PLANTATION ESTABLISHMENT IN THE BOREAL FOREST: PLANTING SEASON EXTENSION

R. F. SUTTON

GREAT LAKES FOREST RESEARCH CENTRE
SAULT STE. MARIE, ONTARIO

REPORT O-X-344

CANADIAN FORESTRY SERVICE
DEPARTMENT OF THE ENVIRONMENT
1982

Copies of this report may be obtained from:

Information Office
Great Lakes Forest Research Centre
Canadian Forestry Service
Department of the Environment
Box 490, Sault Ste. Marie, Ontario
P6A 5M7

Catalogue No. Fo46-14/344E
ISBN 0-662-12298-4
ISSN 0704-7797

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Great Lakes Forest Research Centre
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PREFACE

Cooperative research on the mechanization of silviculture was initiated in 1971 by the forerunner of the Ontario Ministry of Natural Resources (OMNR), and the Canadian Forestry Service (CFS), Great Lakes Forest Research Centre (GLFRC). The main objective of GLFRC Project GLC-15 was to develop mechanized equipment and associated tree growing techniques for economically reforesting typical cutovers in the boreal forest.

The main biological support within the project was provided by the Study GLC-15-915: Nutritional and physiological factors affecting the survival and growth of mechanically planted trees.

A program of research (by contract) to investigate planting season extension was incorporated into the study almost from its inception. The objective of this part of the study, which employed hand planting, was to evaluate the feasibility of extending the planting season, and, in this regard, to determine the usefulness of certain field cultural practices that might be incorporated into mechanized planting operations.

It is now generally recognized that the rate of forest regeneration in Ontario is far short of what is required to keep forest land in production (Heeney 1978, Reed 1978). Implementation of the policy of the Ontario government "to allocate funds, staff, equipment, and nursery expansions to annually regenerate sufficient cut-over areas in need of artificial regeneration to sustain an annual cut of 9.1 million cunits" (26 million m^3) by the year 2020 (Report of the Timber Revenue Task Force to the Treasurer of Ontario and the Minister of Natural Resources, October 1975, p. 54) would require, by 1982, the regeneration of 125,000 ha per annum, which is about double the 1976 program (Forest Policies in Canada, Vol. 1. Major Objectives, Problems and Issues: identification and trends. Canadian Council of Resource and Environment Ministers, Task Force on Forest Policy, 1976, p. 48). In OMNR's Northern Region alone, even if we assume complete success in obtaining satisfactory regeneration in silviculturally treated areas, the regeneration shortfall averaged 17,800 ha per annum, i.e., 41% of the area harvested, over the 4-year period ending March 1977 (Proceedings of the Ontario Conference on Forest Regeneration 1978. Ontario Ministry of Natural Resources, p. 40).

Two major considerations militated for seeking to solve the problem by means of mechanization: the vastness of the job to be done, and the inadequacy of the labor supply. Ketcheson and Smyth (1977) have described factors that "strongly suggest" the insufficiency of readily available labor in boreal Ontario for the proposed level of silvicultural activity. Incidentally, however, Ketcheson doubted that mechanization would solve the labor supply problem.

In any event, there would be obvious advantages to extending the planting season, provided that reasonably successful results could be obtained.

The report now presented covers performance of stock outplanted by hand at intervals after the end of the conventional planting season through mid-October. The results are presented in context with a thorough review of the literature dealing with the range of options available to the forest manager whose bare-root planting program cannot be completed within the spring planting season using fresh, unflushed stock. An abbreviated report concentrating on the new experimental results is also in preparation. A companion report will be forthcoming on the results of conventional planting season studies.

ABSTRACT

This report has two main ingredients: (a) the results of a study to evaluate the possibility of extending the planting season in the boreal forest by using spring-lifted, frozen-stored, shipping-run, bare-root stock; and (b) an in-depth review of the literature relating to other options available to the forest manager who needs to extend the bare-root planting season.

Under (a), at intervals of two weeks from the beginning of July through mid-October in 1971, 1972, and 1973, 2+0 jack pine (*Pinus banksiana* Lamb.), 3+0 black spruce (*Picea mariana* [Mill.] B.S.P.), and 3+0 white spruce (*P. glauca* [Moench] Voss) were outplanted (for a total of 145,000 trees) on a variety of outwash and till sites in boreal Ontario. Despite variation in planting stock, poor storage conditions, adverse weather, and drastic site treatment, the first- through fourth-year results form a pronounced and consistent pattern: reasonably good survival and reasonably good growth among trees in the first and second (July) sequential plantings; a rapid decline in both survival and growth of survivors thereafter; jack pine height growth rate >> black spruce > white spruce. Fertilization (NPK) at the time of planting significantly decreased both survival and growth. Tilling had no major effect on survival or growth. The results show clearly that, even with imperfect cold storage, spring-lifted stock can be used successfully to extend the bare-root planting season in boreal Ontario until the end of July.

RÉSUMÉ

Ce rapport porte sur deux aspects principaux: a) les résultats d'une étude des possibilités de prolonger la saison de plantation dans la forêt boréale au moyen de matériel à racines nues, arraché au printemps, gardé congelé et conditionné en vue de l'expédition; et b) une étude bibliographique approfondie des autres solutions de rechange qui s'offrent à l'aménagiste forestier qui veut prolonger la saison de plantation du matériel à racines nues.

Pour ce qui est du premier aspect, à intervalles de deux semaines à partir du début de juillet jusqu'à la mi-octobre, en 1971, 1972 et 1972 des pins gris *(Pinus banksiana* Lamb.) 2+0, des épinettes noires *(Picea mariana* [Mill] B.S.P.) 3+0 et des épinettes blanches *(P. glauca* [Moench] Voss 3+0 ont été transplantés (145,000 arbres en tout) dans différentes stations à dépots fluvio-glaciaires et à till dans la région boréale de l'Ontario. Malgré les variations du matériel, les conditions médiocres d'entreposage, le temps inclément et le traitement draconien des stations, les résultats obtenus de la première à la quatrième année montrent une tendance prononcée et constante: survie et croissance raisonnablement bonnes parmi les arbres de la première et de la deuxième série plantée (juillet); déclin rapide de la survie et de la croissance des survivants par la suite; rythme de croissance en hauteur du pin gris >> celui de l'épinette noir > celui de l'épinette blanche. La fertilisation (NPK) au moment de la plantation a grandement diminué la survie et la croissance. Le travail du sol n'a eu aucun effet majeur sur la survie ou la croissance. Les résultats montrent clairement que même avec un entreposage imparfait au froid, le matériel arraché au printemps peut être utilisé pour prolonger jusqu'à la fin de juillet la saison de plantation du matériel à racines nues dans la région boréale de l'Ontario.

ACKNOWLEDGMENTS

I wish to acknowledge my indebtedness to T.P. Weldon for technical assistance (including drafting of figures), D.W. Beilhartz and B. Payandeh for biometrics services and statistical advice, J.R. Ramakers for chemical analysis of soils and plant tissues, and Jean McAlpine for typing the draft and final text. I also wish to thank K. McClain (Ontario Ministry of Natural Resources, Northern Forest Research Unit, Thunder Bay) and F.W. von Althen of the Great Lakes Forest Research Centre for particularly helpful critical reviews of the draft manuscript. The study could not have been carried out without generous and sustained cooperation by staff of the Ontario Ministry of Natural Resources and its forerunner, the Ontario Department of Lands and Forests, especially at Chapleau and Manitouwadge, and at Swastika Nursery.

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1. INTRODUCTION

In the temperate and boreal regions, spring has been the generally preferred season for planting forest trees (Kittredge 1929, Toumey and Korstian 1942, Köstler 1956, Sinclair and Boyd 1973, Stiell 1976, Carlson 1977). In Ontario, the practice of spring planting was so firmly established that neither Staley (1970) nor Stevens (1970) mentioned season of planting when describing planting practice in southern and northern Ontario, respectively: planting took place in the spring. Campbell (1977) noted that in eastern Ontario almost all planting of bare-root stock is done in spring between mid-April and the end of May. In the Atikokan District of the Ontario Ministry of Natural Resources' (OMNR) North Central Region, spring planting is considered to be best (Carlson 1977).

There are good reasons for this preference. Soils are generally moist after the spring thaw, the growing season is about to begin, and freshly lifted stock is physiologically attuned to the climatic progression experienced.

The general preference for spring planting is in fact well founded on success. Experience generally supports Toumey and Korstian's (1942) contention that "almost without exception the most favorable time for...planting is two weeks or more before buds [of the planting stock] begin their growth".

If the scale of operations and the availability of affordable labor are such that the outplanting program can be completed with freshly lifted stock that is dormant or nearly so, there is little reason to depart from conventional practice. In other circumstances, however, outplanting practice must, to a greater or lesser degree, depart from the ideal.

Traditionally, autumn has been the second most popular season for planting. By autumn, the current-year shoots have hardened off, the demand for soil moisture by competing vegetation has greatly decreased, access is usually easier, and labor is often more readily available than in spring. Results have sometimes been as good with fall planting as with spring planting (cf. Baldwin [1938a,b]), and both fall and spring planting have their place in the Inland Northwest (Ryker 1976). However, high mortality has often occurred among fall-planted trees (cf. LeBarron et al. [1938]). In Ontario, autumn planting of conifers is now avoided whenever possible because of indifferent results or total lack of success in the past (cf. Bunting and Mullin 1967, Campbell 1977, Brown 1977). Autumn planting of hardwoods may (Köstler 1956) or may not (von Althen 1975, 1980) be more successful.

Attempts to extend the planting season have therefore tended to concentrate on prolonging the spring planting season into the summer (cf. Crossley 1956, Burgar and Lyon 1968, Mullin 1971, Latt 1972, Revel and Coates 1976, Mullin 1978, McClain 1979), sometimes with freshly lifted stock, sometimes with stored stock. The sustained interest in the subject is not surprising in that the season of planting has been the source of most of the serious technical errors committed in artificial regeneration silviculture (Cayford 1978).

What follows is an account of the first- through fourth-year results obtained in extended planting season studies conducted within the Great Lakes Forest Research Centre's Project GLC-15. These results are set in the context of the literature relevant to planting season extension as a whole, in order to provide the forest manager with a consolidated account of the range of options available.

2. 2. OBJECTIVES

The objective of the extended planting season investigation reported here is to determine survival and growth of spring-lifted, cold-stored (i.e., frozen) shipping-run, bare-root, jack pine *(Pinus banksiana* Lamb.), black spruce *(Picea mariana* [Mill.] B.S.P.), and white spruce *(P. glauca* [Moench] Voss) stock outplanted, under various fertilization and tilling treatments, at intervals of two weeks beginning at the end of June and continuing through the growing season to mid-October on a variety of outwash and till soils on typical cutover sites in the B.7 and B.8 Sections of the Boreal Forest Region (Rowe 1972) of Ontario, and thereby to determine the extent to which the conventional planting season may be extended by operational outplanting of spring-lifted, cold-stored, bare-root stock.

3. 3. METHODS AND MATERIALS

For the field experimentation, a semi-operational scale was deemed necessary. Careful handling and planting of stock, e.g., by researchers, are known to give results often dramatically superior to those achieved in operational practice (cf. Anon. 1981, Pierpoint et al. 1981). The present study, however, sought results that could be expected to approximate those that might be achieved with operational practice. Also, to provide some basis for using the results predictively, replications in time and place were considered essential. Thus, influence of site, species, and weather, as well as the main variable of interest, viz., planting date, had to be evaluated. The fertilization treatments were an attempt to manipulate growing medium fertility to promote rooting (cf. Björkman 1953). Tilling as a treatment was included because of its influence on soil temperature (Dobbs and McMinn 1973, 1977, McMinn 1979), a highly important factor determining root growth and root system development (Sutton 1969, 1980b), especially in boreal soils.

Planting stock morphology, planting stock quality, and root growth capacity (RGC) were also of interest, but of these only RGC was investigated experimentally.

The plantings and the application of fertilizer and tilling treatments were carried out by contract, as were most of the assessments.

3.1 EXPERIMENTAL DESIGN 3.1

A fully randomized factorial design was used, with 3 years of planting x 3 sites per annum x 9 sequential plantings per annum x 3 species x 3 fertilization levels x 2 weed control (1971, 1972) or tilling (1973) treatments x 5 replications, in 20-tree plots, for a total of 145,800 trees. Thus 600 trees per species per site were planted in each sequential planting.

3.2 FACTORS 3.2

3.21 YEAR OF PLANTING 3.21

The plantings of 1971 (P71 were repeated, but with independent randomization, in 1972 (P72) and 1973 (P73). This replication in time provides some basis for assessing both the effects of annual variation in weather and stock quality x planting year interaction.

3.22 SITE 3.22

Three sites were planted each year (Table 1). There is a major geographical separation between planting sites: the 1972 outplantings are 80 km north of Lake Superior in the vicinity of Manitouwadge, and the 1971 and 1973 outplantings are about 300 km away to the southeast grouped within 80 km of Chapleau, which is situated 120 km east of Lake Superior (Fig. 1). This separation was occasioned by logistical requirements related to the conventional planting season studies referred to in the Preface. For convenience, the two groups of sites are referred to as the Manitouwadge and the Chapleau sites. They lie, respectively, in the eastern part of the Central Plateau (B.8) and the western part of the Missinaibi-Cabonga (B.7) portions of Rowe's (1972) Boreal Forest Region.

Two of each year's sites were located on pitted outwash sand or gravelly sand (Fig. 2), and one on upland bouldery sandy loam till (Fig. 3). The outwash soils are predominantly coarse to medium sands with a gravel content ranging from negligible at Fawn to 40% or more in some parts of the Block C East, Block C West, and Budd sites. The Fawn sands are a little more acid and somewhat less fertile than are the C East and C West sands and gravelly sands at Manitouwadge, which, how ever, have lower contents of nutrients per unit volume of soil because

Table 1. Location, elevation, and main soil characteristics of the outplanting sites.

Year of planting	Site No. 1	Designation	Township	Mean elevation (m)	Latitude N	Longitude W	Soil texture	Origin
1971	1	Budd	Nadjiwon	430	47°57'	84°08'	gravelly sand	outwash
	2	Fawn	Fawn	400	47°39'	82°30'	sand	outwash[a]
	3	Dalton	Range 24	460	48°04'	84°04'	bouldery loam	till
1972	1	Block C East	Nickle	340	49°10'	85°36'	gravelly sand	outwash
	2	Block C West	Nickle	340	49°10'	85°37'	gravelly sand	outwash
	3	Mooseskull	-	370	49°17'	85°31'	bouldery loam	till
1973	1	Budd	Nadjiwon	430	47°57'	84°08'	gravelly sand	outwash
	2	Fawn	Fawn	400	47°39'	82°30'	sand	outwash[a]
	3	Dalton	Range 24	460	48°04'	84°04'	bouldery loam	till

[a] With some till influence at the higher elevations.

of the dilution effect of gravel (Sutton 1979a). The Budd gravelly sands are similar to the Manitouwadge gravelly sands.

At Fawn, the upper slopes of the low bedrock ridge are influenced by till, and while the soil here is also sandy, its content of fines is higher than that of the outwash material elsewhere at Fawn. This small textural difference is enough to cause a perceptible change in vegetation, the till-influenced cap supporting a somewhat richer vegetation tending towards the mixedwood type, including especially aspen *(Populus tremuloides* Michx.) (Fig. 4).

The bouldery sandy loam tills are fresh to well drained for the most part, but patches affected by impeded drainage occur in association with locally shallow soil over bedrock concavities, and some parts of the sites are affected by telluric water. The till soils are considerably more fertile than the outwash soils.

On all sites, harvesting had been carried out in 1970/1971. The clearcut outwash sites had carried stands of jack pine, either pure or in mixture with black spruce. The till sites, which had been selectively cut for balsam fir *(Abies balsamea* [L.] Mill.) and, especially, white spruce, carried intolerant mixedwood (cf. MacLean 1960).

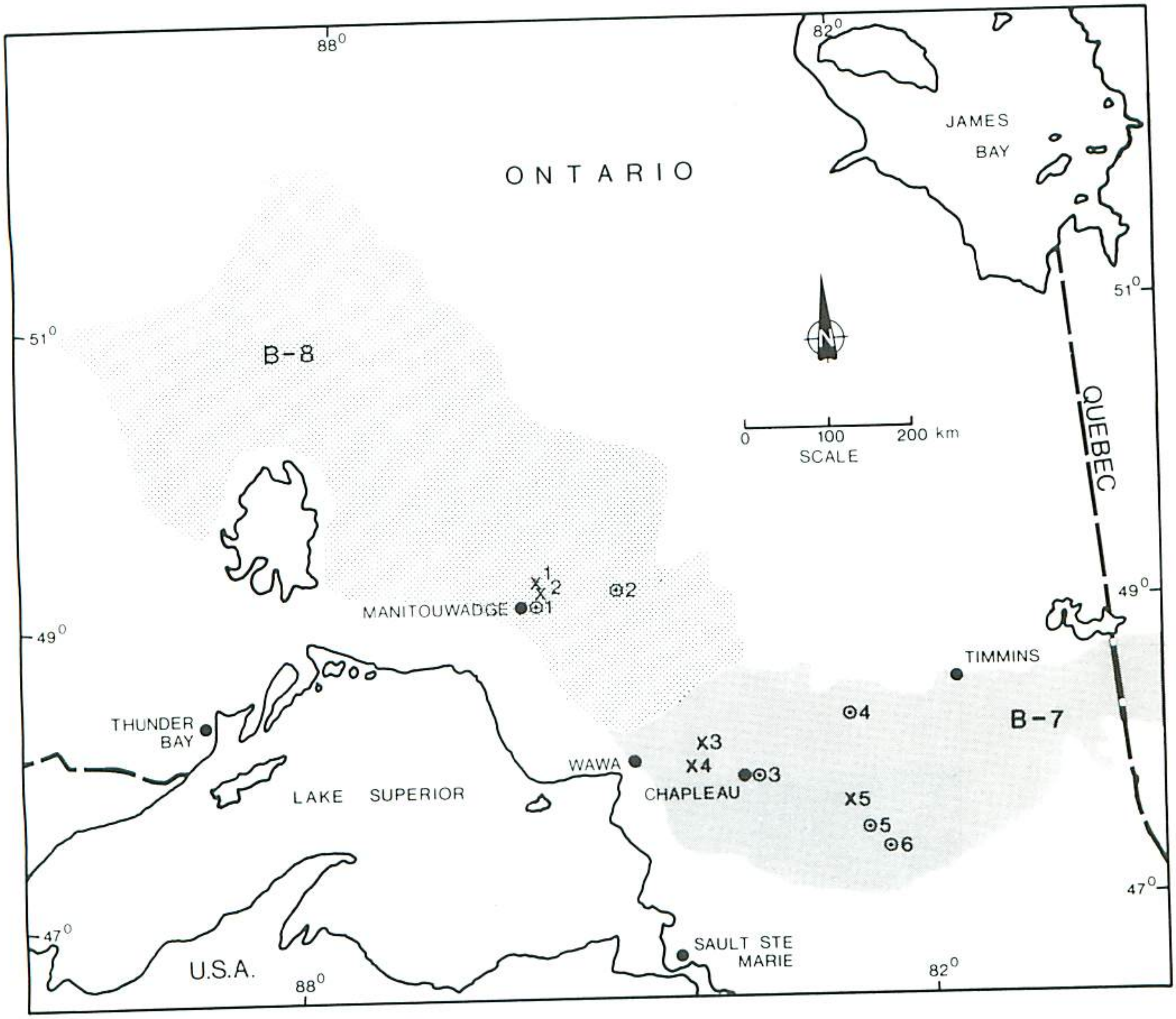


Figure 1. Map showing the locations of study sites (X1 = Mooseskull, X2 = Block C East and West, X3 = Dalton, X4 = Budd, X5 = Fawn) and weather stations (⊙1 = Manitouwadge, ⊙2 = Horne-payne, ⊙3 = Chapleau, ⊙4 = Foleyet, ⊙5 = Ramsay, ⊙6 = Biscotasing) used in weather data calculations. B-7 (shaded) and B-8 (stippled) areas identify Sections of Rowe's (1972) Boreal Forest Region.

Figure 2. Some of the outwash sites: A. P71 and P73 Budd (part), showing windrowing site prepartion; B. P72 Block C East lies to the left of the kettle lake (Figure 2 continued on page 7).

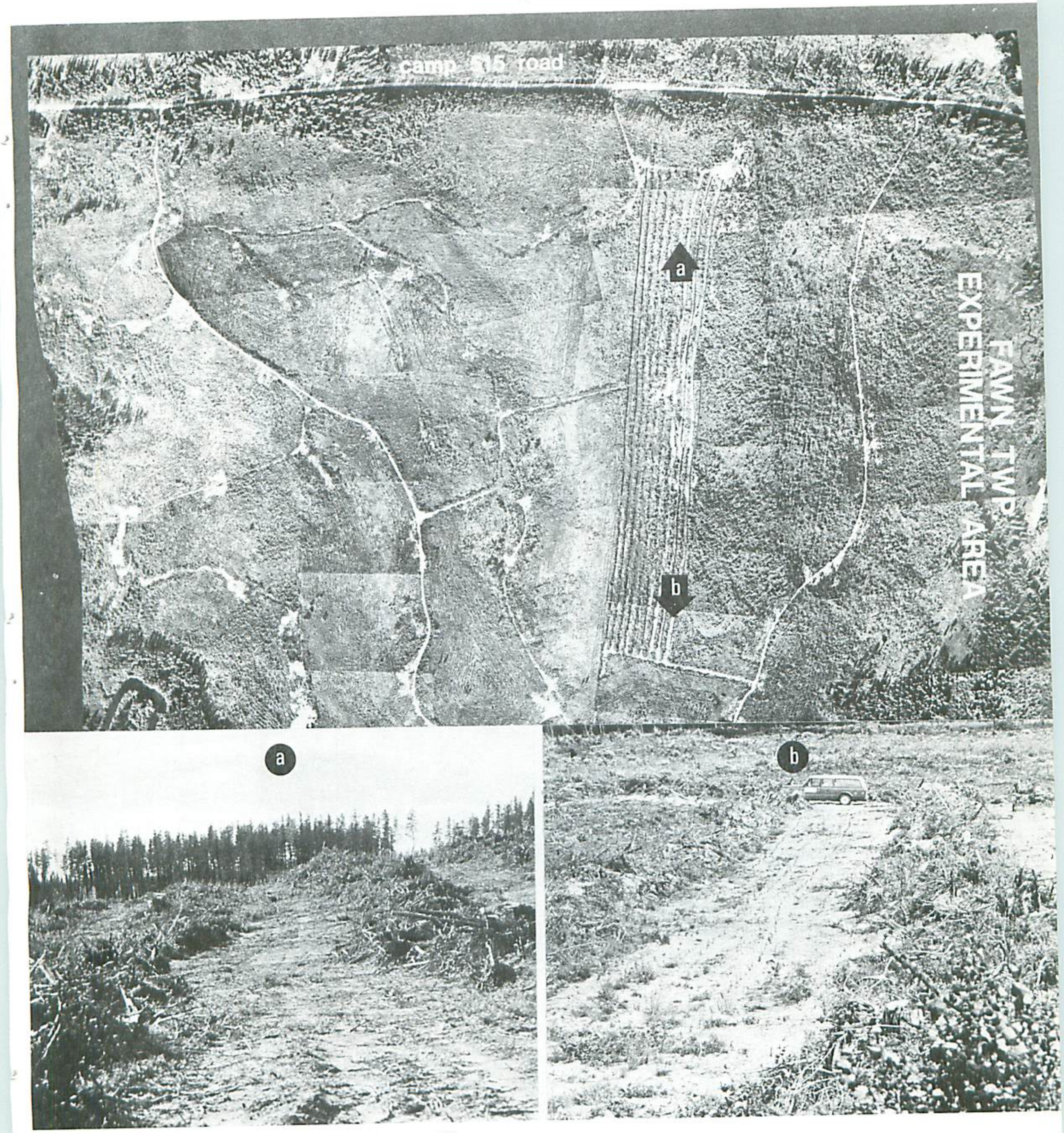


Figure 2. (continued from page 6)
C. P71 and P73 Fawn experimental area. Above, from the air, showing the nine parallel windrowed strips, each 500 m long, with arrows indicating (a) the P71 6th sequential planting strip, and (b) the P73 1st planting strip. Below left (a), ground view west along the P71 6th planting strip. Below right (b), ground view east along the P73 1st planting strip.

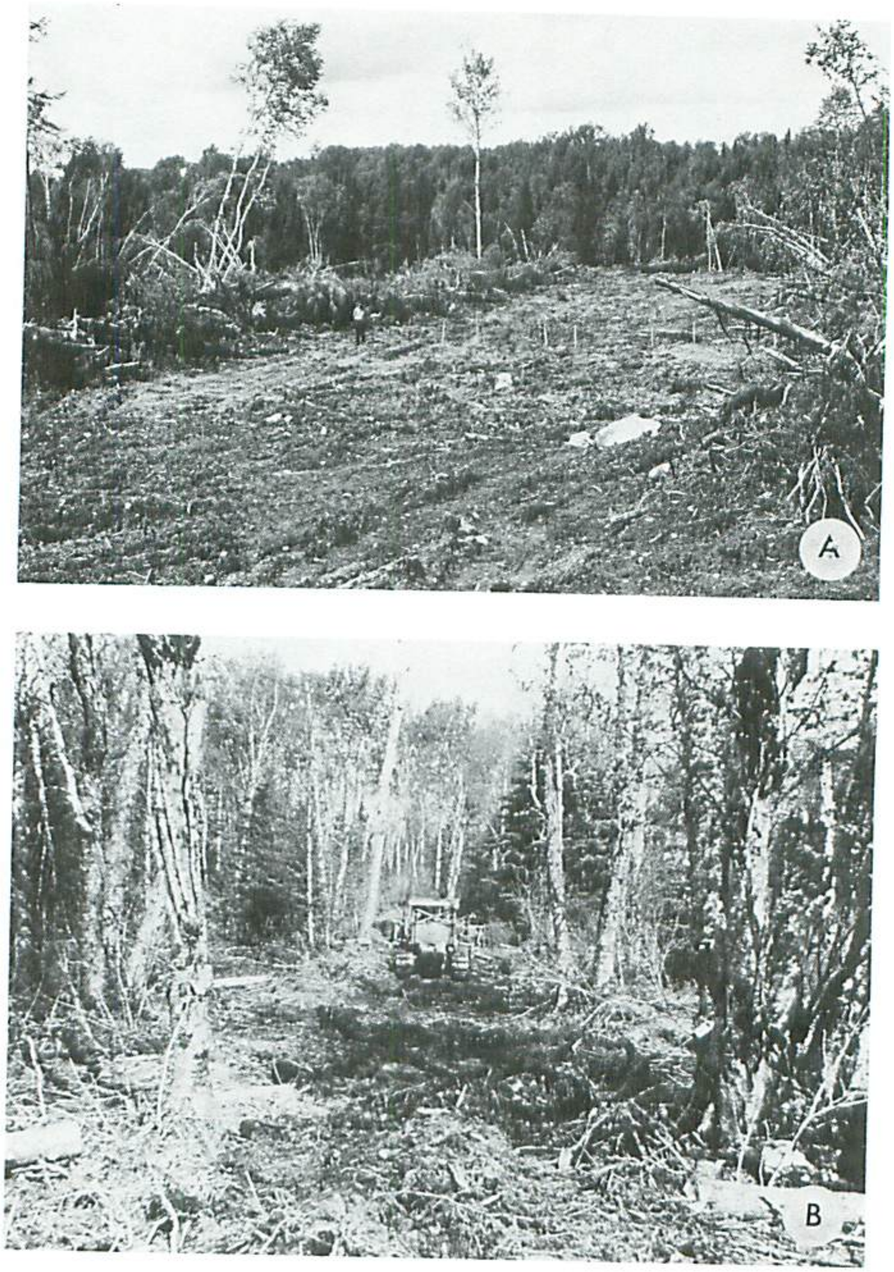


Figure 3. Some of the till sites: A. P71 Dalton, showing the drastic nature of site preparation; B. P72 Mooseskull, showing site preparation in progress.

Before site preparation, the outwash sites carried a lesser vegetation dominated by blueberries (*Vaccinium angustifolium* Ait. and *V. myrtilloides* Michx. and, at Fawn and Budd, sweetfern (*Comptonia peregrina* [L.] Coult.). The lesser vegetation carried by the Manitouwadge outwash soils was generally similar to that of the Chapleau sites, except for the absence of sweetfern from the Manitouwadge sites.

In comparison with the other outwash sites, Fawn is more variable in topography, soil, and, thus, vegetation. This results from the presence of the till-influenced ridge of bedrock trending north-south, more or less at right angles across the sequential planting strips. Aspen was a major component of the ridge cap vegetation, but jack pine was also strongly represented.

The till sites had carried vegetation typical of the intolerant mixedwoods as described by MacLean (1960) (Appendix A). After selective cutting of conifers, the residual vegetation included white birch (*Betula papyrifera* Marsh.) and aspen in the tree layer; mountain maple (*Acer spicatum* Lam.), beaked hazel (*Corylus cornuta* Marsh.), speckled alder (*Alnus rugosa* [Du Roi] Spreng.), and green alder (*A. crispa* [Ait.] Pursh) in the shrub layer.

3.23 SPECIES 3.23

The choice of jack pine black spruce and white spruce was based on the fact that the study sites included some that had carried typical stands of jack pine. some that had carried mixed stands of jack pine and black spruce, and some that had had a white spruce component. Also. virtually the whole of the planting program in the boreal forest of Ontario is with these species.

All three species were used on all sites. notwithstanding the apparent unsuitability of white spruce to some of the outwash sites. This was done to preserve statistical orthogonality, and, more especially, because of the informative nature of species comparisons.

Provenance was not included as a variable. but two provenances were used in the companion conventional planting season studies mentioned in the Preface.

3.24 SEQUENTIAL PLANTING 3.24

Sequential outplantings were begun at the end of June in each year. They were continued at intervals of two weeks through the growing season into mid-October, for a total of nine plantings in each year. The outplantings thus began after the end of what is locally considered to be the normal planting season.

Figure 4. Till-influenced ridge-cap at Fawn, delineated by a stand of sapling aspen.

Outplanting was by hand, according to the operational slit method (Fig. 5). The contract called for trees to be firmed well enough to withstand a sustained pull of about 2 kg, although firming to this degree was not possible after tilling on the outwash sites when the soil was dry. Each sequential outplanting of three species x 600 trees at each site was completed in two or three days.

3.25 3.25 FERTILIZATION

Three levels of fertilization were applied: none. low, and high. The low rate was obtained by hand-broadcasting approximately 12 g of 15-15-15 or 25 g of 7-7-7 commercial NPK fertilizer over a patch, approximately 35 cm in radius, centred on each treated tree for a nominal application of 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K. The high rate was double the low rate.

The aim here was to determine whether, especially on the outwash sites, which are low in available nutrients, root growth could be promoted by inorganic fertilization at the time of planting. That the response of a transplant root system to reduction and deformation (as must necessarily occur in outplanted bare-root stock) may be highly dependent on the fertility of the growing medium is persuasively indicated

Figure 5. Hand planting by the operational slit method in 1973; the contractor, A. McDonald, is on the left.

by Björkman's (1953) experiment with Norway spruce *(Picea abies* [L.] Karst.), although capitilization on this by field fertilization is difficult (cf. Leikola and Rikala 1974).

Fertilizer application, where appropriate, immediately preceded any cultivation. In treatments not involving tilling, the broadcast fertilizer was left on the surface.

A color-coded painted wire pin at the beginning of each plot identified the fertilizer treatment: red = control, white = low, and blue = high rates, respectively.

3.26 WEED CONTROL/TILLING 3.26

Initially, provision was made for a factorial weed control treatment. However, it became clear during the first two years of experimentation that weed growth was insufficient to warrant treatment. This reflected both the low fertility of the outwash sites and the drastic nature of the site preparation carried out on all sites. In effect, this doubled the replication for 1971 and 1972, when all plots, except those in the 1971 mixedwood area (as described under Species on page 6), were rototilled along the line of planting for the full length of the plot.

Tilling was introduced as an orthogonal variable in the P73 plantings: half the number of plots were tilled, and half were not. A

Mang Rotary Tiller fitted with a 9 h.p. Wisconsin engine was used, and cultivation, again along the length of the plot, was to a depth of about 12.5 cm.

3.3 3.3 SITE PREPARATION

As originally conceived, outplanting was to have been into soil that had been rototilled to provide a growing medium of mixed organic and mineral matter. The intention was to conserve fertility while to some degree promoting mineralization, and to raise rooting zone temperatures by eliminating the surface mat of organic matter. The only rototiller that could be obtained for the 1971 season, however, could not till through the root mat even on the easiest site: roots only 5 mm in diameter were enough to stall the 5 h.p. Briggs and Stratton motor of the MTD, and stoppages were incessant. Before rototilling could be done, stumps and most of the tree roots had to be cleared in corridor fashion (cf. Fig. 2, 3). This operation, which employed a D6 crawler tractor with a straight blade fitted with Young's teeth (Fig. 6), removed much of the most fertile part of the soil. For the 1971 plantings, corridor site preparation was carried out immediately beforehand. Rototilling of the mixedwood site still proved to be impossible, and a three-pronged garden hoe was used instead.

For the 1972 plantings, corridor site preparation was carried out on Sites 1 and 2 and on part of Site 3 (Table 1) in the fall of 1971; Site 3 was completed in May and June 1972.

For the 1972 and 1973 seasons, the Mang Rotary Tiller was used. This machine might well have been capable of tilling in the fashion originally intended, provided that logs and heavy slash were removed from its path. The study, however, continued with the corridor site preparation, this being considered to be closer to an operational mode than the tilling would have been: and in fact the 1973 replication was accommodated on the failed parts (late sequential plantings) of the P71 plantings after soil analyses had shown no residual effects from the 1971 treatments. The Mang performed well on all sites after corridor site preparation, even on the mixedwood site (Fig. 7).

3.4 3.4 THE PLANTING STOCK

Spring-lifted bare-root seedlings (2+0 jack pine, 3+0 black spruce, and 3+0 white spruce) of Provenance 4E were used throughout. In Ontario, bare-root stock is almost ten times more commonly planted than is containerized stock. All the planting stock was raised in OMNR nurseries: the 1971 jack pine was supplied by Chapleau Nursery, and all other stock came from Swastika Nursery. The foliage nutrient concentrations were not determined for the P71 stock, but the P72 and P73 stock were similar to one another in many respects (Table 2).

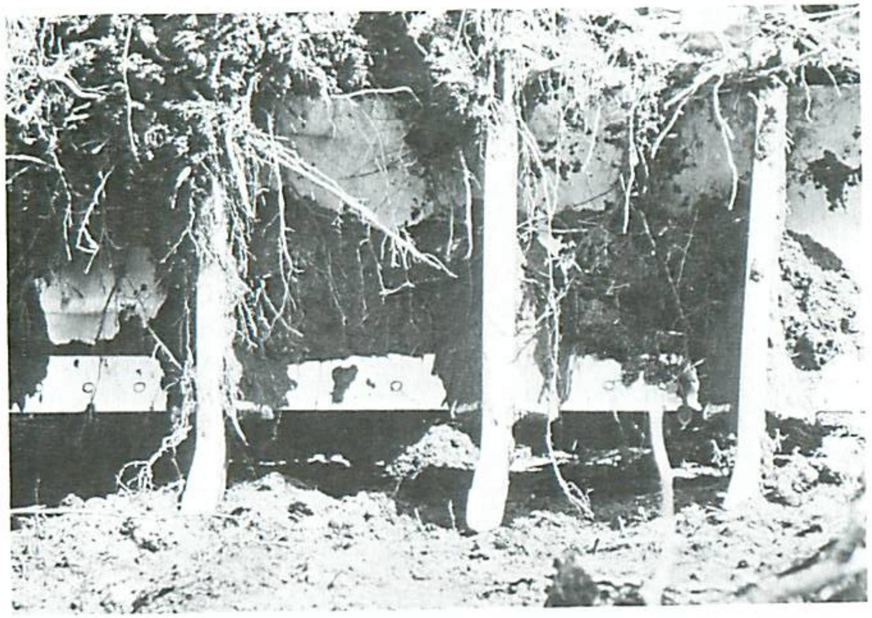


Figure 6. (left)

Young's teeth mounted on straight blade used in Mooseskull site preparation.

Figure 7. Rototilling with the Mang at Mooseskull in 1972.

A. (above) Tilling upslope

B. (left) Fine tilth produced by tilling.

Table 2. Foliage nutrient concentrations in planting stock used in 1972 (P72) and 1973 (P73) sampled prior to cold storage.

Year of planting	Species	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
1972[a]	jack pine (jP)	1.93	-	0.47	0.42	0.057
	black spruce (bS)	1.58	-	0.44	0.58	0.060
	white spruce (wS)	1.67	-	0.34	0.64	0.047
1973[b]	jP	1.90	0.17	0.72	0.39	0.092
	bS	1.33	0.13	0.48	0.59	0.068
	wS	1.56	0.14	0.37	0.97	0.072

[a] Values for 1972 stock are means of four samples each composited from five randomly selected plants.
[b] Values for 1973 stock are means of 10 individual samples.

Shipping-run stock was used in preference to stock specially selected or specially treated. This was to obtain results that would relate as closely as possible to those that could be expected from operational planting programs employing the applied treatments.

Difficulties were experienced in obtaining stock at short notice for the 1971 plantings. All of the stock had flushed before receipt, and the black spruce had been rejected for operational planting because of its high shoot:root ratio, paucity of root system, spindliness of stem, and the dry and blackened condition of most of the needles older than those of the current year, the usual result of over-heating at some stage during storage or transportation.

On receipt, the 1971 stock was placed in refrigerated storage at the Great Lakes Forest Research Centre at Sault Ste. Marie. Severe moulding by *Septocylindricum geotrichum* developed on all planting stock during storage, likely as a consequence of the non-dormant condition of the stock when it was received, and of a cooling unit that malfunctioned on several occasions, allowing temperatures to rise to 10-15°C. The 1971 plantings were nevertheless continued on the basis that the results would represent a lower limit of what might be achieved in excessively poor operational practice (Sutton 1975), and also to obtain procedural and logistical experience that would facilitate subsequent experimentation.

The cold storage facilities that became available at Swastika nursery in 1972 were much superior to those used in 1971. Also, their use minimized the delay between stock lifting and refrigeration. In both 1972 and 1973, stock was spring-lifted, graded, bundled, bagged, and placed in cold storage, probably within an hour, as part of the regular nursery operations. This cold storage facility was used for the whole of the 1972 stock storage period. Planting stock for the 1972 plantings was air-lifted as required from Swastika to a point within a few kilometres of the planting sites, thereby obviating the long road haul.

The Swastika Nursery cold storage facility was used again at the outset in 1973, but on 9 August, the stock was transferred to the provincial cold storage facility at Elk Lake following malfunctions of the Swastika refrigerating units. Subsequent examination of the Swastika cold storage temperature records showed that serious malfunctions had already occurred on 28 June and 5 July when the internal bag temperature rose to 7°C and 11°C, respectively. At the time of the transfer to Elk Lake, which took 2.5 hours, the stock seemed to be in good condition, although some mould had developed on the white spruce, generally in the vicinity of the bundling string. Mould had not developed on those bundles that were held together by elastic bands. The Elk Lake cold storage facility operated between -12°C and -6°C. This was emergency, not operational storage. Stock would not normally be deep-frozen for storage.

The planting stock was withdrawn as required from refrigerated storage.

3.5 ROOT GROWTH CAPACITY 3.5

Root growth capacity (RGC) was determined on subsamples of the planting stock used in alternate sequential outplantings in 1972 and 1973. Batches of stock for these outplantings were randomly subsampled by the bundle to provide a grand total of 3594 trees for RGC testing (Sutton 1980a). For RGC determination, the trees were washed clean and examined for the presence of unlignified roots, then grown in 0.1 strength Arnon and Hoagland's nutrient solution (Hewitt 1966), both in a home-made laboratory growth tank (T) and in an EY15 Plant Growth Cabinet (C) manufactured by Controlled Environment Ltd. of Winnipeg, Manitoba. The solution was changed weekly; it was circulated and aerated continuously to maintain full atmospheric partial pressure of oxygen. The total volumes circulating were 200 L and 230 L in T and C, respectively. The temperature of the nutrient solutions was held constant at 21 ± 1°C. The ambient temperatures were 21-27°C (T) and 21°C (C). An 18-hour photoperiod was provided by fluorescent and incandescent lamps, which at plant height gave approximately 21,000 lux (T) and 32,000 lux (C) respectively. The trees were removed after 21 days, and all fresh, white roots were counted, short roots and long roots (*sensu* Sutton 1969) separately.

3.6 3.6 ANALYSIS

The data were subjected to analysis of variance, using plot means, not individual tree values. Enumeration data, e.g., for survival, were appropriately transformed before analysis.

4. 4. RESULTS AND DISCUSSION

The results of the first four years of field performance are presented, first as an overview, and then in detail by factors. The interrelationship between survival and growth should be kept in mind throughout.

4.1 4.1 OVERVIEW

Overall performance in the outplantings displays a pronounced and consistent pattern. The isometric diagrams (Fig. 82a-i are well suited to showing the main features: reasonably good survival for the first planting or two, a rapid decline in survival thereafter, parallel behavior in terms of height growth of survivors, a height growth rate several times more rapid in jack pine than in the spruces, and the superior height growth rate of black spruce compared with that of white spruce.

This consistency, notwithstanding the large component of uncontrolled variation in the results, suggests that the forces shaping the pattern are strong in comparison with the influence of factors such as stock lot and site. The main determining factor is probably the decline of performance potential among planting stock during prolonged storage (Sutton 1980a).

The results of the present study support observations previously reported (cf. Zeigler 1915, Cummings 1942, Hermann 1962, Mullin 1974a, etc.) that, with initially similar stock, the growth of surviving outplants is poorer where survival is low than where it is high. In other words, the percentage survival among outplants and the growth of survivors are positively correlated. For instance, a mortality rate of 50% would represent much more than a 50% loss in performance in comparison with that of a plantation in which all trees survived.

Note: Henceforth, unless otherwise stated, sequential plantings 6 through 9 (or, in the case of the P71 Dalton till site, plantings 3 through 9) are ignored, survival having been too low to warrant further consideration.

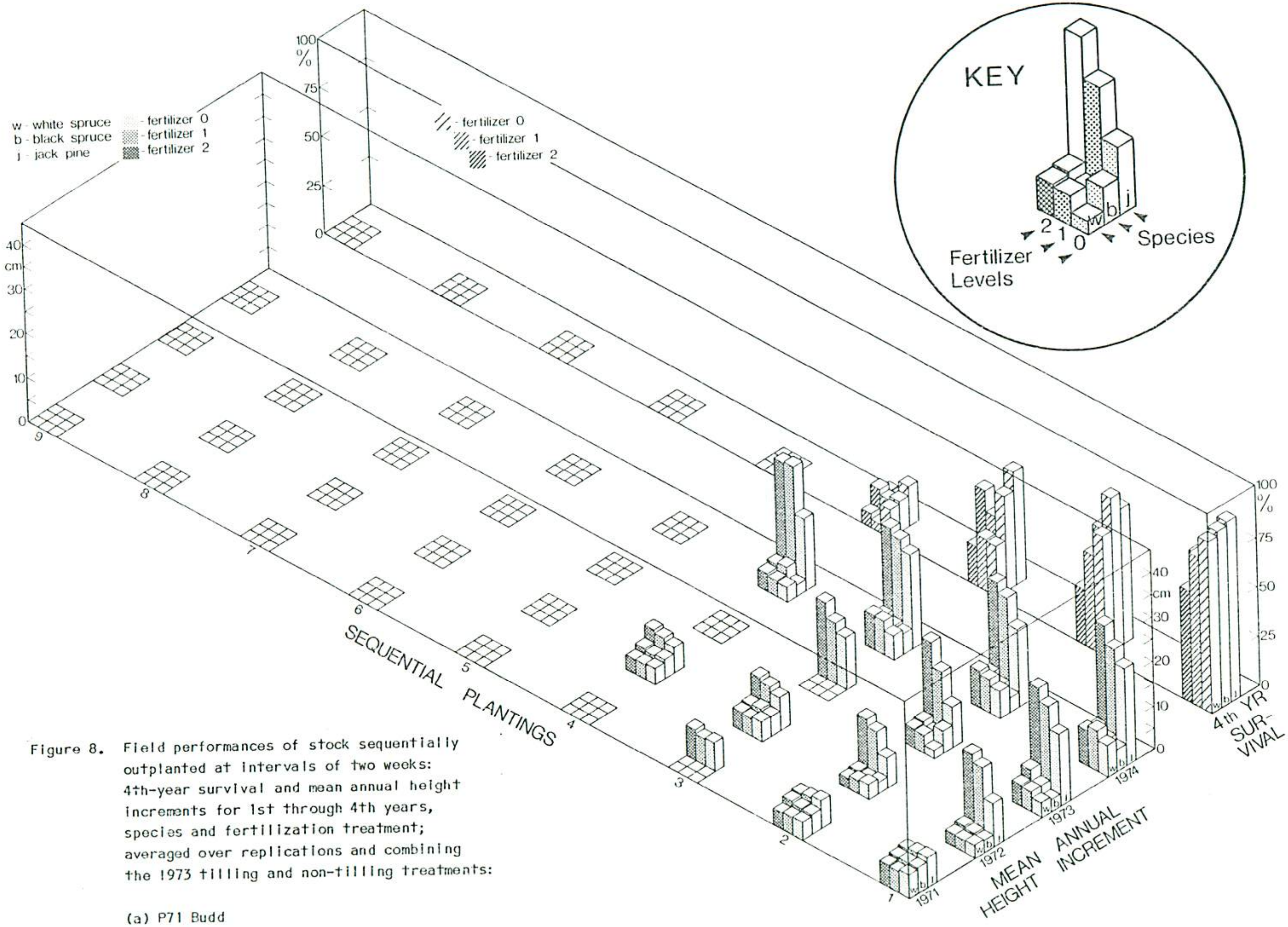


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(a) P71 Budd

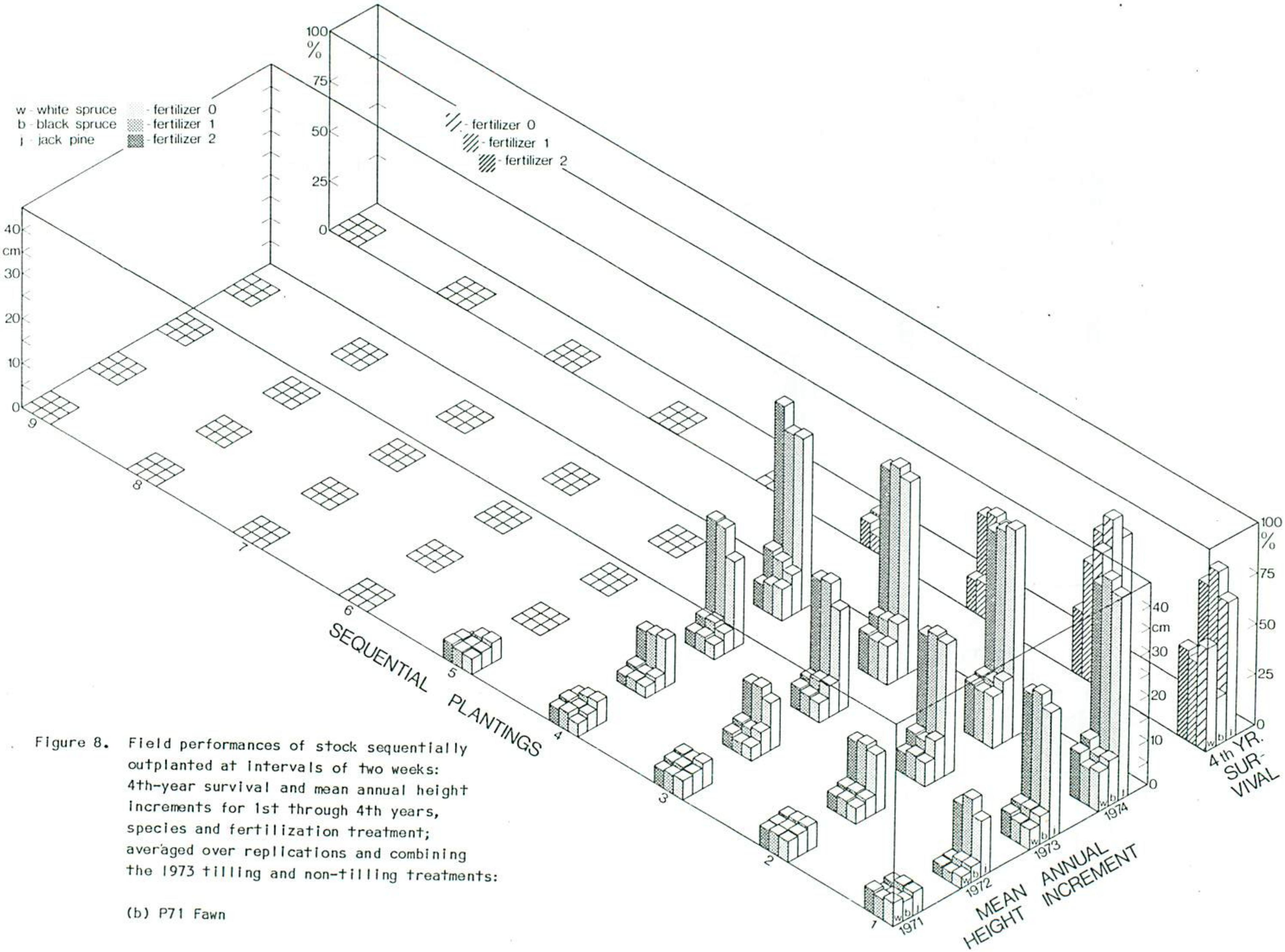


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(b) P71 Fawn

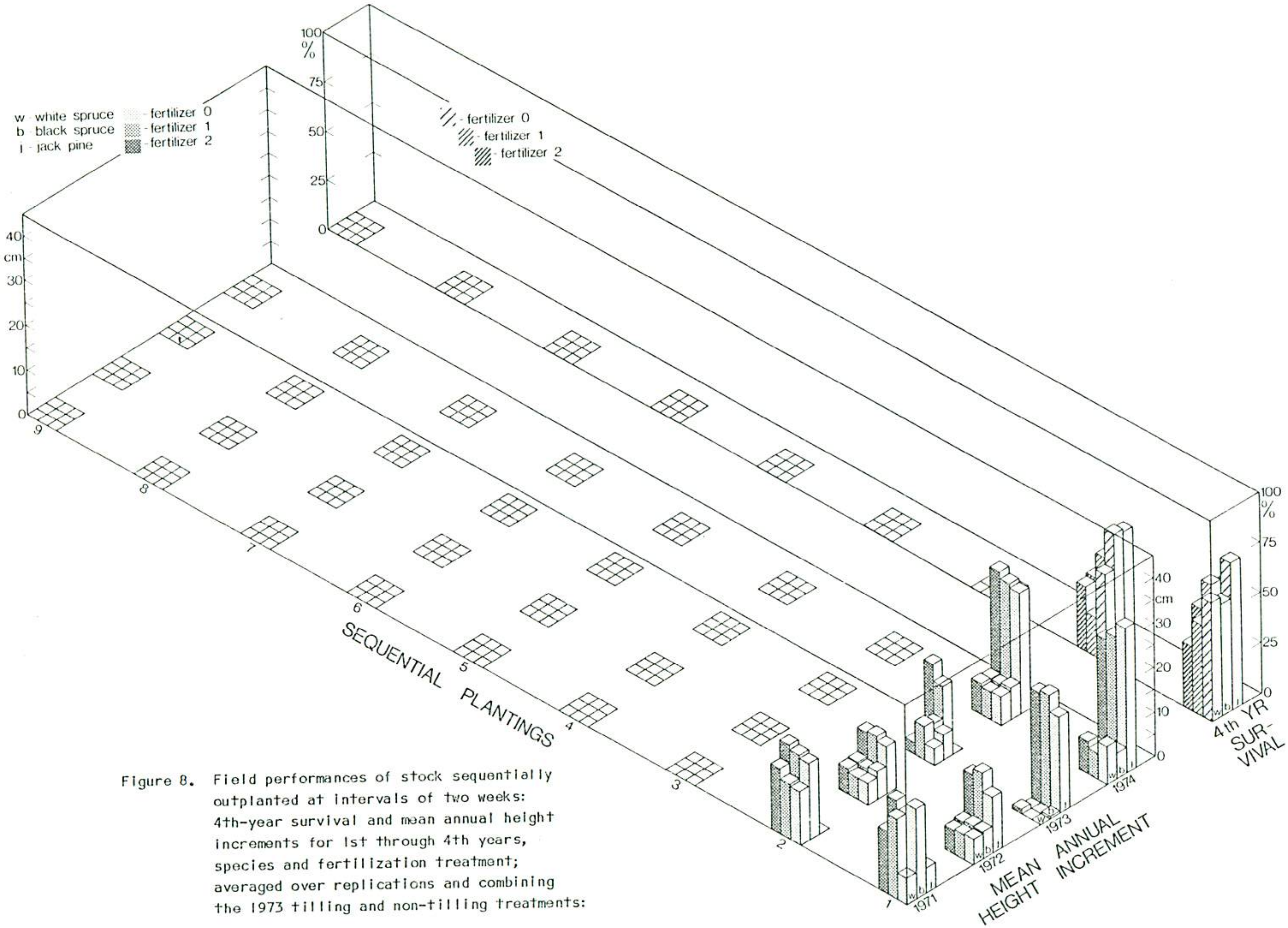


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(c) P71 Dalton

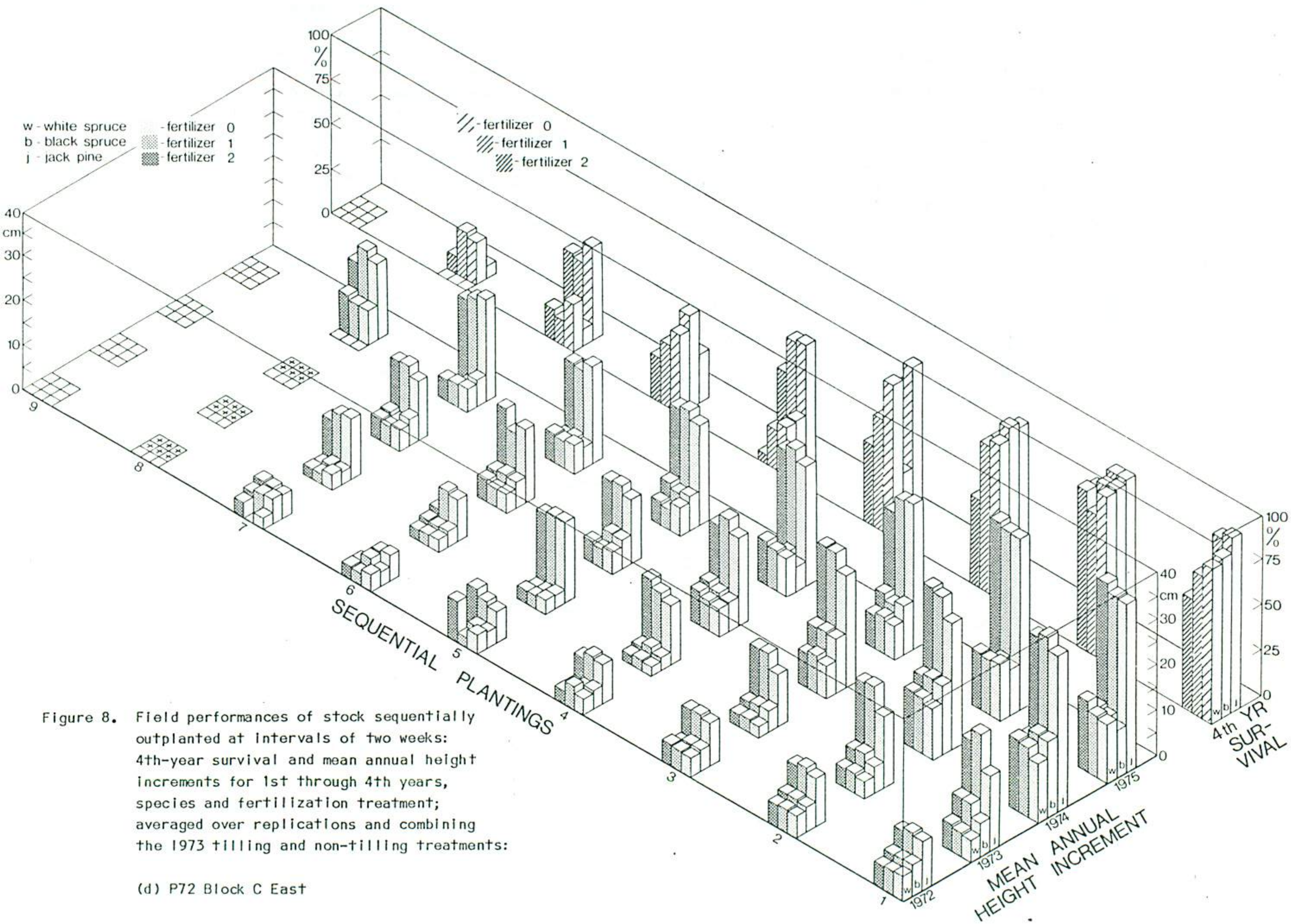


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(d) P72 Block C East

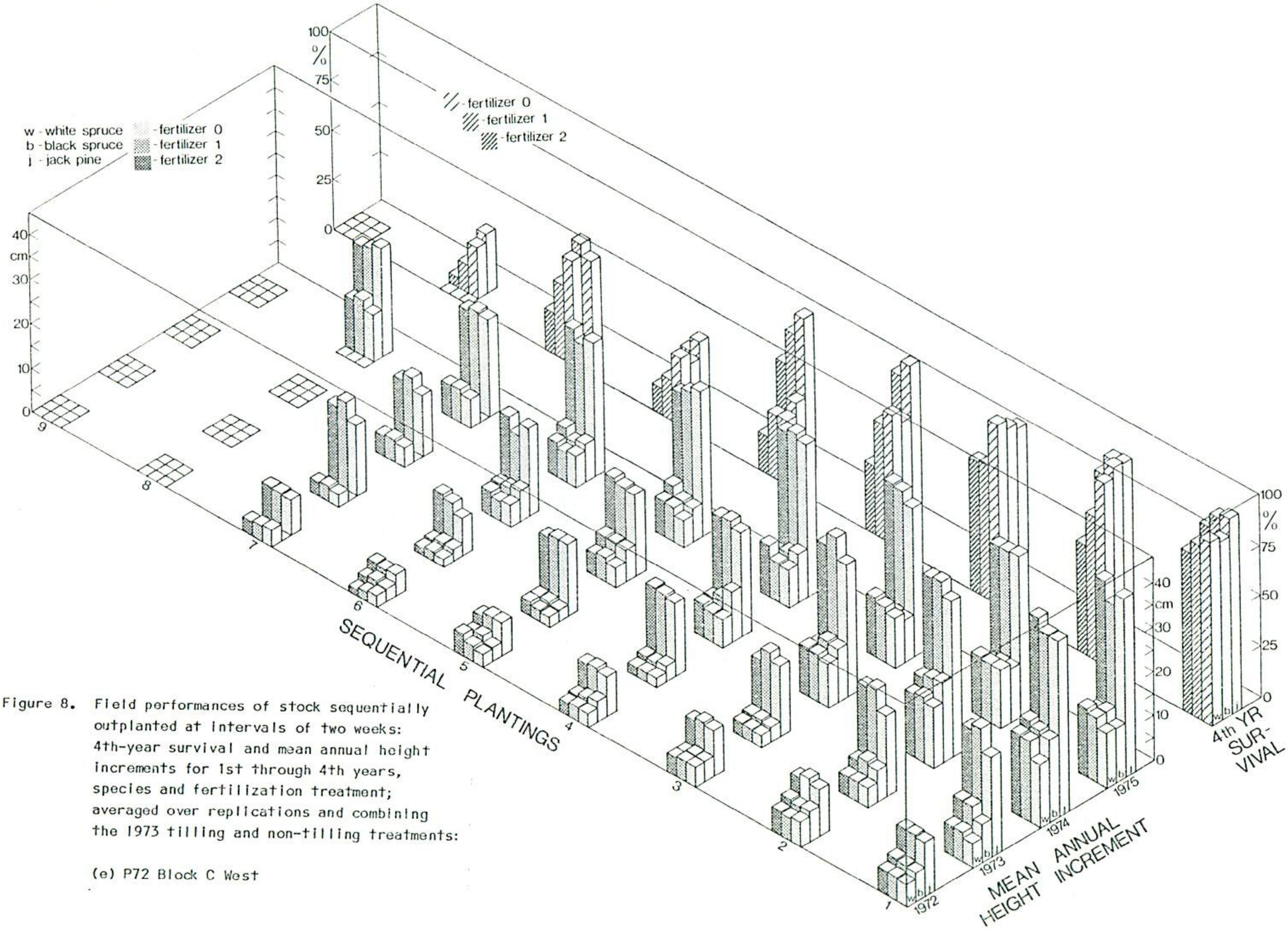


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(e) P72 Block C West

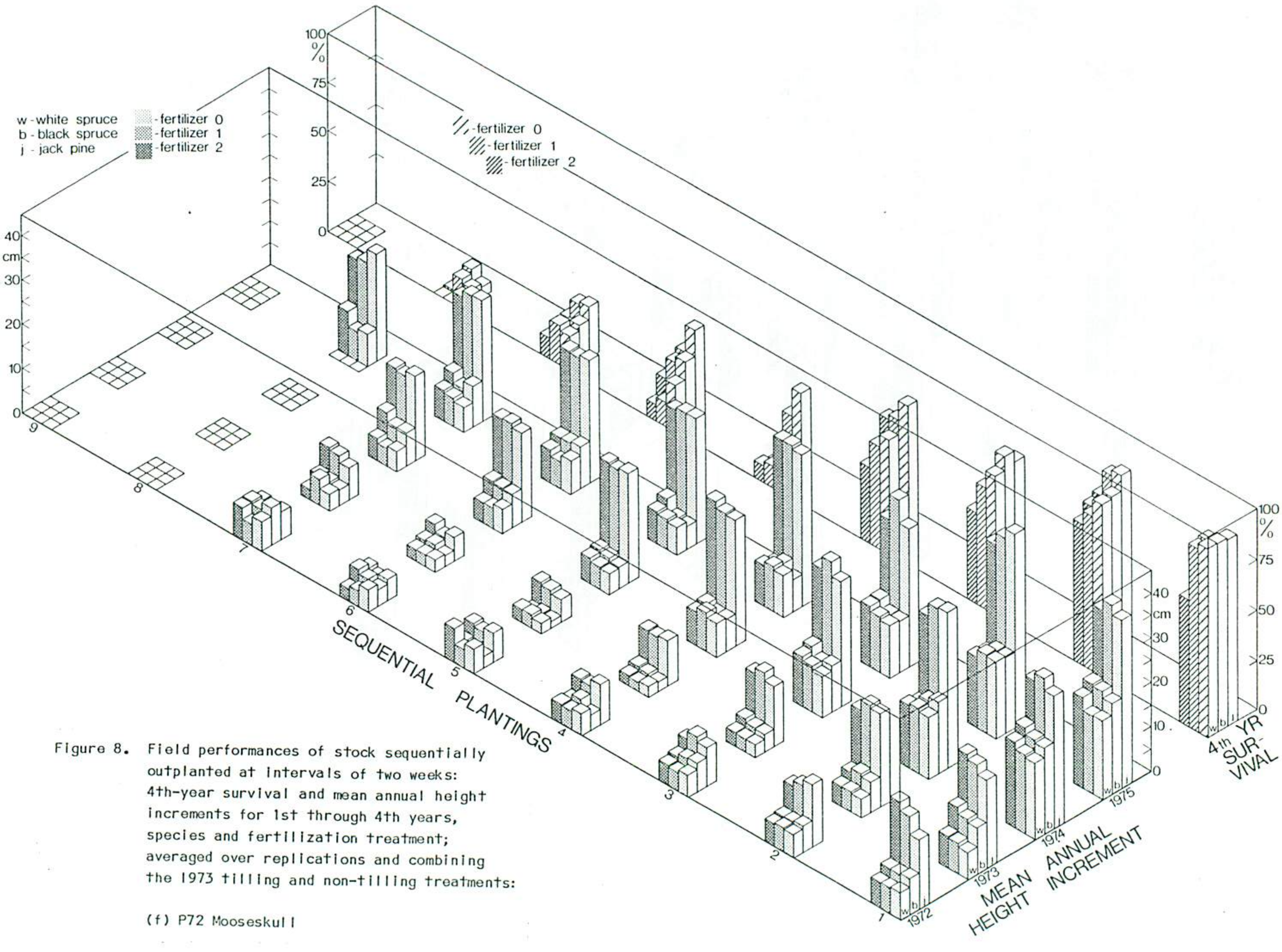


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(f) P72 Mooseskull

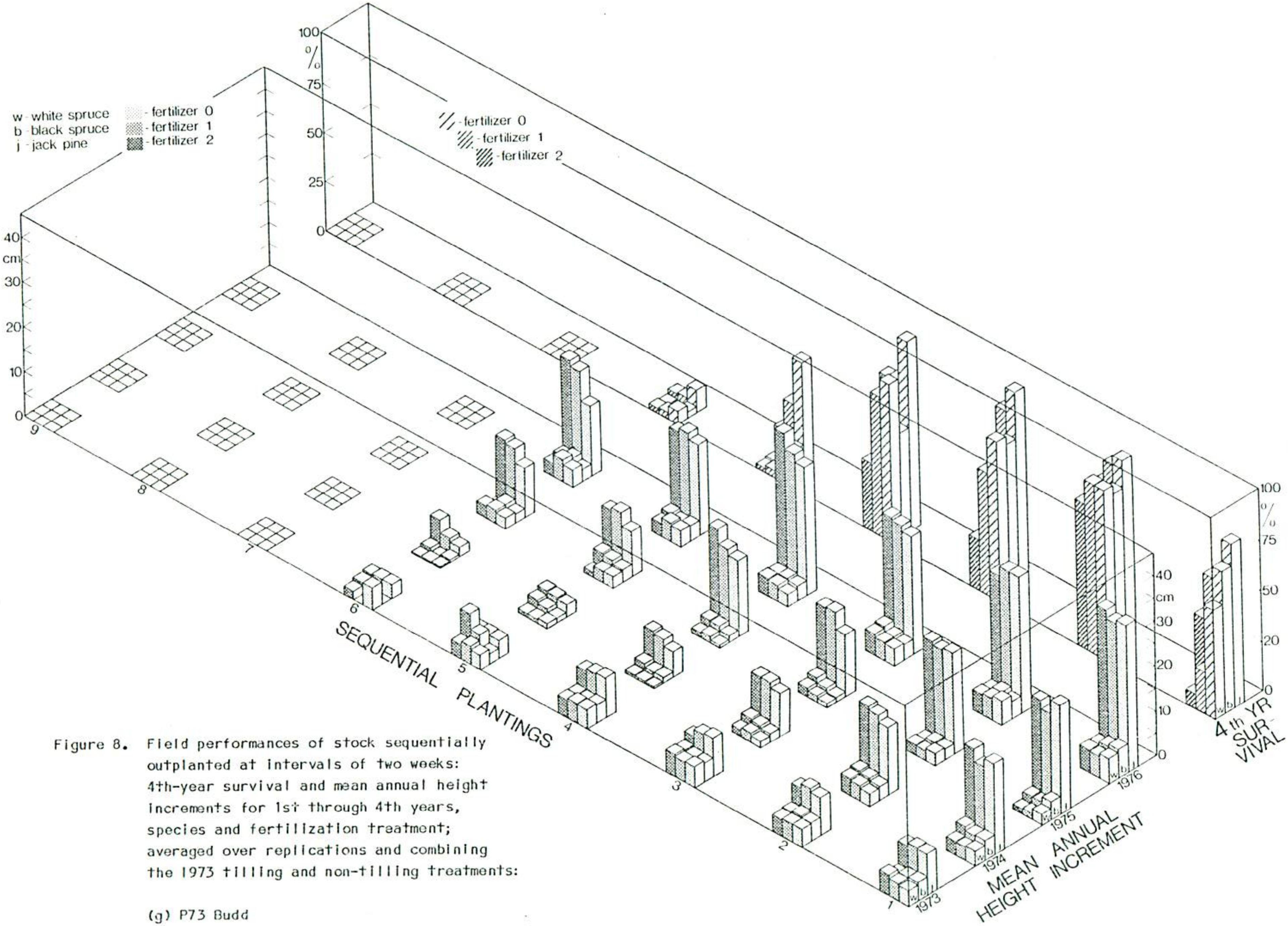


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(g) P73 Budd

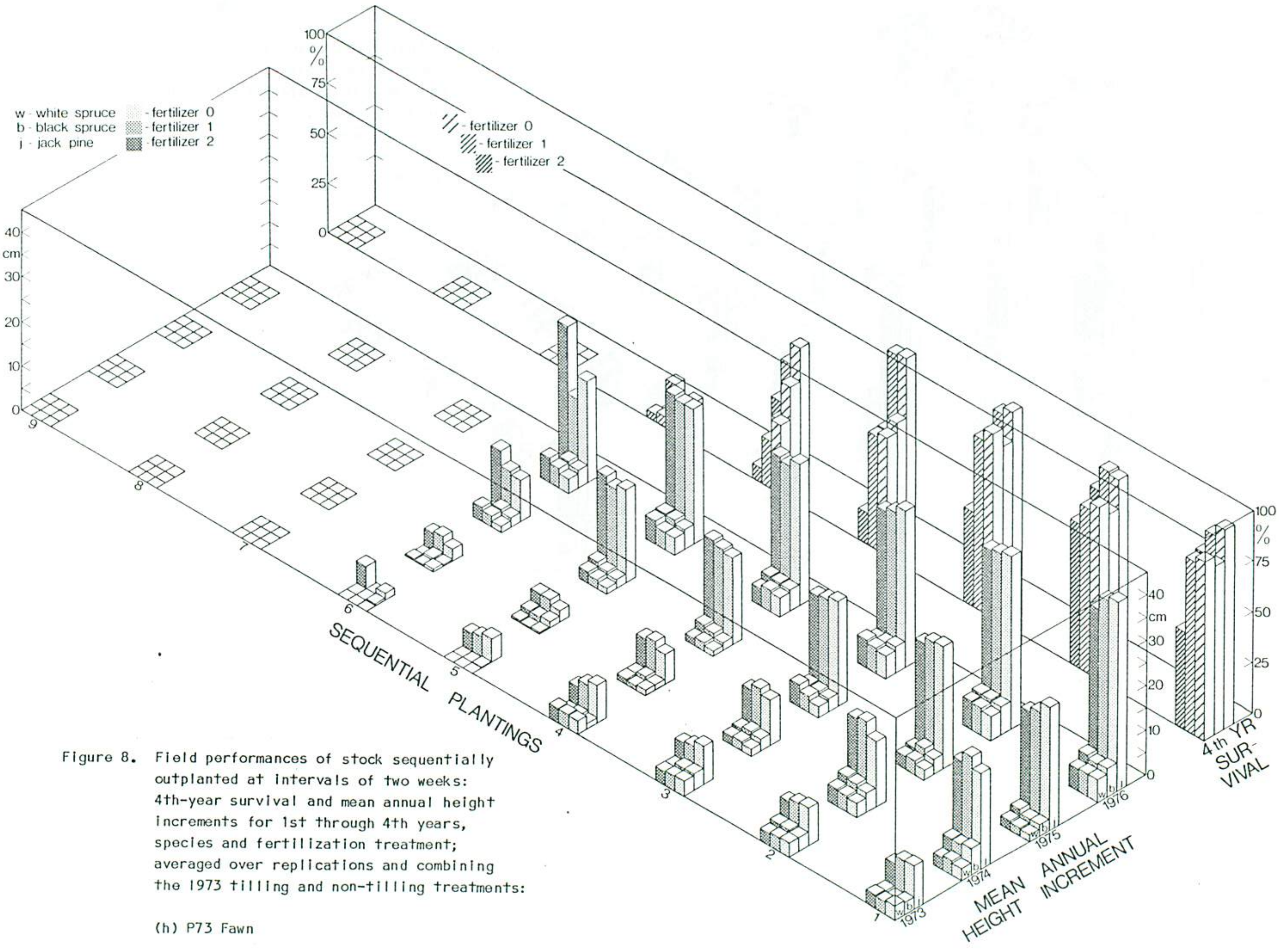


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(h) P73 Fawn

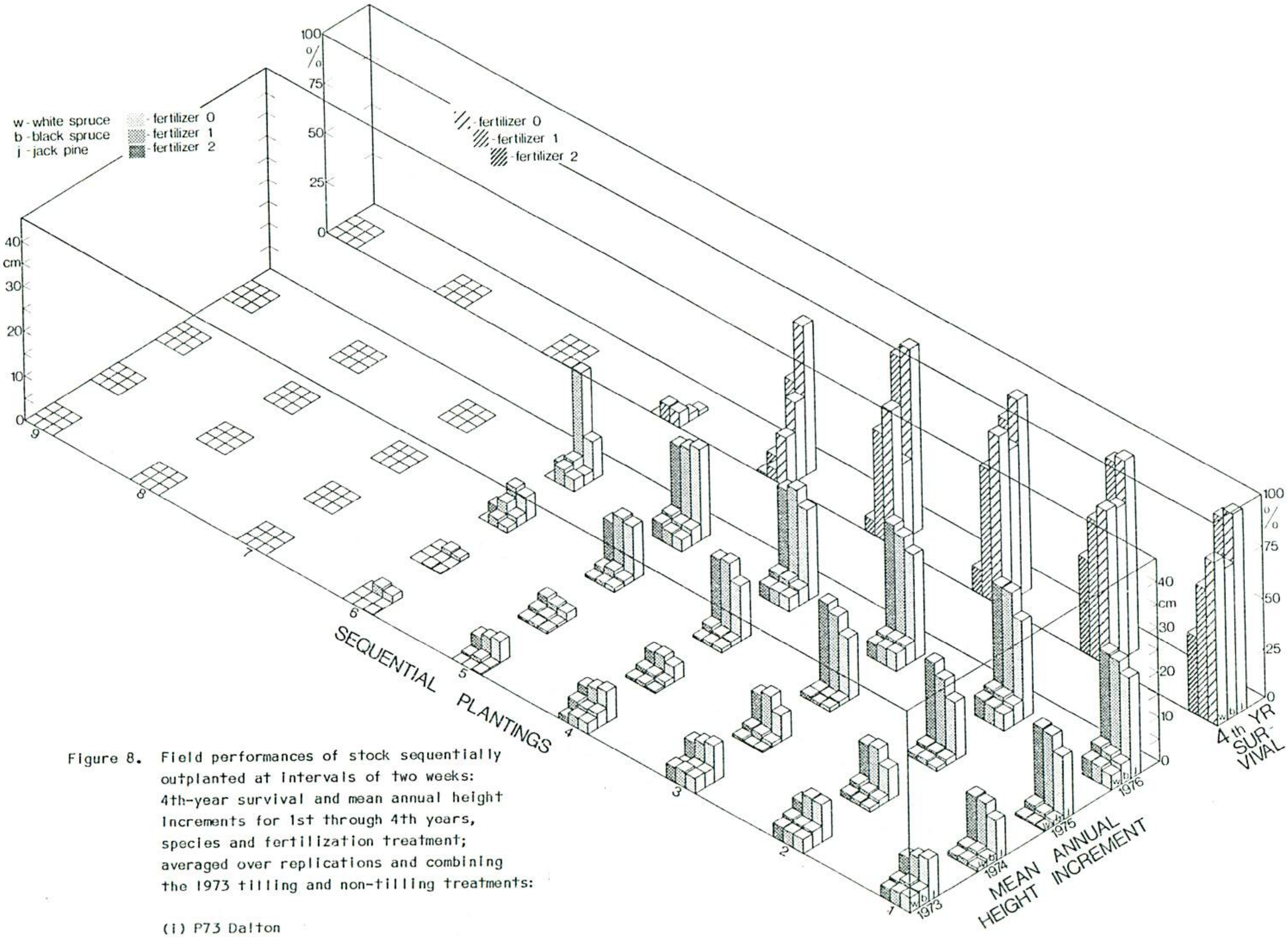


Figure 8. Field performances of stock sequentially outplanted at intervals of two weeks: 4th-year survival and mean annual height increments for 1st through 4th years, species and fertilization treatment; averaged over replications and combining the 1973 tilling and non-tilling treatments:

(i) P73 Dalton

4.2 4.2 FACTORS

4.21 4.21 YEAR OF PLANTING

Attempts to establish forest plantations, if conducted in one year only, would yield results that, no matter how persuasive, would be of little predictive value. A chance peculiarity of weather might produce a once-in-a-lifetime result. Therefore, these stand establishment studies were repeated in each of three consecutive years, with a view to obtaining an indication of the degree to which an ongoing operational program of forestation employing the investigated techniques might be affected by annual variations in the weather. There are, however, at least two important limitations to the inferences that can be drawn from inter-year comparisons: first, the planting stock used in one year's experimentation must necessarily differ from that used in any other year; second, differences in geographical location, as in the present study, inevitably introduce further variation. Even a three-year span is a small climatic sample from which to draw general conclusions (Sinclair and Boyd 1973).

4.211 4.211 *PLANTING STOCK*

The morphology and physiological character of nursery stock grown in northern nurseries may vary widely from year to year, even before lifting, and the series of operations that culminates in outplanting differentially increases variation. Some of the morphological variation may be reduced or obscured by culling and grading, although the large variation in stock size within the same bundle may raise doubts about the existence of cull standards (Kim 1977). The physiological variation among planting stock remains hidden unless exposed by physiological testing (Sutton 1979b).

4.212 4.212 *EPISODIC CONSTRAINTS*

Also contributing to between-year variation in the performance of outplants are episodic constraints that are neither coeval nor coextensive. For example, the Chapleau group of sites was affected by a spruce budworm (*Choristoneura fumiferana* [Clem.]) epidemic, but the Manitouwadge sites were not. The epidemic became intense in 1973 and remained so for several years. Its intensity may be judged by the fact that, in 1975, I counted 51 late instar larvae on one four-year-old black spruce outplant 50 cm tall.

4.213 4.213 *WEATHER*

Given the desiderata of good planting of stock possessed of reasonable performance potential at the time of planting, the site conditions at the time of outplanting and for several weeks thereafter are major determinants of outplant performance, certainly in the first year, probably for several years, and possibly for the lifetime of the tree. In the boreal forest of central Canada, where these studies are being conducted, the storm tracks and weather patterns vary greatly from day to day as well as from year to year, the climate here being characterized by a high frequency of cyclonic passages in summer and almost constant frontal activity (Larsen 1980).

Approximations of the weather experienced by the two groups of sites are given by data averaged from the designated weather stations. Details of the calculations are given in Appendix B. Weather data for the individual sites are not available.

The Chapleau group of sites experienced mean daily air temperatures (Fig. 9) that were 1°C to 2°C lower than normal in July and August, 1971; July was the only month in which a freezing temperature did not occur. In 1972, temperatures were lower than normal from June through October, but neither July nor August experienced freezing temperatures. In 1973, temperatures were higher than normal from June through October (the August mean exceeding normal by as much as 3°C), and below-freezing temperatures did not occur in June, July, and August. With regard to precipitation on the Chapleau group of sites, the May through September period of 1971, after a wet start, was much drier than normal, 1972 was wet, and 1973 was also wetter than normal until July, but August, September and October were considerably drier than normal (Fig. 10, Table 3).

Table 3. Estimated precipitation, May through September, for the Chapleau and Manitouwadge groups of sites, based on Appendix B data.

Year (May-Sept)	Site group: Chapleau (mm)	Site group: Manitouwadge (mm)
1971	360[a]	466
1972	460	363[a]
1973	443[a]	401
1974	399	441
1975	425	285
1976	347	302

[a] outplantings carried out in the area.

'CHAPLEAU'

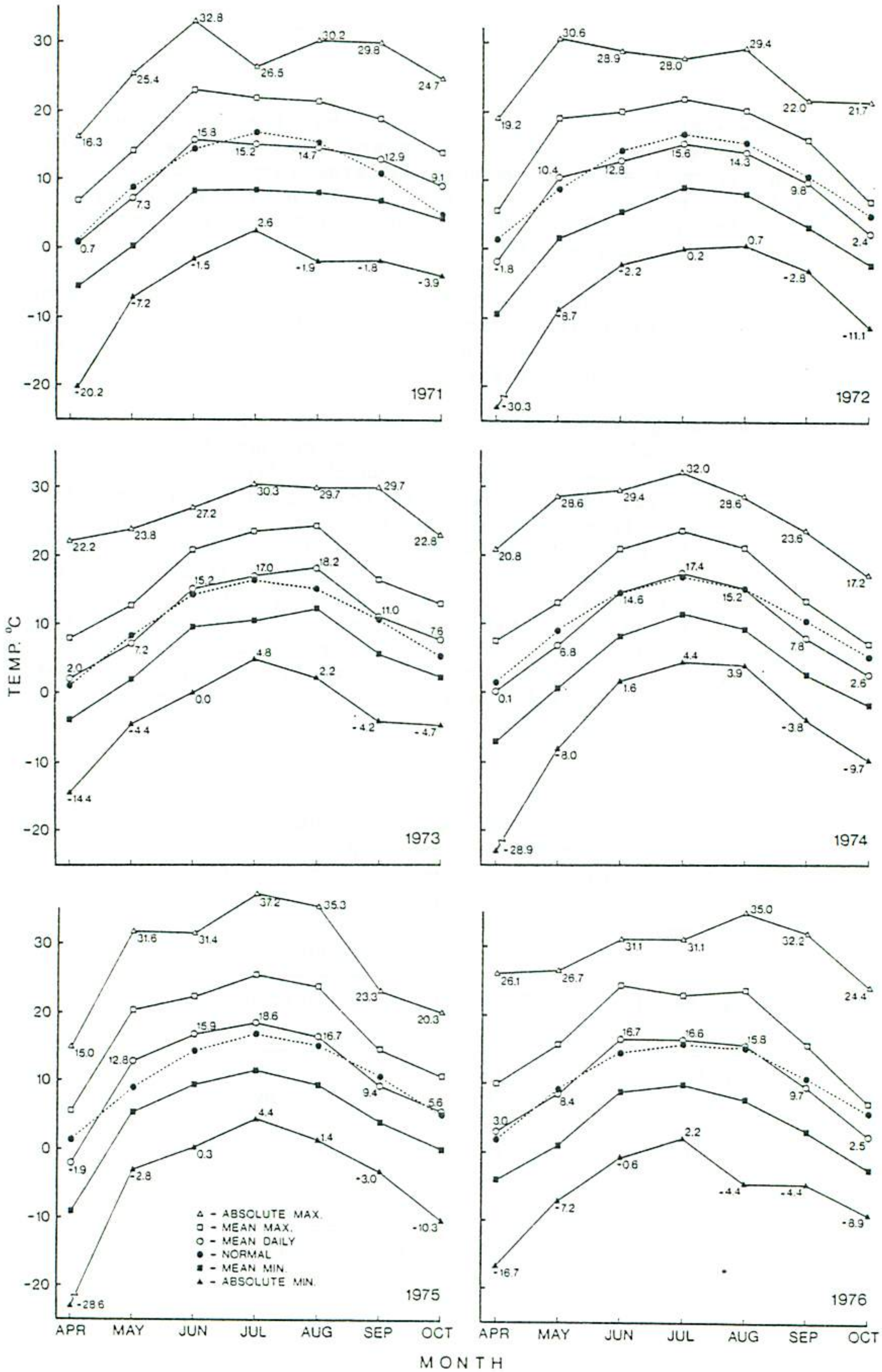


Figure 9. Mean monthly (April through October) temperature 1971 through 1976, computed for the Chapleau group of sites as per Appendix B.

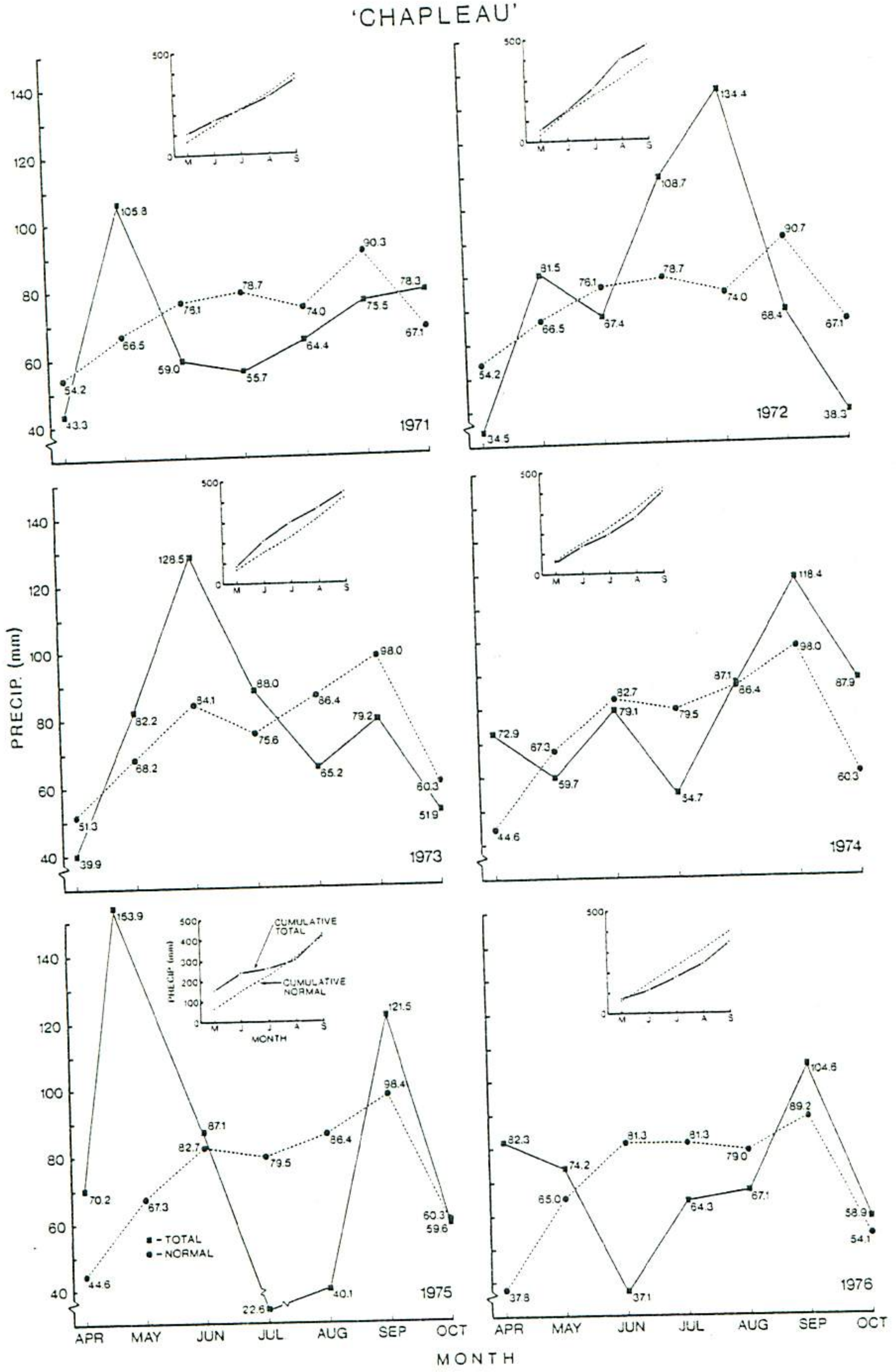


Figure 10. Mean monthly (April through October) precipitation 1971 through 1976, and actual vs normal cumulative precipitation (May through September), computed for the Chapleau group of sites as per Appendix B.

The Manitouwadge group of sites also experienced below-normal mean daily air temperatures (Fig. 11) in July (by as much as 3.9°C) and August, 1971, and, again, July was the only month in which the absolute minimum remained above 0°C. In 1972, the year in which the Manitouwadge group of plots was established, mean daily temperatures averaged 1.5°C lower than normal from June through October, and every month had an absolute minimum of 0°C or below. In 1973, normal mean temperatures occurred until July, after which temperatures exceeded normal by 1°C to 3°C. With respect to precipitation (Fig. 12), the Manitouwadge sites were much wetter than normal in every month from April through October, 1971, except for August and September, in which precipitation was normal. The year 1972 was very dry, with precipitation much below normal in every month except July. For instance, the first sequential outplantings in 1972 on the outwash sites took place at a time when the soil was excessively dry (Fig. 13). The 12 mm of rain that fell on 9 July was the first significant rain for more than a month. The previous rain of consequence occurred well before 13 June, when the soil moisture (determined gravimetrically) on similar soil close by was only 12% at both the 12.5 cm and 37.5 cm depth (Sutton 1979a). The weather remained somewhat dry in 1973.

Frost adversely affected many of the white spruce, and not only those planted late in the growing season. However, the factor that exerted the greatest overall influence on the results was intermittent lack of soil moisture.

Climatic parameters for the region encompassing all the sites within the present study were given by Rodenwaldt (1965) thus: mean growing season precipitation 300 mm to 380 mm, mean annual total precipitation 700 mm to 750 mm, variability of growing season precipitation 20%, and a growing season of 140 days to 160 days.

4.214 4.214 *STOCK PERFORMANCE*

Overall comparisons between years suffer from the geographical complications already mentioned. Also, survival was too low in the third and later sequential plantings on the P71 till site, and in the fifth and later sequential plantings on the P71 outwash sites, to warrant the inclusion of P71 data from any but the first and second sequential plantings at Dalton and the first through fourth sequential plantings at Budd and Fawn. In all other cases, data from the first through fifth plantings are used. Nevertheless, a generally similar pattern of performance during the first four years after outplanting is apparent for each of the three years of establishment when site, species, and treatments are combined (Fig. 14).

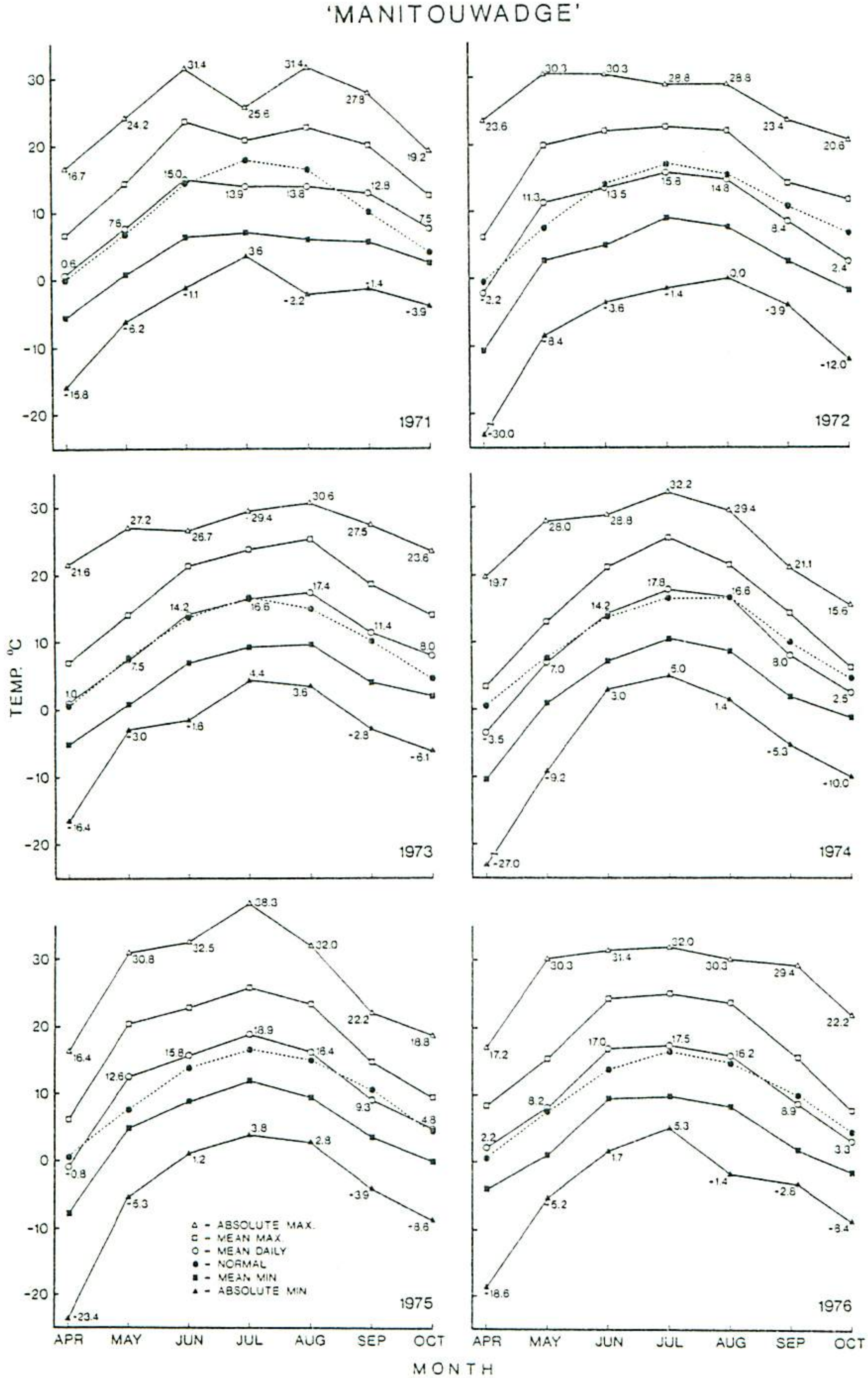


Figure 11. Mean monthly (April through October) temperature 1971 through 1976, computed for the Manitouwadge group of sites as per Appendix B.

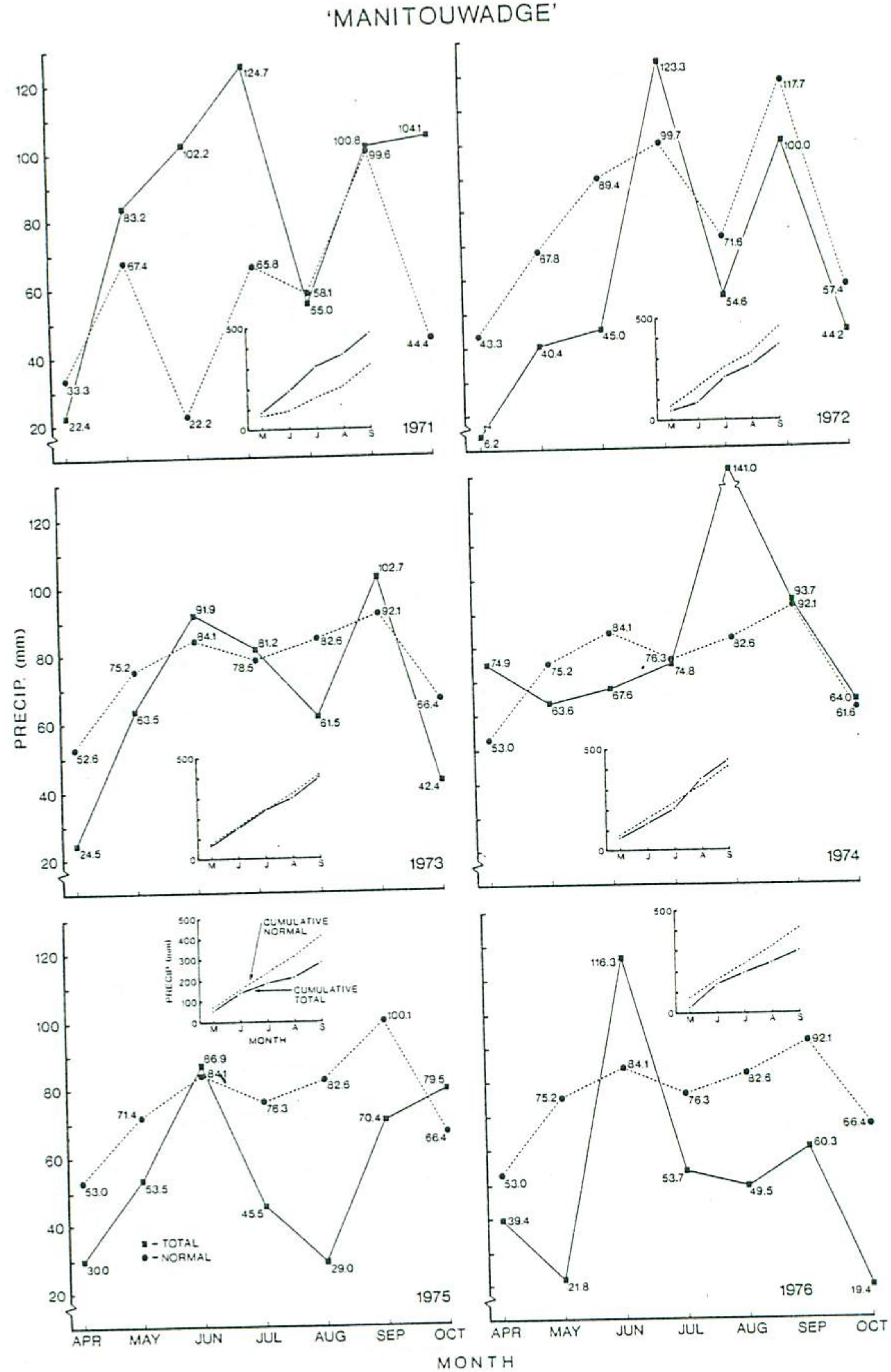


Figure 12. Mean monthly (April through October) precipitation 1971 through 1976, and actual vs normal cumulative precipitation (May through September), computed for the Manitouwadge group of sites as per Appendix B.

Figure 13. Blowing sand, Block C Manitouwadge during 1972 drought.

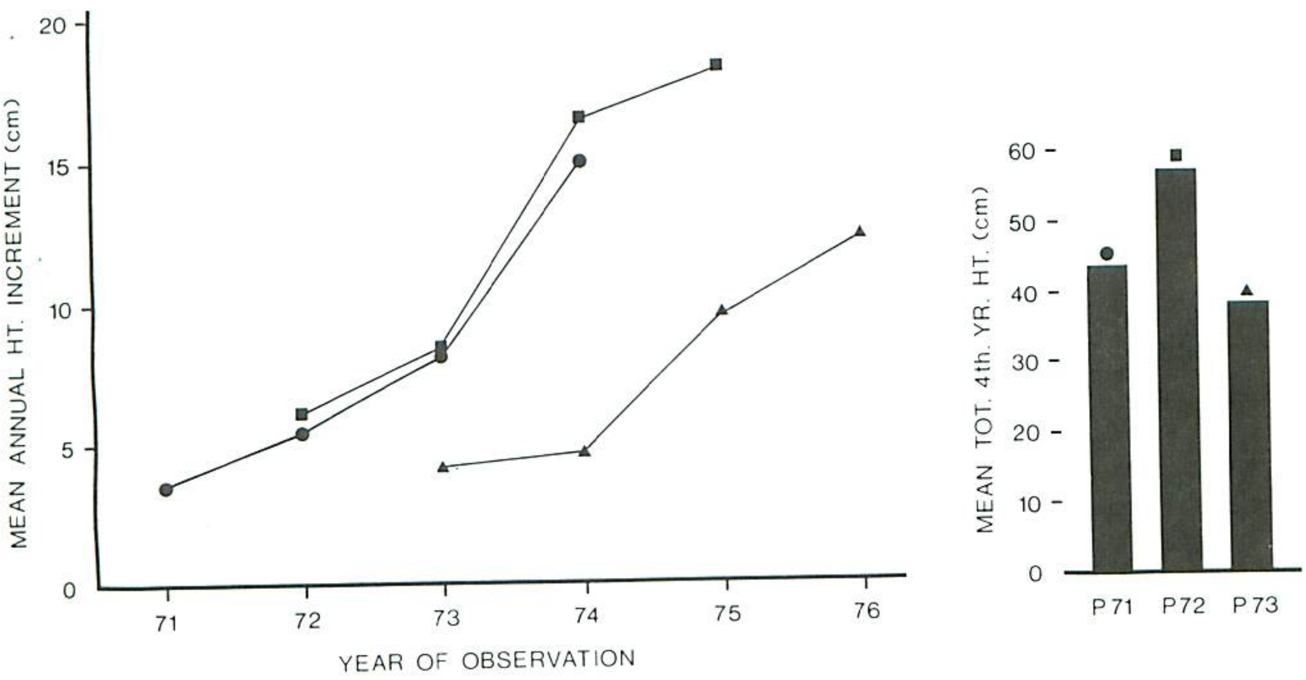


Figure 14. Mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (site, species, sequential plantings 1 and 2, for the P71 till site, 1 through 4 for the P71 outwash sites, and 1 through 5 in all other cases, and fertilization/tilling treatments combined) by year of planting. P71, etc. = planted in 1971, etc.

The overall comparison between the outwash sites of the 1971 plantings and those of 1973, on the same suite of sites, may be used to illustrate the degree of similarity of pattern. The higher survival in the 1973 plantings (Table 4), though not statistically significant, may reasonably be assumed to include a reflection of better quality of the 1973 planting stock, although quantitative evidence as to differences in performance potential are lacking. The 1973 plantings are also superior in terms of growth (Table 5), but the differences are not significant and the similarity is pronounced.

The general similarity in overall growth performance between the P71 and P73 series is evident for all three species (Fig. 15, 16, 17).

Table 4. Overall mean survival one and four growing seasons after outplanting (outwash sites, species, and fertilizer/tilling treatments combined) for the first two plantings in 1971 and 1973. No significant (P .05) differences by chi-square test within either columns or rows.

Year of planting	Sequential planting	1st-year survival (%)	4th-year survival (%)
1971	1	66.8	58.7
	2	63.8	51.5
1973	1	73.6	64.9
	2	85.6	77.1

The basis for comparing the results obtained from studies established in different years is therefore exceedingly insecure. Such comparisons nevertheless serve a useful purpose. Patterns, if stable enough to transcend these insecurities, would be of considerable value in predicting the outcome of operational applications.

4.22

4.22 SITE

Following site preparation, which removed pre-existing vegetation almost completely, the outwash sites were commonly recolonized first by sedges (*Carex* L.), including *Carex adusta* Boott, *C. aurea* Nutt., *C. brunnescens* (Pers.) Poir., and *C. houghtonii* Torr., and then

Table 5. Mean annual height increment for each of the first four years after outplanting, and mean total height after four growing seasons, (outwash sites, species, sequential plantings 1 through 4, (1971) or 1 through 5 (1973), and fertilization/tilling treatments combined) by year of establishment. Within columns, values not followed by the same letter differ significantly (P .05).

Year of planting	Annual height increment				Total height after four growing seasons (cm)
	First (cm)	Second (cm)	Third (cm)	Fourth (cm)	
1971	3.0a	4.3	6.4a	11.9	35.0a
1973	3.9b	4.3	7.5b	12.5	39.0b

by elements of the pre-existing flora, including *Alnus crispa* (Ait.) Pursh, *Amelanchier bartramiana* (Tausch) Roemer, *Anemone quinquefolia* L., *Coptis groenlandica* (Oeder) Fern., *Cornus canadensis* L., *Diervilla lonicera* Mill., *Epigaea repens* L., *Epilobium angustifolium* L., *Fragaria virginiana* Duchesne, *Galium triflorum* Michx., *Linnaea borealis* var. *americana* (Forbes) Rehd., *Lonicera involucrata* (Richards.) Banks, *Lycopodium annotinum* L., *Oryzopsis asperifolia* Michx., *O. pungens* (Torrey) Hitch., *Polygala paucifolia* Willd., *Potentilla tridentata* Ait., *Prunus pensylvanica* L.f., *Pteridium aquilinum* (L.) Kuhn, *Rosa acicularis* Lindl., *Rubus idaeus* var. *strigosus* (Michx.) Maxim., *Salix* L. sp., *Solidago* L. spp., *Viola renifolia* Gray, and naturally regenerated jack pine.

The vegetation that developed on the mixedwood till sites after site preparation was dominated largely by sedges, including *Carex aenea* Fern., *C. brunnescens*, *C. adusta*, *C. houghtonii*, *C. curta* Good, *C. crawfordii* Fern., and *C. laxiflora* Lam. var. *ormostachys* (Wieg.) Gleason. Other species occurring in the till areas included: *Scirpus cyperinus* (L.) Kunth var. *brachypodus* (Fern.) Gilly, and *Juncus brevicaudatus* (Engelm.) Fern., as well as the grasses *Cinna latifolia* (Trev.) Griseb., *Calamagrostis canadensis* (Michx.) Beauv., *Agrostis scabra* Willd., and *A. gigantea* Roth. In other respects, the pattern of vegetative recolonization of these mixedwood till soils approximated that found by Sutton (1964) in boreal mixedwood that had been subjected to seedbed treatments involving the removal of unincorporated organic matter. The till soils were recolonized much more quickly than were the outwash soils.

Figure 15. Jack pine (jP): mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (site, sequential plantings 1 through 2 for the P71 till site, 1 through 4 for the P71 outwash sites, and 1 through 5 in all other cases, and fertilization/tilling treatments combined) by year of planting. P71, etc. = planted in 1971, etc.

Figure 16. Black spruce (bS): mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (site, sequential plantings 1 and 2 for the P71 till site, 1 through 4 for the P71 outwash sites, and 1 through 5 in all other cases, and fertilization/tilling treatments combined) by year of planting. P71, etc. = planted in 1971, etc.

Figure 17. White spruce (wS): mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (site, sequential plantings 1 and 2 for the P71 till site, 1 through 4 for the P71 outwash sites, and 1 through 5 in all other cases, and fertilization/tilling treatments combined) by year of planting. P71, etc. = planted in 1971, etc.

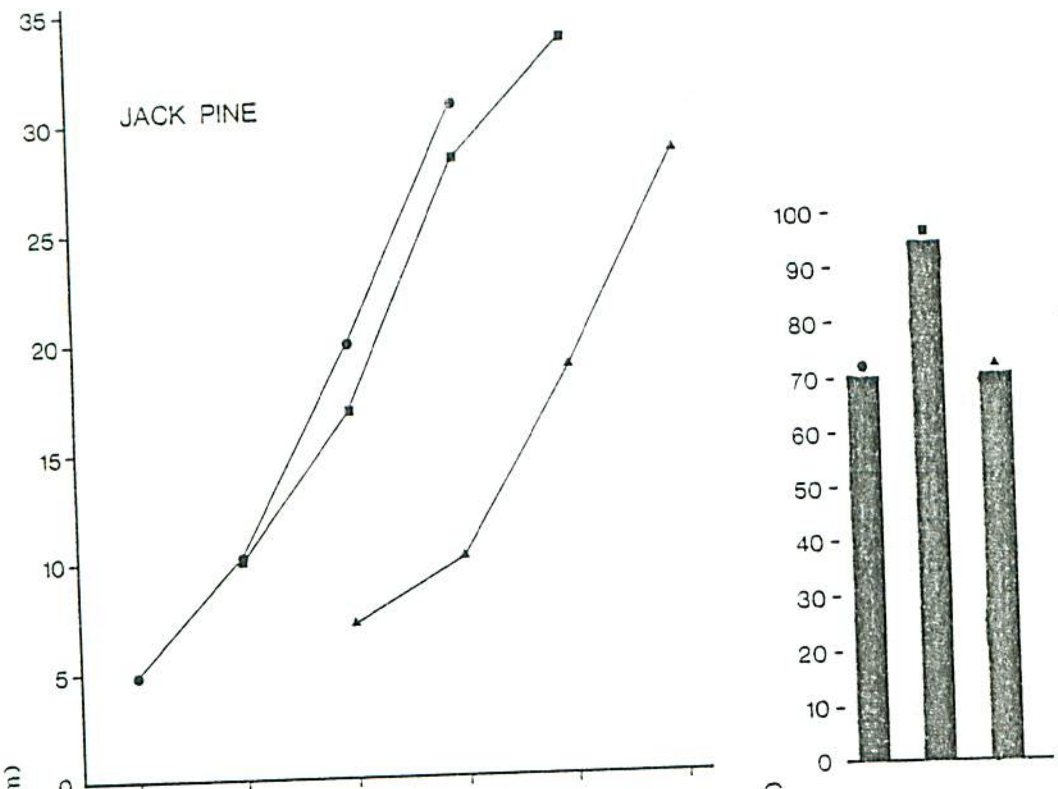


Figure 15

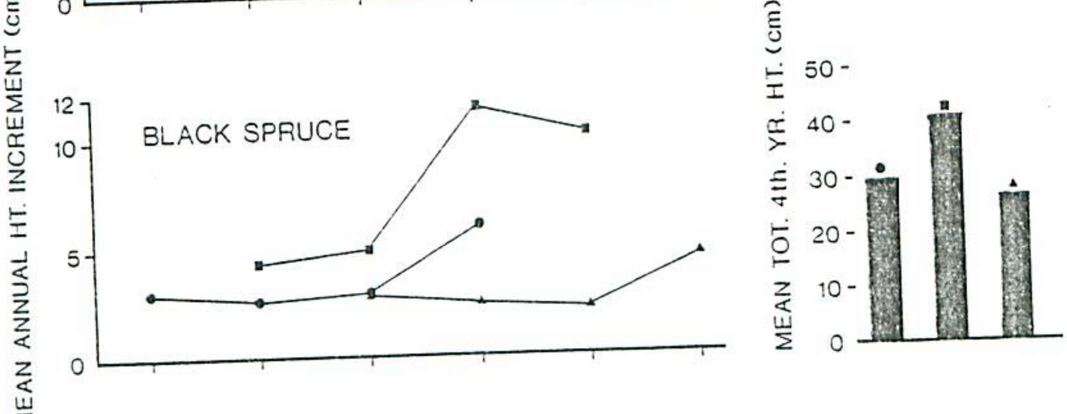


Figure 16

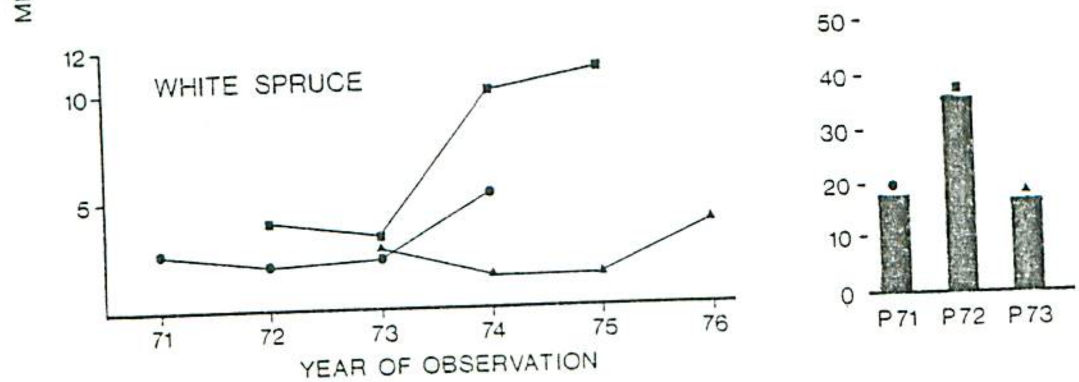


Figure 17

4.221 4.221 *1971 OUTPLANTINGS (P71)*

In terms of survival, the effect of site should be most strongly expressed in the early sequential plantings, survival in the later ones becoming increasingly affected by the deteriorating condition of the planting stock. Looking, therefore, at the first and second sequential outplantings of 1971, we see that fourth-year survival (species and treatments combined) ranged from 76.5% to 41.4% (Table 6). This variation between the P71 sites is quite as much as the variation which occurred between years.

Table 6. Survival (species and treatments combined) among P71 stock one and four growing seasons after outplanting, for the first and second sequential plantings, by site. Within columns, values do not differ significantly (P .05) by chi-square test.

Sequential planting no.	Survival							
	Budd[a]		Fawn[a]		Dalton[b]		Sites over all	
	1st yr (%)	4th yr (%)	1st yr (%)	4th yr (%)	1st yr (%)	4th yr (%)	1st yr (%)	4th yr (%)
1	85.6	76.5	59.6	47.4	55.1	52.3	66.8	58.7
2	74.4	53.6	72.8	59.4	44.2	41.4	63.8	51.5
Mean	80.0	65.0	66.2	53.4	49.6	46.8	65.3	55.1

[a] Outwash site
[b] Till site

Averaged over the first two sequential plantings, fourth-year survival was 65.0% and 53.4% on the P71 outwash sites, and 46.8% on the till. There was, over all, an average decline of 15.4% in survival from the first through the fourth year. The decline was least (5.6%) on the till site and approximately equal (18.8% and 19.3%) on the outwash sites.

Growth performance of P71 stock over all (species, sequential plantings 1 through 4, or, in the case of the P71 till site, plantings 1 and 2 only, and treatments combined) varied significantly (P .05) between sites.

The variation between sites in mean annual height increment was greater in P71 stock (Fig. 18) than in stock outplanted in 1972 or 1973, and the differential widened as time progressed through the four-year period under review. The fourth-year differentials are greatest, not between the till site and the outwash sites, but between the two outwash sites: fourth-year height increment was 77% greater at Fawn than at Budd. At Dalton, on the basis of the first two sequential plantings only, the mean annual height increment in the fourth growing season after outplanting was intermediate between those achieved at Budd and Fawn, a pattern that was repeated on the same suite of sites in the P73 plantings, all of which were based on the first five sequential plantings. 4.222

4.222 *1972 OUTPLANTINGS (P72)*

First-year survival data for the P72 plantings could not be collected because of resource limitations. Fourth-year survival, viz. 83.4% (species and treatments combined, again averaging the first two sequential plantings) was significantly (P .01) higher than in the P71 plantings (55.1%). In contrast with the P71 plantings, there were no significant differences between sites in terms of fourth-year survival in the first two sequential plantings of 1972 (Table 7).

Table 7. Survival (species and treatments combined) among P72 stock four growing seasons after outplanting, for the first and second sequential plantings, by site. No significant (P .05) differences by chi-square test within either columns or rows.

Sequential planting no.	Survival			
	C East[a] (%)	C West[a] (%)	Mooseskull[b] (%)	Sites over all (%)
1	78.7	84.8	84.2	82.6
2	88.3	82.5	82.1	84.3
Mean	83.5	83.6	83.2	83.4

[a] Outwash site
[b] Till site

Because of the lack of survival data for the period before the fourth year, little can be said with certainty about the pattern of mortality. However, first-year mortality was obviously far less in 1972 than in 1971. The single most likely cause of this is the superior condition of the P72 planting stock.

Growth performance over all (species, sequential plantings 1 through 5, and treatments combined), though differing significantly

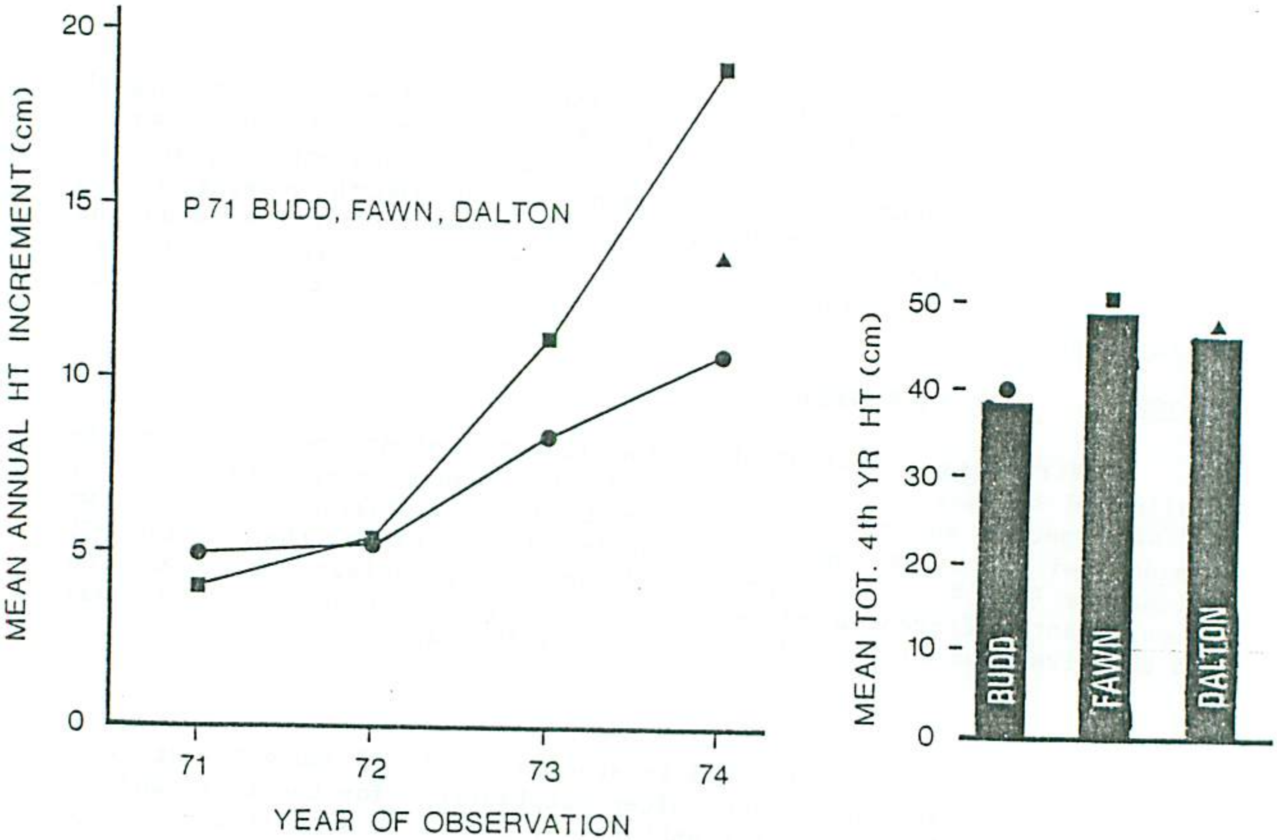


Figure 18. P71 plantings: mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (outwash sites, species, sequential plantings 1 through 4, and fertilization treatments combined). Dalton data are for sequential plantings 1 and 2 only and exclude annual increments, values for which were obtained by retroactive and therefore somewhat unreliable measurement. P71 = planted in 1971.

between sites, was much less variable than in outplantings of the previous year (Fig. 19). In the fourth-year height increment, a difference of less than 3 cm separated the greatest (on the Mooseskull till) from the least (on the C East outwash). The C West outwash site and the till site differed only marginally in terms of fourth-year height increment, and were virtually identical with respect to total height after four growing seasons. (Total height on the C West outwash site exceeded that the C East by 16%.)

Thus, again, the greatest differential was between the two outwash sites (which in this case lie only a couple of hundred metres apart, on either side of a small kettle lake, cf. Fig. 2B), rather than between outwash and till sites. Perhaps the major contributing factor here is gravel content variation in the outwash soils, high contents tending to accentuate any deficiencies in soil moisture and nutrients, and tending also to make firming more difficult during the planting operation.

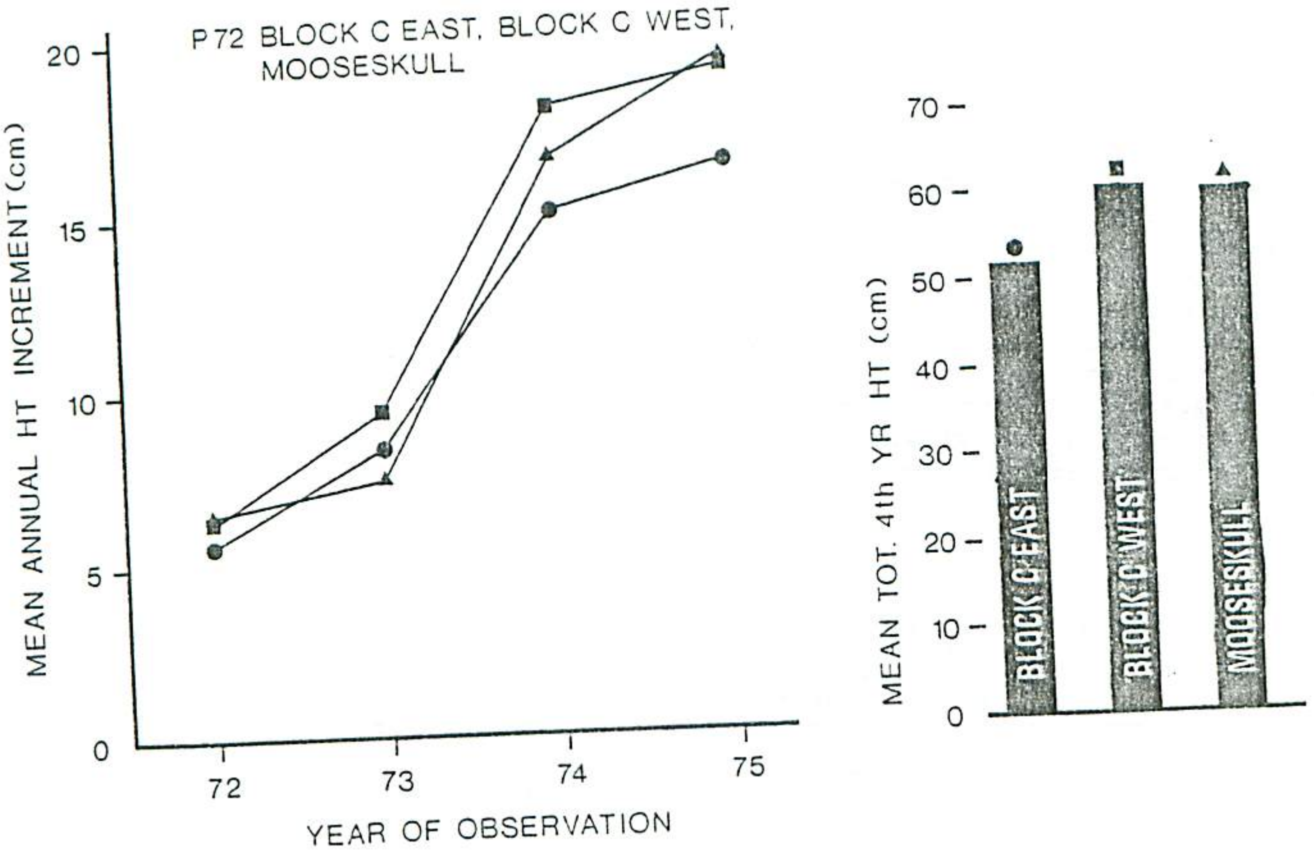


Figure 19. P72 plantings: mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (site, species, sequential plantings 1 through 5, and fertilization treatments combined). P72 = planted in 1972.

4.223

4.223 *1973 OUTPLANTINGS (P73)*

Survival rates were generally significantly (P 0.01) higher over all than in the P71 outplantings on the same suite of sites. The first and second sequential plantings were again used as the basis for comparison (71.0% versus 55.1%). For the P73 stock, fourth-year survival (species and treatment combined) ranged from 80.5% (in the second sequential planting) to 50.8% (in the first planting), both on the Fawn outwash site (Table 8).

Averaged over the first two sequential plantings, fourth-year survival was 69.1% and 65.6% on the P73 outwash sites, and 78.2% on the till. There was an average decline of 11.0% over all from the end of the first growing season through the end of the fourth year. The decline was least (7.2%) on the till site, as in the P71 series, and about twice this (10.0% and 15.5%) on the outwash sites.

The P73 mean annual height increments (Fig. 20) show a pattern similar to that exhibited in the P71 series on the same suite of sites. The fourth-year spread in height increment, as in the P71 series, was widest between the two outwash sites, rather than between the till and the outwash sites, and the Dalton till (with the P73 data based on the same number of sequential plantings as the outwash sites) was intermediate. Growth on the Fawn outwash site was again superior to that on the Budd outwash site: fourth-year height increment over all was almost 50% greater at Fawn than at Budd. In terms of total height four years after outplanting, growth at Fawn was 34% greater than at Budd, the till site again being intermediate in this regard.

Table 8. Survival (species and treatments combined) among P73 stock at the end of the first (1973) and fourth growing seasons after outplanting, for the first and second sequential plantings, by site. No significant (P .05) differences by chi-square test within either columns or rows.

Sequential planting no.	Survival							
	Budd[a]		Fawn[a]		Dalton[b]		Sites over all	
	1st yr (%)	4th yr (%)	1st yr (%)	4th yr (%)	1st yr (%)	4th yr (%)	1st yr (%)	4th yr (%)
1	77.4	69.5	64.8	50.8	78.5	74.5	73.6	64.9
2	76.2	68.8	90.4	80.5	90.1	82.0	85.6	77.1
Mean	76.8	69.1	77.6	65.6	84.3	78.2	79.6	71.0

[a] Outwash site
[b] Till site

Thus the results from outplantings in all three years of establishment show significant differences between sites that are superficially extremely similar to one another. For instance, two sites of greater apparent similarity than the C East and C West outwash sites of the P72 series would be hard to find. However, these sites gave highly significantly different results during the first four years after outplanting. The gravel content of outwash soils, especially in times of soil moisture deficiency, may be a major factor: it can certainly be expected to influence the quality of planting through its effect on packing of soil and firming, and it does influence soil nutrient content and concentration (Sutton 1979a). Data from years subsequent to the initial four-year period will, in a future report, show that growth

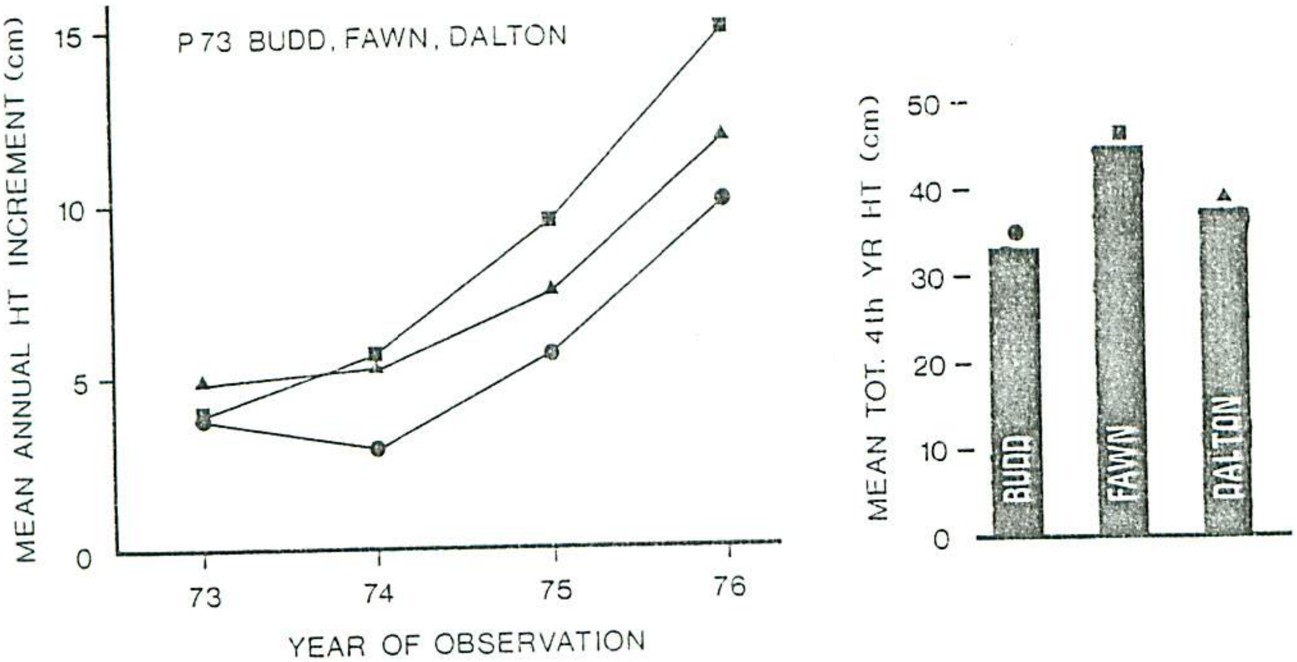


Figure 20. P73 plantings: mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (site, species, sequential plantings 1 through 5, and fertilization/tilling treatments combined). P73 = planted in 1973.

rates on till sites achieve superiority soon thereafter, but during the first four years (especially when any combination of poor quality stock or highly stressful outplanting conditions is involved), better performance has been achieved on some outwash sites of low fertility than on more fertile till sites. A point worth emphasizing is that site preparation on the till sites produced a much higher proportion of *unfavorable* microsites for planting than did site preparation on the outwash sites, not by design, of course, but because of the greater difficulty of operating on bouldery soils with bedrock close to the surface in places, and with much greater variation in topography than was the case with outwash sites.

4.23 SPECIES 4.23

Jack pine clearly outperformed the spruces during the first four years after outplanting. Fourth-year survival over all (combining year of planting, sites and treatments) was significantly (P .01) higher in jack pine than in the spruces (Fig. 21).

When separated by year of planting, the fourth-year survival data for both the P72 and the P73 plantings show the same superiority of jack pine, especially in the fourth and fifth sequential plantings of

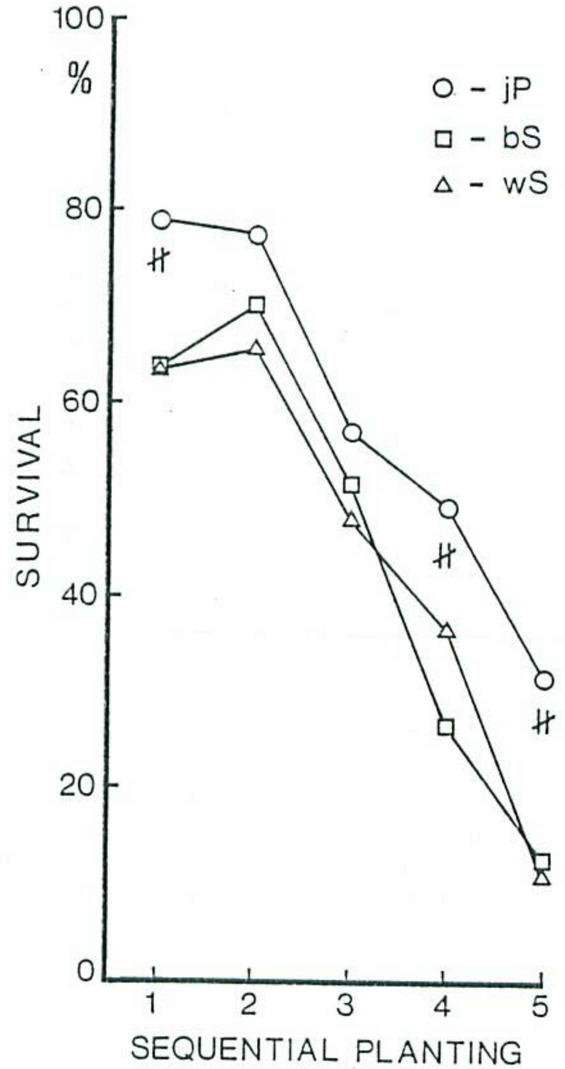


Figure 21. Fourth-year survival over all (site, year of planting, and fertilization/tilling treatments combined) by sequential planting and species: jack pine (jP), black spruce (bS), and white spruce (wS). Within sequential plantings, survival rates differ significantly (P .05) by chi-square test only when separated by the symbol #.

1972 and the third through fifth plantings of 1973 (Fig. 22). The P71 data, which show jack pine as generally intermediate in overall survival between the two spruces, are undoubtedly vitiated to some degree by the excessively poor quality of the planting stock, and should be largely discounted in favor of the results from the second and third years of planting.

Further separation of the P72 and P73 data shows that in all three species fertilization at the low rate decreased survival, and fertilization at the high rate decreased it still more (Fig. 23). The increased mortality at the high rate of fertilization is remarkably similar for all three species when expressed as a ratio of the increased mortality at the low rate of fertilization (Table 9). Thus, for example, the value 6.3 shown in Table 9 under the first sequential planting of jack pine in 1972 is derived as follows: the ratio of the *extra* 23.2% mortality that occurred in the high fertilizer treatment

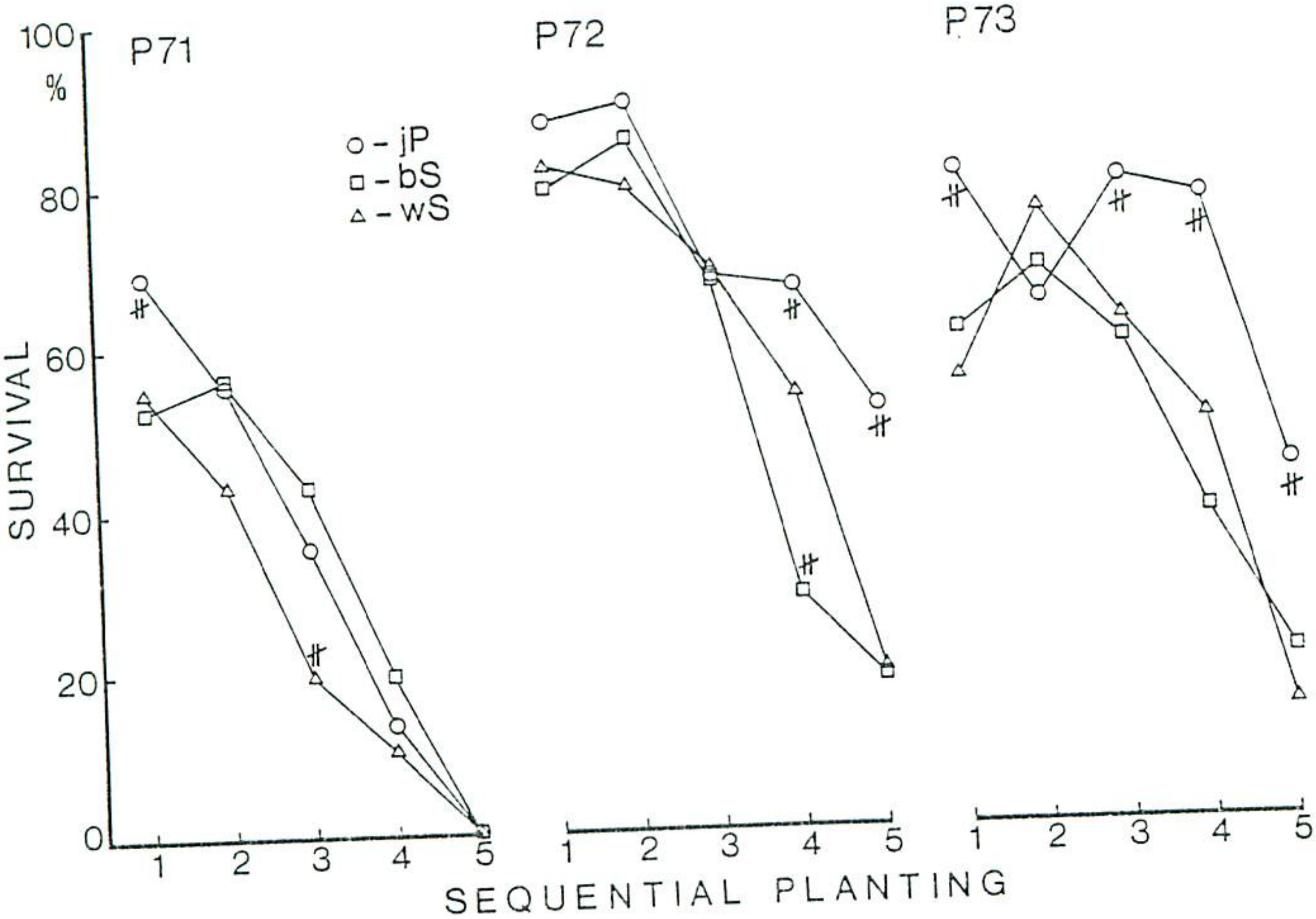


Figure 22. Fourth-year survival over all (site and fertilization/tilling treatments combined) by year of planting, sequential planting, and species: jack pine (jP), black spruce (bS), white spruce (wS). P71, etc. = planted in 1971, etc. Within sequential plantings, survival rates differ significantly (P .05) by chi-square test only when separated by the symbol #.

(27.2%) compared with that in the no fertilizer treatment (4.0%) is 6.3 times the extra mortality (3.7%) that occurred in the low fertilizer treatment compared with the no fertilizer treatment.

Mortality after four growing seasons was very highly correlated between species (years of planting and sites combined), whether fertilized or not (Table 10).

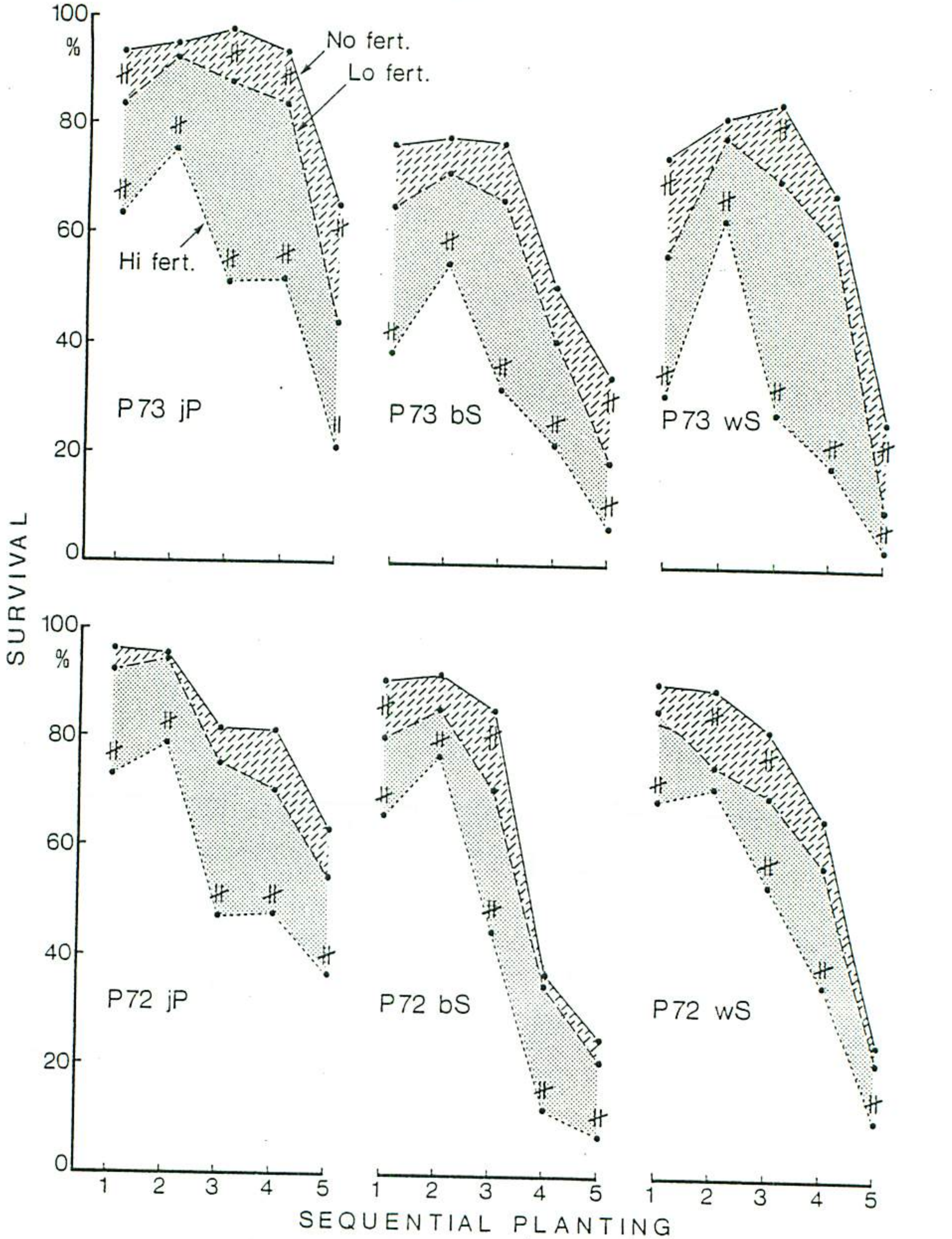


Figure 23. Fourth-year survival in P72 and P73 plantings (sites combined) by fertilization treatment, sequential planting, and species: jack pine (jP), black spruce (bS), and white spruce (wS). Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; High fertilization treatment (Hi) = double the low rate. P72, etc. = planted in 1972, etc. Within sequential plantings, survival rates differ significantly (P .05) by chi-square test only when separated by the symbol #.

Table 9. Increased mortality at the high rate of fertilization as a ratio of increased mortality at the low rate of fertilization (See also Fig. 23).

Year of planting	Species	Sequential planting 1	2	3	4	5	Mean
1972	jP	6.3	13.9	5.3	3.1	3.0	6.3
	bS	2.4	2.4	2.9	12.4	4.4	4.9
	wS	4.4	1.3	2.4	3.5	7.4	3.8
1973	jP	3.0	7.2	4.8	4.4	2.1	4.3
	bS	3.3	3.6	4.1	2.8	1.8	3.1
	wS	2.5	5.2	4.0	5.7	1.5	3.8

Table 10. Correlation coefficients for species mortality in the full series of nine sequential plantings, by fertilizer treatment (years of planting and sites combined). All coefficients highly significant.

	Not fertilized		Fertilized low rate		Fertilized high rate	
Species	jP	bS	jP	bS	jP	bS
bS	.956		.971		.963	
wS	.976	.978	.982	.983	.980	.993

The strength of these relationships suggests a common response over all by the three species to the factors controlling survival.

Height growth of jack pine was several times that of the spruces (Fig. 24), and the mean total height of jack pine four growing seasons after outplanting represented increases over planting height of 3.6 to 6.1 times that shown by black spruce, and 3.6 to 5.8 times that shown by white spruce (Table 11). The superiority of jack pine over black spruce and white spruce on *Vaccinium-Comptonia* sites has also been demonstrated by Mullin and Reffle (1980), with aggregate heights of 4924, 1669, and 1397 m/ha for jack pine, black spruce, and white spruce respectively, 5 years after planting.

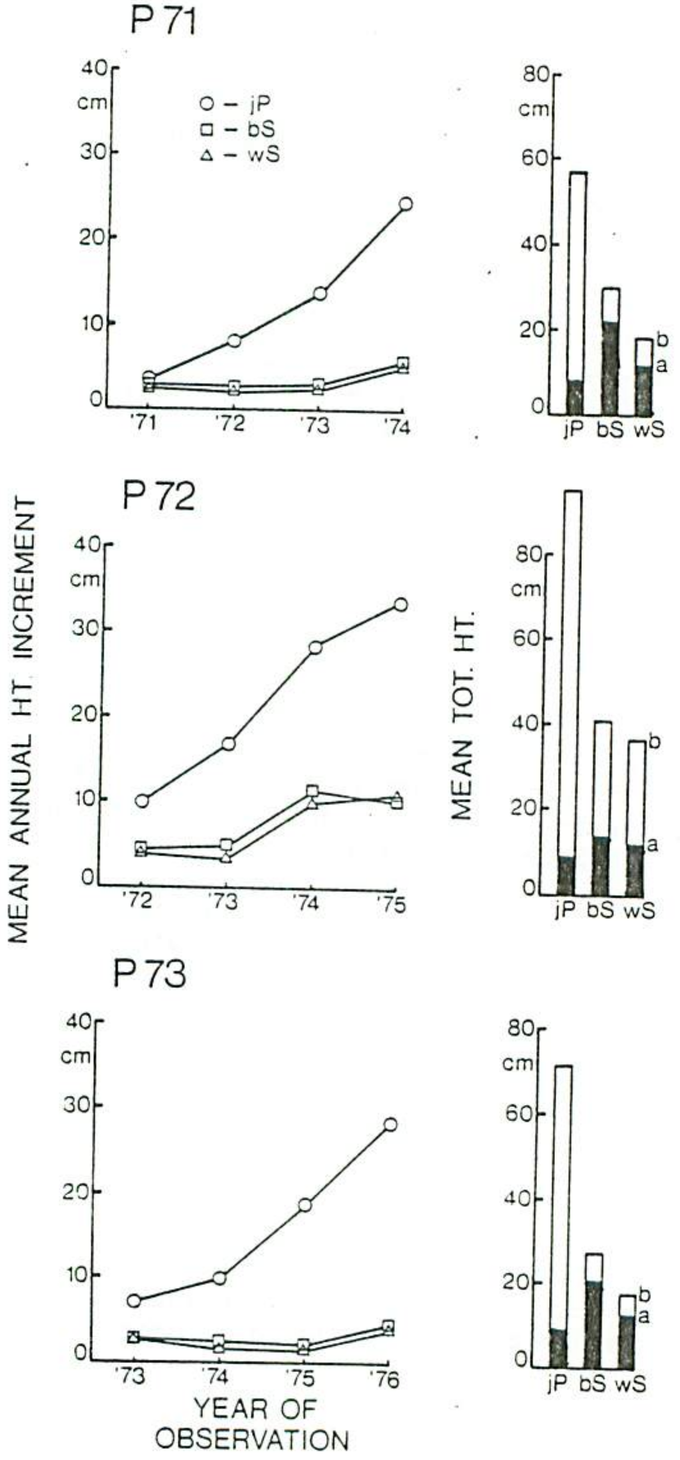


Figure 24. Mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height (a) at planting, and (b) after 4 growing seasons, over all (sites and fertilization/tilling treatments combined) by year of planting and species: jack pine (jP), black spruce (bS), and white spruce (wS). P71, etc. = planted in 1971, etc. Based on sequential plantings 1 through 5 except for P71 outwash sites (plantings 1 through 4) and P71 till site (plantings 1 and 2 only).

Table 11. Mean total height of surviving trees four growing seasons after outplanting, absolutely and as a percentage of height at planting (sites and treatments combined), by species and year of planting. Based on sequential plantings 1 through 5, except for P71 outwash sites (plantings 1 through 4) and P71 till site (plantings 1 and 2 only).

	Total height after four growing seasons					
	jP		bS		wS	
Year of planting	(cm)	% of planting height	(cm)	% of planting height	(cm)	% of planting height
1971	56.6	713	30.0	136	18.2	155
1972	94.8	1093	40.8	305	36.4	307
1973	71.2	816	27.2	133	17.4	140

Diseases and insects are often species-specific or show strong species preferences. Inevitably, the influence of these in such a study as this affects some species and some sites more than others, or at different times, thus confounding comparisons. The spruce budworm, already mentioned, provides the prime example of such an occurrence in the present study: in the area affected, white spruce were damaged more than black spruce, although injury to the latter was considerable (Fig. 25). Jack pine was not affected. The white spruce were particularly susceptible to injury, partly for phenological reasons, partly because of larval feeding preference, and partly because of the small size and low vigor of most of the trees (especially on the outwash sites, where the soils are of low fertility, and where spring frosts severely damage white spruce virtually every year). Other agents, e.g., the pitch nodule maker *(Petrova albicapitana* Busck), affected only jack pine but tended to be diffusely distributed over the study areas, although sweetfern blister rust *(Cronartium comptoniae* Arth.) was confined to the Chapleau group of sites.

Data are lacking for comparisons other than on the basis of survival and growth, but a brief comment may be made on the relative ability of species to retain foliage when stressed: white spruce was superior to black spruce (Fig. 26) in this regard, not only in the P71 plantings (when the black spruce stock showed every sign of having become overheated during storage or transportation before it arrived in Sault Ste. Marie for cold storage), but also in the P72 and even in the P73 plantings (when the white spruce stock had been extensively winter-browned in the nursery). In this connection, it should be noted that

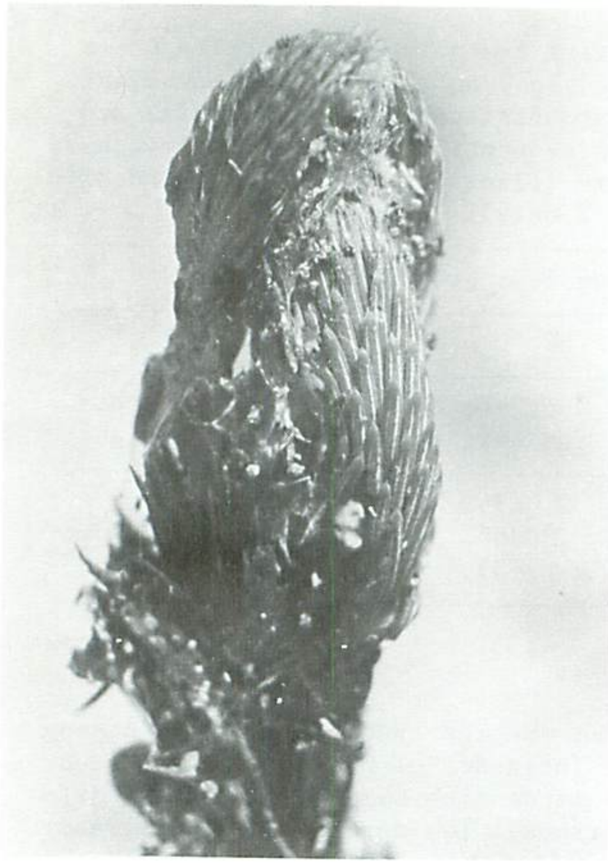


Figure 25

Budworm larvae feeding on elongating leading shoot of P71 Fawn black spruce on 18 June, 1975.

Figure 26

Black spruce, P73 Fawn, 4 days after planting on 14 July, 1973: note poor needle retention.

non-frozen cool storage of spring-lifted stock is now recommended operationally in Ontario, but the present study provides no evidence as to whether the avoidance of frozen storage alleviates the problem of needle drop in black spruce. Jack pine also lost foliage, especially in the later P71 plantings.

Of the three species outplanted in these studies, jack pine showed the furthest deviation from natural form, i.e., the usual straight-stemmed form of naturally regenerated stock in the general study area. The greater the deterioration in the apparent quality of stock at the time of planting, the greater the difficulty the stock seemed to have in achieving the tropistic adjustment necessary to produce straight stems. The problem may relate to reduced tree stability of outplanted as compared with seeded trees, but again, this study yields only speculative observation on this point.

4.24 SEQUENTIAL PLANTING 4.24

The results show clearly that survival rates in the first two or three sequential plantings were fully satisfactory, notwithstanding the doubtful quality of some of the planting stock. The results from the P72 Block C West and the P73 Budd outwash sites are typical: here, fourth-year survival rates over all (treatments combined) remained above 60% for the first three sequential plantings for all three species (Fig. 27). For the control (untreated) condition, survival rates remained above 75% for all three species in the first three sequential plantings (Fig. 28). Beyond that, however, survival rates declined sharply.

Growth and survival rates were highly correlated in the present study as in many others (cf. Hermann 1962, 1964, Mullin 1974a,b, etc.). The lower the survival rate within a plantation, the poorer the growth of the survivors. As the planting season was extended, the growth of survivors declined comparably with the declining survival rate. The effect is clearly evident in overall total height after four growing seasons, as well as in overall mean annual height increments, in all three years of planting, P71 (Fig. 29), P72 (Fig. 30), and P73 (Fig. 31).

All species/site combinations within years clearly show the effect, which may be illustrated by the results from the P72 outplantings: jack pine (Fig. 32-34), black spruce (Fig. 35-37), and white spruce (Fig. 38-40). The relationship between decline in performance and increasing lateness of planting is thus strong and very consistent.

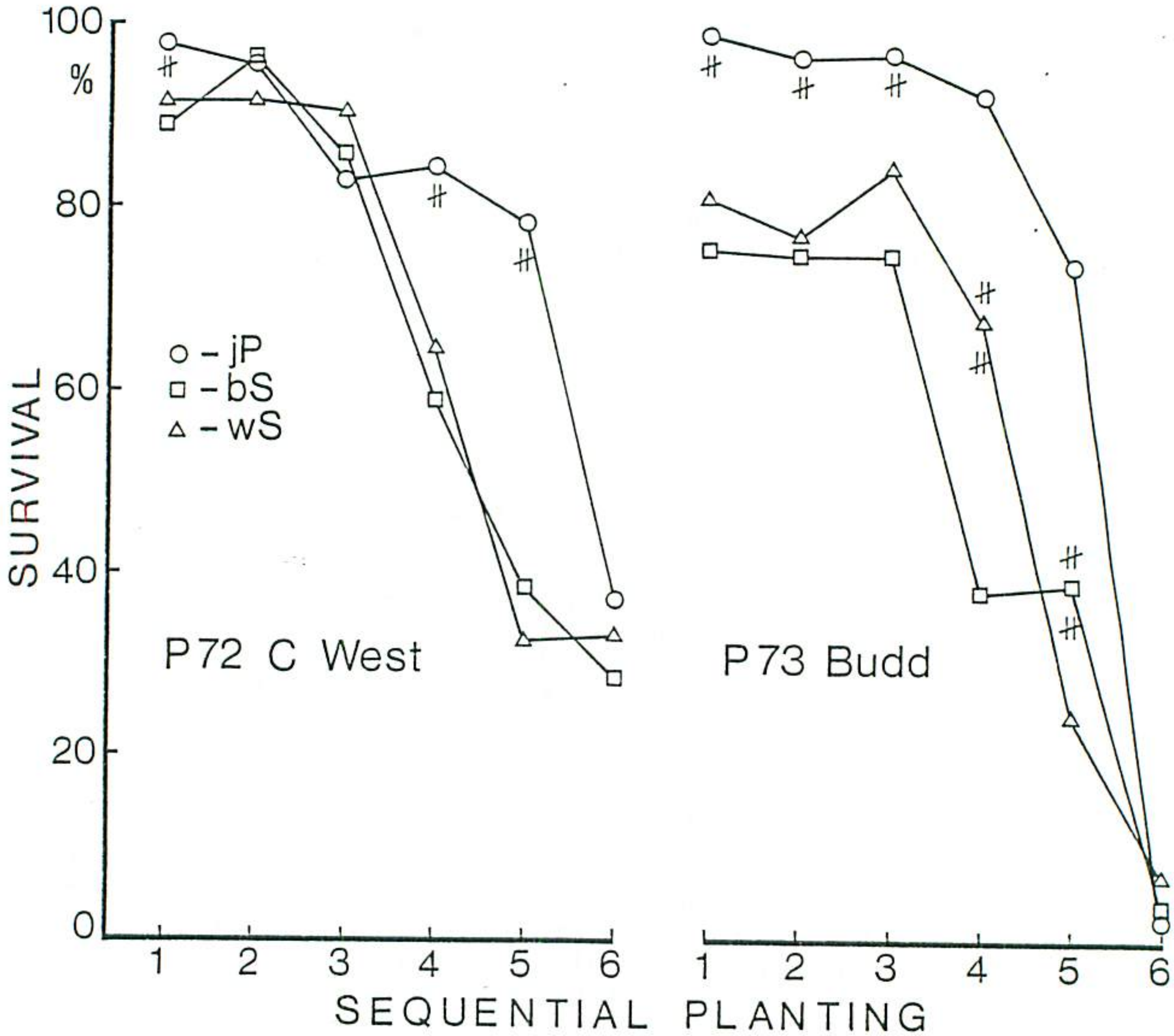


Figure 27. Fourth-year survival in plantings on P72 Block C West and P73 Budd outwash sites (fertilization/tilling treatments combined) by sequential planting and species: jack pine (jP), black spruce (bS), and white spruce (wS). P72, etc. = planted in 1972, etc. Within sequential plantings, survival rates differ significantly (P .05) by chi-square test only when separated by the symbol #.

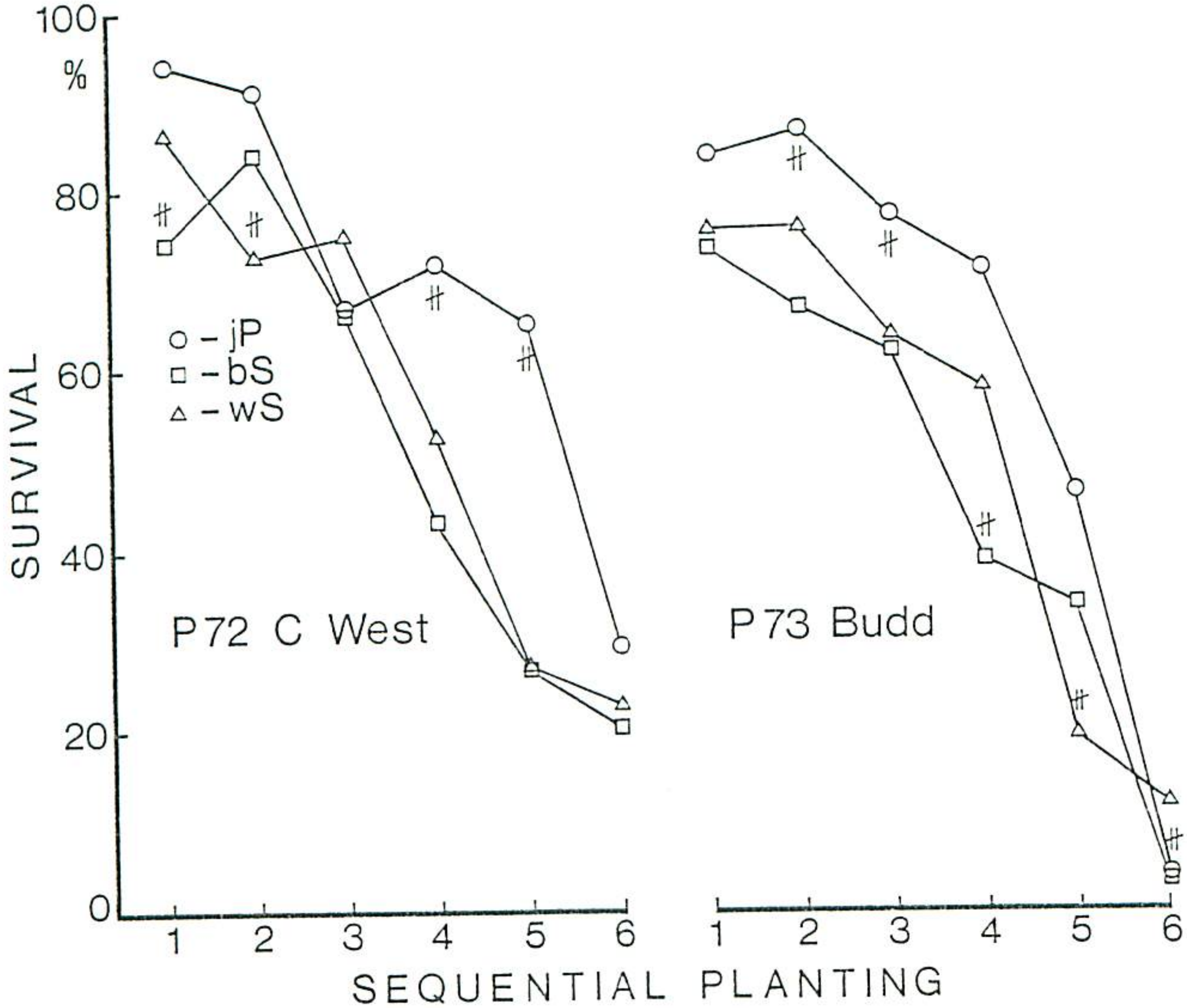
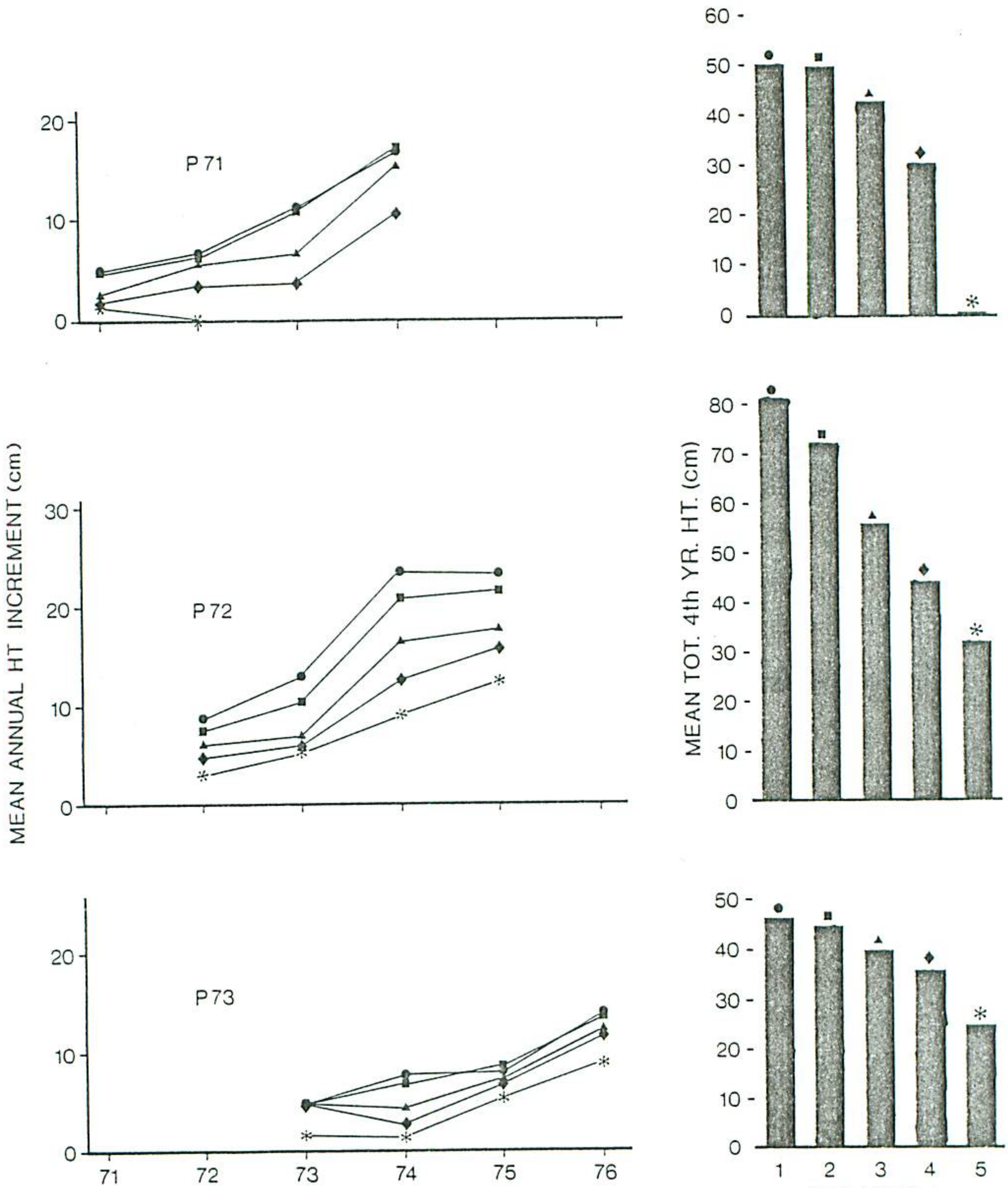
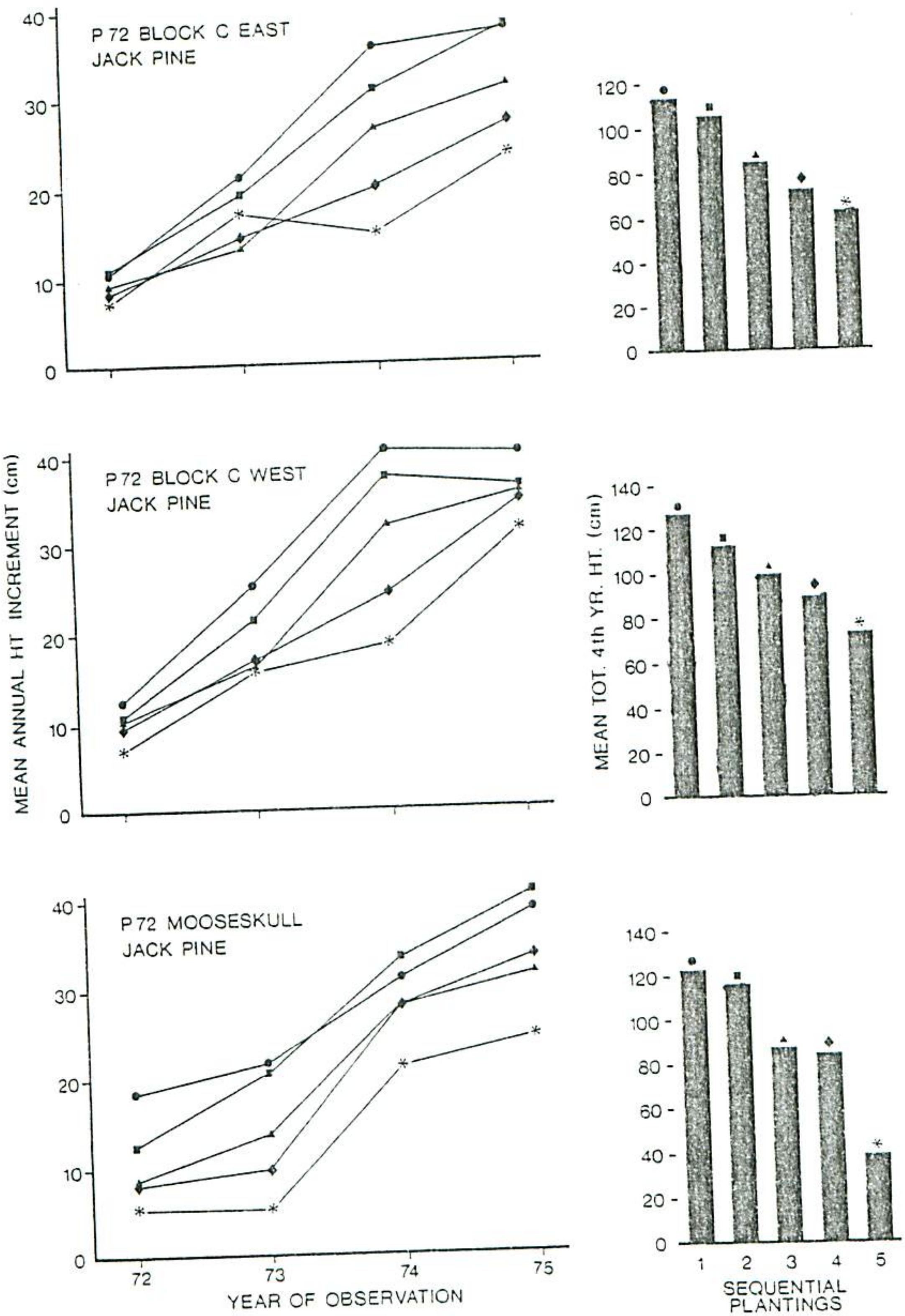


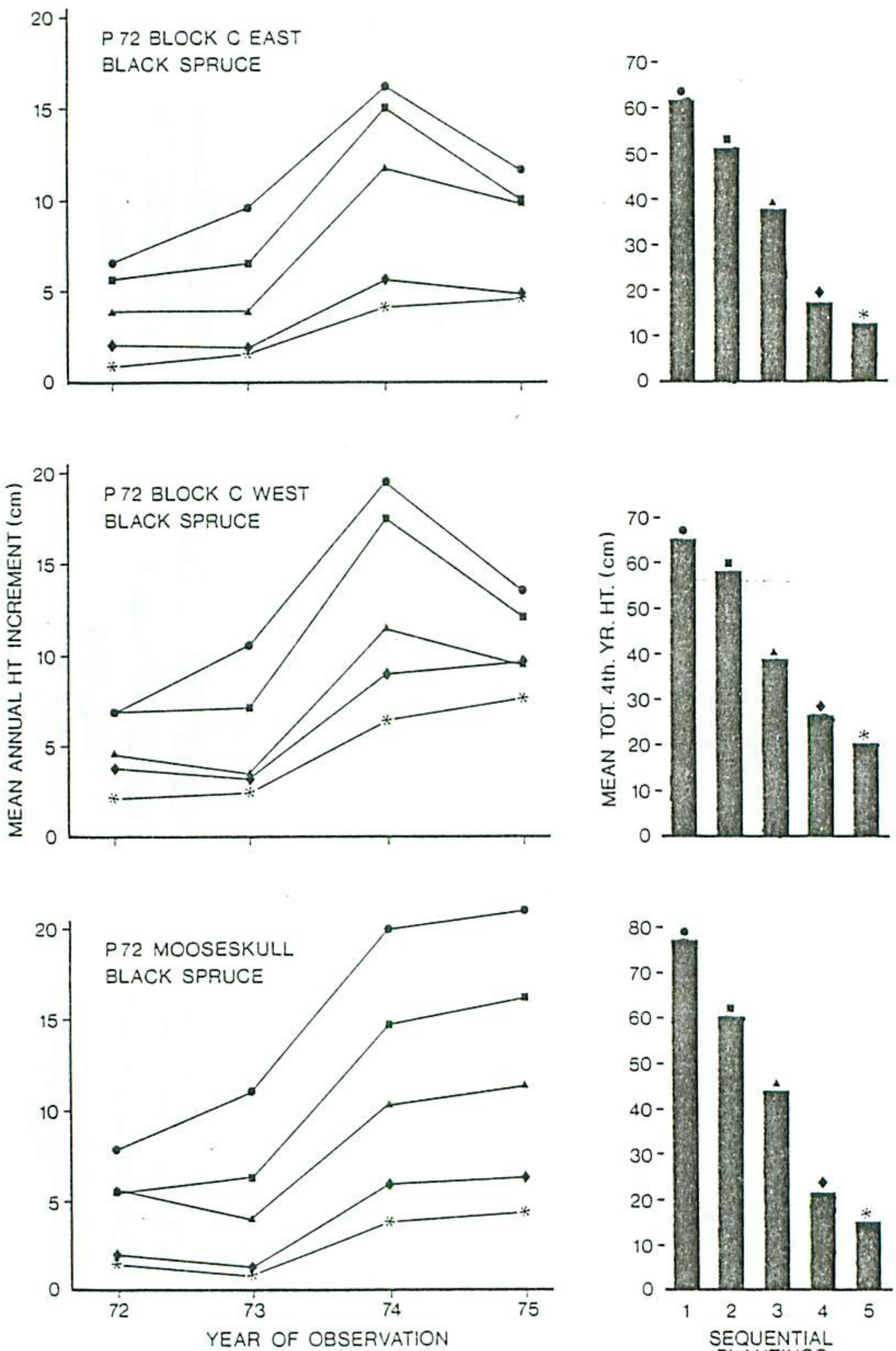
Figure 28. Fourth-year survival in plantings on P72 Block C West and P73 Budd outwash sites (untreated controls only) by sequential planting and species: jack pine (jP), black spruce (bS), and white spruce (wS). P72, etc. = planted in 1972, etc. Within sequential plantings, survival rates differ significantly (P .05) by chi-square test only when separated by the symbol #.



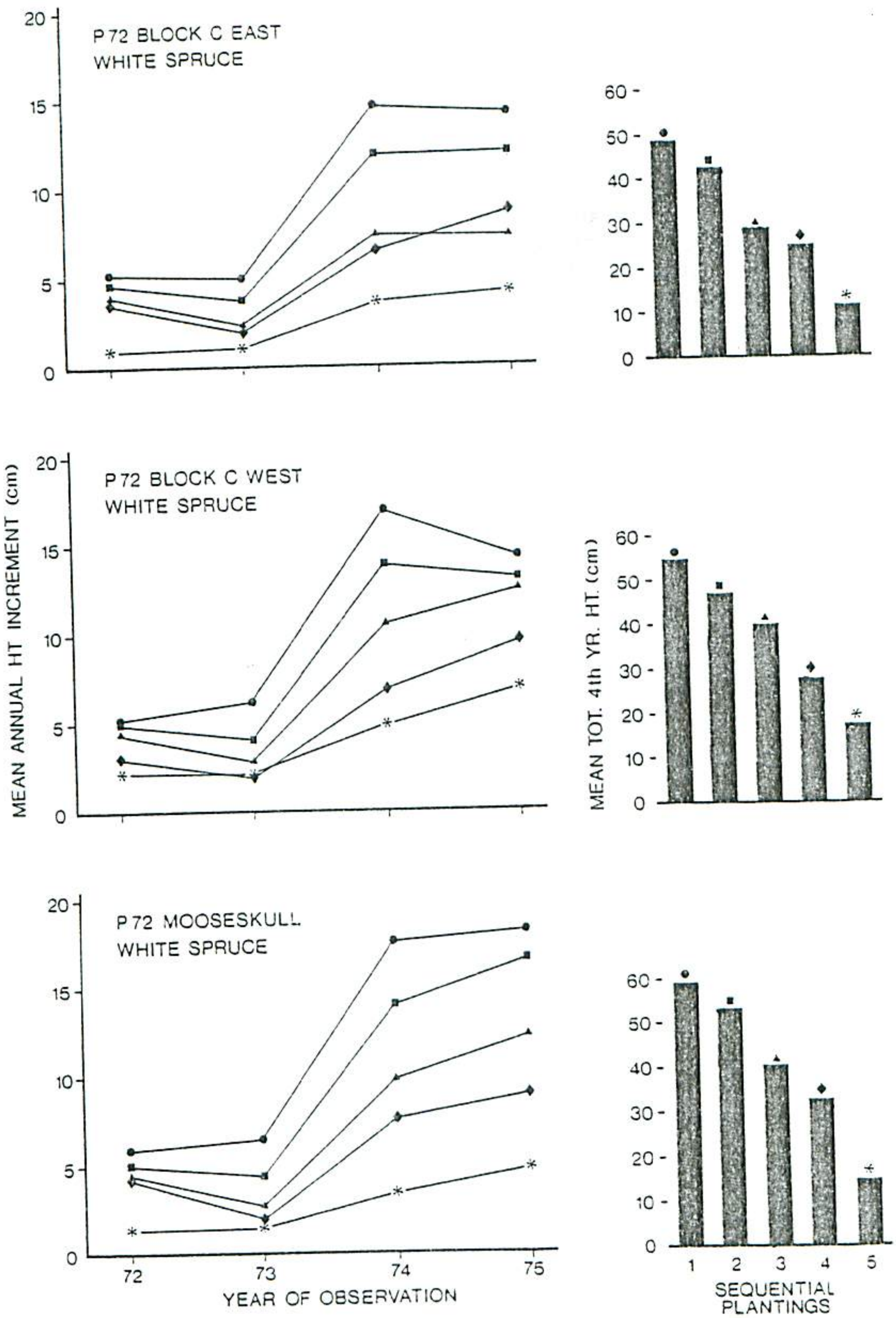
Figures 29, 30, 31. Mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (sites, species, and fertilization/tilling treatments combined) by sequential plantings: P71 (Fig. 29), P72 (Fig. 30), and P73 (Fig. 31). P71, etc. = planted in 1971, etc.



Figures 32, 33, 34. P72 jack pine: mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (fertilization treatments combined) by sequential planting: Block C East (Fig. 32), Block C West (Fig. 33), and Mooseskull (Fig. 34). P72 = planted in 1972.



Figures 35, 36, 37. P72 black spruce: mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (fertilization treatments combined) by sequential planting: Block C East (Fig. 35), Block C West (Fig. 36), and Mooseskull (Fig. 37). P72 = planted in 1972.



Figures 38, 39, 40. P72 white spruce: mean annual height increment, 1st through 4th growing seasons after outplanting, and mean total height after 4 growing seasons, over all (fertilization treatments combined) by sequential planting: Block C East (Fig. 38), Block C West (Fig. 39), and Mooseskull (Fig. 40). P72 = planted in 1972.

The present study provides no evidence as to whether or not the first or second sequential plantings have performed significantly differently from outplantings during the conventional planting season. The conventional planting season studies referred to in the Preface do not provide directly comparable results because site preparation in those studies was entirely different. Turcotte[1] found that severe windrow scarification, obtained by angle-blade bulldozing down to mineral soil, depressed the growth of conventional white spruce outplants between the windrows. Nevertheless, there is no doubt that the results from the first and second sequential plantings are much superior to those achieved in operational spring plantings of bare-root stock in northern Ontario (cf. Scarratt and Reese 1978) for plantings from 1966 through 1971.

4.241 4.241 *SEASON OF PLANTING*

Some elaboration on the introductory discussion of silvicultural seasons of planting would seem to be appropriate at this juncture.

In the context of regeneration silviculture, the terms "spring", "summer", and "fall" are used loosely. "Spring", for instance, is seldom if ever intended to indicate the period that begins with the vernal equinox and ends with the summer solstice. Rather, "spring" almost always refers to an indefinite period that begins when vegetation emerges from winter dormancy and begins to grow. The usage is exemplified by Leslie's (1945) statement that "the trees stored at Guelph were removed in the early summer and planted...during the regular spring season."

In practice, in the boreal and sub-boreal forest regions, the season of spring planting with fresh, bare-root stock begins as soon as planting stock can be lifted in the nursery after the soil has thawed. It continues until the spring planting program has been completed, often without regard to weather. The duration of the spring planting season, therefore, depends on the size of the program and the size and productivity of the labor force employed to carry it out. An upper limit to the size of a spring planting program is usually established by a decision, taken one or more years earlier and based on an educated but arbitrary guess, as to how much planting can be carried out before the flushing of planting stock is far advanced.

The "fall" season of planting is likewise of indefinite duration, and it, too, lacks definite characterizing criteria. It is generally considered to begin when soil moisture reserves have been replenished by autumnal rains and the nursery stock has hardened off. The

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[1] Turcotte, A.J.P. 1976. Effect of severe windrow scarification on white spruce two years after planting. Lakehead Univ., Sch. For., 4th-year thesis (undergraduate), 11 p. + appendices.

fall planting season extends until the planting program has been completed or until it is terminated by freeze-up or heavy snow (cf. Revel and Coates 1976).

4.242 *PLANTING SEASON AND OUTPLANT PERFORMANCE* 4.242

Before suggesting what might be done to extend the planting season, let us consider what has already been achieved with conventional planting practices. A point to be kept in mind throughout these discussions is that *more or less prolonged periods of weather inimical to outplant survival and growth may occur at any time of year* and may be a major factor in determining the outcome of any given planting. Similarly, the weather on any given day may determine the course of events in an outplantation for a rotation (cf. Mullin 1971). Also, it must be re-emphasized that an experiment, even when replicated in three consecutive years, represents but a small climatic sample from which to draw general conclusions (Sinclair and Boyd 1973).

4.2421 Conventional Spring Planting 4.2421

In the temperate and boreal regions, spring planting is normally preferred. The preference is based in part on the assumption that at this time of year a plentiful supply of soil moisture for newly planted stock is assured. In the boreal forest, snowmelt normally replenishes the soil's moisture reserves. The growing season is then just about to begin, and the planting stock is physiologically attuned to this, not least because of appropriate day-length progression. Also, the outplant has the whole of the growing season in which to establish a root system before it is subjected to frost heaving.

However, the driest part of the growing season commonly coincides with the conventional spring planting season in the climatic province that encompasses the studies here reported, as well as in the adjacent Clay Belt of northern Ontario and western Quebec (Dermine 1965) in terms of both amount of precipitation and numbers of days with rainfall of 2.5 mm or more and of 12.5 mm or more. The conventional spring planting season of 1972 was particularly dry in the Manitouwadge area.

Springlike weather in the boreal and sub-boreal forest regions may last for all, most, or little of the spring planting season. The transition from winter to summer conditions may be continuous or not, and slow or rapid. In the Chapleau area in 1972, for instance, the absolute maximum for the year (30.6°C) occurred during the conventional spring planting period in May, although the absolute minimum of the previous month had been - 30.3°C. Especially in areas that experience a continental climate, the period of springlike weather is unreliable and often short (LeBarron et al. 1938, Toumey and Korstian 1942).

The spring planting period is of course far from homogeneous, quite apart from the vagaries of year-to-year variation in weather. All of the major growth factors show temporal variation. Daylength, air temperature, soil temperature, soil moisture, relative humidity, development of competing vegetation, and the physical and physiological condition of planting stock all vary during the planting season. Late spring planting has commonly given results that are inferior to those of early spring planting (Show 1930, Hawley and Smith 1954, Schubert and Adams 1971), but there are exceptions (Sutton 1968, Mullin 1971).

The textbook ideal is to complete spring planting with "dormant" stock before it flushes and becomes "active" (Köstler 1956) and thus unsuitable, both physiologically (because of increased water requirements and decreased root growth capacity) and physically (because of increased vulnerability to mechanical injury). Toumey and Korstian (1942) advocated the planting of stock in the spring one or two weeks in advance of bud swell. That operational spring planting is normally carried out with dormant stock, however, is a myth, at least in the case of spring lifted stock. Such stock is commonly growing actively when lifted (Jorgensen and Stanek 1962, Stiell 1976), and, indeed, the trees are metabolically active in the spring, long before the tops show signs of growth (Ryker 1976). Performance after spring outplanting is commonly highest in the stock lifted earliest (cf. Ackerman and Johnson 1962, Mullin 1971, and Mullin and Reffle 1980), provided that soils are moist and warm enough to support vigorous root growth.

Planting can in fact be undertaken too early in the spring. In this regard, the importance of soil temperature must not be underestimated. Wet or clayey soils, or those which have a thick surface layer of organic matter, tend to warm up slowly in the spring. Mortality may be very high among trees that have been planted in such soils while the soil is still cold, say $< 6°C$ (Sutton 1968). Root growth and the uptake of water and mineral nutrients are inhibited by cold soil (Sutton 1969, Daniel et al. 1979).

The variability in the results within a spring planting period is well illustrated by those obtained by Mullin (1971) with 3+0 white spruce from regular shipping beds in sequential plantings, using fresh-lift, quick-plant procedures, on an old field site that was plowed and disked one week before the first planting. In this experiment, conducted at Midhurst in southern Ontario, the spruce were lifted and "hot" planted (on the day of lifting) after 0, 1, 2, or 3 hours of root exposure, with and without root dipping. Weekly planting for six weeks beginning on 3 May extended the lifting and planting "beyond that considered usual for this area". Second-year survival of trees in the control treatment averaged 80.3% over the six plantings, but the third planting gave only 66.5% survival. Mullin noted that this drop in survival had no apparent correlation with levels of soil moisture, soil temperature, or relative humidity, but that it coincided with the period of bud development and the onset of shoot elongation. Over all, there was no apparent reduction in survival with delayed planting (although there was a reduction in growth). Second-year survival in the control condition varied remarkably little among the six plantings, averaging 83.5 ± 4.7% for the root dipped trees and 77.2 ± 7.0% for the others. In contrast, the variability in survival among stock, the root systems of which had been exposed for 1, 2, or 3 hours before outplanting, was very much greater. For instance, the second-year survival of root dipped trees whose roots had been exposed for 1 hour varied between 17% and 84%. The experiment convincingly demonstrates the need for minimizing stresses on planting stock.

In another study, in more boreal conditions, this time with 2+0 jack pine and 3+0 black spruce as well as with 3+0 white spruce, Mullin and Forcier (1976) found that both survival and growth declined significantly with increasing lateness of planting through a series of five sequential fresh-lift, "hot" plantings at intervals of two weeks beginning on 9 May (Table 12). Results to the end of the fifth year after outplanting (Table 13) fully substantiate the earlier indications (Mullin and Reffle 1980).

Table 12. Survival at 2 years after planting, and mean height increment for the second growing season after planting, for fresh-lift, quick-plant jack pine, black spruce, and white spruce in five sequential plantings in 1973. (n = 2500 per cell) (after Mullin and Forcier 1976)

Species	Planting date, 1973									
	9 May		23 May		5 June		20 June		5 July	
	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)
Jack pine	94.4	39.1	89.6	30.4	68.0	24.9	34.0	20.6	32.0	14.3
Black spruce	84.0	14.4	69.6	13.1	70.8	10.6	49.2	8.3	67.2	8.6
White spruce	91.2	10.8	74.0	10.6	75.2	9.4	69.6	7.2	50.0	7.6

Table 13. Survival and mean total height 5 years after planting, for fresh-lift, quick-plant jack pine, black spruce, and white spruce in five sequential plantings. (n = 2500 per cell) (after Mullin and Reffle 1980)

Species	Planting date, 1973									
	9 May		23 May		5 June		20 June		5 July	
	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)
Jack pine	85.6	192	64.4	182	64.1	149	34.8	150	25.2	119
Black spruce	68.8	77	62.4	84	65.2	62	46.4	65	58.2	70
White spruce	79.2	59	67.0	65	74.8	52	61.2	53	37.9	46

An earlier study in Colorado with three species, including lodgepole pine *(Pinus contorta* Dougl.) and Engelmann spruce *(Picea engelmannii* Parry), similarly indicates loss of performance among fresh lift, quick-plant stock outplanted near the end of the spring planting season (Simon 1961). Weekly plantings were carried out from 6 April to 11 May, and Simon found that, although bud swelling in the pine began between the second and third plantings, lodgepole pine survival remained high until the sixth planting, when it dropped to less than half of what it had been earlier. Survival among Engelmann spruce declined materially in the sixth planting, 10 days after the onset of bud swell in that species.

Nevertheless, conventional spring planting has not always been accepted universally. LeBarron et al. (1938) noted that, in the Lake States, "by far the greater part of the planting done has been carried on in the fall", although a survey of older plantations in Michigan, Wisconsin, and Minnesota showed that spring plantings had "generally resulted in higher survival". They noted further that another analysis of the then recent National Forest plantations in the same states gave the same result, with survival differences in favor of spring planted jack pine, white pine *(Pinus strobus* L.), and white spruce, ranging from 95% to 27%.

The disfavor with which spring planting is regarded in southern California is more solidly founded. In regions with a pronounced dry season following a wet autumn and winter, spring planting is less successful than fall planting because the long dry season so closely follows spring planting that any root development occurring before the dry season begins is insufficient to enable the trees to survive (Toumey and Korstian 1932).

4.2422

4.2422 Conventional Fall Planting

With some reservations, one can accept Toumey and Korstian's (1942) view that "[o]ften the only excuse for autumn planting is when operations are conducted on a large scale and the necessary planting cannot be completed in spring". For, although soil moisture levels and soil temperatures may be just as favorable for plant growth in the fall as in the spring (LeBarron et al. 1938), these are by no means the only factors of importance. A major long-recognized disadvantage of fall planting is that root systems have little time to become firmly anchored before they are, on certain sites, subjected to frost heaving (Hawley and Smith 1954). In the Lake States, experience has shown that fall planting is best confined to very sandy soils that are not subject to frost heaving (Rudolf 1950). Insecurely established trees are also highly susceptible to winter browning, which may in fact occur in the fall soon after outplanting, especially among stock with high shoot:root ratios.

Surveys in North America, comparing the results of operational spring plantings with those of operational fall plantings, have generally revealed spring planting to be superior (cf. LeBarron et al. 1938, Schopmeyer 1940). Fall planting of bare-root stock is no longer practised in eastern Ontario (Campbell 1977) and has been discontinued or greatly reduced in other parts of Ontario because of low survival rates. Campbell (1977) noted that "terrible losses" had been experienced with fall planting, even with freshly lifted stock in years of seemingly favorable weather, and with good planting chances. What Stiell (1976) wrote in regard to white spruce well describes the general planting situation in boreal Ontario: "Fall planting is considered less reliable than spring planting, owing to the risks of frost heaving, particularly on bare and heavy soils..."

The importance of physiological condition of planting stock has been recognized for more than 30 years (cf. Wakeley 1948), but in spite of sterling work by Stone and his co-workers (cf. Stone 1955, Stone et al. 1962, etc.) and others, general appreciation of this factor was slow to develop. There now seems to be wide acceptance of the fact that the requirements for successful planting must include all the terms enunciated by Ryker (1976): "trees that are physiologically capable of responding to a growth environment at planting, a good planting job, and planting when site factors favor tree survival and growth."

In particular, the critical influence of the date of fall lifting is coming to be appreciated. The physiological state of a tree is determined by webs of interrelationships between day length, degree days, nutrition, internal water status, carbohydrate reserves, and plant growth regulators (Sutton 1979b). Research consistently shows that proper physiological condition, particularly dormancy, has a decisive effect on planting success (Cleary et al. 1978), and unless root growth capacity is adequate, outplants will perform poorly or die. Completion of dormancy requirements is necessary if subsequent impairment of root growth is to be avoided, at least in Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) and ponderosa pine *(Pinus ponderosa* Laws.) (Lavender and Cleary 1974), and probably in other species. The attainment of suitable physiological condition varies greatly with species, provenance, cultural treatment, season, and environment. The process begins at different times, proceeds at different rates, and reaches given levels at different times, depending on circumstances. Many of the remarkable differences in outplant performance between trees lifted at different times during the season, or lifted at the same time from different nurseries, may be explained on the basis of the dormancy process and physiological condition (Lavender and Cleary 1974). The variability of the results obtained with fall planting has been widely reported (cf. Schopmeyer 1940, Sinclair and Boyd 1973, Stiell 1976).

Interruption of the dormancy process at an early stage by fall lifting is thus a probable major cause of the disappointing results that have so often attended early fall planting, especially of pines (Baldwin 1938a, Sinclair and Boyd 1973). Another factor affecting early fall lifting/planting is that the trees have a smaller mass than do trees lifted late in the fall or in the following spring (Mullin 1968, Bunting 1977). In southern Ontario, the increase in dry weight of a tree in the nursery between September 1 and the following spring may be as much as 100% (Bunting 1977). In a study at St. Williams Nursery (42°40'N) in southern Ontario, Armson (1960) found that 1+0 and 2+0 white spruce were only half-grown by late August or early September: there was no evidence of a seasonal periodicity of absorption for nitrogen or potassium, but for phosphorus there were two periods of high uptake rates, one early in the growing season, the other in late August and September.

The desire to minimize the drawbacks of fall planting by prolonging the time available for root establishment led to the seemingly logical view that, with adequate soil moisture, the sooner outplanting is carried out in the fall, the warmer the soil, the better the root growth, and the longer the period for root establishment before the onset of winter. The logic fails in the face of physiological realities.

If not early fall planting, then what about late fall planting? As in the present study, the possibility may be entertained that late fall planting might have the effect of merely placing the planting stock in natural cold storage for the winter, with flushing taking place the following spring. To be successful, however, this would no doubt require the use of good late-lifted stock, good planting, continuous snow cover from soon after planting until just before the onset of growth in the spring, and minimal frost heaving. The unreliability of fall weather and the variability of snow-cover patterns would make this system exceedingly difficult to use operationally, even if its practicability were otherwise demonstrated.

Experimentation to compare fall with spring planting has tended to support the indications given by the surveys. For example, Sinclair and Boyd (1973) found that in Idaho, under the conditions of their study, spring plantings of Douglas-fir, Engelmann spruce, grand fir (*Abies grandis* [Dougl.] Lindl.), and western larch (*Larix occidentalis* Nutt.) had an overall survival advantage. They found wide variation in survival rates within the fall planting season, survival in some of the fall plantings exceeding average spring survival rates. Spruce planted early in the fall and larch planted late in the fall exceeded by "wide and fairly consistent" margins the average survival obtained with spring planting. In the Lake States, LeBarron et al. (1938) found that "by far the most striking result of the experiment [with 2+0 red pine (*Pinus resinosa* Ait.)] was the higher survival of the spring-planted trees" compared with fall-planted, 66% vs 33% in the spring following the first growing season in the field. And, with 2+1 jack pine in Ontario, Bunting and Mullin (1967) found that, although mortality at the end of the first growing season seemed to indicate that fall planting had been almost as successful as spring planting, the reassessment after 15 years showed that the growth of spring planted trees had been significantly superior.

Strong species differences are evident in the results obtained with fall planting. One useful generalization that can be made is that the hard pines often show much lower survival rates when planted in fall than in spring: they "obviously never should be planted in the fall" (Baldwin 1938b). Another generalization is that spruces often show little difference in survival between spring and fall plantings. Thus, Baldwin (1938b), in studies with white spruce, red spruce *(Picea rubens* Sarg.), Norway spruce *(P. abies* [L.] Karst.), red pine, white pine, Scots pine *(Pinus sylvestris* L.), and balsam fir, found that spring planting averaged about 10% better survival and 7% better growth than fall planting. Most of the difference, however, resulted from the poor showing of the hard pines in fall plantings: survival among red pine, for instance, was twice as high in spring planted stock as in fall planted stock. White spruce and Norway spruce, in contrast, showed little or no difference between spring and fall plantings. Red spruce gave very slightly better results when planted in spring than when planted in the fall. Mullin (1968), too, found little difference between spring and fall plantings of white spruce and black spruce "in contrast with the [fifth-year] results for red pine and white pine [a soft pine], which performed significantly better in spring plantings".

The wide variability commonly exhibited among fall plantings suggests that "much of the performance of fall-planted trees depends upon their physiological condition at the time of lifting and planting, as well as environmental conditions at the planting site" (Sinclair and Boyd 1973). The external signs of development in young trees are less spectacular in the fall than the phenomena of bud burst and shoot development in the spring, but profound physiological changes nevertheless occur in response to shortened photoperiods and cooling temperatures, as well as to changes in water and nutrient relations. In Douglas-fir, at least, sensitivity of planting stock to root exposure decreases through the fall to reach a minimum in winter, apparently in concert with physiological changes as trees go through their dormancy sequence (Hermann 1967). The physiological changes in fall may take place rapidly: in red pine, for instance, a difference in lifting date of only a week or two in the fall can determine success or failure (Bunting 1977).

With increasing knowledge about the physiological behavior of boreal species of planting stock, including the determination of root growth capacity relationships (cf. Day and MacGillivray 1975, Day et al. 1977, Sutton 1979b), the option of conventional fall planting in the boreal forest may become much more attractive to forest managers.

4.2423 4.2423 Planting Season Extension

To begin the boreal spring planting season with bare-root stock earlier than currently practised is scarcely possible because of frozen soil, snow, or excessive moisture during the spring runoff. The fall planting season is effectively terminated by freezeup and snow. Thus, the only part of the year into which the planting season(s) may feasibly be extended is the period between the end of spring planting and the beginning of fall planting. This period (during which planting stock, if freshly lifted, would be well advanced in flushing or completely flushed but not hardened off) may be referred to as the "summer" season, just as "spring" and "fall" are used as terms of convenience to designate the two conventional planting seasons.

With respect to bare-root planting, the stock may be fresh or cool- or cold-stored before planting.

4.24231 4.24231 Fresh-lifted Bare-root Stock

Probably the simplest way to conceive of extending the planting season is to begin with conventional spring planting, then continue lifting and outplanting until the planting program has been completed.

This has been done with remarkable success, at least with some of the spruces. Revel[2] has stressed 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.)

4.242311 4.242311 *Spruces*

Crossley (1956), working with white spruce *(Picea glauca* [Moench] Voss var. *albertiana* [S. Brown] Sarg.) in Alberta's Subalpine Region (Rowe 1972), conducted fresh-lift/quick-plant outplantings throughout three consecutive growing seasons. Fifth-year results, reported by Ackerman and Johnson (1962), showed that mortality (Table 14) was low, exceeding 25% in only one of the 18 plantings. The average fifth-year survival for the three years of plantings decreased steadily with increasing lateness of planting from 97.0% in May plantings to 80.4% in October. Mean total height increments declined in similar fashion (Table 15). Ackerman and Johnson (1962) concluded that white spruce could be planted successfully throughout the frost-free period in the Subalpine Region, provided that planting programs are sufficiently flexible to avoid planting during extended periods of drought.

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[2] J. Revel, 1981. Planning Coordinator, Silviculture, British Columbia Forest Service, Prince George Forest Region (personal communication).

Table 14. Mortality among white spruce, 5 years after outplanting, by year and month of planting. (after Ackerman and Johnson 1962)

Month of planting	Year of planting 1952 (%)	1953 (%)	1954 (%)	All (%)
May	2.7	2.1	4.5	3.0
June	3.9	13.4	4.2	7.1
July	1.2	8.9	19.6	9.8
August	5.1	24.7	9.2	13.1
September	5.6	19.6	21.1	15.5
October	8.0	13.7	37.2	19.6
All	4.5	13.7	16.4	

Table 15. Mean total height increment of white spruce through the 5th year after outplanting, by year and month of planting. (after Ackerman and Johnson 1962)

Month of planting	Year of planting 1952 (cm)	1953 (cm)	1954 (cm)	All (cm)
May	28.4	32.0	22.9	27.7
June	28.7	22.4	30.2	27.2
July	24.4	22.6	21.8	22.9
August	18.8	20.6	17.3	18.8
September	19.8	20.1	17.0	19.0
October	17.3	16.5	18.3	17.3
All	22.9	22.4	21.1	

In interpreting these results, however, one must keep in mind that none of the three years in which outplantings were carried out was unusually dry. Also, the planting stock that was used was 3+3 in the 1952 plantings, 3+4 in 1953, and 3+5 in 1954, and, by grading, stock for all three years had the same initial top height (25-28 cm). The delay between lifting and planting was minimized, thus sparing the stock much of the stress that would normally be experienced in operational plantings.

Plantings in British Columbia with fresh-lifted white spruce on three different dates during the summer of 1957 were also highly successful, according to Decie (1962, cited by Revel and Coates [1976]).

The results obtained by Burgar and Lyon (1968) wih 2+2 white spruce in northwestern Ontario support these findings. Fresh-lift/quick-plant stock showed survival rates mostly in excess of 90% for plantings in 1964 from early spring through to fall freezeup. Survival rates dipped briefly to minima of 77% during the periods of active shoot elongation and bud formation. Survival at the end of the 1966 growing season averaged 94% for the first four sequential plantings (which may be considered spring planting), 81% for the last four sequential plantings (which may be considered fall planting), and 90.5% for the six intervening "summer" plantings. The height growth of the summer planted trees differed little from that of trees planted in the spring, and it was superior to the height growth of fall planted trees, even though the latter had the supposed advantage of having become 2+3 stock during the course of the growing season. Burgar and Lyon (1968) concluded that, for fresh-lifted stock, "both spring planting and summer planting...are superior in rate of survival as well as in rate of height growth to fall planting." Nevertheless, the results of the fall planting are quite respectable in themselves and certainly would constitute an acceptable supplement to the spring planting program.

In Mullin's (1971, 1974a) study in southern Ontario, the sixth and last of weekly outplantings of fresh-lifted 3+0 white spruce took place on 7 June, later than the normal lifting and planting season for that area. Stock was flushing on 17 May. Aspects of the study relevant to spring planting have already been discussed under "Conventional spring planting". A point of particular interest in the context of planting season extension is that survival rates were highest in the last of the six outplantings. For trees planted without root dipping, second-year survival rates in the last of the six outplantings were 80% in the control (minimal root exposure), and 83%, 80% and 77% in the 1-, 2-, and 3-hour root exposure treatments, respectively, values that are dramatically higher than the comparable averages for the six outplantings over all: 77.2%, 43.7%, 32.3%, and 24.7%, respectively. Root dipping improved survival but did not change the picture in regard to the very high rates of survival in the last of the sequential outplantings. In terms of height growth, Mullin noted that the second year terminal growth was increasingly though irregularly inhibited by increasing lateness of planting, and certainly this is suggested by the data for the control stock. For the stock stressed by 1, 2, or 3 hours of root exposure, however, height increments in the later outplantings, after mid-May minima, increased strongly in the last three successive outplantings (not just in the final outplanting, the only one carried out during rain), and approached or exceeded the growth made by trees in the first of the outplantings. If survival and growth are taken together, the evidence strongly supports the view that, except for the short period of a week or two during which shoot elongation is most rapid, the planting season for white spruce may be extended into the summer with negligible handicap.

In the Sub-boreal Forest Region of British Columbia, the conventional spring planting season for white spruce extends from mid-May to late June. A study reported by Revel and Coates (1976) included outplanting rising 2+1 white spruce every two weeks from mid-June through mid-October in three consecutive years beginning in 1968. "Normal" weather patterns were experienced during the period. Fresh-lift/quick-plant trees after three years of growth showed consistently high survival for all planting dates. Survival rate, averaged over the three years of plantings, was the lowest (90%) in trees that had been lifted at the height of the spring flush. Third-year total heights varied between 33.2 cm and 28.2 cm and height increments in the third year ranged from 12.3 cm to 5.3 cm. In both cases there was a highly significant trend between decreasing growth and increasing lateness of planting. Revel and Coates noted that problems were encountered with the first (mid-June) planting of freshly lifted stock, this being when shoot elongation was most rapid, and the new growth was easily damaged. A further measurement in the fall of 1979, 11 years after the last plantings, confirmed the earlier predictions of the success of freshly lifted seedlings.[2]

Summer planting of fresh-lifted 2+2 and 3+0 white spruce and 1.5+1.5, 2+1, and 3+0 black spruce was initiated in the Thunder Bay district of Ontario in 1962.[3] Lifting for such planting begins in the last week of July, and the stock must be planted within three days, or after mid-August, six days.

Experimentation by McClain (1975, 1981) has generated excellent data with respect to black spruce in northwestern Ontario. Freshly lifted operational 2+0 and 3+0 black spruce were outplanted on two adjacent sites (one lowland, one upland) in sequential outplantings every two weeks from 26 May through 13 October in a pilot project initiated in 1971 (McClain 1975). For each of the 11 outplantings, 300 trees were lifted, handled carefully, and planted no later than the day after lifting. The lowland area (a clearcut black spruce swamp) was planted mainly on cleared strip roads. On the upland area, from which black spruce and interspersed aspen and white birch had been clearcut, the planting lines followed the furrows created by sharkfin barrel site preparation. Four years after planting, survival was significantly

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2 See p. 66

3 L.M. Affleck. 1972. District Forester, Ontario Ministry of Lands and Forests, Thunder Bay, Ontario (personal communication).

higher in 2+0 than in 3+0 stock, 67% vs 39% on the lowland, and 67% vs 54% on the upland. On the lowland, survival rates for the 2+0 stock exceeded 70% in outplantings from 26 May through 24 July, and ranged between 65% and 40% in outplantings made in August and September: in contrast, the 3+0 stock survival rates exceeded 50% in the first three sequential plantings only. On the upland, survival among 2+0 stock exceeded 70% in outplantings from 26 May through July with one anomalous exception. The 30% survival rate for the sixth planting (4 August) is undoubtedly related to the sustained drought in July-August, and also, perhaps, to the very hard frost of 18 August, when a temperature of -6.7°C was observed at the nearby Dog River Silvicultural Project Camp. The 3+0 stock on the upland site attained survival rates greater than 70% in the first two outplantings only. The rate of annual height increment, throughout the period of observation, decreased with increasing deferment in planting for both 2+0 and 3+0 stock on both lowland and upland sites.

The results of McClain's pilot study showed the need to investigate the relationships in considerably more detail, especially in relation to yearly variation in weather and planting stock physiology. The resulting experiment, replicated in each of three successive years, included, as well as stored spring-lifted stock, fresh-lifted operational rising 3+0 and rising 1.5+1.5 (designated in this study as 2+0 and 1.5+0.5, respectively) black spruce in 12 sequential outplantings beginning on 20 May. (Careful handling and quick-plant procedures were again used.) The planting site, about 100 km northwest of Thunder Bay, had formerly carried intolerant mixedwood (cf. MacLean 1960), and has a loess-capped till soil with a fresh moisture regime. In the year prior to planting, the site was prepared by burning. Except for one outplanting, fresh-lifted stock gave fourth-year survival rates in excess of 90%. Growth of the fresh-lifted stock declined from a maximum in the early plantings, but only to the end of July for transplants and the first week of August for seedlings (McClain 1979): after this, growth was maintained at a constant or slightly increased rate in later plantings. As McClain (1981) has noted, it is impossible to say by how much the results that would be obtained with normal operational planting practice would differ from these research results: "As the planting season progresses, handling procedures and planting [quality] become critical to survival and subsequent growth."

Although summer planting of fresh-lifted bare-root spruces has been practised in some parts of northern Ontario at least since 1962 (Affleck 1972[3], Latt 1972), the practice is generally uncommon in boreal Ontario (McClain 1979). This is surprising in view of the favorable indications provided by the considerable weight of evidence outlined in this section: "Indications are that freshly lifted seedling or transplant [black spruce] stock can exhibit exceedingly high survival when

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[3] See p. 69.

planted throughout the frost free period" provided that the stock is properly handled from lifting through planting (McClain 1979).

4.242312 *Pines* 4.242312

With the pines, the situation is less promising. This may be one reason that the amount of experimentation has apparently been much less than with the spruces.

Fresh-lifted 2+1 jack pine were used in 13 sequential outplantings in southern Ontario at intervals of about two weeks beginning on 2 May, 1951 (Bunting and Mullin 1967). The trees were usually planted on the same day that they were lifted. After 15 years, survival was 89%, 98%, and 98%, respectively, in the first three outplantings: the other 10 plantings ranged from 78% to 24% and averaged 57.9%. Height after 15 years averaged 6.04 m over the first three outplantings, 5.47 m over the last 10.

Mullin (1974b) reported on an experiment, begun in 1968, to determine the interacting effects on 3+0 red pine of lifting date, root exposure, and aqueous root dipping. Randomized plots in regular beds at Midhurst Nursery in southern Ontario provided replications of stock for lifting and planting at weekly intervals for 6 weeks over a period that included and extended the regular spring planting season. The first lift was carried out as early as possible after frost had left the ground. The performance of the red pine was much poorer than that of white spruce in the companion study (Mullin 1971, 1974b) already discussed in the previous section on the spruces. Fourth-year survival of red pine in the control condition was between 60% and 70% for the first two outplantings, 50% in the third, 15% in the fourth, 50% in the fifth, and 43% in the sixth. Survival was strongly correlated with relative humidity at the time of planting, but the general downward trend is obvious. Likewise, height growth decreased with increasing lateness of planting, although this decline was less pronounced than that found in white spruce.

Sequential outplantings of 3+0 white pine at weekly intervals for 10 weeks beginning on 22 April, 1971 extended the local, southern Ontario, conventional planting season by several weeks (Mullin 1978a). With "hot" planting (i.e., lifting and planting on the same day) within the conventional planting season (up to approximately the fifth planting, on 20 May), the survival rates for control (minimal root exposure) stock were "good and quite consistent, but subsequently showed some decrease". Mullin calculated that the decrease in survival attributable to extended planting averaged about 4% per week. Similarly, delayed planting accounted for a reducton of about 2.5% per week in total height and about 2.0% per week in terminal growth. A better indication of what might result from operational practice may be the rates of survival averaged over the four (0, 1-, 2-, and 3-hour) root exposure treatments:

54.6%, 85.7%, 37.5%, 34.1%, 50.1%, 76.4%, 70.1%, 39.2%, 27.4%, and 30.9% sequentially for the 10 outplantings: the relative humidity (average of the 3-hour exposure period) exceeded 80% at the time of the second, sixth, and seventh plantings, and ⩾ 53% during all other plantings except the last (67%). Mullin (1978a) concluded that for white pine, therefore, extended planting with fresh trees can be expected to produce inferior plantations.

In spite of the occasional contrary indication, e.g., Wilhite (1966), the same conclusion is probably justifiable in relation to domestic pines generally.

4.24232 4.24232 *Stored Bare-root Stock*

When fresh stock is either unavailable or in a stage of development that renders it unsuitable for planting, it is necessary to use stored stock.

Even with conventional spring planting, stock must be stored in order to supply sites that need to be planted before fresh stock can be lifted in the nursery (cf. Williams and Rambo 1967, Slayton 1970). In other instances, the nursery lifting season may close before planting sites become ready or accessible at higher elevations or higher latitudes (cf. Lindberg 1951, Sinclair and Boyd 1973). Also, storage may be used as a means of reducing spring frost damage (cf. Leslie 1945, Jorgensen and Stanek 1962, Schmidt-Vogt 1963), either by planting late in the conventional spring planting season with unflushed stored stock in preference to fresh stock in which flushing might be well advanced, or by taking advantage of the delay in flushing commonly experienced by stock after refrigerated storage in comparison with fresh stock planted at the same time (cf. Brown 1971, Nyland 1974). As long ago as 1954, Hawley and Smith reported that, in various parts of the United States, experiments using cool stored stock had extended planting seasons by several weeks in some cases.

In the present paper, the term "refrigerated storage" is used to encompass both "cold storage" = "frozen storage" (at or below 0°C) and "cool storage" (slightly above freezing). Natural, uncontrolled refrigerated storage, which may fluctuate between "cold" and "cool", has been used with varying success (cf. Leslie 1945, Sandvik 1957, 1959, Jorgensen and Stanek 1962, Gramsch 1963, Aldhous 1964, Mullin 1966, Mullin and Bunting 1972, Navratil and Dye 1978). To a lesser degree, the storage environment provided operationally by artificial refrigeration is also non-uniform (cf. Mullin and Reffle 1980), and inevitably there will be temperature differences within the bundles, packages, etc. (cf. Ursic 1956, Stoeckeler and Jones 1957, Hocking 1971), which, especially in cool storage, may exceptionally reach or surpass 12°C above ambient (Hocking and Nyland 1971).

Though by no means new (cf. Hopkins 1938, Leslie 1945, Roe 1949), interest in prolonged storage of planting stock has quickened in recent years in response to a number of interacting stimuli: expansion of planting programs, difficulties in labor supply, and increasing realization of the opportunities presented by storage as a tool by which to manipulate the physiological quality of planting stock.

The major problems of prolonged storage are development of mould on stored stock, desiccation of stock, cold injury (Björkman 1956), and unsuitable physical or physiological condition of the stock entering storage.

Mould is commonly developed in cool storage. Sub-freezing temperatures have given almost complete control of moulds on stock kept in storage for up to seven months; in cool storage, maintenance of a constant temperature just above freezing is probably the most effective way of minimizing the development of mould (Hocking and Nyland 1971). Using a pentachlorophenol preparation Björkman (1956) obtained good control of moulding on Scots pine and Norway spruce stored for two months at 2°C to 3°C. It is also important to keep foliage clean and dry, to package trees properly, and to apply effective sanitation practices (Navratil et al. 1975).

Trees in storage will become desiccated unless protected. Much depends on the method of packaging and the ambient relative humidity, which ideally should approach 100%. Relative humidities in the range of 85-90% are critical (Deffenbacher and Wright 1954, Wilner and Vaartaja 1958).

Cold injury is important chiefly in that roots are normally less hardy than other parts of the plant (Levitt 1980), but the freeze-drying effect in directly refrigerated storage is also important.

The duration of storage is obviously an important determinant of condition of stored stock. Experimentally, planting stock has on occasion been successfully held in storage for 12 months. Deffenbacher and Wright (1954), for instance, obtained 100% first-year survival in nursery plantings of ponderosa pine and noble fir (*Abies procera* Rehd.) that had been stored for a full year; and, after 18 months of storage, ponderosa pine still gave 23% survival. Except for the southern pines, trees of most of the species commonly used for reforestation in Canada and the United States had, even a decade ago, been stored successfully for 4 to 7 months (Hocking 1972). Operationally, the duration of storage is seldom as long as eight months. Thus, the five-month storage period maximum to which trees used in the present study were subjected was well within the bounds of feasibility.

Not only the storage environment and the duration of storage, but also the time of lifting plays a critical role in determining the performance of outplants subsequent to storage. Stock that is lifted in the fall for overwinter storage must have completed more than the first stage of the dormancy process (cf. Cleary et al. 1978): plants must have reached a state that has been variously termed "hardened-off" (Kahler and Gilmore 1961), "winter ripeness" (Anon 1961), "full dormancy" (Aldhous 1964), etc., and they must possess adequate physiological hardiness (Stone and Schubert 1959, Aldhous 1964) and "vinterstyrke" i.e., winter vigor (Sandvik 1976). A great weight of evidence has accumulated to support the view that the field performance of stock lifted early in the fall is generally inferior, and, in the pines, often spectacularly so, to that of stock lifted later, whether outplanted in the fall or, after overwinter storage, in the spring (cf. Stone and Schubert 1959, Lavender and Wright 1960, Kahler and Gilmore 1961, Simon 1961, Anon. 1961, Lavender 1964, Aldhous 1967, Oldenkamp and Van Elk 1967, Chedzoy 1968, Lindquist 1970, Hocking and Ward 1972, Mullin 1972, Mullin and Parker 1976, Bunting 1977).

The time of lifting for storage in the spring may be almost as important (cf. Stoeckeler and Jones 1957, Simon 1961, etc.).

Although most North American tree nurseries were equipped with refrigerated cold storage facilities before the present study was begun (Hocking 1972), the OMNR nursery at Swastika, which supplied most of the planting stock used in the present study, brought its cold storage facility on line in 1972. Expertise in the use of these facilities has increased greatly during the ensuing decade. In Ontario, the first draft set of guidelines was issued in March 1975 by R.M. Dixon, then Director, Forest Management Branch, Division of Forests. The preparation of the guidelines was precipitated by the increased use of refrigerated storage and root cellars and a renewed emphasis on improved transportation methods (cf. OMNR Project 258). The guidelines were based on "the growth stage of the nursery stock related to storage temperature and length of the storage period as well as packaging". Lifting guides for frozen overwinter storage of black spruce at Swastika nursery were subsequently prepared by Mullin and Hutchison (1978).

The OMNR guidelines of 1975 recommended practices that differ radically from those to which the 1971/1973 planting stock used in the present study were subjected. In particular, storage temperatures in 1971 were too variable and too high, in 1972 somewhat low (nominally -4.4°C) and rather variable, and in 1973 episodically too high, then persistently too low. Details have been given on p. 12-15 under 3.4 The Planting Stock.

The planting stock used in the present study was thus exposed in part to all of the three main dangers besetting trees in storage: mould, desiccation, and cold injury. A subjective judgment is that mould and desiccation constituted the main agents of deterioration in 1971, desiccation in 1972, and cold and desiccation in 1973.

The essential point here is that the degree of success achieved using rather primitive storage practices should not be difficult to exceed with superior stock handling.

The storage environment is not the only problem facing the stored tree. For stored stock outplanted during an extended planting season, a major problem is to bring its physiology into step with the seasonal progression of weather. As well as the year-to-year variation in weather, the seasonal progression is important in determining the performance of stored stock planted "out of season". Damage by spring frosts, in the regions covered by the present study, is almost always avoided by not planting before the last few days of June. If planting is much deferred, however, the new growth has but an abbreviated growing season in which to complete hardening off before the advent of fall frosts. In the present studies, only the stock outplanted in the first through third sequential plantings consistently had time to complete the hardening off process and escape damage by fall frost. Trees outplanted in the fourth and fifth sequential plantings were particularly vulnerable to damage by fall frost. In later sequential plantings, trees generally did not develop new foliage in the year of planting. Any buds that began to swell among trees of the sixth sequential planting were probably damaged by fall frost, for few of these buds flushed normally the following year. As a case in point, the frost that occurred at Fawn on the night of 19/20 September, 1973 was severe enough to cause widespread damage among outplants in the fourth and fifth sequential plantings: McClain[4] has made similar observations. Not all flushed trees were affected to the same degree, however, even in apparently identical microclimatic and soil conditions. This suggests that physiological differences may have been induced in the stock by exposure to differential environmental conditions at one or more stages between lifting in the nursery and outplanting. Not all trees in the same bundle, and not all bundles in the same batch, experience identical environments during storage and handling, and this may well have differential physiological consequences. Further aspects of storage will be considered under two headings: overwinter storage, and spring storage.

4.242321 *Overwinter Storage (fall lifting)* 4.242321

As will be shown, planting stock that is lifted early in spring almost always performs better than stock lifted later. In large scale operations, obvious difficulties stand in the way of early spring lifting of all or even most of the stock. This raises the question: why not, then, lift in the fall and hold stock in refrigerated storage until it is required for planting? Considerable success has attended efforts in this direction.

[4] K.M. McClain. 1982. Research Scientist, Ontario Ministry of Natural Resources, Northern Forest Research Unit, Thunder Bay, Ontario (personal communication).

4.2423211 4.2423211 Cold Storage

The optimum temperature for overwinter storage of planting stock has not been established. In all probability, the effect of temperature varies not only with species but also especially with the physiological condition of the stock when lifted.

In northern (65°N) Finland, 2+1 Scots pine lifted at the end of October and overwintered in natural cold storage, with temperatures below -10°C for virtually the whole of January and February and reaching a minimum of -15°C, survived in spring planting just as well as did fresh-lifted stock (Yli-Vakkuri et al. 1968). This stock was stored in open plastic bags inside paper bags that were closed tightly at the beginning of December: within-bag temperatures were not reported, but may well have been lower than the -11°C minimum reported by Jorgensen and Stanek (1962) in their study discussed later in this section.

However, overwinter cold storage at -5°C of 2+0 Scots pine lifted on 16 October at the Indian Head Tree Nursery, Saskatchewan was lethal to stock transplanted into the nursery in late spring (16 May), but Scots pine at 2°C stored very well, giving second-year survival of 87.2% and second-year height increment equal to that of fresh-lifted stock transplanted at the same time (Cram and Lindquist 1981). Colorado spruce (*Picea pungens* Engelm.) in the same study fared much better after cold storage over winter at -5°C, with second-year survival of 74.7%, not significantly less than that of spring-lifted stock, fresh or stored (Tables 16, 23). Overwinter cool storage (at 2°C) gave excellent results in both species (cf. Table 23).

Table 16. Second-year survival and second-year height increment of 2+0 Scots pine and 2+0 Colorado spruce, nursery transplanted in late spring (16 May) at Indian Head Tree Nursery, Saskatchewan, after overwinter storage, (after Cram and Lindquist 1981) (cf. Tables 23, 32)

	Storage		Species			
			Scots pine		Colorado spruce	
Lifting date	Temperature (°C)	Duration (days)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
16 Oct	-5	212	0b	-b	74.7b	8.8a
16 Oct	2	212	87.2a	12.9a	90.1a	9.1a
16 May (fresh)		0	78.0a	12.1a	83.5ab	7.3b

Within columns, values not followed by the same letter differ significantly (at an unspecified level of probability, but presumably P .05).

According to Hocking and Nyland (1971), Bunting (1970) found that white spruce and white pine nursery stock stored over winter at -3°C survived and grew better in spring plantings than did fresh-lifted/quick-planted controls. Overwinter storage was better at -3°C than at 1.5°C for both these species and for red pine.

Also according to Hocking and Nyland (1971), Hopkins (1938) found that white spruce and white pine performed poorly when planted in mid-July after overwinter storage at 0°C ± 0.5°C. Hocking and Nyland did not mention the date of lifting.

Naturally refrigerated overwinter storage has advantages that appeal to both nurseryman and planter (Mullin 1966). Natural refrigeration in root cellar storage was used by Jorgensen and Stanek (1962) in northern Ontario in a series of experiments on overwinter storage of jack pine, black spruce, and white spruce (as well as red pine and white pine) that had been grown, as was then the custom, in southern Ontario nurseries. In all cases, fall-lifted stock was received in Cochrane in late November, but the actual lifting dates were not reported. Variation in air temperature (from -17°C to 4°C) in the root cellars was much less than that in the outside air: variation in temperature among the roots of the planting stock within the normal shipping bales was still less, between -11°C and 1°C. With regard to the pines, overwinter storage, in the conditions provided in the root cellars, significantly increased mortality over that of springlifted stock: all three pine species responded similarly. Jorgensen and Stanek had reservations about the value of the part of the experiment dealing with black spruce because of a 12-day delay in planting the stored stock, which was kept in bales at the planting site. White spruce 3+0 and 2+2 stock was retained in dormant condition for approximately six months without apparent detriment to later performance after outplanting. Moreover, stored stock was highly resistant to damage from spring frost and was superior to spring-lifted stock shipped from the same nursery beds and planted at the same time. Jorgensen and Stanek observed that, two years after planting, some of the spring-shipped stock showed no shoot development at all, having stagnated at the stage at which they were planted: most of these trees showed some new shoots but no terminal growth development. Stored stock, however, was in good condition and formed "satisfactory plantings". The results showed that fall-lifted white spruce after overwinter storage in cellars was decidedly superior in subsequent performance to spring-lifted stock, although it must be remembered that the stock was raised in a southern nursery. Northern-grown, spring-lifted stock would probably be less susceptible to spring frost, but overwinter storage should be at least as successful with northern- as with southern-grown stock. Jorgensen and Stanek's results, inconclusive with regard to the other species used, suggest that pines are difficult to store satisfactorily.

Uncontrolled natural cold storage was also used by Mullin (1966), but unlike the situation faced by Jorgensen and Stanek (1962), whose planting stock was raised in nurseries 500 km to 800 km to the south, Mullin's trees were planted on a latitude similar to that of the nursery in which they were grown. Stored and unstored white spruce and red pine of two age classes (3+0 and 2+2) were lifted on 28 November at what is now called the Thunder Bay Forest Station nursery (48°30'N), baled and shipped overnight by rail to the Fort Frances District, and placed on racks in a storage shed near Atikokan (48°45'N) about 160 km west of Thunder Bay, Ontario. The inside-bale temperature decreased from 1°C on 1 December to -15°C in January and rose to about -2°C at the end of March. At the date of planting (23 April), when equal numbers of trees fresh-lifted from the same beds were also planted, the inside-bale temperature was about 1°C. In this experiment, survival of outplanted white spruce was significantly (P .01) better among stock that had been planted fresh (without storage) than among stock that had been stored: first- and third-year survival rates were 91.4% and 76.2% for unstored stock and 85.9% and 65.9% for stored stock, respectively. There were no differences between age classes or between bale types. In this experiment, unlike Jorgensen and Stanek's, unstored white spruce incurred significantly (P .01) less frost damage than did stored stock, even though the stored stock was slower in flushing (more so in the seedlings than in the transplants) and therefore had fewer trees that flushed early. As Mullin noted, the more advanced stock would normally be expected to suffer greater frost damage than would stock that flushed later. As far as white spruce was concerned, Mullin noted that: "[T]he stored stock...showed a reduction in vigour as measured in terms of survival, suceptibility to damage, and growth." For red pine, too, overwinter storage, in the conditions described, was detrimental to survival and growth.

The differential between overwintered frozen stored red pine and fresh-lifted controls in spring planting was less in Mullin and Bunting's (1970) study in southern Ontario. Stock (3+0) was lifted in late fall (25 November) after several weeks during which frost had occurred frequently, packaged by several methods, and placed in refrigerated storage, part in cool storage above freezing at an average temperature of 1.5°C, and part in cold storage at an average temperature of -3°C (range -5°C to 0.5°C). Fresh stock from the same beds was lifted the following spring on 28 April (relatively early in the shipping season), and taken to the shipping barn along with the stored stock. Stock was outplanted on three sites. Several of the overwinter ing packaging methods gave results that did not differ significantly from the results given by the fresh-lifted controls. Frozen storage in this case was as good as or better than unfrozen (cool) storage.

The study reported by Mullin and Bunting (1970) was not confined to red pine: 3+0 white pine and 3+0 white spruce were included on an equal basis with red pine and subjected to the same experimentation.

All three species were reported on by Mullin and Bunting (1972), although no new information was included on red pine. Storage treatment had significant effects on survival, mainly because of the very poor showing of the cool-stored bale-in-polybag treatment. Averaged over all three planting locations, survival was unaffected by the other storage treatments. In terms of height increment, the cool-stored bale-in-polybag treatment was also poorest by far, and the frozen polybag was best. Obviously, white pine can be overwintered in either cool or cold storage for early spring planting. For white spruce, the overall effects of storage treatments on survival were not significant at any location, but when summarized over the three planting locations, the frozen bale was consistently damaging to survival, and the frozen polybag was consistently beneficial. Again, poor survival was associated with poor growth of survivors. Of four satisfactory storage treatments, the frozen polybag was the most promising, with increases in survival and growth of 15.7% and 25.9% respectively, over fresh-lifted control stock. Mullin and Bunting acknowledged that such a single mid-season planting gives little information about the possible extension of the regular spring planting season, one of the chief advantages being sought in overwinter storage.

Third-year survival among outplanted 2+1 black spruce that had been fall-lifted and first cool- then cold-stored over winter was virtually identical with that of fresh-lifted control stock in Upper Michigan (Slayton 1970). Overwinter storage of 3+0 red pine and 2+2 white spruce was somewhat less successful (Table 17) but Slayton described the mortality rate for the spring-lifted and fall-lifted stock of all three species as "uniform". It should be noted that the fall lifting was carried out on 15 October and that later lifting might well have been advantageous. The stock was baled and placed in the Toumey Nursery cold storage facility. From 15 October through 15 November, the air temperature in the facility was held at 1°C and the relative humidity at 100%. During November and December, the temperature was held at -1°C.

Table 17. Third-year survival of fresh and stored 3+0 red pine, 2+1 black spruce, and 2+2 white spruce after outplanting in Upper Michigan. (after Slayton 1970)

Species	No. of trees	Fresh (%)	Stored over winter (%)
Red pine	3643	83	75
Black spruce	699	91	92
White spruce	864	87	81

Throughout the rest of the winter, room temperatures ranged from -3°C to -1°C, with relative humidity at 97% to 100%. The temperature was raised to 1°C to 2°C for two weeks before the stock was removed for use, and it took most of this time for the bales to thaw completely. As with Mullin and Bunting's (1972) study, Slayton's study gives only indirect information about the possibilities of extending the spring planting season: but such studies establish that stock, suitably packaged and stored in a suitable environment, may be carried through the winter in good condition.

The effect of date of fall lifting on the post-planting performance of spring-planted white spruce and jack pine that had been frozen-stored over winter was studied in an experiment begun in 1972 at Midhurst Nursery in southern Ontario. Mullin and Parker (1976) reported second-year results. These workers noted the trend towards overwintering in frozen storage and away from cool storage, and they suggested that the losses that had been experienced in frozen stored stock may have been the result of improper timing of the fall lift for storage. There were five weekly lifts beginning 19 October and ending 16 November, after which lifts were discontinued because of frozen ground. The trees used in the study were selected at random from regular beds of 2+0 jack pine and 3+0 white spruce. The two storage temperatures were -18°C and -4°C. Nearly all of the trees stored at -18°C died. The stock stored at -4°C was planted in shallow furrows in a sparsely sodded field of loamy sand, the jack pine on 9 April, 9 May, and 11 June, and the white spruce on 12 April, 17 May, and 14 June. Fresh-lifted stock was also planted at each planting. The results (Table 18) show clearly the need for late fall lifting of jack pine intended for overwinter storage and "indicate that freshly-dug spring-lifted trees may give better results for early and mid-season planting, whereas stored [jack pine] may give better results for late planting (although well below the results of spring lifting and mid-season planting of unstored stock)." Also, "either freshly-dug or stored white spruce, if lifted at the proper time, will give comparable results when used to extend planting into mid-June [in the area where the study was carried out]."

Mullin and Parker showed in this study that jack pine became ready for fall lifting at about 208 degree hardening days (DHD, based on the cumulative daily differences between 10.0°C and the daily minimum for soil temperature at 15 cm depth), whereas white spruce was ready several weeks earlier at about 111 DHD. Mullin and Parker observed that there were indications that the first planting was too early for both stored and fresh white spruce. They also pointed out that this was not so for fresh-lifted jack pine, but they did not specifically comment on the fact that stored late-lifted jack pine performed much better in the second and third plantings than in the first, despite the extra one and two months of storage: perhaps warmer soil temperatures are necessary to jolt frozen stored stock of this species into action. Survival rates, suggested Mullin and Parker, might have been substantially higher had the shoot:root ratios been lower. These workers interpreted their results to mean that frozen overwinter storage may be used to extend the planting season into late spring using white spruce but not jack pine.

Table 18. Second-year survival and second-year height increment of fresh and cold-stored (-4°C) 2+0 jack pine and 3+0 white spruce in southern Ontario, by lifting date and planting date (after Mullin and Parker 1976).

Species	Lifting date	9 Apr/12 Apr [a] Survival (%)	9 Apr/12 Apr [a] Height increment (cm)	9 May/17 May [a] Survival (%)	9 May/17 May [a] Height increment (cm)	11 June/14 June [a] Survival (%)	11 June/14 June [a] Height increment (cm)
Jack pine	19 Oct	1ab	29.5bc	0a	0a	6a	23.4ab
	26 Oct	2a	32.5c	7a	26.1b	3a	21.3a
	3 Nov	40b	21.9a	45b	31.4c	29b	25.6b
	9 Nov	41b	23.7ab	65bc	34.5c	50b	25.9b
	16 Nov	53c	32.1c	72bc	35.2c	76c	27.6b
Control	(fresh-lifted)	85d ***	33.8c **	86c ***	33.6c **	48b ***	17.6a
White spruce	19 Oct	50a	6.4a	54a	6.9a	57ab	8.1bc
	26 Oct	42a	5.5a	55a	7.3ab	52c	6.3a
	3 Nov	51a	6.8ab	72a	8.3b	71bc	7.0a
	9 Nov	66a	8.0bc	60a	8.0b	76c	9.7c
	16 Nov	60a	8.4c	56a	8.4b	53a	9.2c
Control	(fresh-lifted)	65a	6.5a **	82a	6.6a *	74c *	7.6ab *

[a] The first date refers to jack pine, the second to white spruce.

Values within species and within columns that are followed by the same letter do not differ significantly by range test.

Lifting guides for frozen overwinter storage of black spruce at Swastika Nursery in northern Ontario were subsequently developed by Mullin and Hutchison (1978). Here, well balanced 3+0 and 1.5+1.5 black spruce were lifted on 15, 21, and 28 October, 1975, from randomized plots in the nursery beds, and placed in cold storage at -3°C. On 20/21 May and 7/8 June, stored and fresh stock was outplanted near the nursery: the fresh-lifted trees showed no visible sign of new growth at the first planting, but at the second planting they showed active root growth (white tips up to 5 cm long) and bud growth (swelling and extension of some buds to about 1 cm). Survival ranged from 86.1% (3+0 stock, first planting) to 96.0% (1.5+1.5 stock, second planting) (Table 19), and there were no significant interactions. The second planting, though marginally better in terms of survival, was somewhat poorer in terms of height increment. In both plantings, incidentally, the transplants were superior to the seedlings in both survival and height increment. The last lifting was best, and the data suggest that later lifting might be better still. Mullin and Hutchison suggested that at least 167 DHDs are required for black spruce before it is ready for lifting (based on 10°C).

Table 19. Second-year survival and second-year height increment of fresh and cold-stored (-3°C) black spruce (3+0 and 1.5+1.5 age classes combined) outplanted in northern Ontario, by lifting and planting dates. (after Mullin and Hutchison 1978)

	Planting date			
	20/21 May		7/8 June	
Lifting date	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
15 Oct	90.1ab	8.1a	94.2a	7.6a
21 Oct	87.8a	9.2ab	93.8a	9.1b
28 Oct	94.0c	10.4bc	94.9a	8.5ab
Control	93.3bc	10.8c	93.6a	9.4b
	*	*		*

Within columns values not followed by the same letter differ significantly at the P .05 level or better.

By 1981, Mullin and Laupert were able to state: "Frozen overwinter storage of packaged shipping stock of some species has been an accepted practice at most Ontario nurseries for several years." At Orono, for instance, at 43°55' N the second most southerly nursery of the Ontario Ministry of Natural Resources, frozen overwinter storage has been used successfully for more than 10 years, except for some problems with red pine. Concern that frozen storage might not be successful at St. Williams nursery (42°40'N), the most southerly of the OMNR nurseries, led to the initiation there in 1977 of an experiment to examine the effects of cool and frozen overwinter storage of 3+0 white pine. A series of fall liftings was carried out on 18, 25 October, 1, 8, 15, 22 November, and 1 December, at which times the cumulative DHDs (based on 10°C) were determined to be 23, 46, 62, 66, 89, 126, and 197, respectively. Buds had set before the earliest lifting, but some roots had 0.5-cm white tips at that time. At the second lift, white root tips up to 1.5 cm long were observed, but the length of white root tips declined thereafter from less than 0.5 cm to nothing on and after

22 November. Frozen ground from about 5 December prevented further liftings. Previous work had suggested that white pine would be ready for fall lifting at about 125 DHDs (°C) at Midhurst nursery (Mullin and Parker 1976) about 180 km further north, but the figure was later revised to 165 DHDs(°C) (Mullin and Hutchison 1978).

The stock was transported to Midhurst nursery and placed in cool (1°C) or cold (-3°C) storage. The stored stock and fresh-lifted controls (a total of 16,000 trees) were outplanted in three plantings on well cultivated land late in the spring of 1978. Two of the outplantings were in the vicinity of St. Williams, and the third was at Midhurst. The Midhurst planting was distinctly less successful than were the others, probably in consequence of a three-week delay in planting and perhaps also because of unsuitable provenance (Table 20). The timing of fall lifting was particularly important in relation to frozen storage. For instance, whereas cool-stored stock from the first lifting date gave second-year survival rates of just over 80% in both of the local plantings, the survival of stock that had been frozen-stored averaged only 15% in these two plantings. For the fifth lift, survival in these two plantings was virtually the same for both cool- and cold-stored stock, 94% vs 93%, and the mean second-year height increment of stock that had been cold-stored exceeded that of stock that had been cool-stored, 21.1 cm vs 19.8 cm. Over all, however, the performance of stock that had been cool-stored was superior to that of stock that had been frozen-stored in 18 of 21 survival comparisons and 17 of 21 growth comparisons. Mullin and Laupert (1981) interpreted the results to indicate that at St. Williams nursery, white pine becomes ready for lifting for cool storage at about 95-100°C DHD. Frozen storage became acceptable at about the same time, but with an average growth reduction of about 10%. These DHD levels for white pine at St. Williams are apparently considerably lower than those required further north. Confirmatory tests are in progress, but the relationship between the progression of dormancy and DHD may involve dehardening sequences during spells of warm weather, rendering simple cumulative DHD expressions inadequate.

4.2423212 Cool storage 4.2423212

In the study just described, cool storage of 3+0 white pine gave better results than cold storage in 18 of 21 second-year survival comparisons and 17 of 21 second-year growth comparisons made by Mullin and Laupert (1981). Averaged over all seven lifting dates, cool storage was greatly superior to cold; averaged over the last five lifting dates only, the differential was less but still highly significant (Table 21).

As well as the cold (frozen) storage aspects already discussed, Mullin and Bunting's (1970, 1972) study also involved cool storage. The experiment was established in the fall of 1968 at Orono Nursery about 80 km east of Toronto in southern Ontario. Three species were studied:

Table 20. Second-year survival and height increment of fresh and stored 3+0 white pine from St. Williams nursery spring outplanted at three locations in southern Ontario, by date of fall lifting and type of refrigerated storage. (after Mullin and Laupert 1981)

		Planting date							
		10/12 April				1/2 May		Average	
		Near St. Williams		St. Williams		Midhurst			
Lifting date	Type of refrigerated storage	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
18 Oct	Cool	80.6	16.6	80.8	16.2	63.6	10.7	75.0	14.5
	Cold	6.0	11.7	24.0	10.1	5.2	4.5	11.7	8.8
25 Oct	Cool	46.2	19.1	46.8	19.6	19.4	10.4	37.5	16.4
	Cold	11.2	17.8	23.6	15.4	4.8	6.7	13.2	13.3
1 Nov	Cool	88.4	18.5	96.0	21.4	51.4	10.0	78.6	16.6
	Cold	84.8	18.4	46.4	16.4	52.8	9.7	61.3	14.8
8 Nov	Cool	86.8	18.5	94.0	18.2	44.8	9.8	75.2	15.5
	Cold	54.2	12.5	85.2	13.9	31.8	5.8	57.1	10.7
17 Nov	Cool	90.8	19.1	97.2	20.5	80.0	11.6	89.3	17.1
	Cold	92.2	19.9	94.8	22.4	47.6	12.3	78.2	18.2
22 Nov	Cool	92.4	20.1	94.8	19.3	78.0	12.2	88.4	17.4
	Cold	79.6	19.0	95.2	21.0	64.4	10.9	79.7	17.0
1 Dec	Cool	89.2	18.9	94.0	19.4	73.4	12.0	85.5	16.8
	Cold	83.4	18.9	93.6	18.7	69.4	11.7	82.1	16.4
Over all	Cool	82.1	18.7	86.2	19.3	58.7	11.0	75.6	16.3
Over all	Cold	58.8	16.9	66.1	16.8	39.4	8.8	54.8	14.2
Over all	Cool + Cold	70.4	17.8[a]	76.1	18.1[b]	49.0	9.9[c]	65.2	15.2
Significance		***	***	***	***	***	***		
Least significant difference		4.6	1.1	4.8	1.8	10.1	1.5		
Spring-lifted control		88.3	19.6	94.2	21.8	82.6	13.4	88.4	18.3

[a] Amended from 18.4 in original. [b] Amended from 18.9 in original. [c] Amended from 10.9 in original.

Table 21. Second-year survival and height increment of fresh and stored 3+0 white pine from St. Williams nursery outplanted at three locations in southern Ontario, by type of refrigerated storage, averaged over (a) all seven liftings in spring, and (b) the last five sequential liftings (after Mullin and Laupert 1981).

		Planting date							
		10/12 April				1/2 May		Average	
		Near St. Williams		St. Williams		Midhurst			
Sequential lifting	Type of refrigerated storage	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
1 - 7	Cool	82.1	18.7	86.2	19.3	58.7	11.0	75.6	16.3
	Cold	58.8	16.9	66.1	16.8	39.4	8.8	54.8	14.2
3 - 7	Cool	89.5	19.0	95.2	19.9	65.5	11.1	83.4	16.7
	Cold	78.8	17.7	83.0	18.5	53.2	10.1	71.7	15.4
Spring-lifted control		88.3	19.6	94.2	21.8	82.6	13.4	88.4	18.3

red pine, white pine, and white spruce. The trees for overwinter storage were lifted on 25 November and placed in cold or cool storage, as previously described. The cool storage room was kept above freezing, with an average air temperature of 1.5°C and a maximum of 3.0°C. For the cool-stored stock, there were pronounced differences between species in terms of first-year survival after spring outplanting, and some packaging treatments were obviously inferior for the pines (Table 22). For white spruce, however, there were no significant differences between packaging methods, nor between cool-stored overwintered stock and fresh-lifted controls. Indeed, the poor performance of the control trees in the Kemptville planting compared with the other plantings led Mullin and Bunting to comment that the unplanned delay of seven days in the planting at Kemptville "might indicate a tentative conclusion that the [cool]-stored stock and frozen stock was able to withstand handling and holding better than the freshly lifted stock because the latter may have been more active, or more advanced in the dehardening process." Mullin and Bunting interpreted their results to indicate the possibility of longer storage and later planting, i.e., extension of the planting season. This would seem to be particularly true for white spruce.

A small-scale trial with 1+1 ponderosa pine and 2+0 Douglas-fir in California was carried out by Lanquist and Doll (1960) in the late 1950s. Stock overwintered at 1°C for 5.5 months gave first-year survival rates of up to 94%.

Table 22. First-year survival of outplanted fresh and cool-stored 3+0 red pine, 3+0 white pine, and 3+0 white spruce by planting site. (after Mullin and Bunting 1972)

Species	Packaging	Planting site and date			
		Orono April 30 (%)	Ganaraska May 3 (%)	Kemptville May 6 (%)	Mean (%)
Red pine	Tray	58.4b	35.2b	37.2b	43.6
	Bale	66.4bc	82.4c	80.0c	76.3
	Polybag	70.8bc	76.4c	71.6c	72.9
	Bale-in-polybag	1.6a	9.6a	5.2a	5.5
	Fresh-lifted control	85.6c	94.0c	84.4c	88.0
Significance		***	***	***	
White pine	Tray	80.0b	80.8b	72.0ab	77.6
	Bale	84.0b	79.6b	86.8bc	83.5
	Polybag	88.0b	81.6b	94.4c	88.0
	Bale-in-polybag	48.8a	40.0a	55.2a	48.0
	Fresh-lifted control	84.4b	89.2b	72.8ab	82.1
Significance		**	*	*	
White spruce	Tray	85.2a	76.4a	84.0a	81.9
	Bale	81.2a	85.6a	92.0a	86.3
	Polybag	88.2a	83.6a	85.6a	86.0
	Bale-in-polybag	88.4a	87.6a	86.8a	87.6
	Fresh-lifted control	83.2a	88.0a	68.0a	79.7
Significance		NS	NS	NS	

Within species and columns, values not followed by the same letter differ significantly at level indicated, * = P .05, ** = P .01, *** = P .001. NS = not significant.

Encouraged by the work of Hopkins (1938), who showed that white pine and white spruce could be overwintered in refrigerated storage at 0°C + 1°C and outplanted with intermediate success as late as mid-July, Baldwin and Pleasonton (1952) began an experiment in October 1950 which included cool overwinter storage of 3+0 red pine, white pine, white spruce, and balsam fir. Results were reported in general terms only. Outplantings took place on 26 April, 20/22 June, and 12/13 July. With respect to survival of trees that had been fall-lifted (presumably in October), "good survival was obtained with trees [that had been] kept just above freezing in refrigerator rooms and trees [that had been] kept in a cool damp cellar. Best survival occurred in trees planted in April, but refrigerator-stored trees survived well in July plantings, better in fact than those planted in June. White pine generally was superior to other species in survival, followed by white spruce, red pine and balsam fir in that order." White pine and, to a lesser extent, white spruce, "survived well" when planted in June and July after overwinter storage at about 2°C. All trees that had been deep frozen over winter at - 18°C to - 12°C turned brown a few hours after planting and died.

Trees of eight species, including red pine, white pine, and white spruce, showed "satisfactory" first-year survival when outplanted after overwinter storage at - 1°C to 4°C in relative humidity of 90% (Leslie 1945). Jack pine failed, probably because the stock was large (60 cm to 90 cm) with small root systems. Again, the results bear only indirectly on the question of planting season extension.

Nor did Williams and Rambo (1967) in northern Indiana attempt to prolong the spring planting season with red pine and white pine stored over winter at 1°C to 3°C, but their results on the effect of lifting date on first-year survival are of general interest. First-year survival of 2+1 red pine fall-lifted on 13 November and 3 December was not significantly inferior to that of fresh-lifted stock outplanted on three different sites in southern Indiana after lifting on 28 March, but 1+2 white pine survival increased significantly (P .01) from 76% in stock lifted on 13 November to 88% in stock lifted on 3 December, and fresh-lifted stock lifted at the end of March showed 93% survival after outplanting.

The study reported by Cram and Lindquist (1981) directly addressed the question of whether overwinter and spring storage could be used to delay and expand *nursery* transplanting operations in the prairie region of Saskatchewan. Cold-storage aspects have already been discussed. Overwinter cool storage at 2°C gave excellent second-year results for both 2+0 Scots pine and 2+0 Colorado spruce (Table 23).

Factors controlling vigor and vitality in fall-lifted Douglas-fir stock overwintered in cool storage were studied by Lavender and Wareing (1972) who found that plants that had been subjected to a short day regime prior to lifting showed reduced root activity and were less able to regenerate roots, but were less adversely affected by lifting and storage than were plants that had been given long-day treatment. Chilling and daily exposure to low intensity illumination further reduced the adverse effects of lifting and dark storage. Undoubtedly, much remains to be discovered about these multi-factor systems before they can be used to maximum advantage.

4.242322 *Spring Storage (spring lifting)* 4.242322

A number of other investigations have produced evidence that bears on the questions addressed by the present study, *viz.*, extension

Table 23. Second-year survival and height increment of 2+0 Scots pine and 2-0 Colorado spruce nursery transplanted in late spring (16 May) at Indian Head Tree Nursery, Saskatchewan, after overwinter storage. (after Cram and Lindquist 1981) (cf. Tables 16, 32)

Lifting date	Storage		Species			
			Scots pine		Colorado spruce	
	Temperature (°C)	Duration (days)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
Roots not treated with Captan						
16 Oct	2	212	87.2ab	12.9b	90.1a	9.1b
16 Oct	- 5	212	0.0d	- d	74.7b	8.8b
6 May	2	10	94.4a	17.5a	80.0ab	6.9d
16 May	(fresh)	0	78.0b	12.1b	83.5ab	7.3cd
Roots treated with Captan						
16 Oct	2	212	62.7c	9.8c	88.9a	10.0a
16 Oct	- 5	212	0.0d	- d	79.1ab	7.7c

Within columns, values not followed by the same letter differ significantly (at an unspecified level of probability, but presumably P .05).

of the planting season with spring-lifted, refrigerated stock in delayed plantings.

Jack pine (1+0) and white spruce (2+2) were among four species of conifer that were tested for ability to withstand cool storage after spring lifting (Stoeckeler 1950). Stock was lifted on 3 May and stored for 0, 1, 2, 3, 4, or 5 weeks at 10°C, and afterwards outplanted in the nursery together with comparable but fresh-lifted stock. First-year survival was 95% or more for the pines, irrespective of the duration of storage. With white spruce, however, first-year survival had begun to drop (to 93%) in stock that had been stored for four weeks, and was down to 81% after five weeks of storage. All fresh-lifted stock, "even though in a succulent stage in the late transplantings", survived at rates of 95% or higher. Also, it appeared "that late transplanting with and without cool storage has an adverse effect on growth, and that it is accentuated by long storage" (Stoeckeler 1950).

A limit of 10 weeks in refrigerated storage was set by Lindberg (1951) for Scots pine and Norway spruce destined for planting in northern Sweden after the spring thaw.

Duffield and Eide (1959) reported as "successful" the cool storage, for up to 16 weeks at 2°C, of various species of spring-lifted stock including 2+0 Douglas-fir in closed polyethylene bags.

Scots pine and Sitka spruce *(Picea sitchensis* [Bong.] Carr.) were among seven species that "performed well" after spring cool storage of 16 to 28 weeks at 2°C, although survival decreased after cold storage at - 5°C (Aldhous and Atterson 1963).

In a small study, difficult to relate to operational practice, spring-lifted 1+0 Sitka spruce were stored for up to 20 weeks at between 3°C and 4°C, then potted and exposed to good growing conditions in a growth room for 5 weeks: survival among stock that had been stored for 5 weeks was 100%, but decreased rapidly thereafter to 50% in stock that had been stored for 15 weeks and to about 37% in stock stored for 20 weeks (Buckley and Lovell 1974).

Cool storage for four weeks at 1°C to 2°C for spring lifted lodgepole pine and white spruce was "satisfactory" (Chedzoy 1968).

Tutygin and Veretennikov (1968) spring lifted 2+0 Scots pine and 2+0 Norway spruce, before externally detectable growth had begun, and cool-stored them for up to 12 weeks at 0°C to 3°C and 90% to 92% relative humidity: from their observations of needle pigments, survival, and height growth performance after outplanting, they concluded that Scots pine and Norway spruce should be stored for no more than five weeks and seven weeks, respectively.

In Colorado, Simon (1961) studied the effect of lifting date, refrigerated storage (temperature unspecified), and grading, on the survival of nursery-grown Engelmann spruce (3+0), lodgepole pine (2+0), and ponderosa pine (2+1). Stock was lifted on 6, 13, 20, 27 April, and 4 and 11 May. Bud swelling began in lodgepole pine on 15 April and in Engelmann spruce on 27 April. Forty trees of each species were planted at the Colorado State Forest Nursery the day after lifting: other trees of the same lot were put into refrigerated storage. On 14 June, 40 trees of each species that had been stored at each lifting date were planted in the nursery. For spruce and lodgepole pine, a further 40 stored trees from each lifting date were planted on June 29. Each set of 40 trees was subgraded into superior and inferior grades on the basis of size and apparent vigor. Simon (1961) concluded that: "There were no differences in first-year overall survival that could be attributed to refrigerated storage", overall survival being 83% for stored lodgepole pine vs 85% for unstored in nursery plantings, 85% for stored and fresh Engelmann spruce, and 94% for stored and fresh ponderosa pine (Table 24). However, there are definite signs that plants lifted later were not performing as well as plants lifted earlier. This was particularly true of lodgepole pine. All the spruce, except for those that had been lifted on the last lifting date (11 May) and therefore stored the least (5 weeks), survived equally well in nursery plantings whether planted fresh or after 6 to 10 weeks of refrigerated storage. Field plantings, after two further weeks of storage, were equally successful, and only in the last lifted stock (11 May) did survival drop appreciably.

In nursery plantings, lodgepole pine gave results that were very similar to those described for Engelmann spruce, but in field plantings survival was lower, the decline began earlier and was more pronounced, although the most precipitous drop was from the 40% survival rate for stock of the fifth lifting to the 20% survival rate for stock of the sixth lifting. Survival averaged 83.5% for the 14 June plantings, but only 47.2% in the 25 June plantings with stock that had been stored 2 weeks longer. Clearly, for lodgepole pine, physiological condition rather than the length of storage was the chief determining factor. There was no evaluation of storage duration for a common lifting date.

Table 24. First-year survival of fresh and stored stock in nursery and field plantings, by species and lifting date. Weeks in storage are shown in parentheses. (after Simon 1961)

Species/Treatment	Lifting date											
	6 April (%)	6 April (wk)	13 April (%)	13 April (wk)	20 April (%)	20 April (wk)	27 April (%)	27 April (wk)	4 May (%)	4 May (wk)	11 May (%)	11 May (wk)
Engelmann spruce												
Fresh stock, quick planted in nursery	78	-	75	-	88	-	90	-	90	-	88	-
Stored stock, nursery planted 14 June	80	(10)	85	(9)	85	(8)	95	(7)	90	(6)	78	(5)
Stored stock, field planted 29 June	80	(12)	85	(11)	95	(10)	92	(9)	88	(8)	65	(7)
Lodgepole pine												
Fresh stock, quick planted in nursery	82	-	70	-	98	-	82	-	95	-	85	-
Stored stock, nursery planted 14 June	88	(10)	100	(9)	88	(8)	90	(7)	95	(6)	40	(5)
Stored stock, field planted 25 June	65	(12)	62	(11)	48	(10)	48	(9)	40	(8)	20	(7)

Bud swelling began in lodgepole pine on 15 April and in spruce on 27 April.

Representative lots of four species of nursery stock, including 1+0 jack pine and 2+2 white spruce, were lifted on 3 May, 1938 at Rhinelander, Wisconsin, packed in crates and placed in refrigerated storage (Stoeckeler 1950, Stoeckeler and Jones 1957). Air temperatures in the storage unit up to 15 May were generally at or below 10°C but never below 3°C; thereafter, temperatures occasionally reached 16°C to 18°C for periods of several hours. Trees were taken out of storage for weekly nursery plantings beginning on 10 May and ending on 7 June. At each planting date, similar lots were fresh-lifted from the nursery beds and planted for comparison. First-year survival rates indicated virtually no difference between stored and fresh jack pine (and red pine and white pine, too) throughout the five plantings. White spruce, however, showed a considerable drop in survival (to 81%) for stock that had been stored for five weeks. Stock of all species stored for 5 weeks was "distinctly smaller" at the end of the first season after transplanting than the stock stored for shorter periods: the reduction in weight of stored versus unstored stock was 42% for jack pine, 28% for white spruce, and 20% for each of red pine and white pine.

In another part of the experiment, 1+0 jack pine and 2+2 white spruce were among representative lots of four species of conifer lifted at weekly intervals beginning on 19 April and ending on 24 May. All these trees were outplanted on 25 May, thus giving storage durations of 0, 1, 2, 3, 4, and 5 weeks. First-year survival was between 83% and 88% for jack pine stored for 0 to 3 weeks and 95% for jack pine stored for 5 weeks. Jack pine that had been lifted on 26 April and stored for 4 weeks, however, showed a survival rate of only 76%. White spruce survival was 90% or more for all lifting dates except 26 April, when it dropped to 82%. Stoeckeler and Jones (1957) did not state the numbers of trees involved in these experiments, nor did they give confidence levels, but the consistency of the results with all four species, and the calibre of the researchers, inspire confidence in the results. Stoeckeler and Jones concluded that spring storage can be recommended for conifer nursery stock for up to 5 weeks. Their work underlines the dependence of subsequent performance on lifting date.

Burgar and Lyon (1968), in the Thunder Bay district of Ontario, tested two methods of extending the planting season using 2+2 white spruce on a prepared, well drained, fresh loam mixedwood site carrying a residual stand of 20-30 stems/ha of mature white birch *(Betula papyrifera* Marsh.), white pine, and trembling aspen *(Populus tremuloides* Michx.). In the storage treatment, trees were lifted on 5 May, 1964, as soon as the ground had thawed, and placed in refrigerated storage at 0.5°C to 3°C). Stock was drawn from storage at intervals of two weeks for field planting throughout the growing season from 6 May until 30 September. Fresh stock, lifted two days before each planting, was planted at the same time as the stored stock up to 30 September, then at similar intervals until freeze up (28 October). The test was laid out as four replications of a randomized split block arrangement. Each replication contained 12 plots of stored trees and 14 plots of fresh trees, and there were 25 trees per plot. The study was not replicated in time.

Survival rates at the end of the third growing season for the stored stock were remarkably high even after 19 weeks of storage (Table 25). Survival rates for the last two outplantings differ significantly from the others. In terms of total tree height, however, stock that had been stored for more than 11 weeks exhibited significantly poorer performance than stock stored for shorter periods. In

Table 25. Third-year survival and mean total tree heights of fresh and stored 2+2 white spruce outplanted at intervals through the period of frost-free soil from 6 May. Weeks of storage are shown in parentheses. (after Burgar and Lyon 1968)

	Planting date													
	May			June		July		August		Sept			Oct	
	6	13	27	10	24	8	22	6	19	2	16	30	14	28
Fresh stock														
Survival (%)	96	98	95	87	82	77	92	99	97	96	80	87	77	80
Total ht (cm)	50	59	48	49	46	47	46	46	46	41	40	35	38	36
Stored stock														
Storage (wk)	(0.1)	(1)	(3)	(5)	(7)	(9)	(11)	(13)	(15)	(17)	(19)	(21)		
Survival (%)	96	99	96	97	97	95	88	95	91	84	58	54		
Total ht (cm)	50	58	46	47	43	39	35	26	18	15	14	13		

interpreting these results, one must take into account several factors of importance: the stock was lifted at the first possible opportunity in the spring; it was good 2+2 material, and carefully handled, in fairly small numbers; and the prepared site, with its open overstorey, was particularly well suited to white spruce. The study is an important indicator of what can be achieved when attention is paid to these factors. The results are particularly interesting in conjunction with those reported by Stoeckeler and Jones (1957) as well as in conjunction with the guidelines for the general handling of nursery stock (Dixon 1975) which recommend the species lifting sequence: red pine, white pine, jack pine, and then, surprisingly in view of their phenological sequence, black spruce, before white spruce. The guidelines set the maximum length of storage for stock lifted within one week after all frost has left the ground at six weeks at 0.5°C to 1.0°C plus one week up to 4.5°C. For stock lifted later than this, but before actual flushing (i.e., the emergence of needles from the bud, not merely swelling or elongation of the bud), the guidelines suggest that jack pine, black spruce, and white spruce (as well as two other pines) may be cool stored at 0.5°C to 1.0°C for a period not exceeding 2.5 weeks.

Date of lifting and spring storage of jack pine for delayed planting were investigated in an experiment begun in 1976 at Swastika Nursery in northern Ontario (Mullin and Forcier 1976, 1979). On each of four dates of lifting (10, 13, 18, and 21 May) 2+0 jack pine from randomly selected plots in the regular beds were lifted for delayed planting. Plots of the same stock were reserved for comparative fresh plantings on each of the three dates of planting (26 May, 9 June, and 22 June). Air temperature degree-days (the cumulative difference above 1°C of the averaged daily maximum and minimum) were 80, 88, 122, and 138 for the four lifting dates. Frozen storage at -3°C was compared with cool storage at 1°C. All three plantings were on level sandy loam near Kirkland Lake. The site had been prepared with a Marttiini plow, and the trees were planted in the furrows. There were five replications of each treatment. The results at the end of the second growing season in the field throw much light on the effects of lifting date, length of storage, cold vs cool storage, and survival-growth relationships (Table 26). From the standpoint of the present study, the highly detrimental effect of cold storage is of prime interest: the differential increased with both increasing length of storage and/or lateness of planting, and with lateness of lifting. For the third and fourth lifts with the second and third plants, survival among stock that had been frozen stored was virtually nil, whereas cool stored stock survival was still in the 80.8%-72.8% range for the second plant, and in the 43.2%-30.8% range for the third plant. Mullin and Forcier's results also demonstrate the fact that significant differences in performance can occur in consequence of a few days' difference in lifting date/storage duration.

In an earlier study, Mullin and Forcier (1976) examined the effects of lifting date and planting date on frozen-stored spring-lifted 2+0 jack pine, 3+0 black spruce, and 3+0 white spruce, with fresh-lifted control trees planted on each planting date for comparison. On each date of lifting, trees were stored at -2°C. A total of 12,500 trees of each species was planted. The first lifting of all species gave the highest average survival, and the data illustrate clearly that early lifting is important not only for stock that is to be stored but also for stock that is to be planted fresh (Table 27). Plantings that took place after the end of May with early lifted stock generally gave much higher survival with stored than with fresh-lifted stock, notwithstanding the subsequent indication (cf. Mullin and Forcier 1979) that cool storage is superior to cold storage. The evidence reviewed under *Fresh-lifted bare-root stock* (p. 66) suggests that fresh stock would perform increasingly well once the succulent stage of development is passed. The points of interest in relation to the present study are the high survival rate (84.0%) of the earliest lifted jack pine even after 9 weeks of cold storage, the 82.0% survival of the earliest lifted black spruce after 7 weeks of storage, and the 81.6% survival of the earliest lifted white spruce after 7 weeks of storage. Also, the later the lifting, the more rapid the decline in performance. Again, Mullin and Forcier's results illustrate the strong correlation between survival rate and growth rate of survivors.

Table 26. Second-year survival of outplanted jack pine, by storage treatments, dates of lifting, and dates of planting. (after Mullin and Forcier 1979)

Lifting date and storage treatment	Planting date: 26 May Survival (%)	26 May Days stored	9 June Survival (%)	9 June Days stored	22 June Survival (%)	22 June Days stored
Lift 1, 10 May						
Frozen, dipped	50.0a		24.8a		56.0b	
Frozen, not dipped	68.4a	16	46.8a	30	16.4a	43
Cool, dipped	77.2a		73.6b		66.0b	
Lift 2, 13 May						
Frozen, dipped	66.4a		66.8a		53.2a	
Frozen, not dipped	76.0a	13	77.2ab	27	43.2a	40
Cool, dipped	83.6a		93.2b		84.8b	
Lift 3, 18 May						
Frozen, dipped	43.2c		0.8a		0.8a	
Frozen, not dipped	29.6a	8	4.0a	22	0.8a	35
Cool dipped	97.2b		72.8b		30.8b	
Lift 4, 21 May						
Frozen, dipped	62.0a		2.0a		0.4a	
Frozen, not dipped	51.2a	5	0.0a	19	0.0a	32
Cool, dipped	97.2b		80.8b		43.2b	
Fresh-lifted controls	77.2	0	68.3	0	69.9	0

Within lifts and planting dates, values in columns not followed by a common letter differ significantly at the P .05 level or better.

Table 27. Second-year survival, by species, date of lifting, and date of planting: stored stock cold stored at -2°C. (after Mullin and Forcier 1976)

Species and lifting date	Planting date									
	9 May		23 May		5 June		20 June		5 July	
	Survival	Storage duration	Survival	Storage duration	Survival	Storage duration	Survival	Storage duration	Survival	Storage duration
	(%)	(wk)	(%)	(wk)	(%)	(wk)	(%)	(wk)	(%)	(wk)
Jack pine										
Lift 1, 2 May	93.6	(1)	89.2	(3)	90.0	(5)	65.2c	(7)	84.0c	(9)
Lift 2, 16 May			86.0	(1)	86.0	(3)	60.8bc	(5)	67.2c	(7)
Lift 3, 29 May					75.2	(1)	28.8a	(3)	22.4a	(5)
Lift 4, 12 June							45.6ab	(1)	6.4a	(3)
Lift 5, 26 June									25.6ab	(1)
Fresh-lifted	94.4	(0)	89.6	(0)	68.0	(0)	34.0ab	(0)	32.0b	(0)
							*		***	
Black spruce										
Lift 1, 2 May	86.4	(1)	79.2	(3)	87.6b	(5)	82.0b	(7)	77.6c	(9)
Lift 2, 16 May			76.4	(1)	77.2ab	(3)	83.2b	(5)	71.6bc	(7)
Lift 3, 29 May					62.0a	(1)	62.8a	(3)	51.6ab	(5)
Lift 4, 12 June							55.2a	(1)	34.4a	(3)
Lift 5, 26 June									56.8b	(1)
Fresh-lifted	84.0	(0)	69.6	(0)	70.8a	(0)	49.2a	(0)	67.2bc	(0)
					*		***		**	
White spruce										
Lift 1, 2 May	88.0	(1)	73.2	(3)	86.4	(5)	81.6bc	(7)	36.4	(9)
Lift 2, 16 June			69.6	(1)	82.0	(3)	72.0bc	(5)	52.8	(7)
Lift 3, 29 May					82.4	(1)	84.0c	(3)	37.2	(5)
Lift 4, 12 June							49.6a	(1)	41.6	(3)
Lift 5, 26 June									33.6	(1)
Fresh-lifted	91.2	(0)	74.0	(0)	75.2	(0)	69.6b	(0)	50.0	(0)
							***			

*, **, *** = significant at P .05, P .01, and P .001 levels, respectively.
Within species and planting dates, values in columns not followed by the same letter differ significantly at the P .05 level.

Spring storage of frozen 3+0 white spruce was also studied by Mullin (1978b) in relation to lifting date and planting date at Midhurst Nursery in southern Ontario. At each of four lifting dates, stock was placed in cold storage at -3°C and held until the scheduled planting date. At each planting date, fresh lifted stock was also planted. Five years after planting, survival of early-lifted, stored white spruce was equal to that of unstored stock in the first planting and much higher in the later plantings (Table 28). As noted by Mullin, outplantings of stored white spruce were consistently successful, at least to the end of June, only for the first lifting. A survey of soil temperatures was made with a view to characterizing the time for spring lifting, in a manner similar to attempts by Mullin and Parker (1976) and others to relate readiness for fall lifting to soil temperature (DHDs: cumulative daily minimum below 10°C). In the case of spring lifting, Mullin used a base of 0°C and accumulated daily minimum soil temperatures (to the nearest 0.5°C) at a depth of 15 cm. He interpreted the evidence as showing that the cutoff for storage of white spruce was about 50 degreedays. The cutoff for red pine, which was also included in the study, was similarly estimated to be about 300 degree-days. On the basis of this evidence, notwithstanding the Dixon (1975) guidelines, white spruce should be lifted before red pine in spring lifting for refrigerated storage. The poor performance of fresh-lifted stock in the later plantings is perhaps more a reflection of unfavorable conditions at the

Table 28. Fifth-year survival for fresh and frozen-stored 3+0 white spruce outplanted in southern Ontario, by lifting date and planting date. (after Mullin 1978b)

	Planting date				
Lifting date	16 May (%)	30 May (%)	13 June (%)	27 June (%)	11 July (%)
Stored stock					
25 April	93.2b	92.8b	93.6c	92.8c	48.4a
9 May	38.4a	74.4a	27.6a	68.0b	37.6a
23 May		86.4ab	78.4b	27.2a	42.0a
6 June			67.6b	54.4b	35.2a
Fresh stock	90.8b	80.4a	81.6bc	66.8b	32.4a

Within planting dates, values in columns not followed by the same letter differ significantly at the P .01 level or better.

planting site than loss of potential: the weight of evidence, reviewed under *Fresh-lifted bare-root stock* (p. 66) suggests strongly that good results can be obtained with white spruce in fresh-lift/quick-plant procedures throughout the growing season, except for the short period of rapid shoot extension (cf. Burgar and Lyon 1968). Mullin did not comment on this point. His concern was with the use of storage, and he concluded that "the results suggest that stored spruce can be safely used to extend the planting season within reason".

Performance of fresh-lifted white spruce in summer plantings was also poor in another study, this one in northern Ontario. Jack pine and black spruce, as well as white spruce, were the subject of a spring-lifting, cold storage (at -2°C) experiment at Swastika Nursery (Mullin and Forcier 1976, Mullin and Reffle 1980). Mullin and Reffle noted that the use of frozen storage in association with spring lifting has received less attention than frozen overwinter storage, and needs further investigation. Randomized plots were laid out in regular seedbed shipping stock of 2+0 jack pine, 3+0 black spruce, and 3+0 white spruce: stock was lifted on five dates (2, 16, and 29 May, 12 and 26 June 1973) and planted after cold storage on 9 and 23 May, 5 and 20 June, and 5 July on a nearby sandy *Vaccinium/Comptonia* cutover. Fresh-lifted controls were planted at each planting date after overnight storage in bags. The spring of 1973 in the experimental area was about normal in temperature and about 25% wetter than average for April through July. The weather at the time of the second planting was hot (23°C) and dry (relative humidity below 40%). The results after two years and five years have been reported by Mullin and Forcier (1976) and Mullin and Reffle (1980), respectively. Here, survival only will be used to illustrate the outcome (Table 29). The main trends exhibited by the data are clear. For jack pine, already by the second planting there was considerable depression of fifth-year performance in fresh stock, whereas for plantings 2 through 5, stored stock, especially from the first and second liftings, was much superior. Jack pine of the first lifting, for instance, gave fifth-year survival of 70% in the 5 July planting. Mullin and Reffle suggested a 25 May cutoff date for planting of fresh jack pine and about 10 June for stored stock. For black spruce, fifth-year survival rates reached 69.6% or more with stored stock from the first lift on the first, second, third, and fifth planting date, and with stored stock from the second lift on the second, third, and fourth planting dates. Fifth-year survival rates for fresh-lifted black spruce ranged from 62.4% to 68.8% for the first three plantings, dipped to less than 50% for the fourth planting, and then recovered to 58% for the fifth. Mullin and Reffle interpreted these results to indicate cutoff planting dates for black spruce of about 25 May for fresh stock and 20 June for stored. For white spruce, fifth-year survival rates reached 70% or more with stored stock from the first lift in the first, second, third, and fourth planting dates, with stored stock from the second lift in the third and fifth plantings, and with stored stock from the third lift in the third and fourth plantings. Fifth-year survival rates from

Table 29. Second- and fifth-year survival for fresh and frozen-stored 2+0 jack pine, 3+0 black spruce, and 3+0 white spruce outplanted in northern Ontario, by species, lifting date, and planting date. (after Mullin and Forcier 1976 and Mullin and Reffle 1980)

Species and lifting date	Planting date: 9 May Yr 2 (%)	9 May Yr 5 (%)	23 May Yr 2 (%)	23 May Yr 5 (%)	5 June Yr 2 (%)	5 June Yr 5 (%)	20 June Yr 2 (%)	20 June Yr 5 (%)	5 July Yr 2 (%)	5 July Yr 5 (%)
Jack pine										
Stored stock										
2 May	93.6a	86.8	89.2a	78.4	90.0a	78.7	65.2a	50.4	84.0c	70.4
16 May			86.0a	76.0	86.0a	81.2	60.8a	55.2	67.2c	57.6
29 May					75.2a	73.6	28.8a	21.2	22.4a	24.4
12 June							45.6a	40.8	6.4a	10.2
26 June									25.6ab	25.8
Fresh-lifted	94.4a	85.6	89.6a	64.4	68.0a	64.1	34.0a	34.8	32.0b	25.2
										***
Black spruce										
Stored stock										
2 May	86.4a	70.8	79.2a	74.8	87.6a	86.4	82.0b	64.4	77.6c	69.6
16 May			76.4a	70.4	77.2a	70.4	83.2b	69.6	71.6bc	67.7
29 May					62.0a	56.8	62.8a	56.4	51.6ab	58.0
12 June							55.2a	44.0	34.4a	27.2
26 June									56.8b	45.2
Fresh-lifted	84.0a	68.8	69.6a	62.4	70.8a	65.2	49.2a	46.4	67.2bc	58.2
						**		*		**
White spruce										
Stored stock										
2 May	88.0a	73.2	73.2a	72.2	86.4a	84.3	86.6bc	78.4	36.4a	65.6†
16 May			69.6a	56.4	82.0a	76.0	72.0bc	63.6	52.8a	73.2†
29 May					82.4a	72.8	84.0c	74.4	37.2a	61.5†
12 June							49.6a	57.2	41.6a	36.0
26 June									33.6a	31.3
Fresh-lifted	91.2a	79.2	74.0a	67.0	75.2a	74.8	69.6b	61.2	50.0a	37.9
						*		*		***

For 2nd-year data, within species and planting dates, values in columns not followed by the same letter differ significantly at the P .01 level. For 5th-year data, *, **, and *** indicate significance at the P .05, P .01, and P .001 levels, respectively.

† Mullin and Reffle (1980) do not offer an explanation as to why 5th-year survival is so much greater than 2nd-year.

fresh-lifted white spruce ranged from 61.2% to 79.2% for the first four plantings before dropping sharply to 37.9% for the fifth. Stored white spruce from the late lifts performed poorly. The data were interpreted by Mullin and Reffle to suggest cutoff dates for planting of white spruce of about 25 May for fresh stock and 15 June for stored. All dates refer to plantings in the general area of Swastika. Mullin and Reffle drew attention to an implication of the study that becomes obvious when the growth data are taken into consideration, viz., the superiority of jack pine over the spruces on this *Vaccinium/Comptonia* site: combining the stored and fresh in Plant 1 only, fifth-year survival rates of jack pine, black spruce, and white spruce were 86.2%, 69.8%, and 76.2%, respectively; and fifth-year total heights were 190.4 cm, 79.7 cm, and 61.1 cm, respectively. Fourth-year data from the present study (cf. Table 11) indicate similar relationships, although, except for the P72 series, growth has been generally slower than that reported by Mullin and Reffle.

McClain (1976, 1979, 1980), in studies aimed at extending the planting season of black spruce in northern Ontario, used cool-stored (1°C to 3°C) black spruce in addition to the fresh-lifted bare-root stock already discussed. To recapitulate, the experimentation required that black spruce be planted every two weeks throughout the frost-free period on typical mixedwood sites: thus, in May 1975, 1.5+1.5 and 3+0 black spruce were lifted and placed in cool storage from which stock was withdrawn as needed. At each of 12 planting times from 21 May through 20 October, stored and fresh-lifted (1.5+0.5 and 2+0, i.e., rising 1.5+1.5 and 3+0) trees were outplanted on two sites, one in the Thunder Bay District, the other in the Geraldton District. In all, 14,400 trees were planted. First-year results (McClain 1976), which were essentially the same for both sites, showed excellent survival for spring stored 1.5+1.5 stock for the first through eighth sequential plantings. On the ninth and tenth plantings, survival was almost 90% and almost 70%, respectively. Survival was less than 10% thereafter. For 3+0 stock, survival was 95% or more for the first through fifth sequential plantings, and it then declined steadily to just under 60% in the tenth planting, and less than 20% thereafter. Fourth-year survival rates were not significantly lower (McClain 1981). McClain, however, emphasized that it was unrealistic to assess plantation success solely on survival: his data provide an excellent illustration of the point. Despite high survival rates, the first-year current annual increments for stored stock decreased steadily with increasing deferment of planting. For several of the first five sequential plantings, the first-year growth of stored 1.5+1.5 black spruce was 12% to 35% superior to that of unstored stock. For all but one planting, however, the growth of stored 3+0 black spruce was inferior to that of fresh-lifted rising 3+0 stock. The fourth-year data show that these relationships were maintained (McClain 1981). The remarkably superior performance of the black spruce in McClain's experiment as compared with that of Mullin and Reffle's (1980) is probably related to the more hospitable mixedwood site conditions in which McClain's studies were carried out. McClain (1979) concluded that the rates of both survival and growth were good enough to justify the use of spring-stored 1.5+1.5 black spruce in outplantings until the end of July without loss of performance. McClain recommended that fresh-lifted stock be used in plantings undertaken after the end of July. Again, McClain recognized that because considerable (though not unpractical) care was taken with stock handling, the degree to which operational procedures would approach these results is an open question.

In another, though limited, study (Christilaw 1981) with black spruce in Robson Township, northwest of Thunder Bay in northwestern Ontario, 3+0 stock was outplanted both fresh on 16 May, 1972, and after 2, 4, 6, or 7 weeks of cool storage in the ice house described by Clarke and Clark (1973) at temperatures that did not exceed 1.4°C in May and June but rose to a maximum of 3.5°C before the last planting took place on 7 July. Remarkably, first-year survival rates increased progressively and significantly (P .05) with increasing length of storage, from 89% among fresh stock to 99% among stock that had been stored for 7 weeks. After nine growing seasons, the differences in survival were no longer significant, but survival among stock that had been stored for 7 weeks before planting was still 9% higher (86.5% vs 77.5%) than that of fresh stock. Only 1 year of outplanting was involved in this study, but taken with other evidence such as McClain's (1979) the results provide good support for recommending spring storage and delayed planting for black spruce, at least into early July, and, presumably, if a good storage environment can be maintained.

McClain's (1979) point regarding the need to take growth rates into account when assessing performance is particularly valuable in that his results clearly show that good survival and good growth do not necessarily go hand in hand. When survival is poor, however, growth too can be expected to be poor, and, as in the present study, there is seldom other than a strong correlation between the rates of survival and growth of survivors. Performance has been assessed mainly in terms of survival in the discussions up to this point. Operationally, there would be need to recognize loss of growth potential as well as loss of survival potential in choosing among options for plantation establishment.

According to Revel and Coates (1976), Decie (1962) found that survival decreased rapidly with increasing length of storage among spring-lifted white spruce cool-stored at 1.5°C until planted at monthly intervals between May and September, but details were not given.

Revel and Coates (1976) themselves undertook an investigation to determine the dates at which the planting of stock drawn from refrigerated storage becomes not practical in the Sub-boreal Forest Region of British Columbia (Krajina 1965), and the dates at which the planting of fresh-lifted stock becomes practical. In the springs of 1968, 1969, and 1970, white spruce (2+0 and 2+1) were lifted and immediately put into cool storage at 1.5°C to 2.0°C. Outplantings on a medium spruce, devil's club, site were carried out every two weeks from 13 June through 3 October (dates averaged over the three years of establishment). The performance of fresh-lifted control stock has already been discussed. Stored white spruce survival in both age classes was high in the early sequential plantings, and declined to lowest in the last (Table 30). Survival failed to reach 50% only in the final planting with 2+1 stock: in the last five plantings 2+0 stock survival averaged 12% higher than that of 2+1 stock. The depression of growth with increasing lateness of planting (or increasing duration of storage of stock that has been stored) is well shown by Revel and Coates' (1976) data (Table 31). In that experiment, the two age classes gave remarkably similar results in terms of third-year growth performance, and the 2+0 stock survival rates were generally better than the 2+1 survival rates.

Table 30. Third-year survival (mean of three years of planting) of spring-lifted cool-stored white spruce outplanted in Sub-boreal British Columbia, by age class and planting date. (after Revel and Coates 1976)

	Planting date								
Age class	13 June (%)	27 June (%)	11 July (%)	25 July (%)	8 Aug (%)	22 Aug (%)	5 Sept (%)	19 Sept (%)	3 Oct (%)
2+0	89ab	94a	82bc	90ab	83abc	63cd	75bcd	69cd	59d
2+1	91ab	95ab	84b	97a	68c	59c	59c	59c	44c

Within age classes, any two means not followed by the same letter differ significantly at the P .05 level.

Table 31. Total height after three growing seasons in the field and third-year height increment (means of three years of planting) of spring-lifted cool-stored white spruce outplanted in Sub-boreal British Columbia, by age class and planting date. (after Revel and Coates 1976)

	Planting date								
Age class	13 June (cm)	27 June (cm)	11 July (cm)	25 July (cm)	8 Aug (cm)	22 Aug (cm)	5 Sept (cm)	19 Sept (cm)	3 Oct (cm)
2+0									
Total ht	31.7	31.1	24.4	24.1	17.7	12.5	13.1	13.1	12.2
3rd yr incr.	10.7	9.4	7.3	7.6	5.8	4.3	4.0	4.0	4.3
2+1									
Total ht	32.6	30.2	25.3	22.3	17.4	11.3	13.1	11.0	10.4
3rd yr incr.	11.6	9.4	8.2	7.3	6.4	3.6	4.3	3.6	2.4

Revel and Coates (1976) concluded that survival of cool-stored stock was adequate in plantings up to mid-July, and that the later plantings are characterized by widespread mortality of the main stem as a result of frost injury, followed by limited lateral growth from adventitious buds over the subsequent few years. Cool-stored stock was recommended for June plantings, because fresh-lifted stock, while capable of giving excellent performance, is extremely tender at that time and would require very careful handling that it would be unlikely to get in operational plantings. Fresh-lifted stock planted in July out-performed cool-stored stock, but cool-stored stock would give acceptable results until mid-July. Revel and Coates further concluded that the results of their studies indicate that "the conventional planting period can be extended to include the entire snow-free period in the sub-boreal forest region of British Columbia by using a combination of [cool-] stored and freshly-lifted planting stock."

Revel and Coates recognized the vital importance of good stock handling practice and suggested that, on an operational basis, no more than three days' supply of stock be held at the planting site. Close liaison with the nursery is very important.

Revel[2] noted that, in the studies described above, planting stock and planting site were representative of typical stock and planting conditions in the sub-boreal zone, and that planting was undertaken at accepted production rates (600+ trees per 7-hour day) with no "special" care.

In Saskatchewan, Cram and Lindquist (1981) carried out an experiment to evaluate several storage treatments mainly for fall- but also for spring-lifted 2+0 Scots pine and 2+0 Colorado spruce destined for late spring *nursery* transplanting. Spring-lifted stock that was stored at 2°C for 10 days performed as well as or better than stock freshly lifted on 16 May (when the terminal buds of some of the seedbed pine were beginning to enlarge) and transplanted the same day together with the stock that had been stored since lifting on 6 May. Second-year survival and second-year height increments for spring-stored Scots pine were particularly good (Table 32).

Table 32. Second-year survival and second-year height increment of 2+0 Scots pine and 2+0 Colorado spruce, nursery transplanted in late spring (16 May) after various storage treatments. (after Cram and Lindquist 1981) (cf. Tables 16, 23)

Lifting date	Storage		Scots pine		Colorado spruce	
	Temperature (°C)	Duration (days)	Survival (%)	Height increment (cm)	Survival (%)	Height increment (cm)
6 May	2	10	94.4a	17.5a	80.0a	6.9a
16 May	-	0	78.0b	12.1b	83.5a	7.3a

Within columns, values not followed by the same letter differ significantly (at an unspecified level of probability, but presumably P .05).

4.25

4.25 FERTILIZATION

Fertilization in this study was clearly unsuccessful. It significantly decreased survival and, except for some of the early sequential plantings, also had a negative effect on height increment. Mortality increased with increasing level of fertilization in every year of planting, on every site, with every species, and in every sequential planting. The response is well illustrated by the P73 data (Table 33). An inexplicable peculiarity of these data is that, in the high fertilization treatment, survival was invariably higher in the second sequential planting than in the first. The low fertilization treatment and the control (unfertilized) both gave muted indications of a similar relationship.

[2] See p. 66.

Table 33. First-year survival among P73 outplanted stock, by species, site, fertilization treatment, and sequential planting.

Sequential planting no.	Jack pine 0 (%)	Jack pine Lo (%)	Jack pine Hi (%)	Black spruce 0 (%)	Black spruce Lo (%)	Black spruce Hi (%)	White spruce 0 (%)	White spruce Lo (%)	White spruce Hi (%)
	Level of NPK fertilization[a]								
Budd									
1	100	95	58	87	85	49	98	83	46
2	99	93	68	89	76	36	94	80	53
3	98	86	47	90	67	29	98	77	17
4	93	88	32	62	33	22	93	66	15
5	78	47	15	58	32	12	47	10	1
Fawn									
1	100	97	85	88	60	35	98	91	56
2	99	96	86	92	83	82	97	93	85
3	98	94	58	92	80	34	98	92	53
4	95	93	54	73	56	21	96	76	23
5	69	60	37	67	39	18	63	38	13
Dalton									
1	90	83	77	82	77	50	72	37	17
2	98	94	86	95	90	79	97	96	82
3	100	88	60	87	80	48	92	68	36
4	96	81	78	68	59	38	89	78	42
5	68	49	28	30	18	7	38	18	8

[a] 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K at the low (Lo) rate; double this at the high (Hi) rate.

Averaged over the first five sequential plantings, the increased cumulative fourth-year mortality attributable to fertilization was significant (P .05) in the case of black spruce on the P72 Mooseskull site, highly significant (P .01) in both the P72 white spruce at Mooseskull and the P73 black spruce at Fawn, and very highly significant (P .001) in all of the other 15 species/site combinations in the P72 and P73 series (Fig. 41).

In all three species, mortality occurred at very similar rates through the sequential plantings. When planting years and sites are considered on an overall basis, correlations between species mortality are all significant at the P .001 level (Table 34).

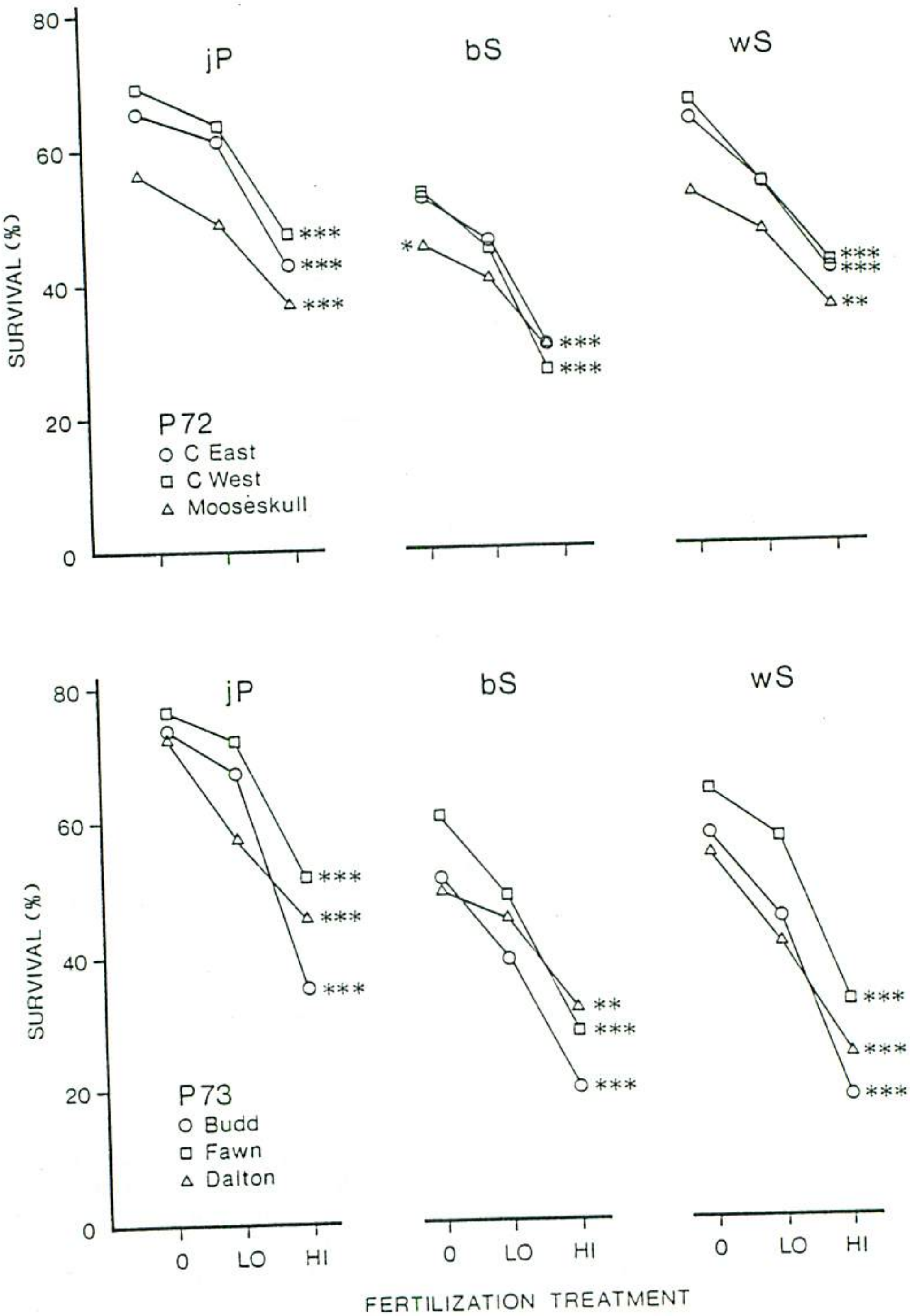

Figure 41. Fourth-year survival over all (sequential plantings 1 through 5 combined) by year of planting (P72 and P73 only), site, species, and fertilization treatment. P72, etc. = planted in 1972, etc., jP = jack pine, bS = black spruce, wS = white spruce. Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; high fertilization treatment (Hi) = double the low rate. *, **, *** = significant depression of survival at P = .05, .01, and .001, respectively.

Table 34. Correlation coefficients between cumulative fourth-year species mortality, planting years and sites over all, by level of fertilization.

Species	Jack pine	Black spruce
No fertilization		
Black spruce	0.956***	
White spruce	0.976***	0.978***
Low fertilization		
Black spruce	0.971***	
White spruce	0.982***	0.983***
High fertilization		
Black spruce	0.963***	
White spruce	0.980***	0.933***

*** indicates significance at the P .001 level.

The control condition within species may be treated as an independent variable (X) and the fertilization treatments as dependent variables (Y_1, Y_2) whose effects may be predicted (Table 35). The similarity between species in their response to fertilization, at least in terms of mortality, is again remarkable. The regression equations indicate that if survival among control trees were 100%, then mortalities of 9%, 12%, and 14% would be expected to occur respectively in jack pine, black spruce, and white spruce fertilized at the low rate. Fertilization at the high rate would be expected to cause mortalities of 32%, 34%, and 38% in jack pine, black spruce, and white spruce, respectively.

Obviously, fertilization was highly detrimental to survival in this study. How did fertilization affect growth? The important preliminary point should be made that below-ground growth is an unknown factor in this study. Root system development may be affected differentially by fertilization treatments (Sutton 1980b), and this may or may not generate an above-ground growth response. Any such response may not occur for several years. Even without detectable growth response, root system morphology may be affected, perhaps to influence tree stability decades hence. The present discussion, therefore, relates to above-ground growth only, and it will concentrate on the P72 and P73 data because of the poor condition of the P71 stock. As will be shown, fertilization of the sort carried out in this study merely agravates stress in severely stressed plants, primarily in consequence of the osmotic effect of high salt concentrations.

Table 35. Regressions relating mortality among control (X), i.e., unfertilized, and fertilized trees, by species and fertilizer level.

Species	Fertilizer treatment[a]	Regression	r^2	Additional mortality attributable to fertilization when control mortality is 0%	20%
				(%)	(%)
Jack pine	Low	Y = 9.49 + 0.927X	98.8	9	28
	High	Y = 31.9 + 0.715X	94.3	32	46
Black spruce	Low	Y = 11.6 + 0.898X	99.7	12	30
	High	Y = 34.1 + 0.701X	96.1	34	48
White spruce	Low	Y = 14.0 + 0.877X	99.6	14	32
	High	Y = 37.9 + 0.653X	93.8	38	51

[a] 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K at the low rate; double this at the high rate.

The growth response to fertilization was mixed. No clear patterns emerge. In P72 plantings of jack pine, for instance, fertilization had a significant (P .01) positive effect on fourth-year total height, sites and sequential plantings (one to five only) over all, but in P73 plantings fertilized trees did not do as well as control trees, although the effect was not significant. In the P72 plantings of spruces, the effect of fertilization on fourth-year total height was not significant, but in the P73 plantings, fertilization had a significant (P .01) negative effect on both spruces (Fig. 42). Mean annual height increments for the first through fourth years (Fig. 43) also show no consistent pattern.

When the P72 results are separated into sequential plantings, however, fertilization can be seen to have become increasingly detrimental to height growth with increasing lateness of planting, in terms of both total height after four years (Fig. 44) and annual height increment (Fig. 45). Similar indications are given by the P73 data for individual sites (Fig. 46).

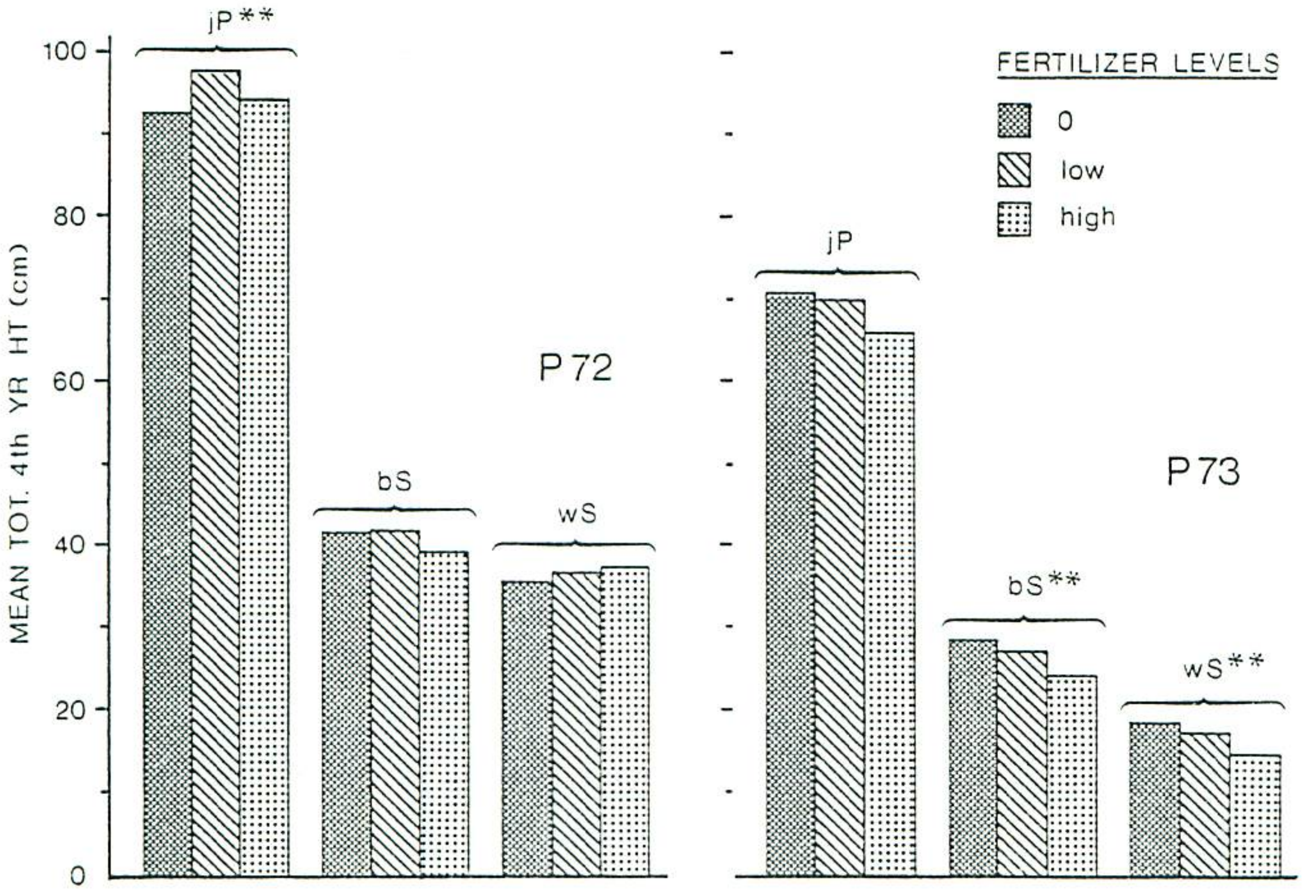

Figure 42. Mean total height after 4 growing seasons, over all (sites and sequential plantings 1 through 5 combined, tilling excluded) by year of planting (P72 and P73 only), species, and fertilization treatment. P72, etc. = planted in 1972, etc., jP = jack pine, bS = black spruce, wS = white spruce. Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; high fertilization treatment (Hi) = double the low rate. ** = significant (P .01) effect of fertilization.

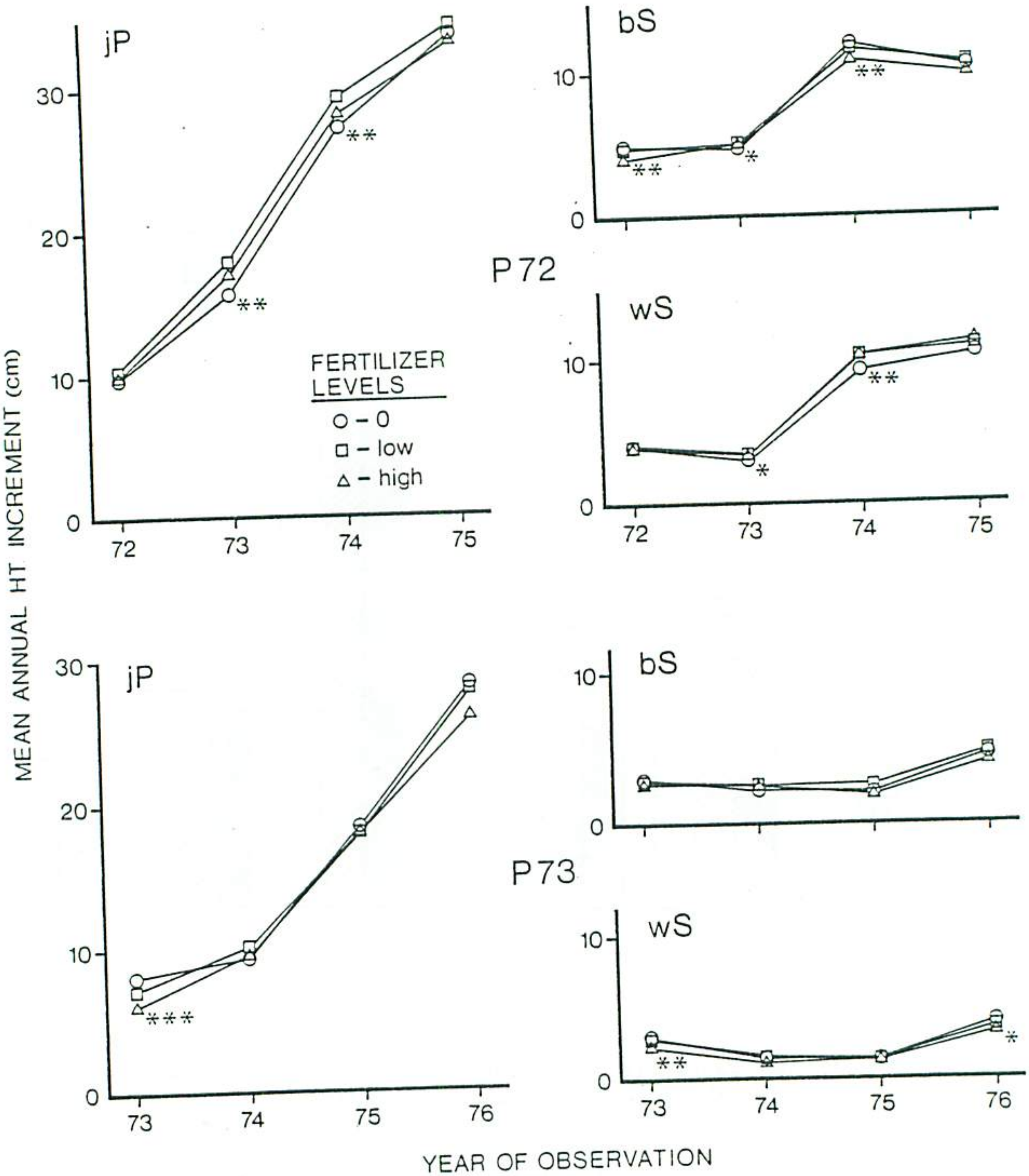

Figure 43. Mean annual height increment, 1st through 4th growing seasons after outplanting, over all (sites and sequential plantings 1 through 5 combined, tilling excluded) by year of planting (P72 and P73 only), species, and fertilization treatment. P72, etc. = planted in 1972, etc., jP = jack pine, bS = black spruce, wS = white spruce. Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; high fertilization treatment (Hi) = double the low rate. *, **, and *** = significant effect (P = .05, .01, and .001, respectively) on height increment in indicated year of observation.

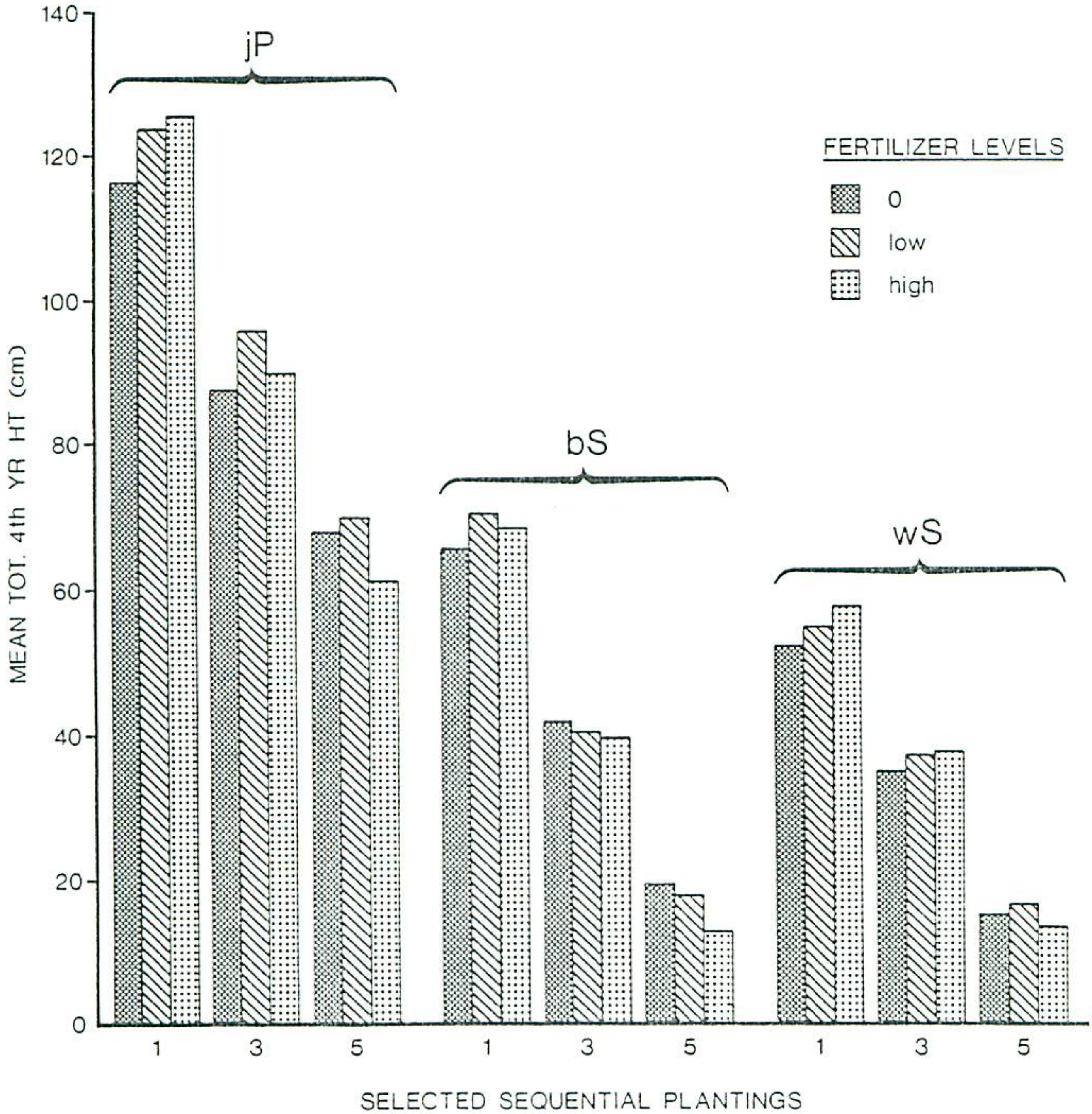

Figure 44. P72 mean total height after 4 growing seasons (sites combined) by selected sequential plantings, species, and fertilization treatment. P72 = planted in 1972; jP = jack pine, bS = black spruce, and wS = white spruce. Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; high fertilization treatment (Hi) = double the low rate.

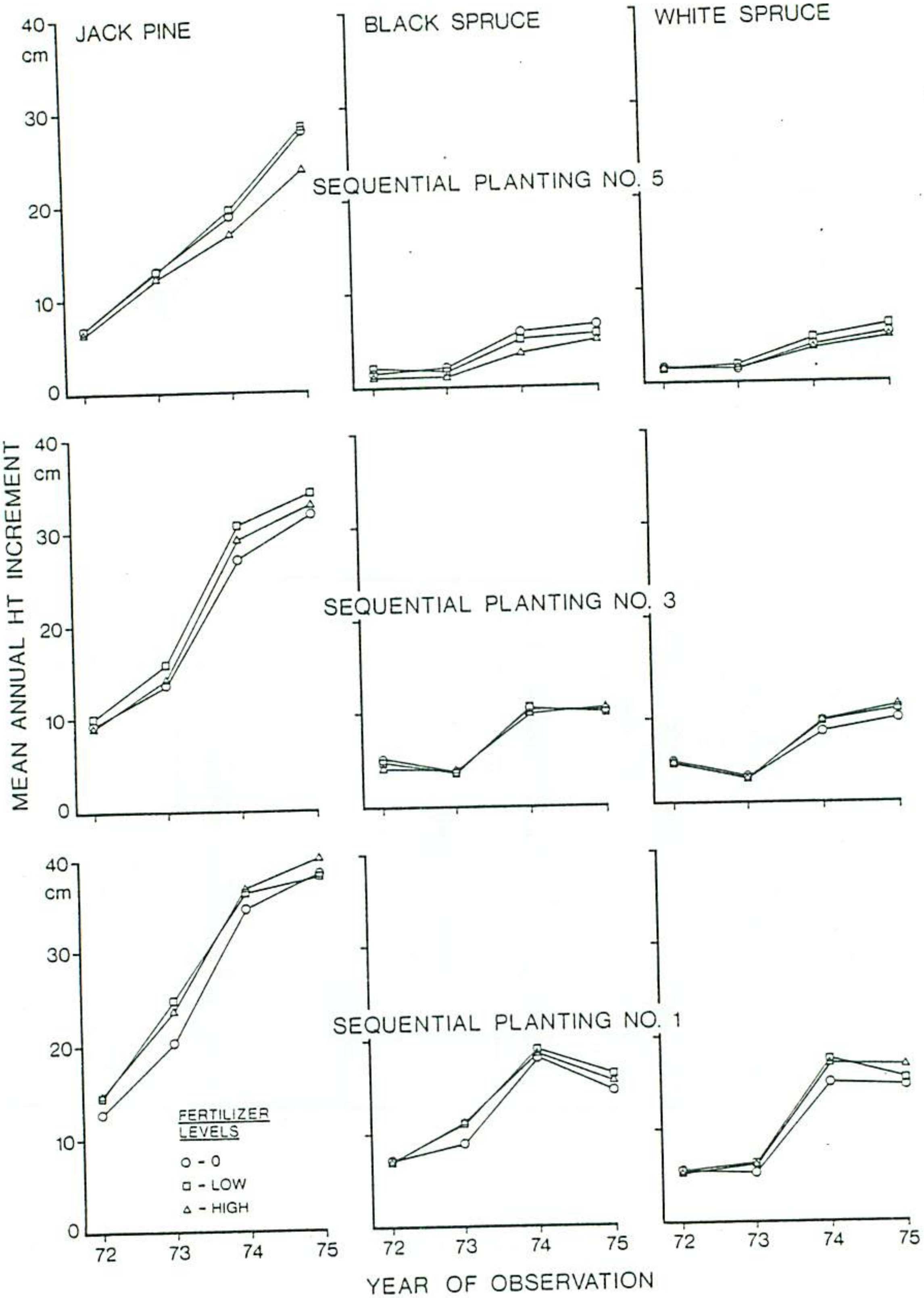

Figure 45. P72 mean annual height increment, 1st through 4th growing seasons after outplanting (sites combined) by selected sequential plantings, species, and fertilization treatment. P72 = planted in 1972; jP = jack pine, bS = black spruce, and wS = white spruce. Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; high fertilization treatment (Hi) = double the low rate.

Figure 46. P73 mean annual height increment, 1st through 4th growing seasons, by (a) Budd, (b), Fawn, (c) Dalton, selected sequential plantings, species, and fertilization treatment. P73 = planted in 1973; jP = jack pine, bS = black spruce, and wS = white spruce. Low fertilization treatment (Lo) = 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K; high fertilization treatment (Hi) = double the low rate.

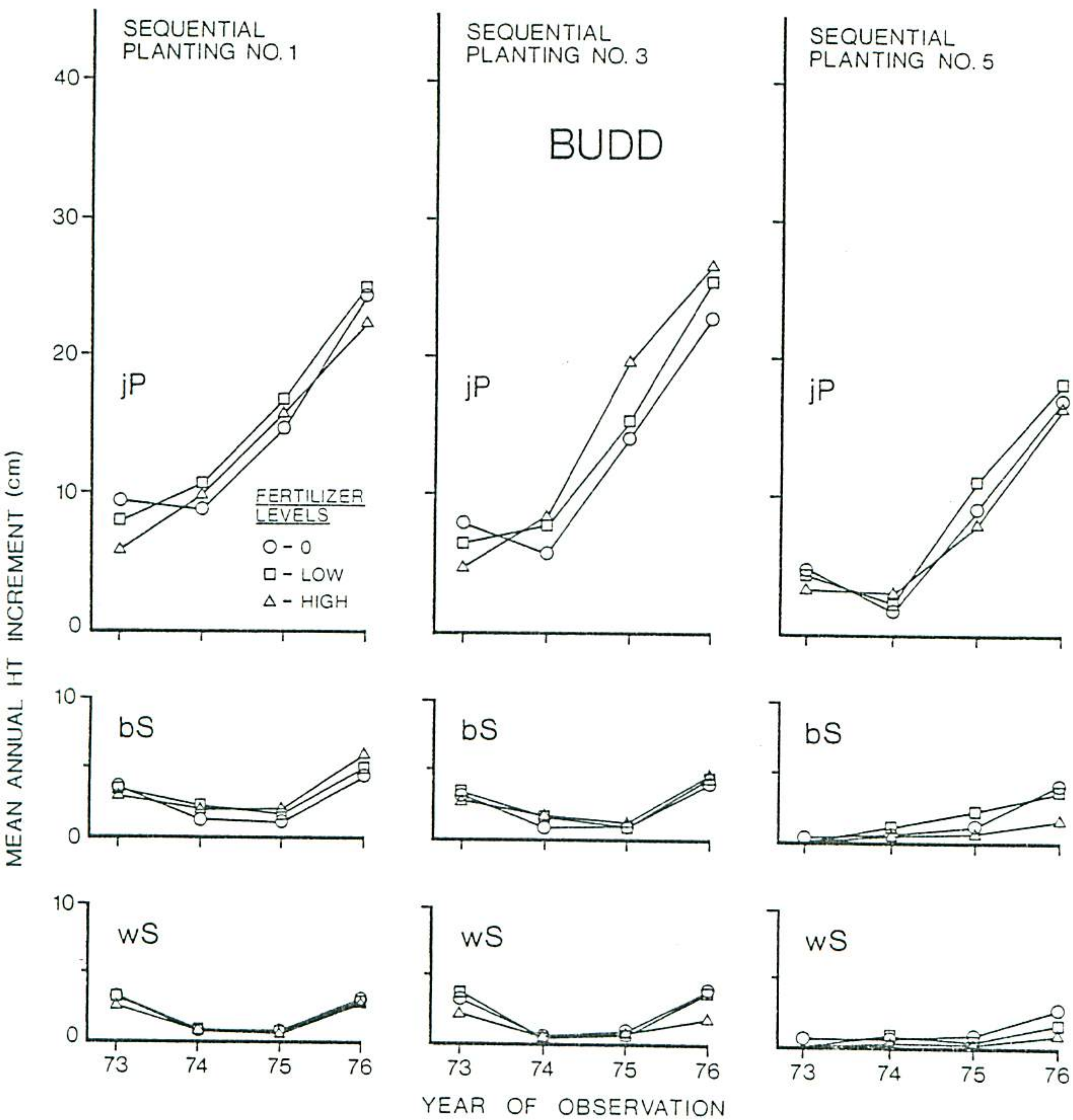

Figure 46 (a)

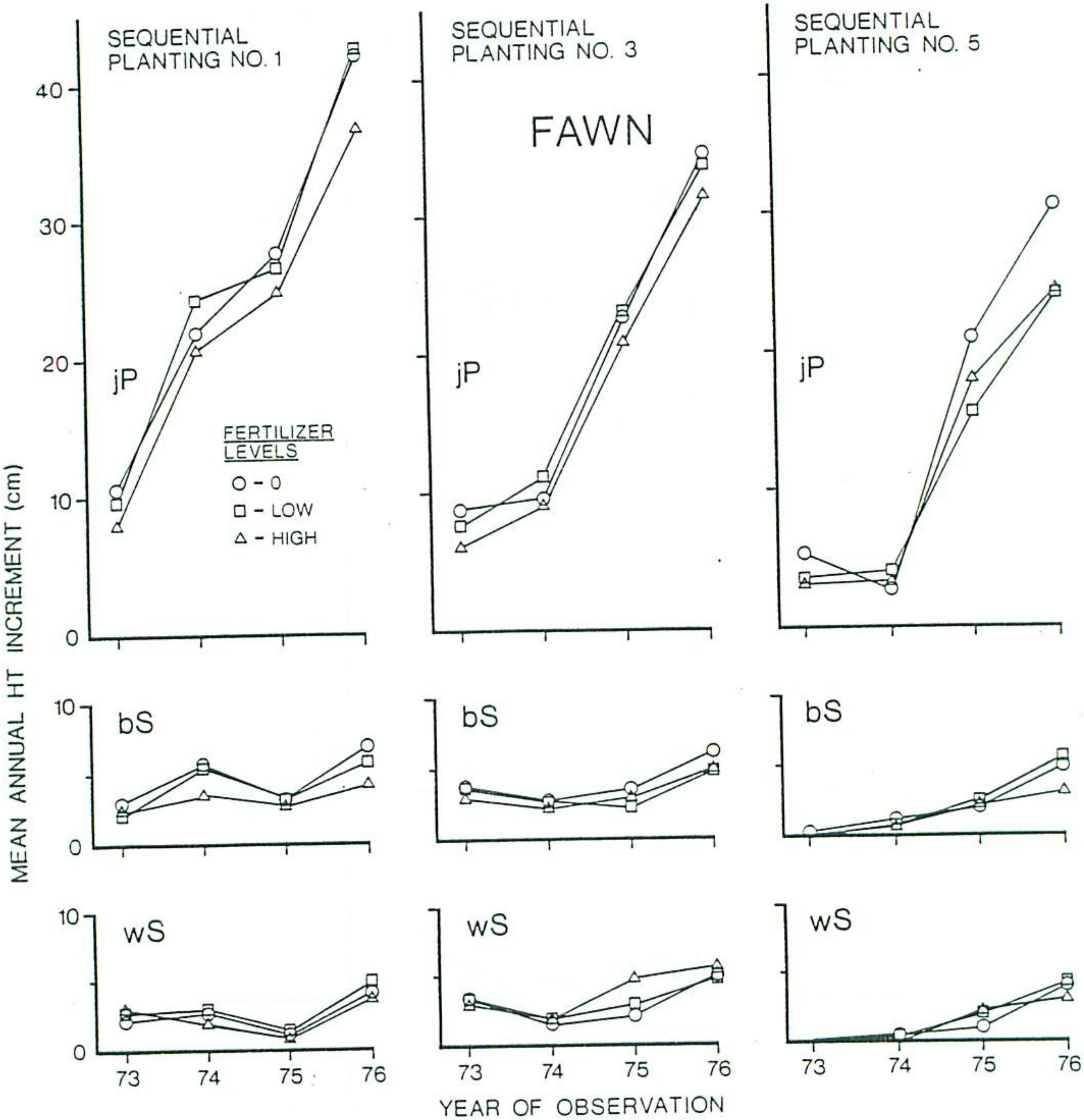
SEQUENTIAL PLANTING NO. 1
SEQUENTIAL PLANTING NO. 3
SEQUENTIAL PLANTING NO. 5
FAWN
jP
bS
wS
FERTILIZER LEVELS
○ - 0
□ - LOW
△ - HIGH
MEAN ANNUAL HT INCREMENT (cm)
0
10
20
30
40
73
74
75
76
YEAR OF OBSERVATION

Figure 46 (b)

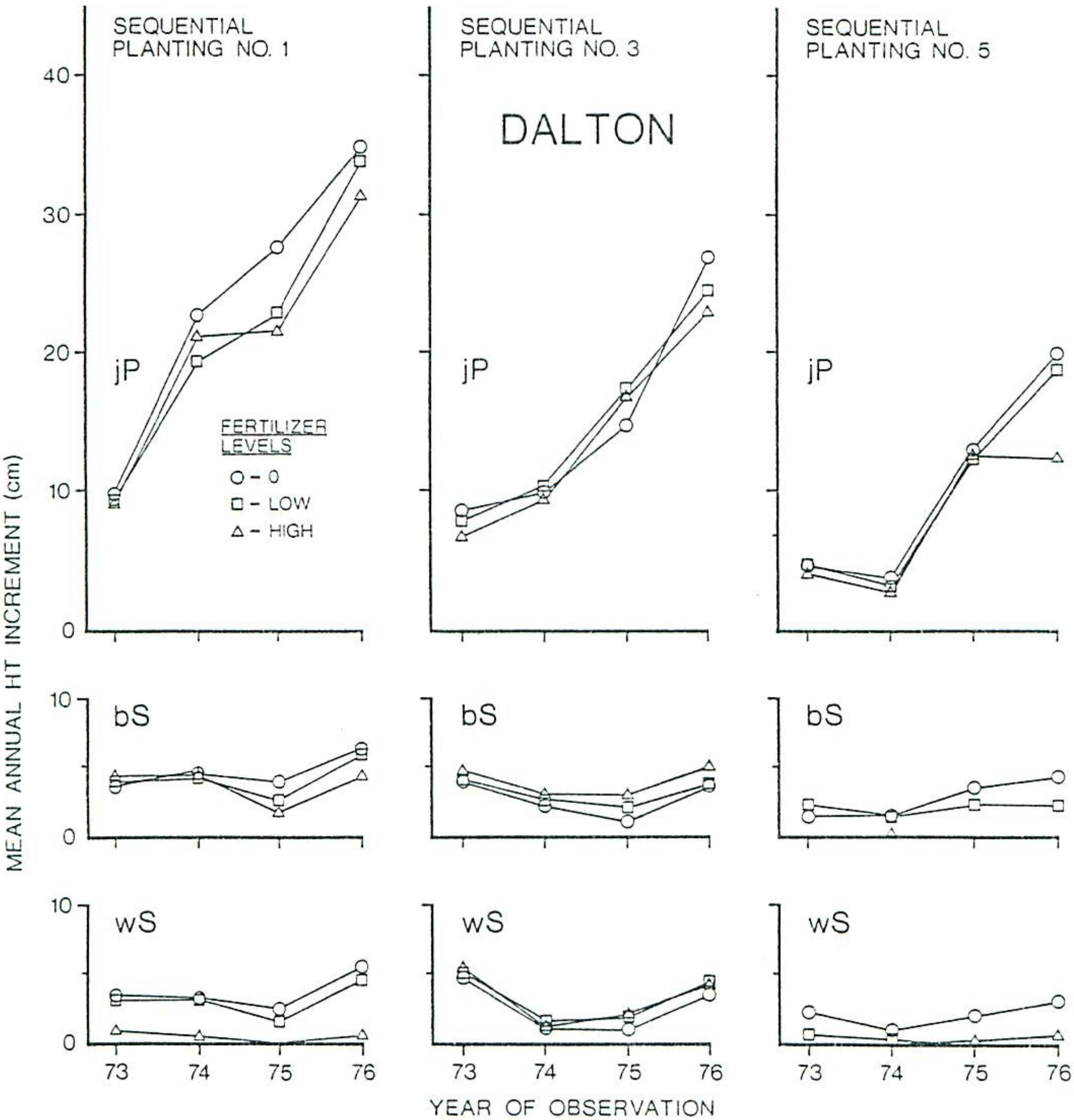
SEQUENTIAL PLANTING NO. 1
SEQUENTIAL PLANTING NO. 3
SEQUENTIAL PLANTING NO. 5
DALTON
jP
bS
wS
FERTILIZER LEVELS
○ – 0
□ – LOW
△ – HIGH
MEAN ANNUAL HT INCREMENT (cm)
0
10
20
30
40
73
74
75
76
YEAR OF OBSERVATION

Figure 46 (c)

The effect on growth of the fertilization treatments may be summed up thus: inconsistent, small, and unpromising. On other sites, in other years, and especially with less severely stressed planting stock, some sort of fertilization might be more successful, but similar results were reported by Leikola and Rikala (1974), who applied seven different treatments to one-tree plots of Scots pine and Norway spruce on various sites throughout Finland, and found that, in general, fertilization increased mortality in both species and that, at least during the first five growing seasons, neither height increment nor diameter increment was affected.

4.26

4.26 TILLING

Tilling, included as a variable only in the P73 plantings, generally improved survival but by no means consistently (Table 36). It was mainly disadvantageous in sandy soils that were dry at the time of planting and that therefore could not be properly firmed around the root systems of the outplants.

Table 36. Differential survival in favor of tilling compared with no tilling, by site, species, and P73 sequential planting, after one and four growing seasons.

		Species					
		Jack pine		Black spruce		White spruce	
		No. of growing seasons completed					
P73 Site	Sequential outplanting no.	1 (%)	4 (%)	1 (%)	4 (%)	1 (%)	4 (%)
Budd	1	- 0.3	- 0.3	- 4.2	+ 0.1	+16.3	+19.6
	2	- 1.0	- 0.4	+ 4.3	+ 1.4	+ 2.7	- 3.3
	3	+15.7	+15.6	+13.7	+17.7	+ 2.7	+ 8.0
	4	+ 9.7	+ 9.7	- 1.3	- 0.7	+13.7	+ 5.0
	5	+ 4.0	+ 4.0	+ 4.3	+ 1.3	+ 0.3	- 2.0
Fawn	1	- 4.0	- 1.4	+16.7	+16.4	+ 1.3	+ 0.7
	2	- 6.4	- 4.0	- 2.0	+ 0.3	- 3.6	- 4.4
	3	- 5.4	- 4.6	-11.3	- 8.0	- 1.0	+ 0.7
	4	- 3.7	+ 4.0	+ 1.7	- 3.0	+ 7.7	+ 1.3
	5	+ 0.6	+ 1.0	+ 1.4	- 1.7	+ 7.4	- 0.4
Dalton	1	- 4.4	- 9.2	+ 9.0	+ 2.4	- 7.3	-10.7
	2	+ 3.3	+ 4.0	+ 4.7	+ 0.4	+ 5.7	+ 4.7
	3	+ 6.3	+ 5.6	- 3.3	- 6.0	- 2.0	+ 0.3
	4	- 2.0	- 1.2	+ 7.3	+ 0.3	+ 9.0	+ 6.0
	5	+ 8.3	+ 7.6	+ 4.3	+ 1.0	+ 5.4	+ 0.6

With sequential planting included as a factor, tilling in several cases interacted significantly with other factors with respect to survival (Table 37). In such cases, discussion of tilling as a main effect is rendered inappropriate, but in two instances, viz., first-year survival in black spruce at Dalton and white spruce at Fawn, there were no significant interactions, and here the effect of tilling was significantly beneficial. As might be expected, the effect of tilling on survival tended to decline with time.

Table 37. Significance of effects of sequential planting date, fertilization, and tilling, by species and site, on survival after 1 and 4 years.

		Species					
		Jack pine		Black spruce		White spruce	
		Survival at end of year:					
P73 Site	Factor	1	4	1	4	1	4
Budd	PFT[a]	↓↓[b]	↓	NS	NS	NS	NS
	FT	↓↓	NS	NS	NS	↓↓	↓↓
	PT	↓↓	NS	NS	↓	↓	↓
	T	↑	NS	NS	↑	↑↑	↑
Fawn	PFT	NS	NS	↓	NS	NS	NS
	FT	NS	NS	NS	NS	NS	NS
	PT	NS	NS	↓↓↓	↓	NS	NS
	T	NS	NS	NS	NS	↑	NS
Dalton	PFT	NS	NS	NS	NS	NS	NS
	FT	NS	NS	NS	NS	↓	↓
	PT	NS	NS	NS	NS	NS	NS
	T	NS	NS	↑	NS	NS	NS

[a] P = Sequential planting date, F = Fertilization, T = Tilling.

[b] Arrows indicate significance at the P .05 (↓), P .01 (↓↓), and P .001 (↓↓↓) levels respectively. Arrows that point downwards indicate decreased survival; arrows that point upwards indicate increased survival.

In treatments not involving fertilization, the effect of tilling on growth was small and, in jack pine and black spruce, as often negative as positive (Table 38). In white spruce, the effect of tilling, though small, was always positive at all levels of fertilization and for mean annual height increments in each of the first four years after outplanting as well as for total height after four years.

Table 38. Differential mean height increments (years 1 through 4) and mean total heights in favor of tilling compared with no tilling, sequential plantings 1 through 5 and sites over all, by species and fertilization treatment.

		Differential				
		Mean annual height increment				Total height after four growing seasons (cm)
P73 Species	Fertilization level[a]	1st yr (cm)	2nd yr (cm)	3rd yr (cm)	4th yr (cm)	
Jack pine	0	-0.04	-0.42	-0.40	0.84	0.10
	Lo	0.47	0.09	1.86	2.68	5.89
	Hi	0.42	0.48	1.78	4.03	7.62
Black spruce	0	0.03	0.22	-0.09	-0.14	-0.41
	Lo	0.02	0.35	0.02	0.07	1.45
	Hi	0.32	0.51	0.76	0.67	3.32
White spruce	0	0.25	0.06	0.13	0.26	1.52
	Lo	0.21	0.38	0.43	0.62	2.27
	Hi	0.24	0.40	0.30	0.49	2.07

[a] 43 kg/ha N, 19 kg/ha P, and 36 kg/ha K at the low (Lo) rate: double this at the high (Hi) rate.

The effect of tilling in the fertilization treatments was, without exception, beneficial in all three species, although the mean differentials ([low rate differential + high rate differential] ÷ 2) were small: 0.44 cm, 0.28 cm, 1.82 cm, and 3.35 cm in the first- through fourth-year mean annual height increments, respectively, and 6.75 cm in fourth-year total height in jack pine; differentials were much lower in the spruces.

Interaction between tilling and fertilization is negligible when sequential plantings are considered over all (Table 39). White spruce responded to tilling more than did the other species: white spruce showed significant positive responses in mean annual height increment in each of the second, third, and fourth years as well as in total height after four years. The incremental amounts were of course small.

In summary, tilling generally improved survival and growth, but not by much, and the effect was achieved mainly in consequence of amelioration of the adverse effects of other treatments.

Table 39. Significance of tilling and fertilization for mean height increments for years 1-4 and mean total height after four years, sequential plantings (1-5) over all, by species.

P73 Species	Treatment	Mean annual height increment				Mean total height after 4 yrs
		1st yr	2nd yr	3rd yr	4th yr	
Jack pine	Tilling	NS[a]	NS	NS	**	*
	Fertilization	***	NS	NS	NS	NS
	T x F	NS	NS	NS	NS	NS
Black spruce	Tilling	NS	*	NS	NS	NS
	Fertilization	NS	NS	NS	NS	**
	T x F	NS	NS	*	NS	NS
White spruce	Tilling	NS	*	*	**	**
	Fertilization	**	NS	NS	*	**
	T x F	NS	NS	NS	NS	NS

[a] NS = not significant; *, **, and *** = significant at P .05, P .01, and P .001 levels, respectively.

5. SUMMARY AND CONCLUSIONS 5.

Nine sequential outplantings per year were carried out with 2+0 jack pine, 3+0 black spruce, and 3+0 white spruce shipping-run, spring-lifted, cold-stored, bare-root stock, in the boreal forest of Ontario at intervals of two weeks through the growing seasons of 1971, 1972, and 1973 after the close of the conventional planting season. The trees were planted on three sites (two sandy outwash sites and a mixedwood till site) a year, and various fertilization and tilling treatments were applied. The objective was to determine the extent to which the conventional planting season may be extended in normal operational plantings by the use of such stock. A fully randomized factorial experimental design was used, with 3 years of planting x 3 sites x 9 planting dates of sequential planting x 3 species x 3 levels of NPK fertilization x 2 weed control or tilling treatments x 5 replications, in 20-tree plots, for a total of 145,800 trees. The results of the first four years after outplanting are reported here.

The main features of the outplantation performance are dominated by the effect of sequential planting date: reasonably good survival for the first one or two outplantings up to about the end of July, a rapid decline in survival thereafter, parallel behavior in terms of height growth of survivors, i.e., the poorer the survival rate, the poorer the growth rate of survivors; much more rapid growth in jack pine than in the spruces, and the superior height growth rate of black spruce over white spruce. There was no sign of stock being able to endure storage (of the kind used) long enough to be outplanted in late summer or fall, then to survive in natural cold storage until the following spring. In broad terms, the first- through fourth-year results were remarkably similar for all sites and for all years of establishment. This would seem to indicate that deterioration of planting stock in storage was the main determining factor. Evidence from the literature suggests strongly that, especially with the spruces, the planting season could most effectively be extended by using late-fall-lifted, cold-stored stock during the first part of the season, then, once the fresh planting stock in the nursery has passed through the period of most active shoot extension, changing to fresh-lift/quick-plant procedures.

Considerable improvement in the results obtained in the present study should be possible with improved storage practice, but the main conclusions would probably not require revision.

Time of lifting, whether the stock is to be planted fresh or after storage, is another major factor determining the outcome of outplantings. Once the physiological interactions between lifting date, storage environment, and planting environment have been ascertained, the potential for extending the planting season and for improving the results from plantings in the conventional planting season should be good.

Fertilization, as carried out in this study, was clearly unsuccessful. It significantly decreased survival, and, except for some of the early sequential plantings, also had a negative effect on height increment.

Tilling was modestly beneficial, mainly because it relieved some of the adverse effects of fertilization.

The study shows that spring-lifted, shipping-run, bare-root stock, even after primitive cold storage, may be used to extend the planting season in boreal Ontario until the end of July.

6. 6. LITERATURE CITED

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APPENDICES

APPENDIX A. Till site flora.

The lesser vegetation on the till soils in the study included: wild sarsaparilla *(Aralia nudicaulis* L.), ciliate aster *(Aster ciliolatus* Lindl.), large-leaved aster *(A. macrophyllus* L.), corn-lily *(Clintonia borealis* [Ait.] Raf.), goldthread *(Coptis groenlandica* [Oeder] Fern.), bunchberry *(Cornus canadensis* L.), bush-honeysuckle *(Diervilla lonicera* Mill.), sweet-scented bedstraw *(Galium triflorum* Michx.), twinflower *(Linnaea borealis* var. *americana* [Forbes] Rehd.), fly-honeysuckle *(Lonicera canadensis* Bartr.), wild lily-of-the-valley *(Maianthemum canadense* Desf.), bishop's cap *(Mitella nuda* L.), bracken *(Pteridium aquilinum* [L.] Kuhn), one-sided wintergreen *(Pyrola secunda* L.), greenish wintergreen *(P. virens* Schweigger), raspberry *(Rubus idaeus* var. *strigosus* [Michx.] Maxim., twisted-stalk *(Streptopus roseus* Michx.), star-flower *(Trientalis borealis* Raf.), and kidney-leaved violet *(Viola renifolia* Gray) in the ground layer, as well as some grasses, including *Oryzopsis canadensis* (Poir.) Torr. and *Panicum columbianum* Scribn.

APPENDIX B. Basic data used in weather summaries.

CHAPLEAU REGION PRECIPITATION

(a) Precipitation (mm), monthly April through October and total May through September

Year	Station	Period							
		Apr	May	June	July	Aug	Sept	Oct	May-Sept
1971	Biscotasing	44.20	91.69	31.50	59.69	89.92	75.18	89.15	347.98
	Chapleau	42.40	134.11	101.35	55.37	49.78	78.23	84.33	418.84
	Foleyet	-	91.69	44.20	52.07	53.34	73.15	61.47	314.45
	Mean	43.30	105.83	59.02	55.71	64.35	75.52	78.32	360.43
1972	Biscotasing	44.45	73.66	58.93	90.93	177.80	57.15	33.78	458.47
	Chapleau	24.64	80.77	81.28	116.08	178.05	87.38	53.34	543.56
	Foleyet	-	90.17	61.98	119.13	47.50	60.71	27.69	379.49
	Mean	34.54	81.53	67.40	108.71	134.45	68.41	38.27	460.55
1973	Chapleau	39.88	88.90	128.52	108.71	43.94	97.28	56.39	467.35
	Foleyet	-	75.44	-	67.31				
	Ramsay					86.36	61.21	47.50	
	Mean	39.88	82.17	128.52	88.01	65.15	79.25	51.94	443.1
(No data for Biscotasing)									
1974	Chapleau	81.03	58.42	101.35	43.43	122.68	125.98	78.23	451.86
	Ramsay	64.77	60.96	56.90	66.04	51.56	110.74	97.54	346.2
	Mean	72.90	59.69	79.12	54.74	87.12	118.36	87.88	399.03
(No data for Biscotasing or Foleyet)									
1975	Chapleau	61.98	115.06	71.37	19.05	16.00	98.30	57.15	319.78
	Ramsay	78.49	192.79	102.87	26.16	64.26	144.78	61.98	530.86
	Mean	70.24	153.92	87.12	22.60	40.13	121.54	59.56	425.31
(No data for Biscotasing or Foleyet)									
1976	Ramsay	82.30	74.17	37.08	64.26	67.06	104.65	58.93	347.22
(No data for Biscotasing, Chapleau or Foleyet)									

(b) Precipitation (mm), differences from normal

Year	Station	Period							
		Apr	May	June	July	Aug	Sept	Oct	May-Sept
1971	Biscotasing	-8.13	25.91	-46.99	-25.65	19.05	-13.97	16.26	-41.65
	Chapleau	-13.72	67.31	24.89	-22.86	-27.69	-19.56	17.53	22.09
	Foleyet	-	24.89	-29.21	-20.57	-20.32	-10.92	-0.25	-56.13
	Mean	-10.92	39.37	-17.10	-23.03	-9.65	-14.82	11.18	-25.23

(cont'd.)

APPENDIX 3. Basic data used in weather summaries (cont'd.)

(b) Precipitation (mm), differences from normal

Year	Station	Period							
		Apr	May	June	July	Aug	Sept	Oct	May-Sept
1972	Biscotasing	-7.87	7.87	-19.56	5.59	106.93	-32.00	-39.12	68.83
	Chapleau	-31.50	13.97	4.83	37.85	100.58	-10.41	-13.46	146.82
	Foleyet	-	23.37	-11.43	46.48	-26.16	-24.48	-34.04	7.78
	Mean	-19.68	15.07	-8.72	29.97	60.45	-22.30	-28.87	74.47
1973	Chapleau	-11.43	19.30	44.45	30.99	-49.78	-9.65	-10.16	35.31
	Foleyet	-	8.64	-	-6.10				
	Ramsay					7.37	-27.94	-6.60	
	Mean	-11.43	13.97	44.45	12.44	-21.20	-18.79	-8.38	30.87
	(No data for Biscotasing)								
1974	Chapleau	29.72	-11.18	17.27	-34.29	28.96	19.05	11.68	19.81
	Ramsay	26.92	-4.06	-24.38	-15.24	-27.43	21.59	43.43	-49.52
	Mean	28.32	-7.62	-3.56	-24.76	0.76	20.32	27.56	-14.86
	(No data for Biscotasing or Foleyet)								
1975	Chapleau	10.67	45.47	-12.70	-58.67	-77.72	-8.64	-9.40	-112.26
	Ramsay	40.64	127.46	21.59	-55.12	-14.73	55.63	7.87	135.13
	Mean	25.66	86.62	4.44	-56.90	-46.22	23.50	-0.76	11.44
	(No data for Biscotasing or Foleyet)								
1976	Ramsay	44.45	9.14	-44.20	-17.02	-11.94	15.49	4.83	-48.53
	(No data for Biscotasing, Chapleau or Foleyet)								

MANITOUWADGE REGION PRECIPITATION

(a) Precipitation (mm), monthly April through October and total May through September

Year	Station	Period							
		Apr	May	June	July	Aug	Sept	Oct	May-Sept
1971	Manitouwadge	17.02	85.60	49.28	124.71	44.45	114.05	93.73	418.09
	Hornepayne	27.69	80.77	155.19	124.70	65.53	87.63	114.55	513.82
	Mean	22.36	83.18	102.24	124.70	55.02	100.84	104.14	465.98
1972	Manitouwadge	10.92	43.18	39.62	155.19	57.66	131.32	46.74	426.97
	Hornepayne	1.52	37.59	50.29	91.44	51.56	68.58	41.66	299.46
	Mean	6.22	40.38	44.96	123.32	54.61	99.95	44.20	363.22

(cont'd.)

APPENDIX B. Basic data used in weather summaries (cont'd.)

(a) Precipitation (mm), monthly April through October and total May through September

Year	Station	Apr	May	June	July	Aug	Sept	Oct	May-Sept
		Period							
1973	Manitouwadge	34.80	76.71	75.44	73.91	70.36	119.63	53.59	416.05
	Horneypayne	14.22	50.29	108.46	88.39	52.58	85.85	31.24	385.57
	Mean	24.51	63.50	91.95	81.15	61.47	102.74	42.42	400.81
1974	Manitouwadge	76.20	48.26	80.26	96.01	190.25	102.11	73.91	516.89
	Hornepayne	73.66	78.99	54.86	53.59	91.69	85.34	54.10	364.47
	Mean	74.93	63.62	67.56	74.80	140.97	93.73	64.00	440.68
1975	Manitouwadge	39.12	32.77	122.43	34.80	29.72	70.36	114.55	290.08
	Hornepayne	20.83	74.17	51.31	56.13	28.19	-	44.45	
	Mean	29.98	53.47	86.87	45.46	28.96	70.36	79.50	285.12
1976	Manitouwadge	44.45	4.32	118.62	56.39	54.36	72.64	24.64	306.33
	Hornepayne	34.29	39.37	114.05	51.05	44.70	48.01	14.22	297.18
	Mean	39.37	21.84	116.34	53.72	49.53	60.32	19.43	301.75

(b) Precipitation (mm), differences from normal

Year	Station	Apr	May	June	July	Aug	Sept	Oct	May-Sept
		Period							
1971	Hornepayne	-10.92	15.75	80.01	58.93	-3.05	1.27	59.69	152.91
(No data for Manitouwadge)									
1972	Hornepayne	-37.08	-27.43	-24.42	25.65	-17.02	-17.78	-13.21	-61.00
(No data for Manitouwadge)									
1973	Manitouwadge	-22.10	-2.03	-16.51	-2.79	-23.37	19.56	-16.26	-25.14
	Hornepayne	-34.04	-21.34	32.26	8.13	-18.80	1.78	-31.75	2.03
	Mean	-28.07	-11.68	7.88	2.67	-21.08	10.67	-24.00	-11.54
1974	Manitouwadge	19.30	-30.48	-11.68	19.30	96.52	2.03	4.06	75.69
	Hornepayne	24.64	7.37	-21.34	-22.35	20.32	1.27	-8.89	-14.73
	Mean	21.97	-11.56	-16.51	-1.53	58.42	1.65	2.42	30.47
1975	Manitouwadge	-17.78	-38.35	30.48	-41.91	-64.01	-29.72	44.70	-143.51
	Hornepayne	-28.19	2.54	-24.89	-19.81	-43.18	-	-18.54	
	Mean	-22.98	-17.90	2.79	-30.86	-53.60	-29.72	13.08	-129.29

(cont'd.)

APPENDIX B. Basic data used in weather summaries (cont'd.)

(b) Precipitation (mm), differences from normal

Year	Station	Period							
		Apr	May	June	July	Aug	Sept	Oct	May-Sept
1976	Manitouwadge	-12.45	-74.42	26.67	-20.32	-39.37	-27.43	-45.21	-134.87
	Hornepayne	-14.73	-32.26	37.85	-24.89	-26.67	-36.07	-48.77	-82.04
	Mean	-13.59	-53.34	32.26	-22.60	-33.02	-31.75	-46.99	-108.45

CHAPLEAU REGION TEMPERATURES

(a) Mean daily temperature (°C), monthly April through October

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Biscotasing	1.2	7.7	16.0	15.3	15.1	13.1	9.4
	Chapleau	0.2	7.2	16.1	15.1	14.8	12.6	8.7
	Foleyet	0.6	7.1	15.2	15.1	14.3	12.9	9.2
	Mean	0.7	7.3	15.8	15.2	14.7	12.9	9.1
1972	Biscotasing	-1.6	10.3	12.9	15.7	14.1	10.1	2.0
	Chapleau	-2.1	10.7	13.2	15.4	14.3	9.6	2.3
	Foleyet	–	10.3	12.4	15.4	14.4	9.8	2.9
	Mean	-1.8	10.4	12.8	15.6	14.3	9.8	2.4
1973	Chapleau	2.0	7.4	15.2	17.1	18.3	11.1	7.6
	Foleyet	–	7.0	–	16.9			
	Ramsay					18.2	10.8	7.6
	Mean	2.0	7.2	15.2	17.0	18.2	11.0	7.6
1974	Chapleau	-0.5	6.6	14.4	17.4	15.2	7.7	2.7
	Ramsay	0.7	7.1	14.7	17.5	15.3	8.0	2.6
	Mean	0.1	6.8	14.6	17.4	15.2	7.8	2.6
(No data for Foleyet)								
1975	Chapleau	-2.2	12.4	15.9	19.0	16.8	9.3	5.6
	Ramsay	-1.6	13.3	15.9	18.1	16.6	9.4	5.5
	Mean	-1.9	12.8	15.9	18.6	16.7	9.4	5.6
(No data for Foleyet)								
1976	Ramsay	3.0	8.4	16.7	16.6	15.8	9.7	2.5

(No data for Chapleau or Foleyet)

(cont'd.)

APPENDIX B. Basic data used in weather summaries (cont'd.)

(b) Absolute monthly maximum temperature (°C)

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Biscotasing	16.1	24.4	31.7	27.2	30.0	30.0	25.6
	Chapleau	15.0	25.0	32.8	25.6	30.0	29.4	22.8
	Foleyet	17.8	26.7	33.9	26.7	30.6	30.0	25.6
	Mean	16.3	25.4	32.8	26.5	30.2	29.8	24.7
1972	Biscotasing	20.0	30.6	28.3	28.3	27.2	22.2	21.7
	Chapleau	18.3	30.6	28.9	27.8	27.8	20.5	21.7
	Foleyet	-	30.6	29.4	27.8	33.3	23.3	21.7
	Mean	19.2	30.6	28.9	28.0	29.4	22.0	21.7
1973	Chapleau	22.2	23.3	27.2	28.9	29.4	29.4	23.3
	Foleyet	-	24.4	-	31.7			
	Ramsay					30.0	30.0	22.2
	Mean	22.2	23.8	27.2	30.3	29.7	29.7	22.8
1974	Chapleau	21.1	28.3	29.4	31.7	27.8	23.9	17.8
	Ramsay	20.5	28.9	29.4	32.2	29.4	23.3	16.7
	Mean	20.8	28.6	29.4	32.0	28.6	23.6	17.2
(No data for Foleyet)								
1975	Chapleau	15.0	31.1	31.7	37.2	35.0	24.4	20.0
	Ramsay	15.0	32.2	31.1	37.2	35.6	22.2	20.6
	Mean	15.0	31.6	31.4	37.2	35.3	23.3	20.3
(No data for Foleyet)								
1976	Ramsay	26.1	26.7	31.1	31.1	35.0	32.2	24.4

(No data for Chapleau or Foleyet)

(c) Absolute monthly minimum temperature (°C)

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Biscotasing	-21.7	-7.8	-2.2	1.1	-2.8	-2.8	-4.4
	Chapleau	-19.4	-6.1	0.6	5.0	0.0	-0.5	-2.2
	Foleyet	-19.4	-7.8	-2.8	1.7	-2.8	-2.2	-5.0
	Mean	-20.2	-7.2	-1.5	2.6	-1.9	-1.8	-3.9

(cont'd.)

APPENDIX B. Basic data used in weather summaries (cont'd.)

(c) Absolute monthly minimum temperature (°C)

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1972	Biscotasing	-29.4	-11.7	-2.8	-0.6	0.0	-3.3	-12.2
	Chapleau	-29.4	-6.7	-1.7	2.8	2.8	-1.7	-9.4
	Foleyet	-32.2	-7.8	-2.2	-1.7	-0.6	-3.3	-11.7
	Mean	-30.3	-8.7	-2.2	0.2	0.7	-2.8	-11.1
1973	Chapleau	-14.4	-4.4	0.0	5.6	3.3	-2.8	-5.0
	Foleyet	-	-4.4	-	3.9			
	Ramsay					1.1	-5.6	-4.4
	Mean	-14.4	-4.4	0.0	4.8	2.2	-4.2	-4.7
1974	Chapleau	-30.0	-10.0	3.3	5.6	5.0	-3.3	-8.3
	Ramsay	-27.8	-6.1	0.0	3.3	2.8	-4.4	-11.1
	Mean	-28.9	-8.0	1.6	4.4	3.9	-3.8	-9.7
(No data for Foleyet)								
1975	Chapleau	-28.3	-3.3	0.6	6.1	1.7	-2.2	-10.0
	Ramsay	-28.9	-2.2	0.0	2.8	1.1	-3.9	-10.6
	Mean	-28.6	-2.8	0.3	4.4	1.4	-3.0	-10.3
(No data for Foleyet)								
1976	Ramsay	-16.7	-7.2	-0.6	2.2	-4.4	-4.4	-8.9
(No data for Chapleau or Foleyet)								

(d) Mean daily temperature (°C), difference from normal

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Biscotasing	-0.7	-1.8	0.9	-2.1	-1.1	1.6	3.7
	Chapleau	-0.2	-1.5	1.6	-1.9	-0.5	2.4	4.7
	Foleyet	0.7	-1.1	1.5	-1.1	-0.9	2.4	4.1
	Mean	-0.1	-1.5	1.3	-1.7	-0.8	2.1	4.2
1972	Biscotasing	-3.5	0.8	-2.2	-1.7	-2.1	-1.4	-3.7
	Chapleau	-2.8	2.1	-1.3	-1.3	-1.1	-0.6	-1.8
	Foleyet	-	2.1	-1.3	-0.7	-0.8	-0.8	-2.2
	Mean	-3.2	1.7	-1.6	-1.2	-1.3	-0.9	-2.6

(cont'd.)

APPENDIX 3. Basic data used in weather summaries (cont'd.)

(d) Mean daily temperature (°C), difference from normal

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1973	Chapleau	1.0	-1.2	0.9	0.4	3.5	0.9	3.1
	Foleyet	-	-1.0	-	0.8			
	Ramsay					2.6	-0.1	1.6
	Mean	1.0	-1.1	0.9	0.6	3.0	0.4	2.4
1974	Chapleau	-1.5	-2.1	0.1	0.8	0.3	-2.4	-1.8
	Ramsay	-1.1	-2.2	0.0	0.3	-0.3	-2.9	-3.3
	Mean	-1.3	-2.2	0.0	0.6	0.0	-2.6	-2.6
(No data for Foleyet)								
1975	Chapleau	-3.2	3.7	1.6	2.4	1.9	-0.8	1.1
	Ramsay	-3.4	4.0	1.2	0.9	0.9	-1.6	-0.4
	Mean	-3.3	3.8	1.4	1.6	1.4	-1.2	0.4
(No data for Foleyet)								
1976	Ramsay	1.2	-0.9	2.0	0.6	0.2	-1.3	-3.4

(No data for Chapleau or Foleyet)

MANITOUWADGE REGION TEMPERATURES

(a) Mean daily temperature (°C), monthly April through October

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Manitouwadge	1.7	7.3	15.8	15.2	15.4	12.8	7.5
	Hornepayne	-0.5	7.9	14.2	12.6	12.1	12.7	7.5
	Mean	0.6	7.6	15.0	13.9	13.8	12.8	7.5
1972	Manitouwadge	-0.6	11.7	14.0	16.5	15.6	9.2	2.7
	Hornepayne	-3.9	10.9	13.0	15.2	14.0	7.5	2.2
	Mean	-2.2	11.3	13.5	15.8	14.8	8.4	2.4
1973	Manitouwadge	1.6	7.4	14.5	17.5	18.7	10.8	8.1
	Hornepayne	0.3	7.6	13.9	15.6	16.2	11.9	7.9
	Mean	1.0	7.5	14.2	16.6	17.4	11.4	8.0
1974	Manitouwadge	-0.7	6.3	14.1	18.0	15.4	7.7	2.8
	Hornepayne	-6.3	7.8	14.3	17.7	17.7	8.4	2.2
	Mean	-3.5	7.0	14.2	17.8	16.6	8.0	2.5

(cont'd.)

APPENDIX B. Basic data used in weather summaries (cont'd.)

(a) Mean daily temperature (°C), monthly April through October

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1975	Manitouwadge	-0.9	12.9	16.2	19.2	16.6	9.3	5.0
	Hornepayne	-0.6	12.4	15.3	18.6	16.1	-	4.6
	Mean	-0.8	12.6	15.8	18.9	16.4	9.3	4.8
1976	Manitouwadge	2.6	8.6	17.0	17.9	16.9	9.7	2.5
	Hornepayne	1.9	7.9	17.1	17.1	15.4	8.1	4.1
	Mean	2.2	8.2	17.0	17.5	16.2	8.9	3.3

(b) Absolute monthly maximum temperature (°C)

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Manitouwadge	17.8	24.4	31.1	25.6	32.2	28.3	18.3
	Hornepayne	15.6	23.9	31.7	25.6	30.6	27.2	20.0
	Mean	16.7	24.2	31.4	25.6	31.4	27.8	19.2
1972	Manitouwadge	22.2	31.7	30.6	28.3	29.4	20.6	19.4
	Hornepayne	25.0	28.9	30.0	29.4	28.3	26.1	21.7
	Mean	23.6	30.3	30.3	28.8	28.8	23.4	20.6
1973	Manitouwadge	22.2	27.8	26.7	30.6	31.1	28.3	24.4
	Hornepayne	21.1	26.7	26.7	28.3	30.0	26.7	22.8
	Mean	21.6	27.2	26.7	29.4	30.6	27.5	23.6
1974	Manitouwadge	19.4	27.2	29.4	32.8	30.0	21.1	15.0
	Hornepayne	20.0	28.9	28.3	31.7	28.9	21.1	16.1
	Mean	19.7	28.0	28.8	32.2	29.4	21.1	15.6
1975	Manitouwadge	16.7	31.7	34.4	39.4	32.8	22.2	19.4
	Hornepayne	16.1	30.0	30.6	37.2	31.1	-	18.3
	Mean	16.4	30.8	32.5	38.3	32.0	22.2	18.8
1976	Manitouwadge	17.8	31.7	32.2	33.9	30.6	30.6	22.8
	Hornepayne	16.7	28.9	30.6	30.0	30.0	28.3	21.7
	Mean	17.2	30.3	31.4	32.0	30.3	29.4	22.2

(cont'd.)

APPENDIX B. Basic data used in weather summaries (cont'd.)

(c) Absolute monthly minimum temperature (°C)

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Manitouwadge	-15.6	-5.6	0.0	3.9	-1.1	-0.6	-2.2
	Hornepayne	-16.1	-6.7	-2.2	3.3	-3.3	-2.2	-5.6
	Mean	-15.8	-6.2	-1.1	3.6	-2.2	-1.4	-3.9
1972	Manitouwadge	-30.0	-11.1	-2.8	-1.1	0.6	-2.8	-11.1
	Hornepayne	-30.0	-5.6	-4.4	-1.7	-0.6	-5.0	-12.8
	Mean	-30.0	-8.4	-3.6	-1.4	0.0	-3.9	-12.0
1973	Manitouwadge	-16.1	-3.3	-1.1	5.0	5.0	-2.2	-8.3
	Hornepayne	-16.7	-2.8	-2.2	3.9	2.2	-3.3	-3.9
	Mean	-16.4	-3.0	-1.6	4.4	3.6	-2.8	-6.1
1974	Manitouwadge	-27.8	-13.3	1.7	5.6	1.7	-5.6	-10.6
	Hornepayne	-26.1	-5.0	4.4	4.4	1.1	-5.0	-9.4
	Mean	-27.0	-9.2	3.0	5.0	1.4	-5.3	-10.0
1975	Manitouwadge	-22.8	-3.9	1.7	4.4	2.2	-3.9	-8.9
	Hornepayne	-23.9	-6.7	0.6	3.3	3.3	-	-8.3
	Mean	-23.4	-5.3	1.2	3.8	2.8	-3.9	-8.6
1976	Manitouwadge	-13.9	-4.4	2.8	5.6	-0.6	-2.8	-8.9
	Hornepayne	-23.3	-6.1	0.6	5.0	-2.2	-2.8	-7.8
	Mean	-18.6	-5.2	1.7	5.3	-1.4	-2.8	-8.4

(d) Mean daily temperature (°C), difference from normal

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1971	Hornepayne	0.7	0.9	0.6	-3.9	-2.6	2.8	3.6
(No data for Manitouwadge)								
1972	Hornepayne	-2.7	3.9	-0.6	-1.2	-0.7	-2.3	-1.7
(No data for Manitouwadge)								
1973	Manitouwadge	0.6	-0.7	0.2	0.1	2.9	0.1	2.9
	Hornepayne	0.1	0.4	0.7	-0.3	1.9	2.4	3.9
	Mean	0.4	-0.2	0.4	-0.1	2.4	1.2	3.4

(cont'd.)

APPENDIX B. Basic data used in weather summaries (concl'd.)

(d) Mean daily temperature (°C), difference from normal

Year	Station	Period						
		Apr	May	June	July	Aug	Sept	Oct
1974	Manitouwadge	-1.6	-1.8	-0.3	0.6	-0.3	-3.0	-2.4
	Hornepayne	-6.5	0.6	1.1	1.8	0.3	-1.1	-1.8
	Mean	-4.0	-0.6	0.4	1.2	0.0	-2.0	-2.1
1975	Manitouwadge	-1.8	4.8	1.9	1.8	0.8	-1.4	-0.2
	Hornepayne	-0.8	5.3	2.1	2.6	1.8	-	0.6
	Mean	-1.3	5.0	2.0	2.2	1.3	-1.4	0.2
1976	Manitouwadge	1.7	0.6	2.7	0.5	1.2	-1.0	-2.7
	Hornepayne	1.7	0.7	3.8	1.2	1.2	-1.4	0.1
	Mean	1.7	0.6	3.2	0.8	1.2	-1.2	-1.3