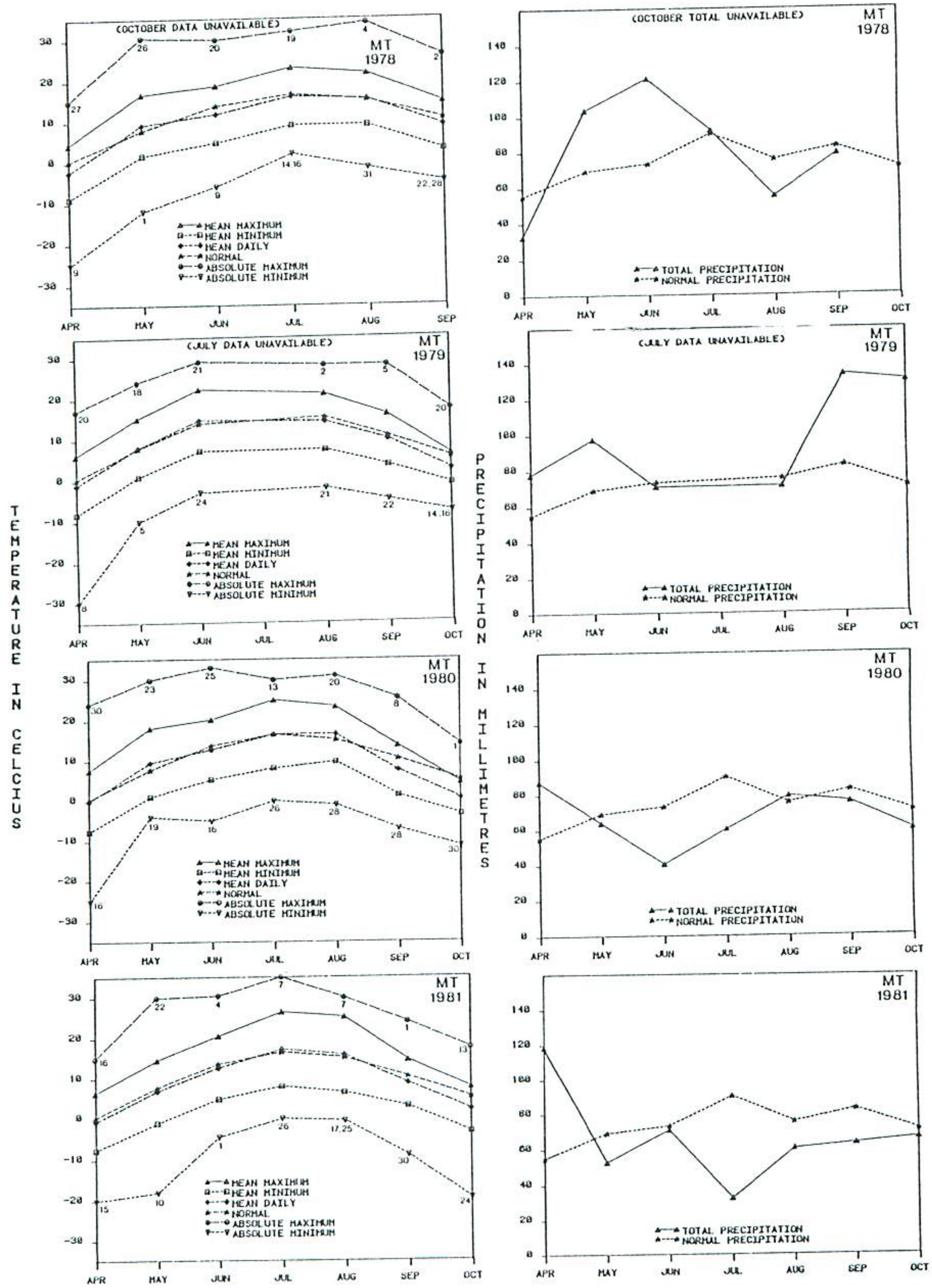
APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



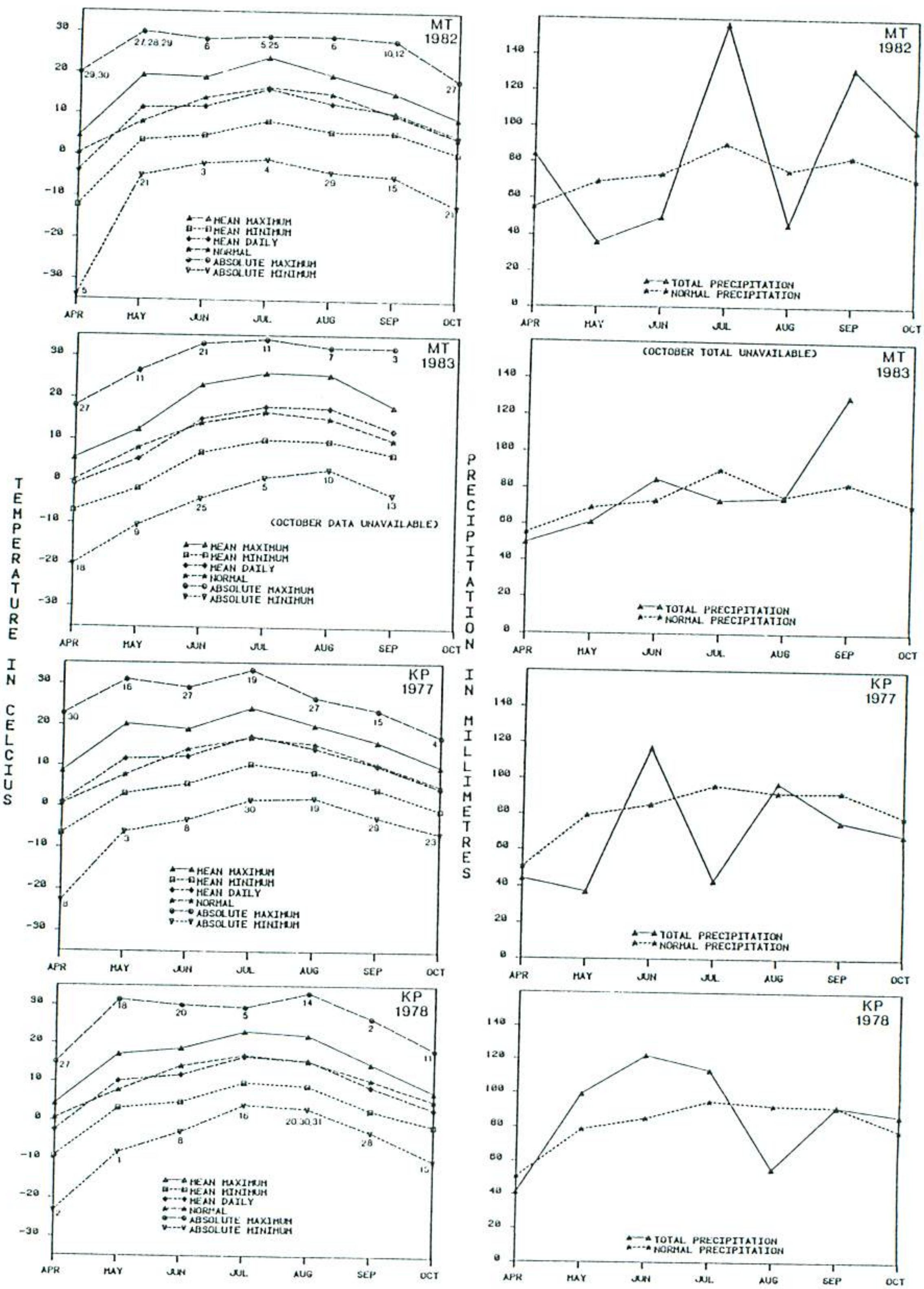
APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



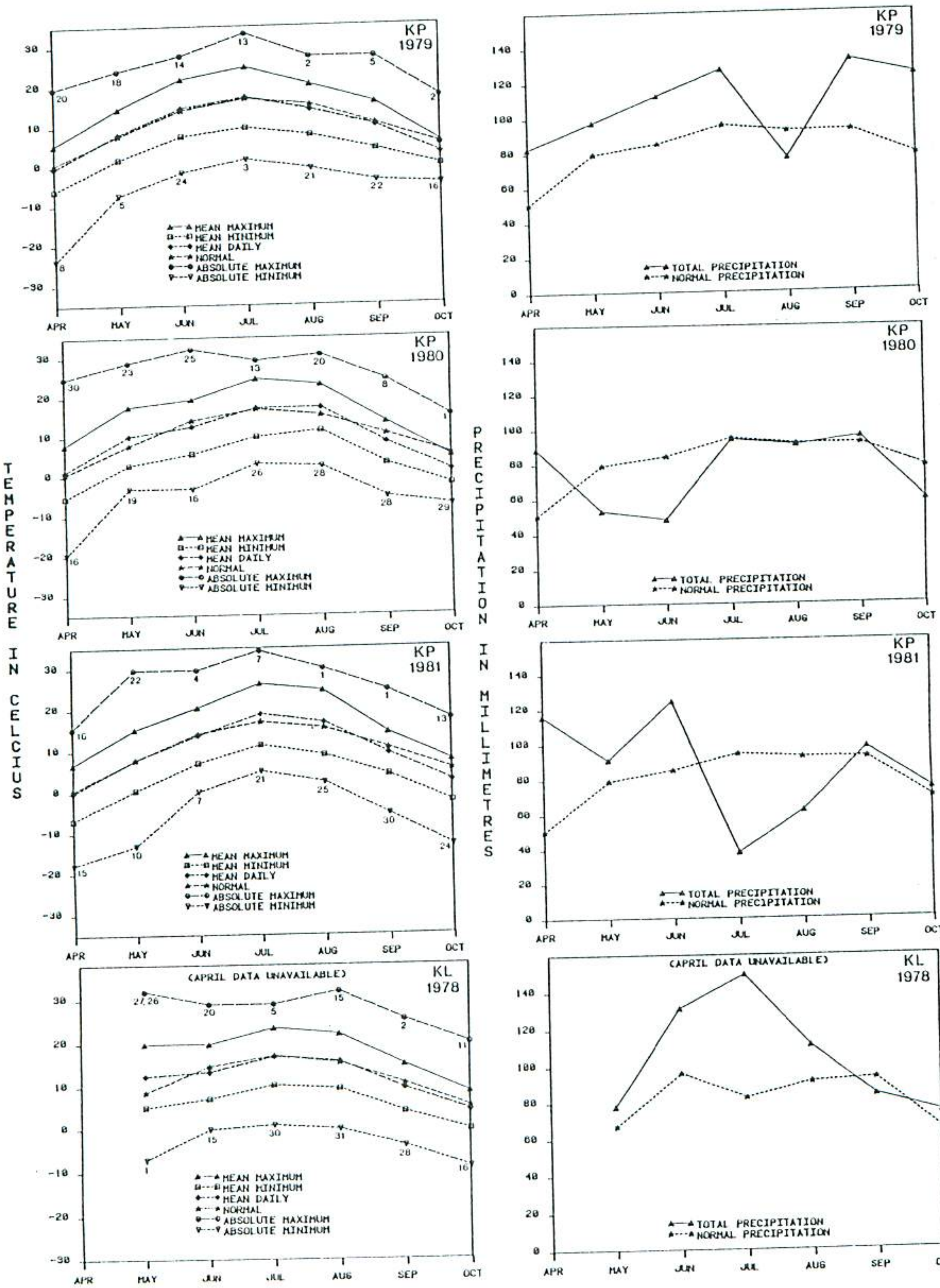
APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



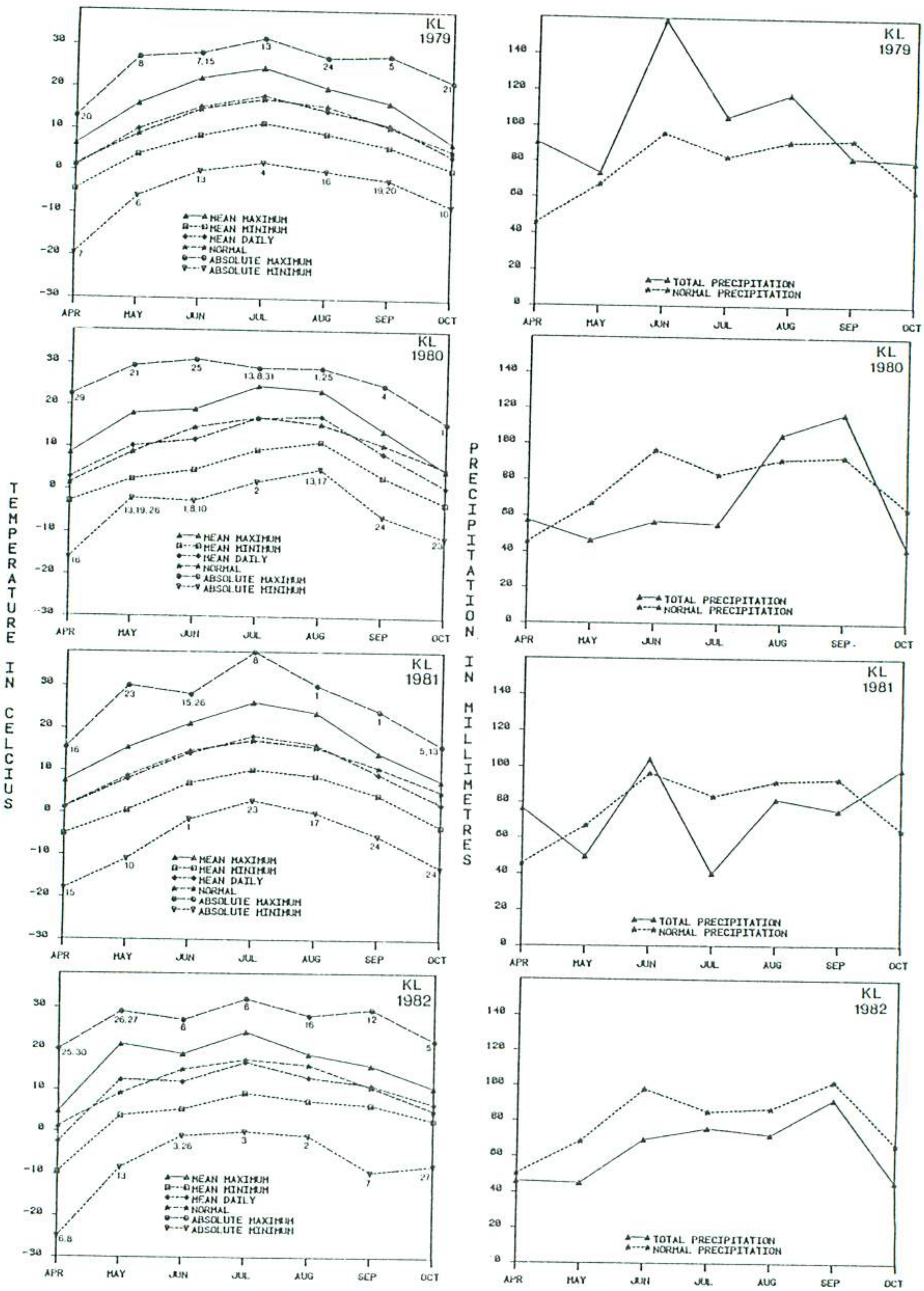
APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



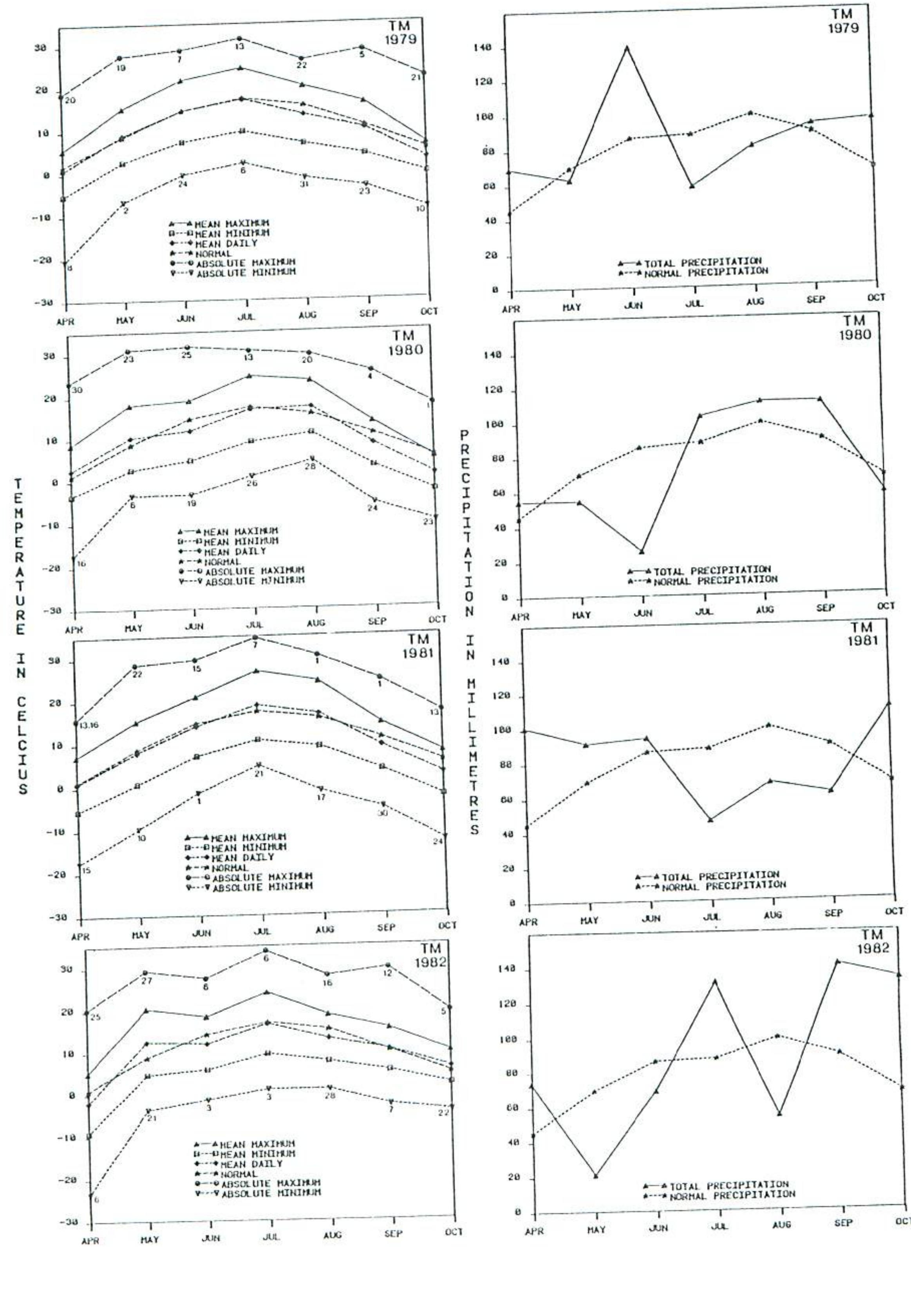
APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (cont'd)



APPENDIX E. April to October temperature and precipitation data for weather stations at Raith (RT), Mattice (MT), Kapuskasing (KP), Kirkland Lake (KL) and Timmins (TM), Ontario for years corresponding to experimental assessments (Anon. 1974 to 1979a and 1980 to 1983). Dates of absolute monthly maximum and minimum temperatures are given. See Fig. 1 for weather station locations. (concl.)