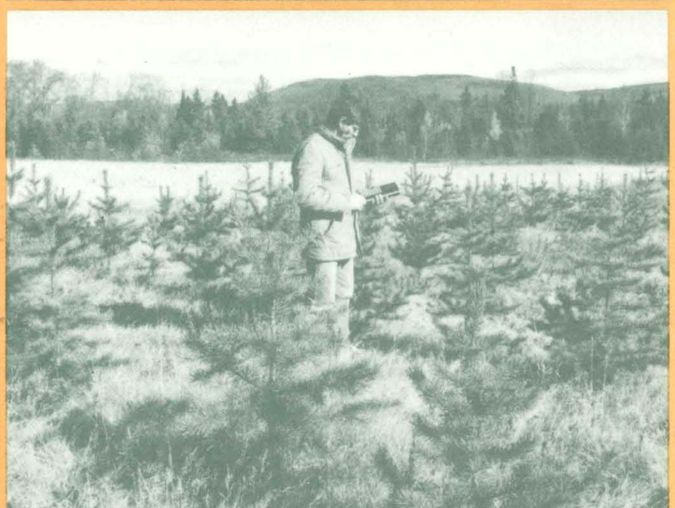
Main causes of mortality and height growth of containerized seedlings following four reforestation tests

Claude Delisle

Quebec Region • Information Report LAU-X-106E



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ERRATA

The following corrections should be made as soon as possible :

Page 5, the equation should read : $n_0 = \frac{t^2 S^2}{d^2}$

where

d^2 = margin ...

Page 8, 2^{nd} paragraph, 4^{th} line : ... and for that in the <u>fall</u> of 1982.

Page 13, 3^{rd} paragraph, 6^{th} line : 0.5 year<u>s</u>

Page 19, 4^{th} paragraph, 9^{th} line : 0.5 year<u>s</u>

Page 24, In the figure, the locations should be identified as :

<u>Lac</u> Bean and <u>Lac</u> Trenche

Page 27, 3^{rd} paragraph, 8^{th} line : 0.5 year<u>s</u>

Page 29, 4^{th} paragraph, 1^{st} line : at an elevation of about <u>155 m</u>.

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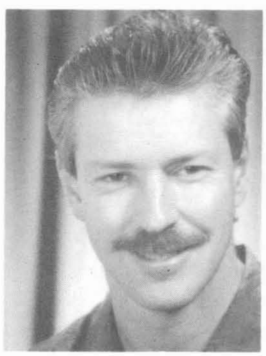

Claude Delisle

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Main causes of mortality and height growth of containerized seedlings following four reforestation tests

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Information Report LAU-X-106E
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ABSTRACT

From 1981 to 1984, nineteen experimental plantations were established on a range of eight typical reforested sectors in seven regions of Quebec. Included in the experiments, which took place during two planting seasons, were one or more of the following species: black spruce, white spruce, jack pine and Scots pine. As well, at least two of the following containers were used: Quebec Tube, Styroblock 2a, Styroblock 4, Styroblock 8, Can-Am 2, and Paperpot 508.

This report presents the results of plant height growth for the first five years in the field, and the rate and probable causes of mortality in the field after the first, third and fifth year following plantation. Analyses of variance were done on the fifth year data and several trends were evident in most of the experiments, namely: spring-planted seedlings had higher survival rates; spring-planted and fall-planted seedlings frequently demonstrated equivalent height growth performance; survival and height growth performance are not affected significantly in more than 75% of cases by container type. Pine had higher survival rates and growth rates than spruce. Competing vegetation and animal depredation were the two main causes of mortality in spring and fall plantations, while early frosts mainly affected fall-planted black spruce.

RÉSUMÉ

De 1981 à 1984, dix-neuf plantations expérimentales ont été créées sur une série de huit emplacements représentatifs de secteurs reboisés dans sept régions du Québec. Les travaux ont eu lieu pendant deux saisons de plantation et ont mis à l'essai une ou plusieurs des espèces suivantes: l'épinette noire, l'épinette blanche, le pin gris et le pin sylvestre. De plus, au moins deux types de conteneurs ont été utilisés: le tube québécois, le styrobloc 2a, le styrobloc 4, le styrobloc 8, le Can-Am 2 et le paperpot 508.

Le présent rapport présente les résultats de la croissance en hauteur des plants au cours des cinq premières années sur le terrain de même que les taux et les causes probables de mortalité après les première, troisième et cinquième années. Des analyses de variance effectuées sur les données de la cinquième année ont permis de dégager certaines constantes pour la plupart des tests, à savoir : les taux de mortalité sont beaucoup moins élevés pour les plantations de printemps que pour celles d'automne; la croissance en hauteur ne diffère pas significativement entre les deux saisons de plantation; et le type de conteneur, dans plus de 75 % des cas, ne change pas de façon significative la croissance et la survie des plants dans les sites expérimentaux. Les plants de pins montrent une meilleure croissance et un meilleur taux de survie que ceux d'épinettes. La végétation compétitive et les animaux sont les causes les plus souvent associées à la mortalité dans les plantations de printemps et d'automne, tandis que des symptômes de gel hâtif sont principalement observés chez les épinettes noires plantées à l'automne.

INTRODUCTION

Reforestation in Quebec already goes back many years: from 1913 to 1932 close to 4,000 ha of private land were replanted in the vicinity of Grand-Mère (Cunningham 1953; Gagnon 1972), and between 1939 and 1955, the Southern Canada Power Co. Ltd. planted conifers on approximately 800 ha in the Drummondville area (Côté 1991). But it was only around the mid-60s that reforestation really began in earnest (Hawey 1980). In 1978 the ministère de l'Énergie et des Ressources du Québec (MER) set up an artificial regeneration program under which, starting in 1983-1984, 70 million plants would be produced, including 20 million in containers.

When Quebec opted for the production of containerized plants, it endorsed to a certain extent a practice which had been very popular throughout the world in the late 1970s (20% compared with bare-root production) (Cousin and Lanier 1976), as well as in Scandinavia (50%, Rahkonen 1983), Alberta, and the Maritimes with 75% and 65% respectively, whereas in Quebec this type of production accounted for only 2.8% (Smyth 1980).

Although a number of studies have shown that in certain parts of Canada, the survival and height growth of bare-root plants vary depending on the planting date (Crossley 1956; Ackerman and Johnson 1962; Mullin 1968; Burgar and Lyon 1968; Mullin and Howard 1973; Veilleux 1979 and 1983), very few studies deal with the subject using containerized seedlings. The only information comes mainly from western Canada (Walters 1969; Arnott 1971; Walter and Johnson 1980) and Ontario (McLean 1959; MacKinnon 1970; Scarratt 1974; Mullin 1980). In Quebec information appeared only later with studies by Hatcher (1981), Sheedy (1984) and Dorais (1991).

The main reasons why the MER gave priority to the production of plants in containers were the following: shorter production time, better seed utilization, better-controlled growing conditions, greater mechanization, good planter yield, less transplantation shock, and a longer planting period than for bare-root plants. Notwithstanding all the benefits possible with containerized seedlings, a number of questions were raised with respect to the planting season, choice of container type and environmental conditions as they affect the future performance of plants in the field.

To find answers to some of these questions, we carried out a study to analyze the behavior of plants from this new type of production. The objectives of this study were three-fold: 1) determine the mortality rate of seedlings based on the type of container used and the planting season; 2) evaluate the causes of mortality; and 3) analyze the height growth of plants.

To do so, we carried out four tests. Each of these tests was designed to assess, on at least two sites, the performance of seedlings produced in different ways (species x container x season x year) and planted for at least two consecutive years in the spring and fall.

This document is divided into four chapters describing the results of each of the four reforestation tests carried out between spring 1981 and fall 1984. The results on mortality and height growth of seedlings for the five years following planting are presented, although occasionally the results may cover up to the eighth year following planting. We speak here of mortality rather than survival because this was a real problem on all reforested sites.

Although many different types of containers were used in this study, the results on mortality level and height growth of plants are presented regardless of the types of containers. Nevertheless, there is a brief discussion of the differences obtained using the different containers.

MATERIALS AND METHODS

The four tests covered by this study are summarized in Table 1. The species used in these tests were produced in at least two types of containers and planted on at least two test sites. Planting was carried out for at least two consecutive years with the exception of the sites at Saint-Antoine-de-Tilly, Lac Bean and Lac Trenche, which were too small for the test to be repeated.

Table 1. Summary of four tests by species, type of container, location, and year of planting

Test number	Species	Type of container	Planting location	Planting year
1	Jack pine	Quebec Tube	Grand-Mère	1981-1982-1983
	Scots pine	Styroblock 8	Lac-Drolet	1981-1982-1983
2	Black spruce	Quebec Tube	Grand-Mère	1981-1982
		Can-Am 2	Lac-Drolet	1981-1982
		Styroblock 4	Saint-Antoine-de-Tilly	1981
		Styroblock 8		
3	Black spruce	Quebec Tube	Lac Bean	1982
	Jack pine	Styroblock 2a	Lac Trenche	1983
		Styroblock 4	Lac Métis	1982-1983
4	Black spruce	Paperpot 508	Thurso	1983-1984
	White spruce	Styroblock 8	Saint-Martin	1983-1984

Species

Four conifer species totalling over 50,000 seedlings were used in the field tests, namely: black spruce (*Picea mariana* [Mill.] B.S.P.) (BS), white spruce (*P. glauca* [Moench] Voss) (WS) and jack pine (*Pinus banksiana* Lamb.) (JP), because of their economic importance in Quebec (50% of gross merchantable volume) and their popularity for reforestation (83.2% of species planted)

(Parent 1990), and Scots pine (*P. sylvestris* L.) (SP) because of the excellent results obtained from plantings at Grand-Mère in the early 1920s (Conway 1964).

Provenance and production

Biological material used in each test always came from the same provenance. For Test 1, the jack pine seed came from the Ottawa River Valley, and the Scots pine seed from the Stone Consolidated plantations at Grand-Mère. For tests 2, 3 and 4, the jack pine and black spruce seed came from Roberval County (Danville Township), and the white spruce seed from the Lower Gatineau River.

The production of jack pine and Scots pine seedlings for Test 1 was awarded to Stone Consolidated of Grand-Mère (Conway 1980). This production included 23,000 seedlings, or approximately 40% of all the seedlings planted under this project.

The other seedlings for tests 2, 3 and 4 were produced at the Laurentian Forestry Centre (Canadian Forest Service - Quebec Region). The seedlings were grown in heated greenhouses and cultivated in accordance with the provincial standards in effect at the time. The cultivation period lasted between ten and seventeen weeks followed by an acclimation period of one to six weeks in a shade house (D'Aoust and Trudel 1985; Gonzalez and D'Aoust 1987). There were two productions of seedlings per year; one for the spring planting (June) and the other for the fall planting (September). The spring production took place from February to May, and fall production from May to August. For the fall production, there was no special treatment to promote earlier dormancy in the seedlings. In all, six types of containers (Table 1) were used with at least two different ones per test. The characteristics of the Styroblock and Paperpot containers are described in Carlson (1983), and those of Can-Am 2 in Sutherland (1984).

Choice of test sites

Planting sites (Figure 1) were chosen so as to be representative of reforested sectors in a given area. Six of the eight test sites were located next to, or very near, sectors under operational reforestation. The longitude, latitude and elevation of these sites are shown in Table 2.

A detailed description of the sites is presented in the chapter dealing with each test. It should be noted that a pedon was dug on each site in order to classify the type of deposit present (Canada Soil Survey Committee 1978).

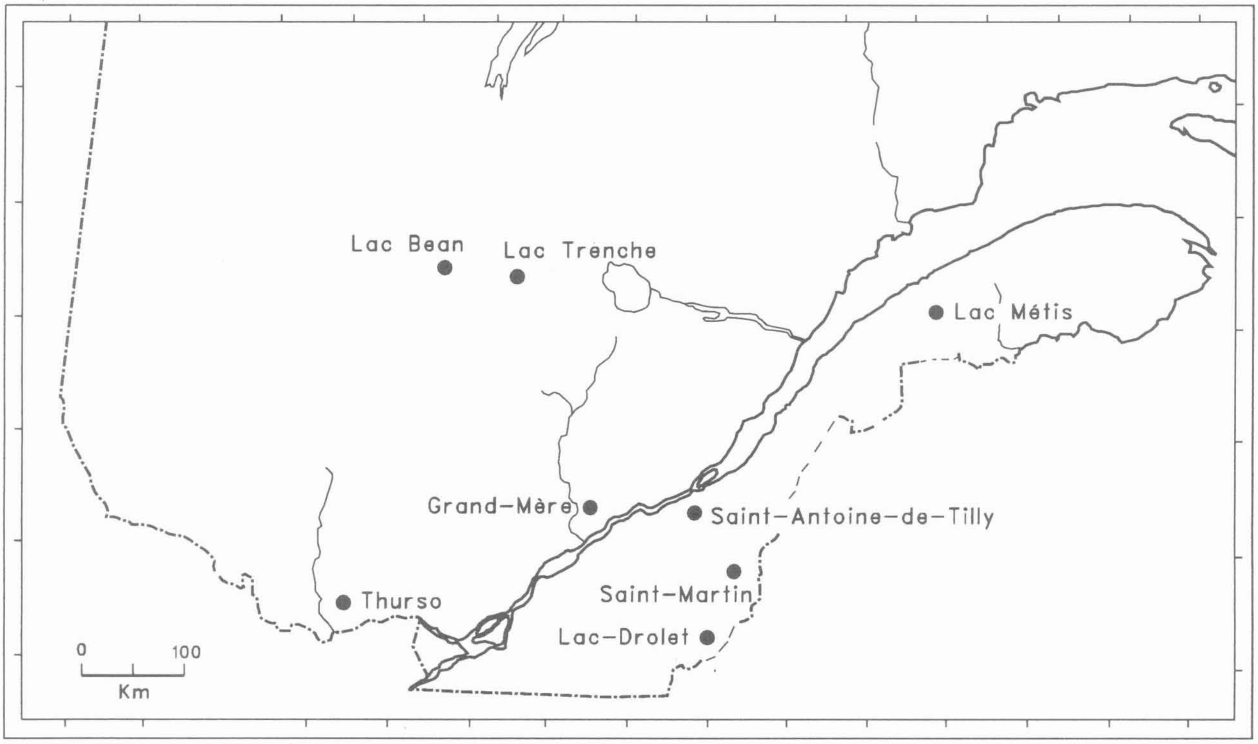

Figure 1. Location of test sites.

Table 2. Geographical location of test sites

Location	North Latitude	West Longitude	Elevation (m)
Grand-Mère	46° 41'	72° 41'	90
Lac-Drolet	45° 31'	70° 49'	415
Saint-Antoine-de-Tilly	46° 38'	71° 31'	58
Lac Bean	48° 44'	73° 50'	412
Lac Trenche	48° 39'	73° 25'	410
Lac Métis	48° 21'	67° 56'	245
Thurso	45° 36'	75° 16'	155
Saint-Martin	45° 57'	70° 39'	100

Experimental designs

Of the 19 experimental arrangements used in the field, 15 were randomized blocks and 4 were complete random designs. Each design was repeated a minimum of four times.

With the exception of two arrangements in which seedlings were spaced 1.0 m by 1.0 m, all seedlings were planted with a spacing of 2.0 m by 2.0 m. The seedlings produced in Styroblock 2a were planted with a dibble (Scarratt 1973; Scarratt and Ketcheson 1974), while all the other seedlings were planted with the Pottiputki tube (*Ibid.)*.

Monitoring

Observations of survival, damage and deformities caused by insects and other environmental factors were made on all individual seedlings during the spring and summer of the first, third, and fifth year following planting. In certain cases, survival observations were postponed to the fourth or sixth year. At other times, when the mortality rate had reached an excessively high level, survival observations were suspended after the third year.

Height growth was measured in the fall of the fifth year. To do so, stems were chosen at random, and height measurements after each year of growth were determined based on scars left by the terminal bud of previous years. Growth observations were extended into the eighth year on pines planted at Grand-Mère and Lac-Drolet in 1981 (Test 1).

The number of stems chosen to assess the growth of each species was calculated on the basis of pre-sampling in each arrangement. The following formula (Cochran 1963) was used to calculate this number:

$$n_o = \frac{t^2 S^2}{d}$$

where

n_o = size of sample;

t = 1.96 at 5% probability level;

S^2 = variance in total height obtained in pre-sampling;

d = margin of error in estimating height, set at 5 cm.

Development of individual seedlings was noted on forms up until 1986, and then recorded using the PSP program (Delisle 1989) on Microflex PC-1000 field microcomputers (DAP Technologies[1]).

During the field study, it soon became difficult to find plants because of the thickness of competing vegetation, mainly where there was herbaceous cover. Most of the seedlings were eventually found, dead or alive, but it was a long and difficult task. More importantly, this operation was done by manual clearing which, due to the high cost, would never be done in the case of operational planting. Dead and damaged seedlings were noted on each visit, and the immediate environment of seedlings was also taken into consideration. This information was useful in attempting to identify the probable cause of mortality in seedlings later found dead. Nineteen main causes of, or probable associations with, mortality were noted during this study and are presented in Table 3.

Table 3. List of causes of mortality and problems observed on plants during monitoring of plantations

1. Frost heaving	8. Defoliation by insects	15. Pine root collar weevil
2. Browsing of terminal shoot	9. Improper planting	16. White pine weevil
3. Browsing of lateral shoots	10. Mechanical breakage	17. Jack pine nodule-maker
4. Frost crack	11. Multiheading	18. Late frost
5. Drought	12. Competing vegetation	19. Early frost
6. Waterlogging (WLG)	13. Chemical spraying	
7. Girdling	14. Root coiling	

TEST 1

Description of sites

The two sites selected for this test were located at Grand-Mère, in the Mauricie region, and at Lac-Drolet, in the Beauce region. The Grand-Mère site is in the hardwood forest region, while the Lac-Drolet site is in the mixed forest region (Thibault 1985).

The Grand-Mère site was a flat area with a deposit made up of a thick layer of fine to medium sand with good drainage. The mean annual temperature is approximately 4.5°C, and the July average is 19.5°C. The number of frost-free days ranges from 96 to 143. Annual precipitation is 1,060 mm (min. Environnement 1978 to 1988). The site was former farmland

[1] DAP Technologies, 995 place Dufour, Ville Vanier, Quebec G1M 3B2, Canada.

which had been reforested with white spruce in the early 1930s, and then clearcut in the winter of 1980.

The Lac-Drolet site was loam with a number of boulders. The terrain sloped slightly, but drainage was poor. The mean annual temperature is approximately 3.7°C, and the July average is 17.7°C. The number of frost-free days ranges from 89 to 103. Annual precipitation is 1,000 mm (min. Environnement 1978 to 1988). The origin of this site is the clearcutting of a mixed stand in 1980.

Experimental designs

Seedlings were planted on the two sites using an experimental arrangement of four complete random blocks (2 species x 2 containers x 2 planting seasons). Jack pine and Scots pine cultivated in Quebec Tube and in Styroblock 8 and then planted in the spring and fall were the eight treatments used. Planting was carried out at both locations on adjacent sites, in June and September of 1981, 1982, and 1983. Each plot was planted with 121 seedlings arranged in a checkerboard pattern with a spacing of 2.0 m by 2.0 m between plants.

At Grand-Mère, the site was prepared with a Bräcke scarifier in the spring of each planting year. This type of preparation was recognized as a method for improving the growth and survival of plants replanted in cold climates (Edlun 1980; McMinn 1980). Seedlings were planted on the shoulder of the Bräcke plot in the exposed inorganic part which, according to Sutton (1991), is the best place to plant seedlings.

At Lac-Drolet, however, there was only one scarification with barrels and chains in the spring of 1981 for the three years of planting. The barrels and chains scarifier has been used successfully in Quebec since 1974 (Dancause 1977) and also in Ontario, mainly on flat to slightly rolling terrain (O'Donnel 1977).

The average height of jack pine planted in 1981, 1982, and 1983 was 21.7 cm, 16.6 cm, and 16.5 cm respectively. For Scots pine and for the same planting years, the heights were 20.2 cm, 14.6 cm and 15.6 cm. The average root collar diameter was 3.2 mm for both species in 1981.

It is important to note that some forest management procedures were carried out at Grand-Mère. Thus, in 1983, mechanical clearing with circular saws was carried out on the entire site. Then, given the regrowth of vegetation the next spring, over half the 1982 and 1983 planting was sprayed with glyphosate during the summer of 1984.

Results and discussion

Mortality rate at Grand-Mère

The first year following spring planting and the first winter following fall planting were not critical periods for the survival of plants, with the exception of those planted in the fall of 1983. These plantings had a mortality rate of over 21% for both pine species after the first year in the field (Table 4). This rate increased substantially after the third year, and then rose to over 61% for Scots pine after five years.

Table 4. Mortality rates (%) after the first, third, and fifth year following planting, for jack pine and Scots pine planted at Grand-Mère in the spring and fall of 1981, 1982, and 1983

Year	Planting period	Species	Year following planting		
			1	3	5
1981	Spring	JP	2.3	13.1	24.0
		SP	0.5	6.1	14.6
	Fall	JP	6.0	21.0	34.6
		SP	1.0	8.1	22.1
1982	Spring	JP	8.1	16.7	18.2
		SP	3.6	15.9	20.8
	Fall	JP	0.2	15.6	22.3
		SP	0.2	6.3	12.6
1983	Spring	JP	4.0	19.9	28.1
		SP	3.4	27.0	37.4
	Fall	JP	21.6	46.9	57.3
		SP	22.3	56.1	61.4

Variance analyses performed on survival rates five years following outplanting showed that plantings in the spring of 1981 and 1983 did much better than those in the fall of the same years. The 1982 plantings showed no significant difference between the two planting seasons. Scots pine did better than jack pine for the two 1981 planting periods and for that in the spring of 1982. Of the two types of containers used - Quebec Tube and Styroblock 8 - no significant difference was observed in the survival rate[2].

Examination of causes of mortality (Figures 2 to 4) showed that the main problems encountered on this site were losses due to competing vegetation, drought and browsing by animals. Among the latter, hare and white-tailed deer were found responsible for much of the damage to plants. As noted by Arnott (1972) and Van Eerden (1972), browsing by deer and hare

[2] For brevity in the presentation of results, the variance analysis tables are not shown in this report, but are available for consultation at the LFC.

is not fatal, but severely affects seedling growth in the establishment phase. The highest losses were observed mainly in areas where plant competition had not been eliminated, thus creating some shelter for animals.

However, following glyphosate spraying of certain plots, the 1982 plots showed no significant difference in survival rates three years after treatment; for the 1983 plots, the survival rate was 92% higher than for unsprayed plots.

Mortality rate at Lac-Drolet

As in the case of the pines planted at Grand-Mère, the first year following planting was not critical; however, the mortality rate increased significantly between the first and fifth year to yield total losses of close to 50% in the case of pines for the three planting years (Table 5).

Table 5. Mortality rates (%) after the first, third, and fifth year following planting for jack pine and Scots pine planted at Lac-Drolet in the spring and fall of 1981, 1982, and 1983

Year	Planting period	Species	Year following planting		
			1	3	5
1981	Spring	JP	3.6	16.1	34.2
		SP	1.1	10.9	19.3
	Fall	JP	5.2	16.5	29.1
		SP	3.1	22.8	36.4
1982	Spring	JP	1.1	22.8	29.4
		SP	1.3	23.6	35.6
	Fall	JP	1.5	49.8	61.9
		SP	3.3	66.9	71.3
1983	Spring	JP	8.2	52.9	59.8
		SP	3.5	44.2	46.0
	Fall	JP	10.4	77.0	78.8
		SP	7.9	65.1	69.0

Variance analyses on survival rates five years following outplanting showed that, for the three planting years, spring-planted trees did significantly better than those planted in the fall. Of the two species used, only Scots pine planted in the spring of 1981 did better than jack pine planted at the same time. Moreover, it was in the spring of 1981 that we found the only significant difference regarding containers, when jack pine produced in Styroblock 8 showed a survival rate 42% higher than jack pine produced in Quebec Tubes.

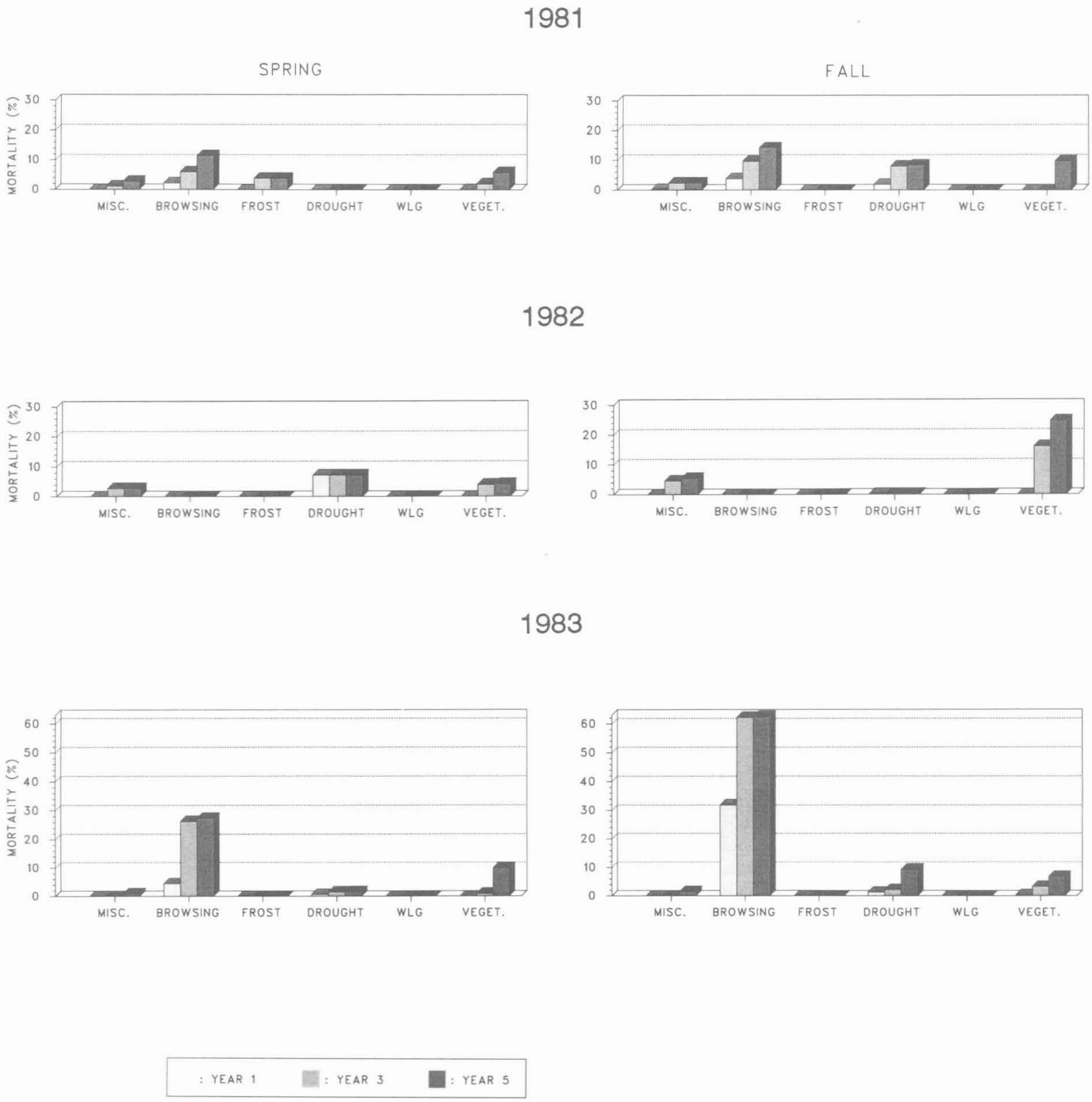

Figure 2. Breakdown of causes of mortality in jack pine planted at Grand-Mère in the spring and fall of 1981, 1982, and 1983. Results correspond to monitoring in the first, third, and fifth year following planting.

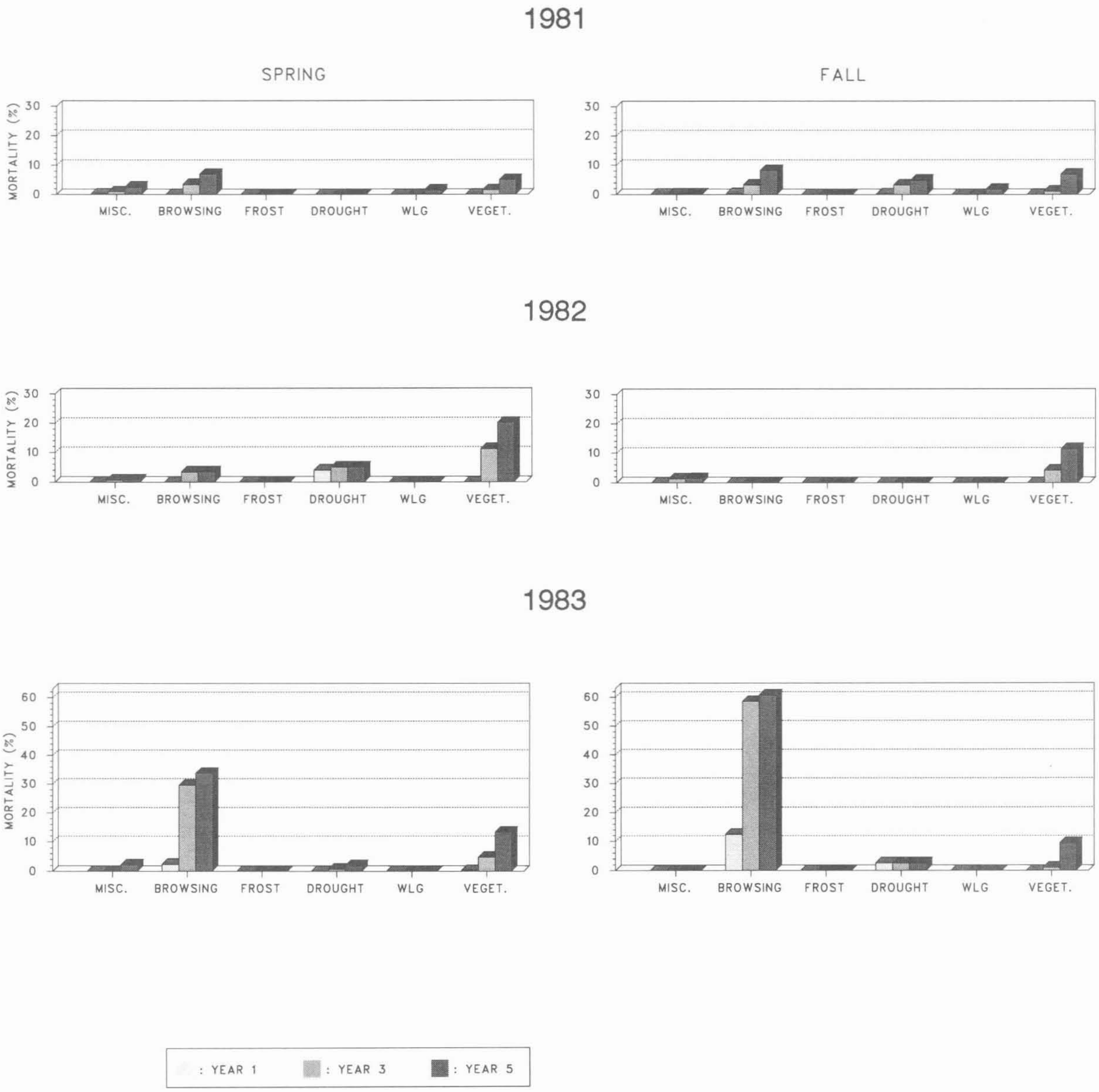

Figure 3. Breakdown of causes of mortality in Scots pine planted at Grand-Mère in the spring and fall of 1981, 1982, and 1983. Results correspond to monitoring in the first, third, and fifth year following planting.

Figure 4. Breakdown of causes of mortality in jack pine and Scots pine planted at Grand-Mère in the spring and fall of 1982 and 1983. Results correspond to monitoring in the first, third, and fifth year following planting. The area was sprayed with glyphosate during the summer of 1984.

Mortality rates due to plant competition remained very high, mainly in seedlings planted in the fall (Figures 5 and 6). Moreover, we noted an increase in that mortality coincided with a time lapse between scarification of the site, which took place in 1981, and planting dates. For example, the mortality rate was twice as high for the 1983 planting as for that of 1981, five years following planting. Pohtila (1977) demonstrated after a series of tests that it was detrimental to wait too long after ploughing to plant. Plant competition sets in, and the soil becomes re-compacted. The survival rate may decrease by 30% or more for each year's delay (Fletcher 1990).

Losses caused by hare and white-tailed deer were at acceptable levels, but the damage encountered on the introduced plants was enormous. This damage occurred during the winter of 1988, when deer settled in our experimental arrangement following chemical spraying on adjacent land to eliminate plant competition in these young plantations. Our design was the only area remaining untreated in a block of approximately 250 ha and thus served as a shelter and food supply for these animals. Almost all plants in the block planted in 1983 were eaten. All branches, including the terminal shoots which were situated at a height of less than 1.5 m, were eaten. Only the stem was left intact. Damage was much less extensive in blocks planted in 1981 and 1982 since the plants had already reached a considerable size.

Height growth

The average height of jack pine on the two sites, five years following planting, compares well with the average height of plantings done by the ministère des Forêts du Québec (MFO) in the Trois-Rivières region with seedlings produced in greenhouses in 67-50 multi-pots (Figure 7). Data on the average height of the MFO plantations comes from a sampling performed on 39,000 jack pine seedlings planted in 1981 and 200,000 seedlings planted in 1983[3]; all these seedlings were 0.5 year old when outplanted. It should be noted that there was a great similarity in height growth in jack pine and Scots pine on the two sites. Although the Lac-Drolet site is not recommended for jack pine because of its inadequate drainage (Cauboue 1988), the fact remains that height growth was equal to that obtained at Grand-Mère, which had the rapid drainage better suited to this species.

At Grand-Mère and at Lac-Drolet, variance analyses on the height of plants after five seasons of growth showed no significant difference between spring-planted and fall-planted trees for the three years of planting. Jack pine had significantly better growth than Scots pine on the two sites for the six planting periods. At Grand-Mère, we found no difference in height growth between plants produced in Quebec Tube and Styroblock 8. At Lac-Drolet, however, plants produced in the spring of 1981 in Styroblock 8 showed growth 10.7% better than plants produced

[3] Information provided by Mr. François Trottier, who is in charge of the ministère des Forêts du Québec's data bank on monitoring of plantings (SPMF).

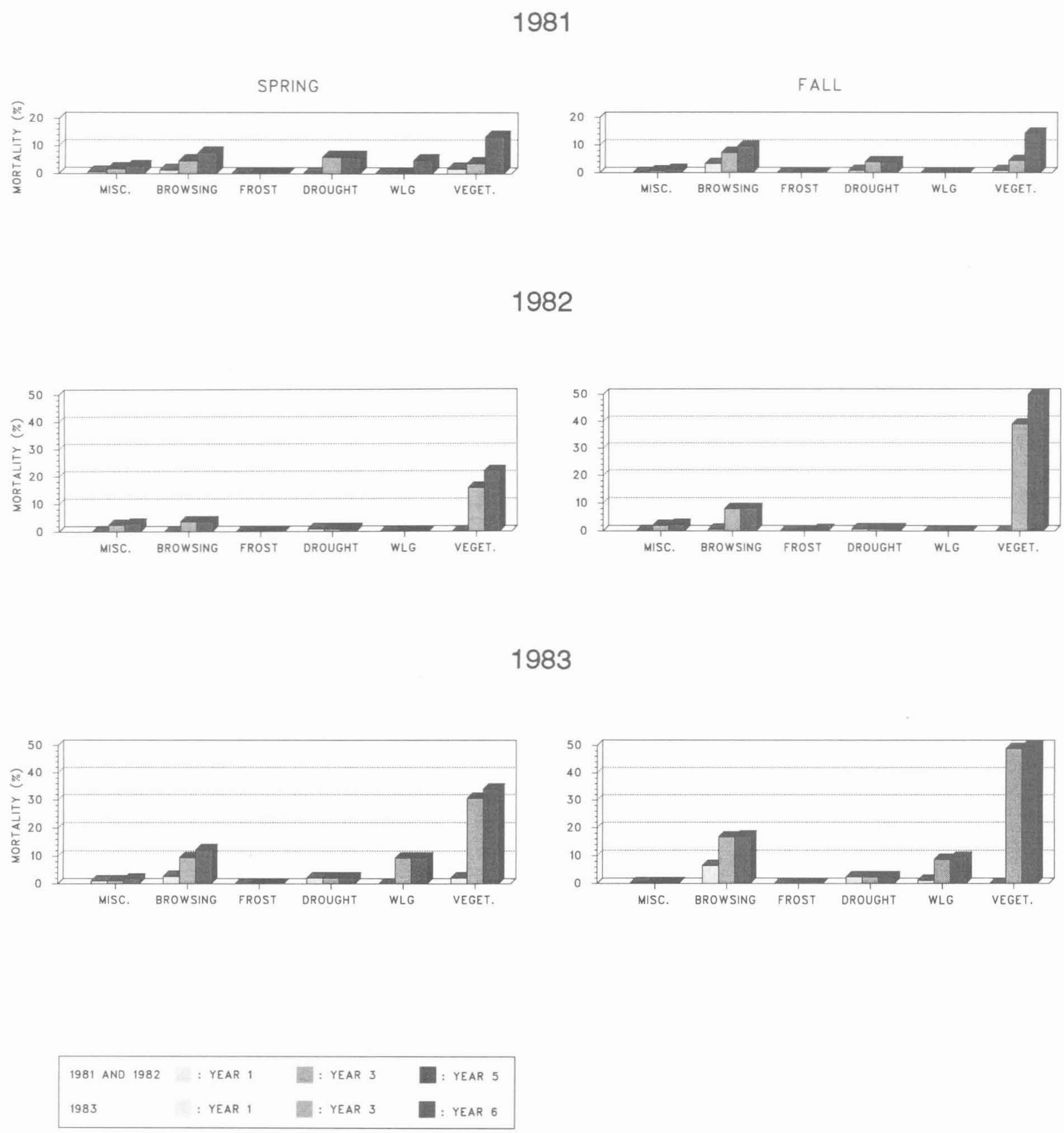

Figure 5. Breakdown of causes of mortality in jack pine planted at Lac-Drolet in the spring and fall of 1981, 1982, and 1983. Results correspond to monitoring in the first, third, fifth or sixth year following planting.

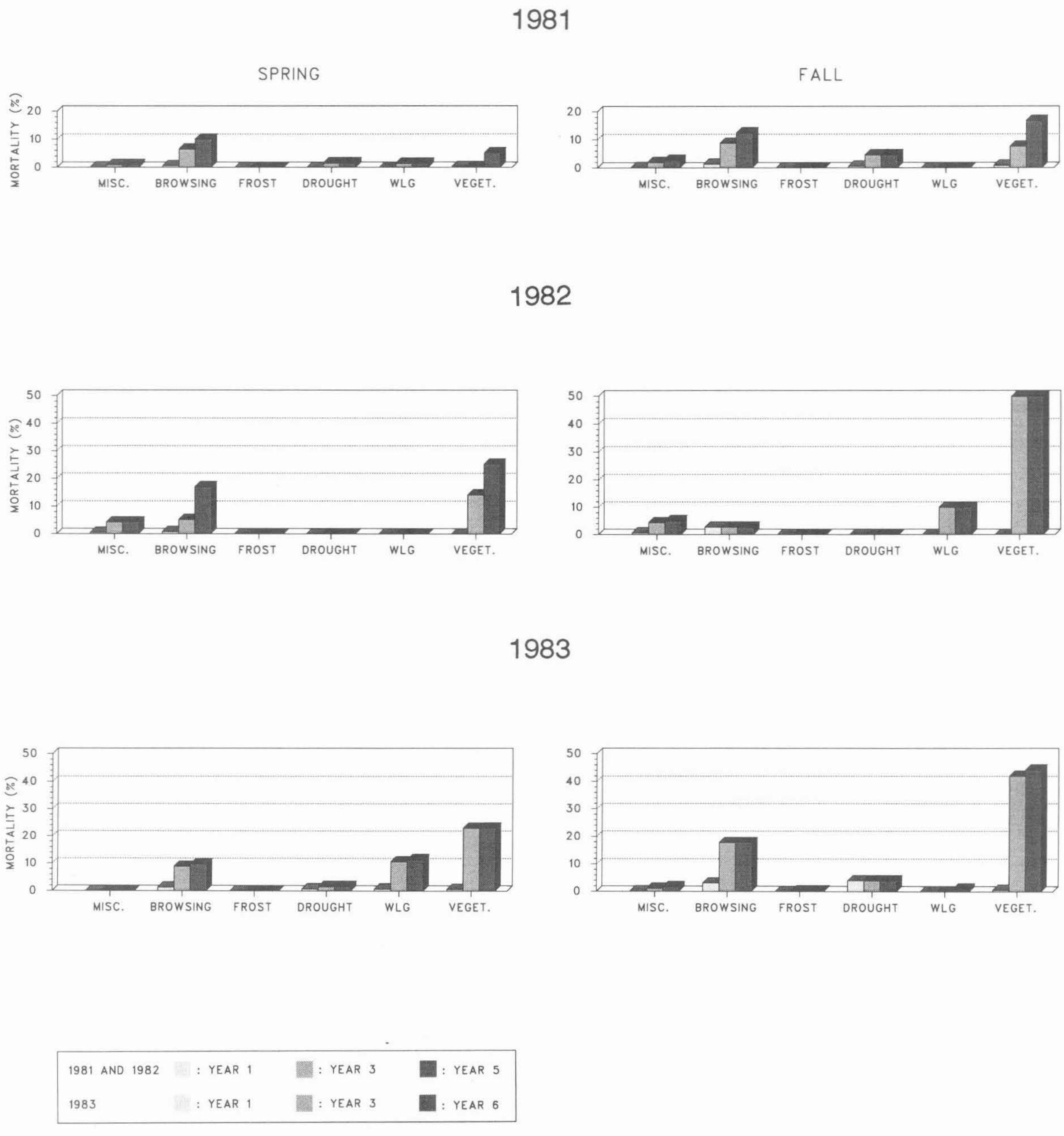

Figure 6. Breakdown of causes of mortality in Scots pine planted at Lac-Drolet in the spring and fall of 1981, 1982, and 1983. Results correspond to monitoring in the first, third, fifth or sixth year following planting.

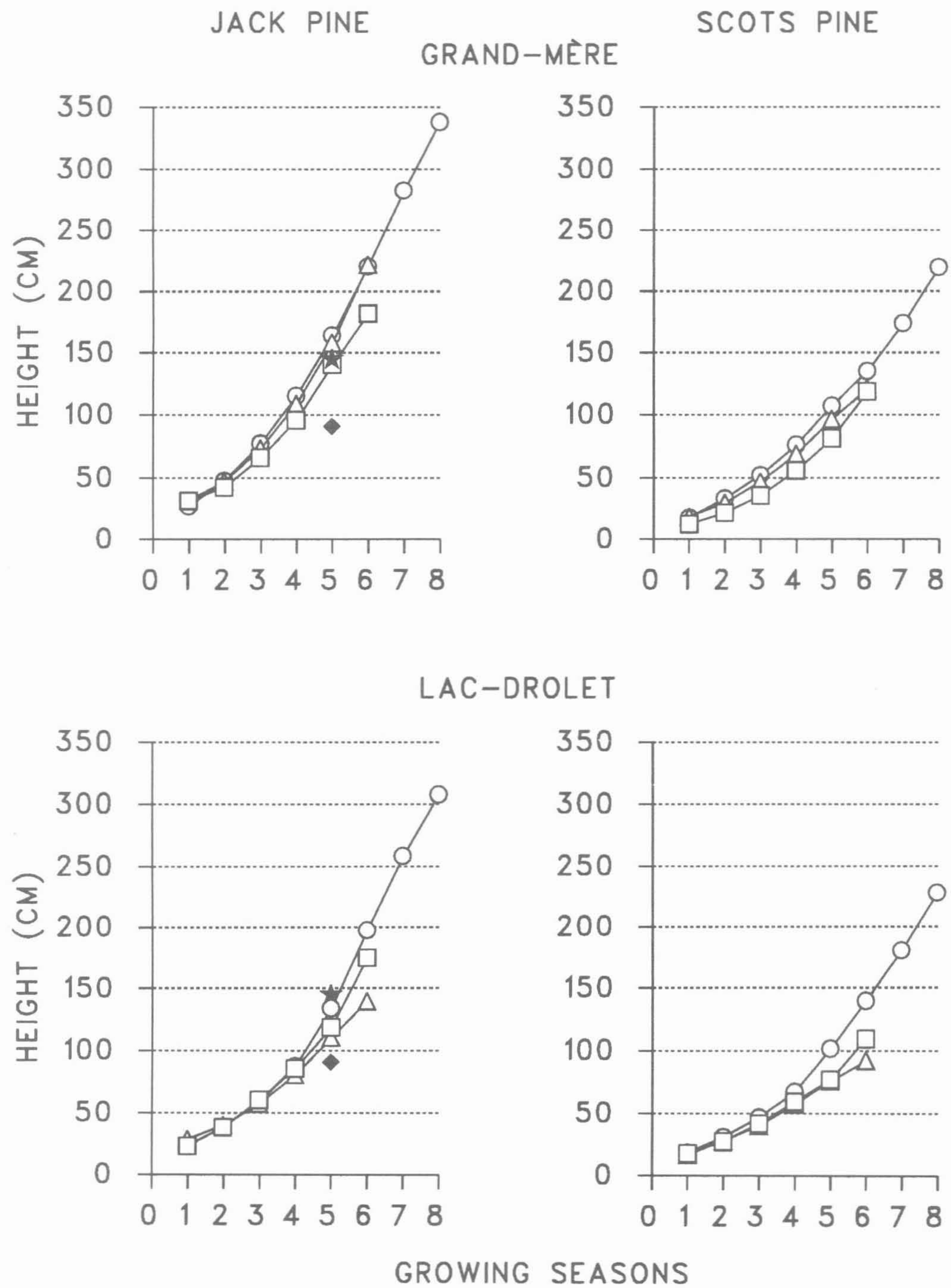

Figure 7. Height growth in jack pine and Scots pine planted at Grand-Mère and at Lac-Drolet in 1981 (○), 1982 (△), and 1983 (□). For reference, five-year average height of outplantings of jack pine produced in greenhouses in 67-50 multi-pots and planted by the MFO in the Trois-Rivières administrative district in 1981 (★) and 1983 (♦) is given.

in Quebec Tubes. This difference dropped to 8.5% in the fall planting. In 1982, only the plants produced in the spring in Styroblock 8 showed better growth, while in 1983, there was no difference in height growth, after five years, between the two types of containers.

Following spraying with glyphosate at Grand-Mère in August 1984 on over half of the plots planted in 1982 and 1983, a variance analysis showed a significant difference in height growth in the trees planted in the fall of 1982. Thus, three years after this treatment, jack pine and Scots pine showed a height gain of 18% and 15% respectively in treated plots compared with controls (Delisle 1990). For the 1983 planting, variance analyses showed significant differences for the two planting seasons with a 23% gain in height for the two species treated.

TEST 2

Description of sites

The three sites selected for this test were located at Grand-Mère, Lac-Drolet and Saint-Antoine-de-Tilly near Quebec City. The first two sites were adjacent to those of Test 1 and were described in the previous chapter. The last site was located in the hardwood forest zone (Thibault 1985). The mean annual temperature is approximately 4.1°C, and the July average is 19.1°C. The number of frost-free days ranges from 112 to 137. Annual precipitation is 1,175 mm (min. Environnement 1978 to 1988).

The Saint-Antoine-de-Tilly site was a recently abandoned hayfield. The terrain was flat with a relatively well-drained deposit of fine to medium sandy silt. No site preparation was carried out, although manual weeding was done in a radius of 15 to 20 cm around the seedlings during the three years following plantings. Without this precaution, most of the seedlings would probably have died. At Grand-Mère, the site was prepared with a Bräcke scarifier in the spring of 1981 only. This scarification served for both the 1981 and 1982 plantings. The same was done at Lac-Drolet, where the site was prepared using barrels and chains in the spring of 1981 only. Afterwards, no vegetation clearing was done on these two sites.

Experimental designs

In the three sites, a total of 8,600 black spruce seedlings, divided into 140 sample plots, were planted in 1981 and 1982, with the exception of Saint-Antoine-de-Tilly, where planting took place only in 1981. Seedlings were produced in four types of containers: Quebec Tube, Styroblock 4, Styroblock 8, and Can-Am 2. The latter container was used only in the spring of 1981. The average height of seedlings at planting ranged from 13.5 cm to 19.5 cm depending on the container used and the production season. The average root collar diameter was 1.7 mm.

Seedlings were planted on the three sites using an experimental arrangement of four complete random blocks with one missing combination for the fall of 1981 planting corresponding to the Can-Am 2 container. Planting was done in June and September of each year.

The sample plots were linear in shape. At Grand-Mère, the spacing between rows and plants was 2.0 m, while at Lac-Drolet and Saint-Antoine-de-Tilly, this spacing was 1.0 m. The plots were made up of 25 plants in the case of spruce produced in Styroblock 4, 50 plants for those produced in Can-Am 2, and 70 plants for spruce produced in Styroblock 8 and Quebec Tubes.

Results and discussion

Mortality rate

The mortality rate in spring-planted trees was at a very acceptable level one year following planting, varying from 2% to 14% (Table 6). The mortality rate of trees planted in the fall of 1981, however, was catastrophic, rising to over 43% at Grand-Mère the first year. Mortality continued to increase significantly between the first and third year, finally reaching a cumulative level of 88% at Grand-Mère. The only planting that could be considered a success was that of Saint-Antoine-de-Tilly in the spring of 1981, which had a mortality rate of 18.8% after five years. This success might be due to the fact that the seedlings were weeded mechanically for the three years following planting; nonetheless, the fact remains that weeding once a year was not enough to eliminate losses due to plant competition. The level of these losses in fall-planted seedlings (Figure 8) was cause for concern.

Table 6. Mortality rates (%) for black spruce after the first, third, and fifth year following planting

Location	Year	Planting period	Year following planting		
			1	3	5
Grand-Mère	1981	Spring	7.2	32.9	43.7
		Fall	43.3	80.0	88.1
	1982	Spring	9.6	28.6	35.1
		Fall	13.1	37.2	45.0
Lac-Drolet	1981	Spring	8.4	37.5	39.4
		Fall	35.7	70.4	72.1
	1982	Spring	14.1	54.3	57.6
		Fall	8.1	72.2	77.6
Saint-Antoine-de-Tilly	1981	Spring	2.0	13.2	18.8
		Fall	22.2	40.2	50.4

At Grand-Mère, Lac-Drolet and Saint-Antoine-de-Tilly, competing vegetation remained the leading cause of mortality, mainly in fall-planted trees (Figure 8). This mortality, which increased substantially between the first and third year following planting, was probably due to inadequate site preparation in the spring of 1981. Since black spruce is not considered a very aggressive species (Cauboue 1988), seedlings planted in the fall failed to provide adequate competition for the well-established herbaceous vegetation.

Another major cause of mortality was browsing by animals. In the planting of 1982 at Grand-Mère, we observed losses of over 20% due to animals after three years. Hare was unquestionably the main cause of these losses, which once again indicates that the risk of losses and damage caused by animals is higher when plant cover increases. As well, a number of seedlings that had been planted in shallow depressions were found dead due to problems caused by waterlogging.

Variance analyses on survival rates five years following outplanting gave highly significant indications that spring-planted trees do better than fall-planted ones. The only exceptions were those planted at Grand-Mère in 1982, where there was no significant difference between the two planting seasons. Variance analyses also showed no significant difference between the containers used for all plantings performed in 1981 and for the fall planting at Grand-Mère in 1982. For the fall planting at Saint-Antoine-de-Tilly, Styroblock 4 proved less successful than Quebec Tubes and Styroblock 8. These two containers showed no significant difference in terms of survival of seedlings. However, for the fall 1982 planting at Lac-Drolet, Quebec Tubes gave the least satisfactory results, while there was no difference between Styroblock 4 and Styroblock 8.

Height growth

The average height of black spruce on the Grand-Mère and Lac-Drolet sites five years following outplanting compares well with the average height of plantings done by the MFO in the Trois-Rivières region (Figure 9). However, in Saint-Antoine-de-Tilly, we found plants that were below the regional average. Indeed, at this place, significant competing vegetation was harmful to plant growth, and as we mentioned previously, manual weeding had to be done around seedlings for three years following outplanting to reduce losses. The average height of the MFO plantations comes from a sampling performed on about 3.5 million black spruce seedlings produced in greenhouses in 67-50 multi-pots and planted in the Trois-Rivières region in 1983 and 1984[4] at 0.5 year.

[4] Information provided by Mr. François Trottier, who is in charge of the ministère des Forêts du Québec's data bank on monitoring of plantings (SPMF).

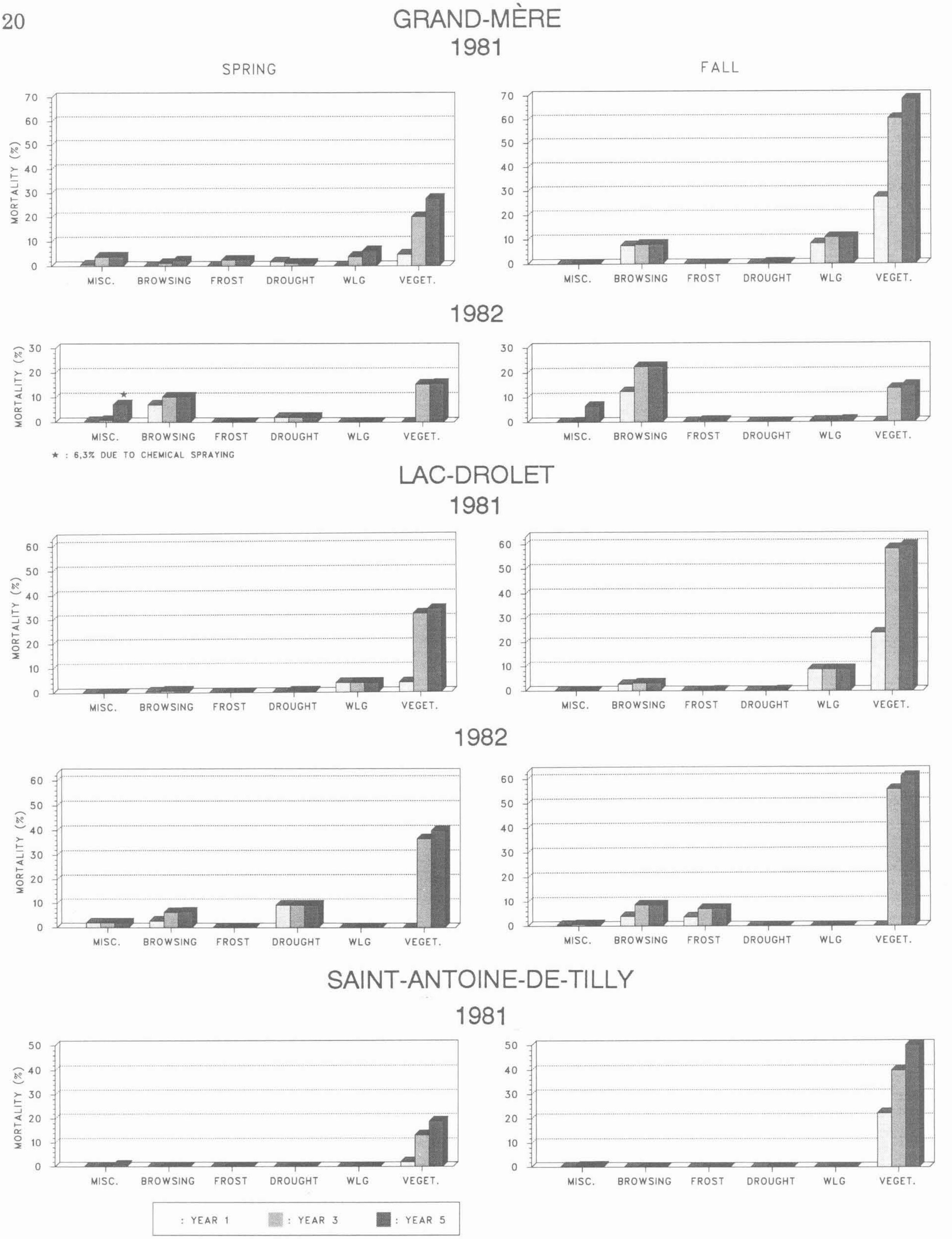

Figure 8. Breakdown of causes of mortality in black spruce planted at Grand-Mère and Lac-Drolet in the spring and fall of 1981 and 1982 and at Saint-Antoine-de-Tilly in 1981. Results correspond to monitoring in the first, third, and fifth year following planting.

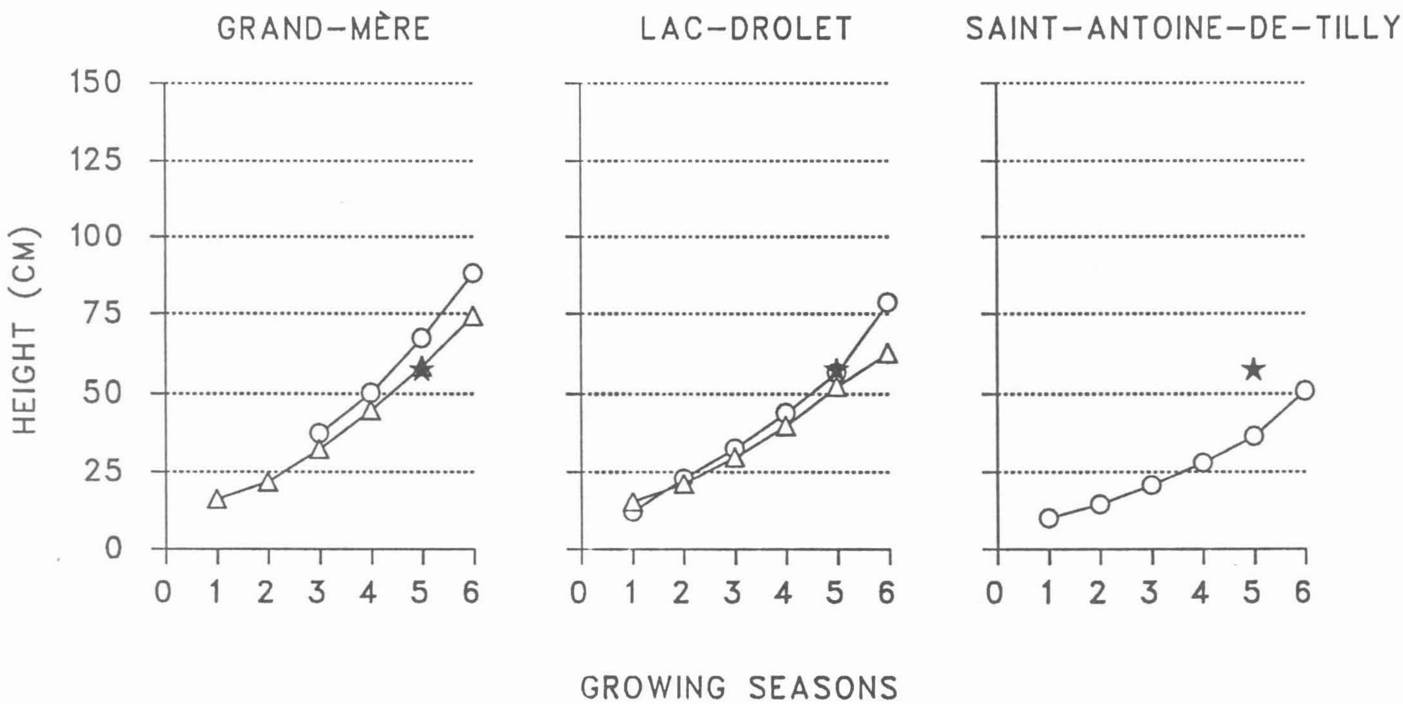

Figure 9. Height growth in black spruce planted in 1981 (○) and 1982 (△) at Grand-Mère and Lac-Drolet, and in 1981 (○) at Saint-Antoine-de-Tilly. For reference, five-year average height of outplantings of black spruce produced in greenhouses in 67-50 multi-pots and planted by the MFO in the Trois-Rivières administrative district in 1983 and 1984 (★) is given.

Black spruce, because of its slower growth, is at a clear disadvantage compared with a fast growing species when planted on sites with significant plant competition. It requires clearing a number of times before it reaches the "free to grow" stage, whereas jack pine or Scots pine might require only one clearing around the second year following planting. In general, in Quebec, it takes over seven years following planting for black spruce produced in containers to reach a height greater than 1 m (Dorais 1991).

Variance analyses carried out on the average height of plants at Lac-Drolet and Saint-Antoine-de-Tilly five years following outplanting showed no significant difference between the types of container. At Lac-Drolet, analyses showed that seedlings planted in the spring of 1981 were 18.6% taller than those planted in the fall of the same year.

TEST 3

Description of sites

The three sites selected for this test were located at Lac Bean, Lac Trenche and Lac Métis. The first two sites were approximately 135 km north of La Tuque, while the third was about 50 km southeast of Mont-Joli (Figure 1). All these sites are in the boreal forest region (Thibault 1985).

The Lac Bean site was an undulating terrain with slopes ranging from moderate to steep. The surface deposit was a thin morainic layer on the parent rock and drainage was rapid. The elevation is around 412 m. The mean annual temperature is 0.8°C, and the July average is 16.0°C. The number of frost-free days ranges from 21 to 53. Annual precipitation is over 940 mm (min. Environnement 1978 to 1988). The site was a former black spruce stand, clearcut in 1972, and burned in 1981. No scarification was done before plantings, which took place on July 1 and September 20, 1982.

The Lac Trenche site is located 32 km east of Lac Bean. The terrain was flat and there was a layer of fine to medium sand with an indurated horizon at a depth of approximately 40 cm. Drainage was rapid. The elevation is about 410 m. Weather conditions were the same as at Lac Bean. The site was a former jack pine and black spruce stand, clearcut in 1972 and burned in 1982. No site preparation was done before plantings, which took place on June 22 and September 20, 1983.

At Lac Métis, the terrain was slightly sloping and the deposit was fine to medium sand over gravel. Drainage was good to rapid. Elevation is around 245 m. The mean annual temperature is 1.7°C, and the July average 16.9°C. The number of frost-free days varies from 43 to 87. Annual precipitation is over 1,064 mm (min. Environnement 1978 to 1988).

The site was a former pure balsam fir stand, clearcut in the winter of 1981. The terrain was scarified with barrels and chains in the spring of 1982, and plantings took place on June 16 and September 13 in 1982 and 1983.

Experimental designs

A total of 11,820 seedlings, evenly divided between jack pine and black spruce, were planted in 240 sample plots. Seedlings were produced in three types of containers: Quebec Tube, Styroblock 2a, and Styroblock 4. On each site, planting arrangements were test plots with five complete random blocks (2 species x 3 containers x 2 planting seasons). With the exception of the 1983 Lac Métis arrangement where sample plots were linear in shape with 50 plants spaced 2.0 m by 2.0 m, the other arrangements were square plots of 49 plants in a checkerboard pattern with a spacing of 2.0 m by 2.0 m between plants. The average height of seedlings at planting was 16.1 cm for black spruce and 14.3 cm for jack pine.

Results and discussion

Mortality rate

As we can see from Table 7, the plantings of jack pine at Lac Bean and Lac Trenche gave fairly encouraging results with a mortality rate ranging from 7% to 26.5% after five years in the plantation. However, for the fall plantings with black spruce, we obtained high to very high mortality rates on all three sites starting with the first year. The worst performances were at Lac Métis, where we had over 95% mortality after only one year. In Quebec, the acceptable survival rate should be over 80% after three seasons of growth (Dancause 1977). In Ontario, the minimum success level for all species planted is a 75% survival rate (Mullin 1979).

In looking at the causes of mortality (Figures 10 and 11), several important points can clearly be seen. The first, and probably the most important, is that early frosts had a devastating effect on fall-planted black spruce seedlings. This may have occurred because the seedlings, which were produced in an area further south than the planting sites, were not sufficiently hardened to withstand the much more severe early frosts found in northerly areas. The two to four week period in a shade house before planting failed to provide sufficient acclimatization. A treatment made of short days combined with lowering of temperature would have helped the seedlings withstand the sharper early frosts (D'Aoust and Trudel 1985; Bigras and D'Aoust 1992). It is interesting to note that a large number of seedlings damaged by early frost in the year of planting were found dead the third year.

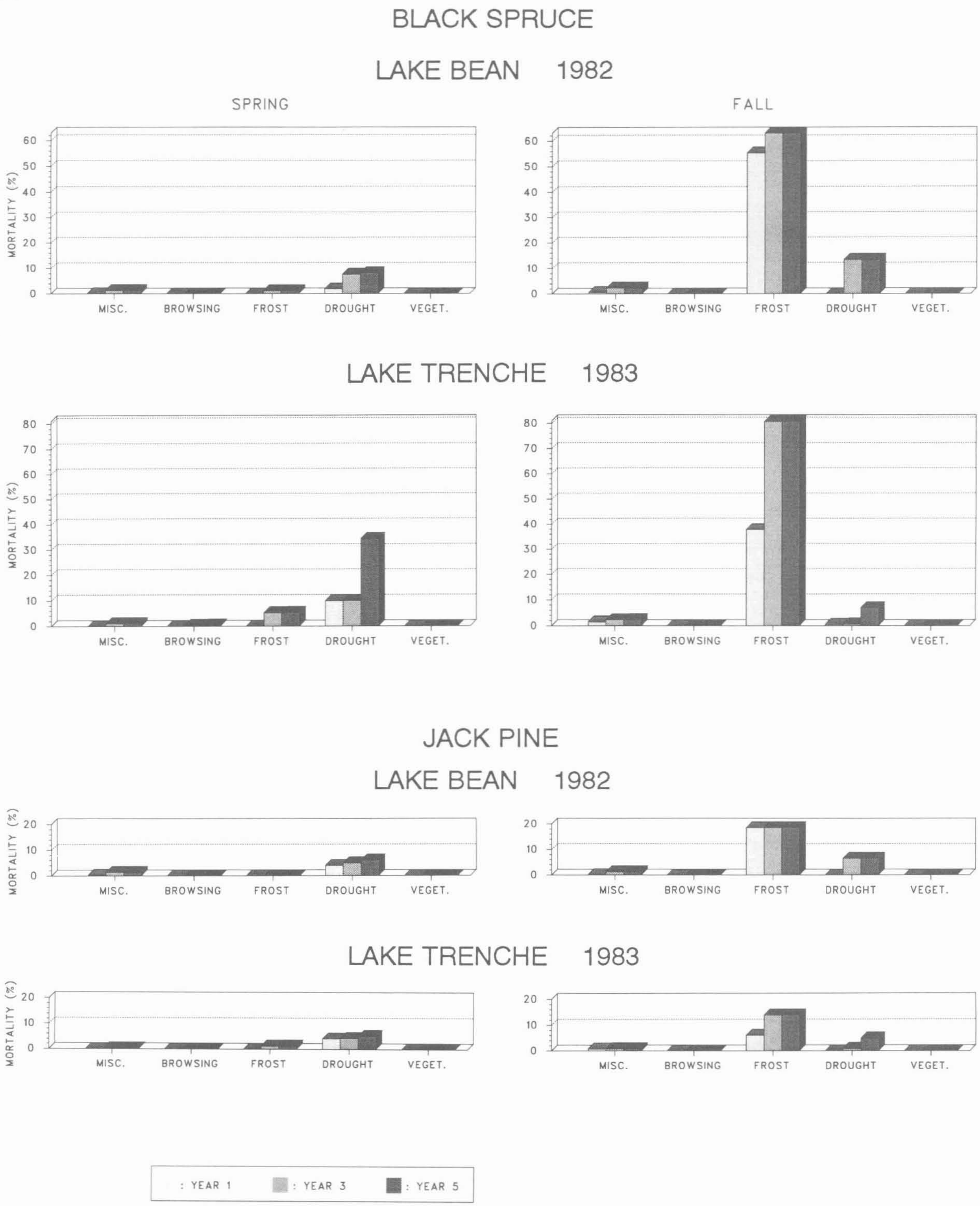

Figure 10. Breakdown of causes of mortality in jack pine and black spruce planted in the spring and fall of 1982 at Lac Bean and 1983 at Lac Trenche. Results correspond to monitoring in the first, third, and fifth year following planting.

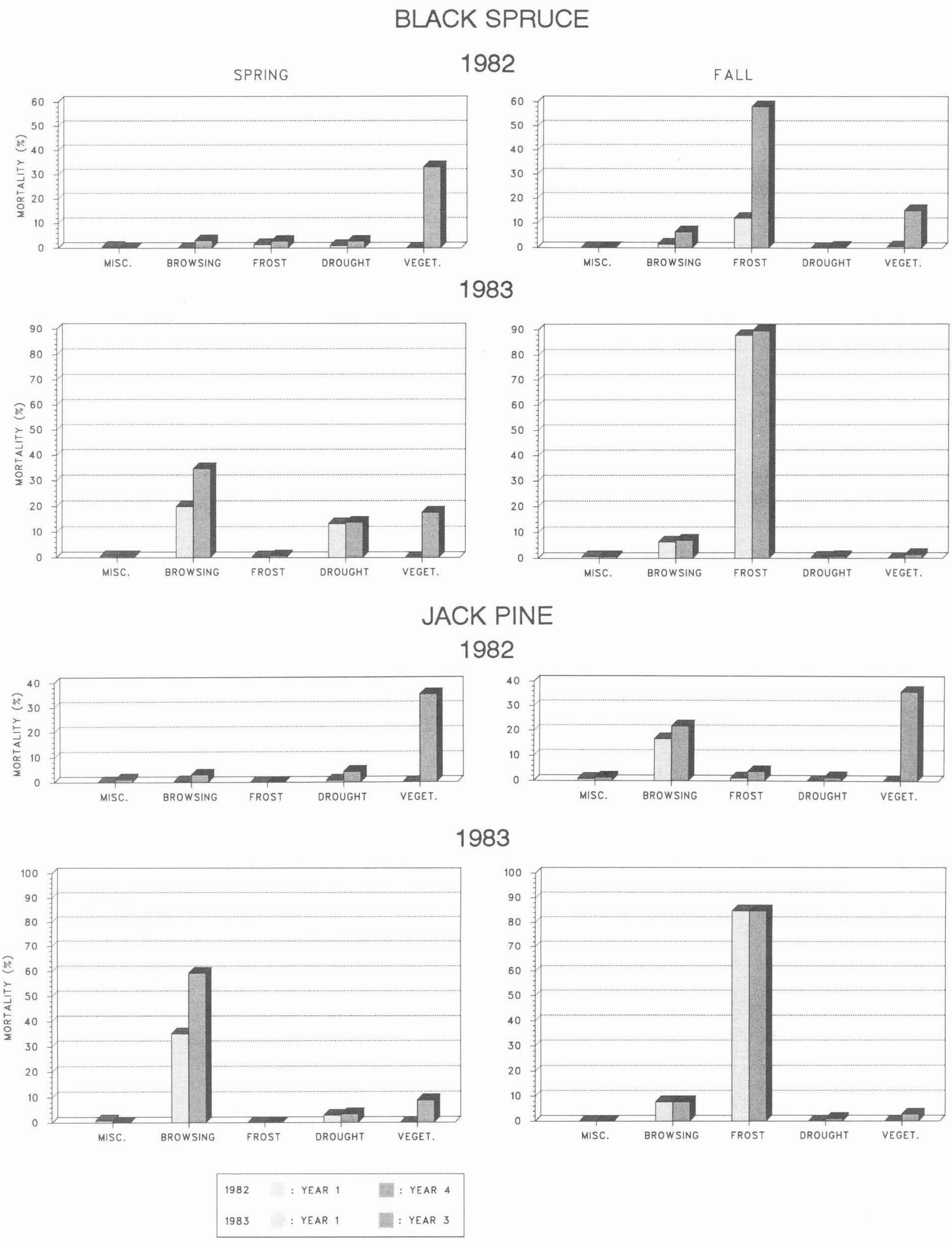

Figure 11. Breakdown of causes of mortality in jack pine and black spruce planted at Lac Métis in the spring and fall of 1982 and 1983. Results correspond to monitoring in the first, third or fourth year following planting.

Table 7. Mortality rates (%) after the first, third, and fifth year following planting for black spruce and jack pine planted at Lac Bean, Lac Trenche and Lac Métis in the spring and fall of 1982 and 1983. Monitoring at Lac Métis was suspended in the fifth year because of the high rate of mortality encountered the third year

Location	Year	Planting period	Species	Year following planting		
				1	3	5
Lac Bean	1982	Spring	JP	4.3	6.4	7.5
			BS	2.1	10.3	10.9
		Fall	JP	18.8	26.5	26.5
			BS	56.0	79.0	79.0
Lac Trenche	1983	Spring	JP	4.2	6.0	7.0
			BS	9.9	16.7	41.3
		Fall	JP	6.9	15.9	19.9
			BS	39.9	83.6	89.8
Lac Métis	1982	Spring	JP	1.3	43.9[a]	
			BS	3.0	42.3[a]	
		Fall	JP	18.8	64.3[a]	
			BS	14.6	80.7[a]	
	1983	Spring	JP	39.0	75.3	
			BS	34.2	67.5	
		Fall	JP	92.6	96.5	
			BS	95.4	99.6	

[a] Monitoring of the 1982 planting at Lac Métis took place the fourth year following planting.

The second point is that the particularly dry summer of 1983 had a severe impact on black spruce seedlings planted in the fall of 1982 and the spring of 1983. At Lac Bean and Lac Trenche, July precipitation was 30 mm instead of the 100 mm normally recorded. Moreover, the month of July in both 1984 and 1985 was also very dry, with 61 mm and 58 mm of rain respectively. On all three sites, jack pine proved more tolerant to drought than black spruce. The greatest losses were observed at locations with the fastest drainage and the least plant competition. According to Spittlehouse and Stathers (1990), cleared land is more susceptible to evaporation of water stored in the ground. These authors, therefore, recommend keeping an organic or plastic mulch on the ground to reduce evaporation losses.

Thirdly, the Lac Bean and Lac Trenche sites, which were burned areas, had virtually no plant competition problems, nor was any mortality caused by animals noted at these two sites, probably because of the lack of plant cover to protect animals against predators. At Lac Métis, however, there were greater losses due to plant competition and animals. Indeed, jack pine planted in the spring of 1983, i.e. a year after site preparation, had the greatest losses due to animals, at close to 60%. These losses were caused by hare and white-tailed deer. Because of the very dense cover of herbaceous plants and underbrush, many seedlings planted at this location were not found the year following planting, whereas practically all seedlings planted at Lac Bean and Lac Trenche were found.

Variance analyses on survival rates corresponding to the last visit to the site showed that, for the three sites, spring plantings did significantly better than fall plantings. These analyses also showed that there was no significant difference between black spruce and jack pine planted at Lac Bean in the spring of 1982 and at Lac Métis in the spring of 1982 and 1983. In all other cases, jack pine gave significantly higher survival rates than black spruce. The same type of analysis also showed that there was no significant difference in survival rates in the three types of container used.

Height growth

The average height of jack pine and black spruce (Figure 12) at Lac Bean and Lac Trenche sites five years following planting was below the average height of plantings done by the MFO in the Saguenay–Lac-Saint-Jean region. It is the same for the average height of black spruce planted at Lac Métis, which is slightly below the regional average. This average comes from a sampling performed on more than 220,000 black spruce seedlings planted in 1984 in both regions and on more than 235,000 jack pine seedlings planted the same year in the Saguenay–Lac-Saint-Jean region. Those plants had been produced in greenhouses in 67-50[5] multi-pots and were 0.5 year for black spruce seedlings and 2.0 years for jack pine ones at the time of outplanting in the Saguenay–Lac-Saint-Jean and Bas-Saint-Laurent–Gaspésie regions.

The slower growth of plants in the Lac Bean and Lac Trenche plantations may have been due to the generally colder climate, since there are on average 950 degree-days above 5.6°C compared with 1,200 at Lac Métis (min. Environnement 1978 to 1988).

Variance analyses on the total height of plants after five years were performed only for the Lac Bean and Lac Trenche plantations. At Lac Métis, not enough plants could be measured in the fifth year because of the excessively high mortality rate.

At Lac Bean, the analyses showed that there was no significant difference between the spring and fall plantings. The growth of jack pine was better than that of black spruce with a difference of 72% after five years. The analyses also showed that the average height of black spruce produced in Quebec Tubes was significantly greater than that of plants produced in Styroblock 2a, with a difference of 34% for spring planting and 56% for fall planting. Plants produced in

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[5] Information provided by Mr. François Trottier, who is in charge of the ministère des Forêts du Québec's data bank on monitoring of plantings (SPMF).

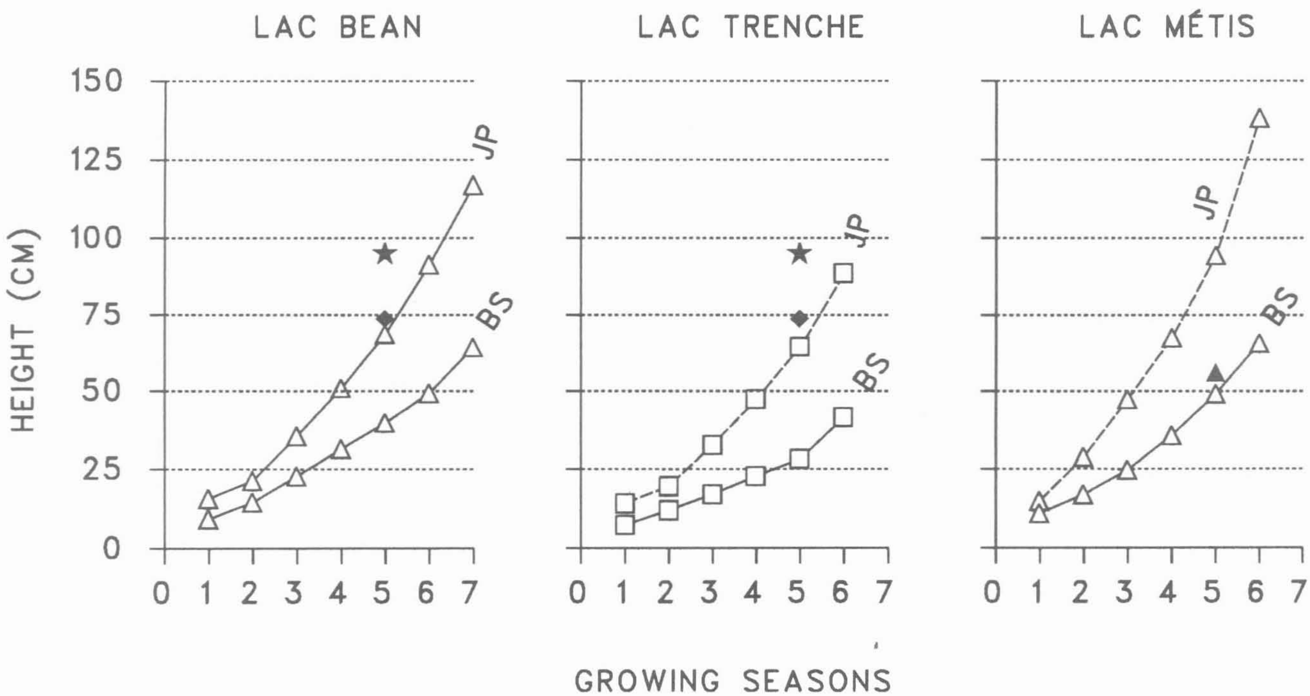

Figure 12. Height growth in black spruce (BS) and jack pine (JP) planted at Lac Bean and Lac Métis in 1982 (▲) and Lac Trenche in 1983 (□). For reference, five-year average height in plantings of jack pine (★) and black spruce (♦ and ▲) produced in greenhouses in 67-50 multi-pots and planted in 1984 by the MFO in the Saguenay–Lac-Saint-Jean and Bas-Saint-Laurent–Gaspésie administrative districts (▲) is given.

Styroblock 4 showed no noteworthy difference compared with plants produced in the other two types of container.

At Lac Trenche, we found no difference between spring-planted and fall-planted jack pine; however, the height of black spruce planted in the spring was on average 84% greater than that of the fall-planted ones. Jack pine proved superior to black spruce in all respects, and no difference was noted between the three types of container used.

TEST 4

Description of sites

The sites selected for this test were located at Thurso in the Outaouais region and at Saint-Martin in the Beauce region (Figure 1). The two sites are in the hardwood forest zone (Thibault 1985). The terrain was slightly sloping with drainage ranging from good to moderate.

The Thurso site was a clayey loam, at an elevation of about 55 m. The mean annual temperature is approximately 5.4°C and the July average is 20.2°C. The number of frost-free days ranges from 104 to 133. Annual precipitation is above 900 mm (min. Environnement 1978 to 1988).

The Thurso site was an old pasture that had been abandoned in 1982. The site was prepared in the spring of 1983 using a Finnish motorized disk scarifier known as the "TTS Disk Trencher". In use in Quebec since 1976, this scarifier had given good results on sites where the density of logging residue was not too great (Dancause 1977). On former farmland like the Thurso site, this type of preparation rather encouraged the growth of abundant vegetation. By the next spring, the site was thus overgrown by high, very dense vegetation made up mainly of grasses, daisies (*Chrysanthemum*), buttercups (*Ranunculus*) and goldenrods (*Solidago*).

The Saint-Martin site was clay containing many stones. The elevation is approximately 100 m. The mean annual temperature is 3.8°C and the July average is 18°C. The number of frost-free days ranges from 63 to 101. Annual precipitation is 980 mm (min. Environnement 1978 to 1988).

The site at Saint-Martin was a young mixed stand cut during the winter of 1982. Site preparation took place in the spring of 1983. A bulldozer was used to push down the small trees still standing and to level logging residues. Very dense vegetation, composed of herbaceous plants and shrubs, became established in the months following site preparation. Afterwards, no clearing of vegetation was carried out on either site.

Experimental designs

The Thurso arrangement was made up of two rectangular blocks with 40 plots of 50 plants each. This was an entirely random arrangement with five repetitions of the eight treatments (2 species x 2 containers x 2 seasons). The plots had two rows of plants with a 2.0-m spacing between rows and within rows. Each block corresponded to one planting year.

At Saint-Martin, we used an experimental arrangement of five complete random blocks (2 species x 2 containers x 2 seasons) for each year of planting. The plots were square with seven rows of seven plants. Spacing between plants was 2.0 m by 2.0 m.

The two sites were replanted in the spring and fall of 1983 and 1984 with white spruce and black spruce 19 to 22 weeks old. Seedling characteristics at the time of planting are shown in Table 8.

Table 8. Average height of white spruce and black spruce planted at Thurso and Saint-Martin in 1983 and 1984

Year	Planting period	Type of container	Species	Height (cm)
1983	Spring	Paperpot 508	WS	11.7
			BS	13.1
		Styroblock 8	WS	10.2
			BS	11.7
	Fall	Paperpot 508	WS	16.0
			BS	17.6
		Styroblock 8	WS	13.2
			BS	17.9
1984	Spring	Paperpot 508	WS	11.2
			BS	13.6
		Styroblock 8	WS	10.7
			BS	15.2
	Fall	Paperpot 508	WS	7.3
			BS	14.9
		Styroblock 8	WS	7.5
			BS	11.7

Results and discussion

Mortality rate

The mortality rate in the 1983 plantings was below the acceptable level of 20% (Dancause 1977) on the two sites after the first year in the field (Table 9). However, in 1984, fall-planted seedlings showed less acceptable results starting in the first year, when mortality on black spruce was 37.1% at Thurso and 62.5% at Saint-Martin. On the other hand, white spruce showed more encouraging signs, but the mortality rate remained high, at 27.8% at Thurso and 30.5% at Saint-Martin. At the latter site, the plant cover, which resulted from site preparation, provided an excellent habitat for hare, which was one of the main causes of mortality (Figure 13) and damage to seedlings.

Table 9. Mortality rates (%) after the first, third, and fifth year following planting, for black spruce and white spruce planted at Thurso and Saint-Martin in the spring and fall of 1983 and 1984

Location	Year	Planting period	Species	Year following planting		
				1	3	5
Thurso	1983	Spring	BS	7.3	31.0	48.1[a]
			WS	5.6	24.5	38.3[a]
		Fall	BS	18.4	66.0	79.8[a]
			WS	6.2	44.2	55.7[a]
	1984	Spring	BS	7.9	47.4	55.3
			WS	7.8	44.9	55.0
		Fall	BS	37.1	85.3	91.6
			WS	27.8	68.6	83.1
Saint-Martin	1983	Spring	BS	13.7	29.4	39.6
			WS	10.7	25.4	34.1
		Fall	BS	18.4	47.5	60.8
			WS	14.5	40.9	48.2
	1984	Spring	BS	23.1	66.7	
			WS	9.4	56.3	
		Fall	BS	62.5	94.8	
			WS	30.5	87.3	

[a] Monitoring of the 1983 planting at Thurso took place six years following planting.

The mortality rate continued to increase markedly after the first year, mainly in the fall plantings, where we noted the worst performance with losses of over 80%. Faced with this difficulty in the 1984 plantings at Saint-Martin, we stopped monitoring for the fifth year, so no further analysis was done on this plantation.

Variance analyses performed on survival rates after the fifth year in the field showed quite clearly that spring-planted trees did better than fall-planted ones. Black spruce gave just as good results as white spruce in the 1983 Saint-Martin and the 1984 Thurso plantings. In the latter case, we found no difference between Styroblock 8 and Paperpot. In the Saint-Martin planting, however, only the Styroblock 8 used in the fall planting gave a lower performance, with differences of up to 30% in white spruce and 57% in black spruce.

Finally, in the 1983 Thurso planting, a two-fold interaction appeared between species and container and between season and container. The results show that for plants produced in Styroblock 8, there was no difference between the two species and that the spring planting had a survival rate significantly higher (60%) than the fall planting (22%). For plants produced in Paperpots, however, the fall planting gave the same results (40%) as those of the spring planting (54%), and white spruce had a survival rate (63%) significantly higher than that of black spruce (31%).

Examination of causes of mortality at Thurso (Figure 14) shows several interesting points. First, the large proportion of dead plants associated with abundant herbaceous vegetation suggests significant competition at this site. In fact, beginning in the spring of 1984, very dense herbaceous vegetation grew on the site, making it very difficult to locate the seedlings planted the previous year. As well, a damp mulch several centimetres thick shaded or covered the young seedlings that had been planted at the bottom of the furrows. Over 20% of the plants were not found on the first visit. Second, although losses due to early fall frosts were not alarming, the fact remains that damage to live seedlings was high. Third, mortality due to animals was mainly caused by meadow voles (*Microtus pennsylvanicus*). The large number of tunnels found in the mulch led us to suspect a large field mouse population.

At Saint-Martin, we found a slightly different mortality cause profile (Figure 13). At this location, mortality due to animals was much higher than at Thurso, and snowshoe hare (*Lepus americanus* Erxleben) was the main culprit. According to Sinclair and Smith (1984), white spruce is a preferred species for hare, and these authors found that hare prefers the older parts of the stem rather than the current year's shoots. The seedlings are exposed to browsing by hares, which can result in serious damage if repeated from year to year or if it increases when the population cycle of these animals peaks (Stiell 1981).

Early fall frosts and competing vegetation remained at acceptable levels. As well, losses due to drought occurred in seedlings planted in the spring of 1983. Indeed, the summer of 1983 was remarkably dry; total precipitation was 47% less than the normal level of 217 mm for July and August (min. Environnement 1978 to 1988).

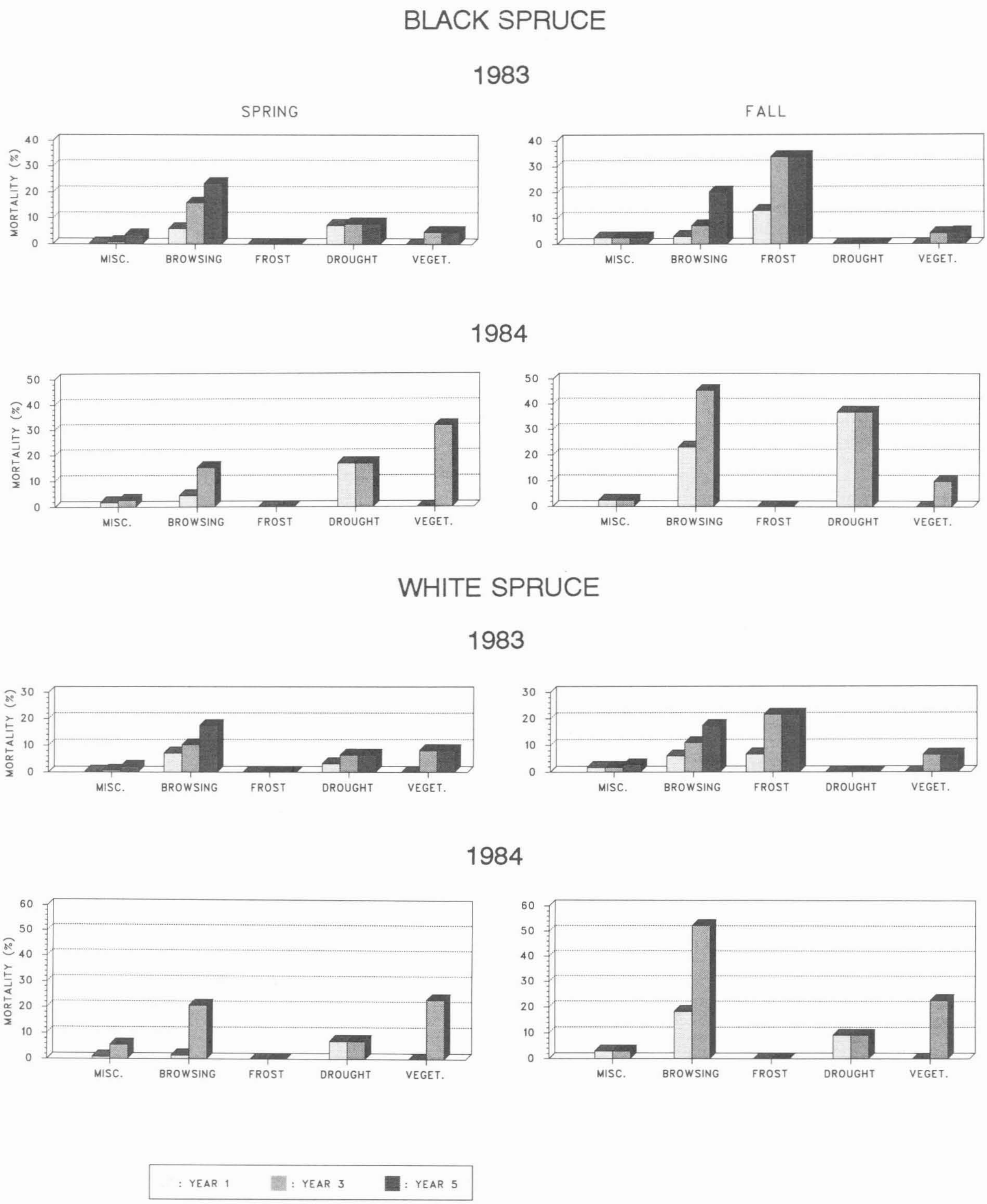

Figure 13. Breakdown of causes of mortality in black spruce and white spruce planted at Saint-Martin in the spring and fall of 1983 and 1984. Results correspond to monitoring in the first, third and fifth year following planting.

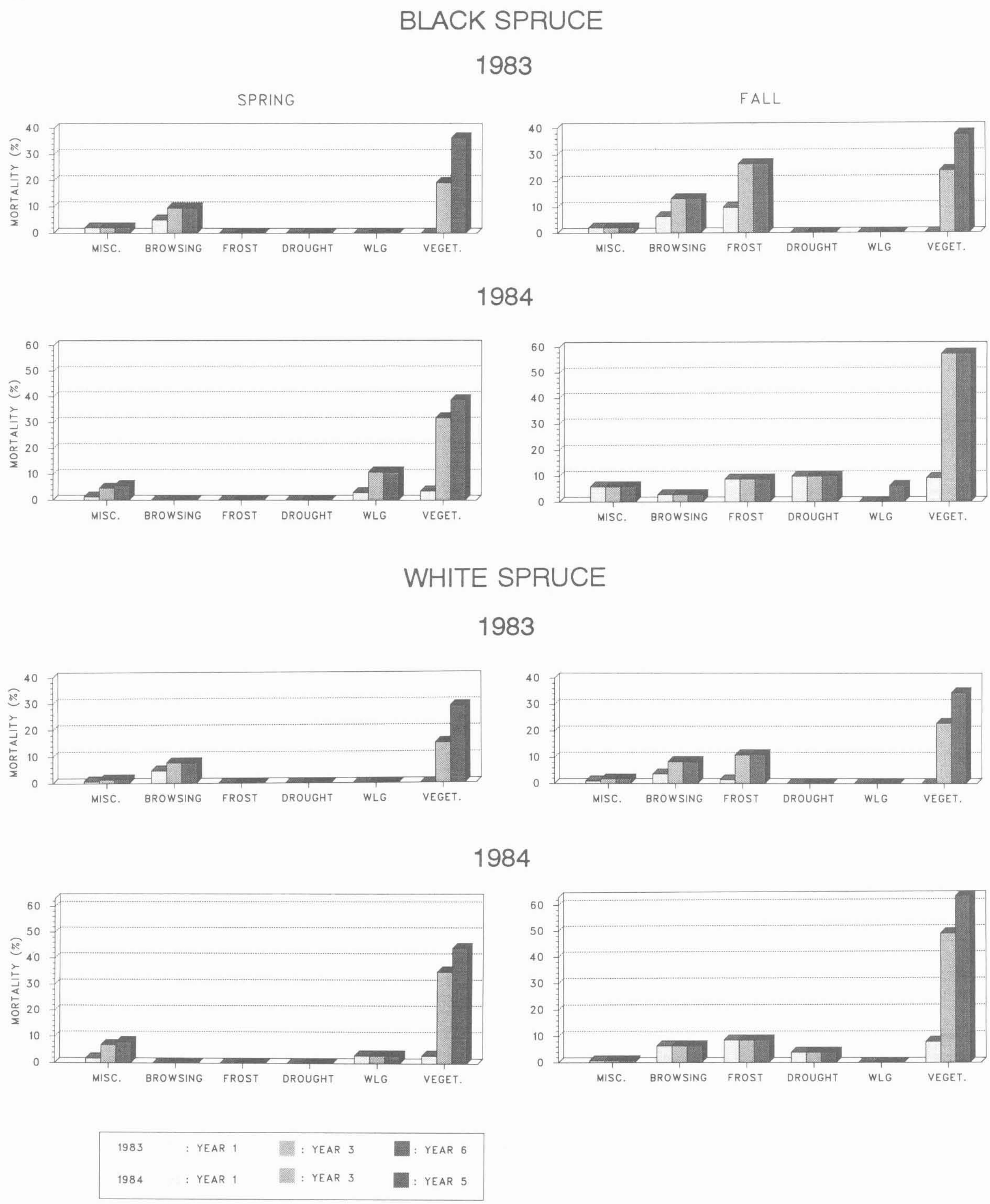

Figure 14. Breakdown of causes of mortality in black spruce and white spruce planted at Thurso in the spring and fall of 1983 and 1984. Results correspond to monitoring in the first, third, fifth or sixth year following planting.

In 1984, the very dense vegetation already on the site caused a number of problems at the time of planting. The first problem was that seedlings were choked by this vegetation, while the second had to do with losses due to hydric stress associated with heavy competition for water. As well, losses due to browsing by animals that had found shelter in this plant competition remained high at this site.

Height growth

The average height of white spruce at the Saint-Martin site, five years following planting, is comparable to the average height of plantations done by the MFO in the Beauce region (Figure 15). However, at Thurso, the average height of black spruce plants is below the average height of plantings done by the MFO in the Lièvre inférieure management unit. Average heights obtained by the MFO come from a sampling performed on about 92,000 black spruce seedlings and on more than 182,000 white spruce seedlings produced in greenhouses in 67-50 multi-pots and planted in 1984[6] at 1.0 and 1.5 years respectively.

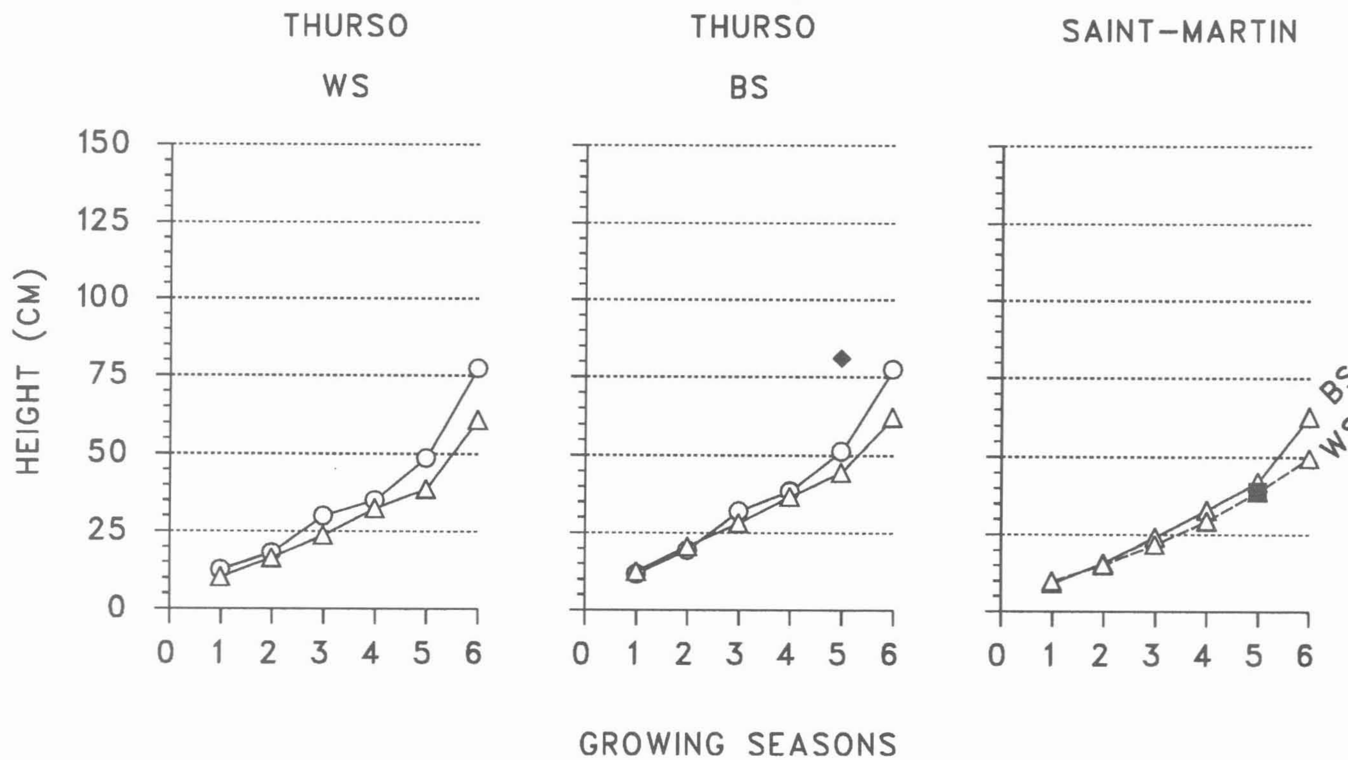

Figure 15. Height growth in black spruce (BS) and white spruce (WS) planted at Thurso and Saint-Martin in 1983 (○) and 1984 (△). For reference, five-year average height in outplantings of black spruce (◆) and white spruce (■) produced in 67-50 multi-pots and planted in 1984 by the MFO in the Beauce and Lièvre inférieure management units respectively is given.

[6] Information provided by Mr. François Trottier, who is in charge of the ministère des forêts du Québec's data bank on monitoring of plantings (SPMF).

Variance analyses on the average height of trees planted at Thurso in 1983, five years following outplanting, indicated that only white spruce produced in Styroblock 8 and planted in the spring showed a significant difference. A gain ranging from 11% to 35% was noted for this treatment compared with other treatments. At Saint-Martin, variance analyses on average height showed no difference between treatments.

For the plantings in 1984 at Thurso and Saint-Martin, no analysis was made of average height due to a lack of data caused by an excessively high mortality rate.

MORTALITY RATE FIVE YEARS FOLLOWING OUTPLANTING FOR ALL FOUR TESTS AND BREAKDOWN OF CAUSES OF MORTALITY

A mortality rate (%) was calculated based on the two planting seasons and the two types of plants (spruce and pine) used in the four tests. The mortality rates shown in Figure 16 are derived from the ratio between the number of dead plants five years following outplanting and the number of seedlings initially planted. We have included in these calculations the results of monitoring in a period other than the fifth year. This was the case in monitoring carried out the sixth year under Test 1 at Lac-Drolet in 1983, in monitoring carried out in the third and fourth year of Test 3 at Lac Métis in 1983 and 1984, and in monitoring carried out in the sixth year of Test 4 at Thurso in 1983.

Figure 16 shows that fall plantings had much higher mortality rates than spring plantings: pines had mortality rates of 48% and 31% respectively, while spruces had rates of 74% and 42%. Examination of this figure shows three major causes of mortality: competing vegetation, animals and early frosts. Of the various types of vegetation encountered, herbaceous plants and raspberry canes (*rubus* sp.) proved the most harmful. Animals also caused significant losses. These were due to girdling of the stem by small rodents or complete browsing of the seedlings by cervidae. It was observed that losses due to animals were proportional to the presence of vegetation in plantings.

Fast action to control plant competition would achieve two objectives: reduce the mortality rate due to vegetation and decrease the losses and damage caused by animals. The reduction or elimination of plant cover by mechanical or chemical means would force animals to take refuge in better-protected areas, as occurred at Grand-Mère and Lac-Drolet (Test 1).

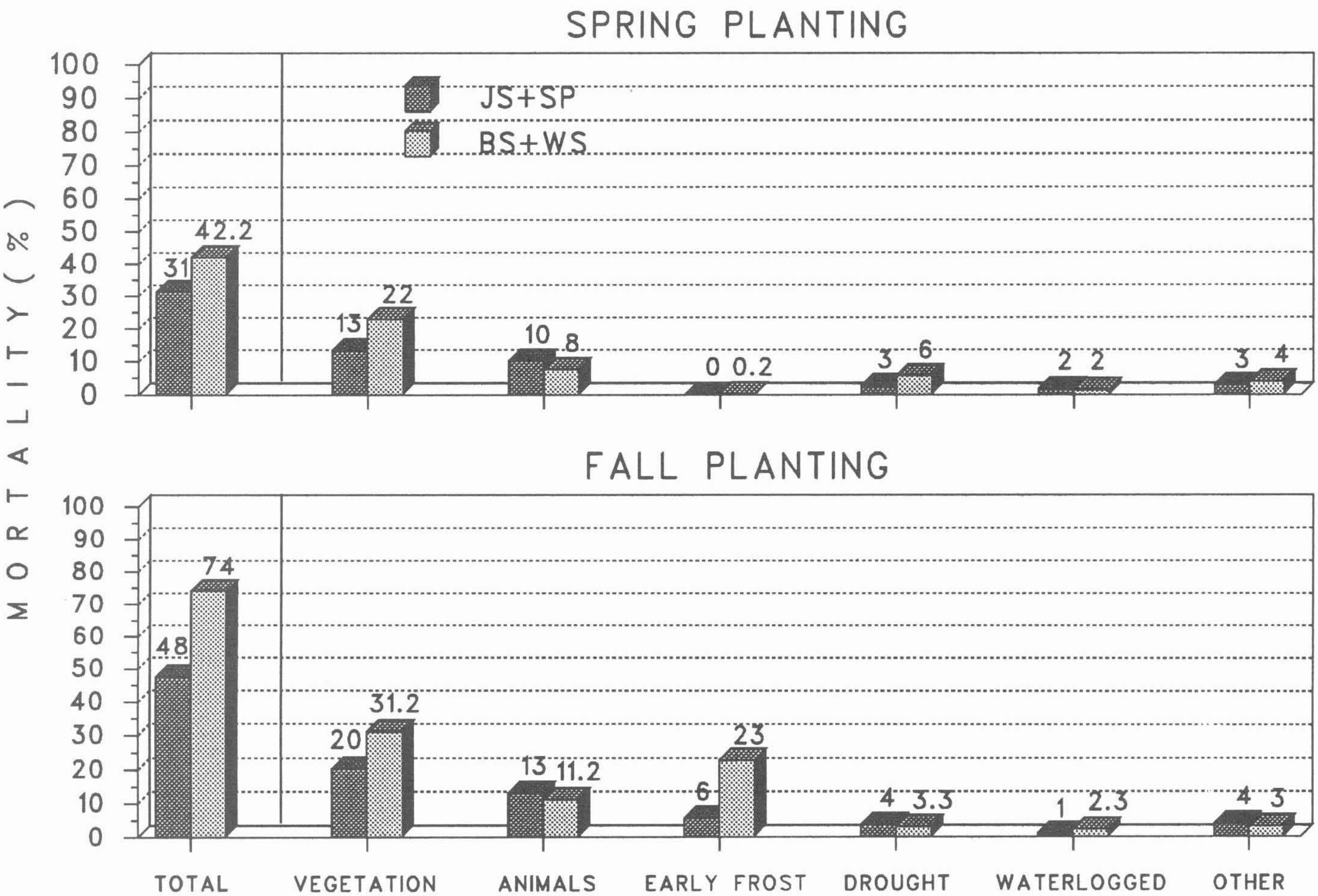

Figure 16. Mortality rate and main causes of mortality five years following outplanting for all four tests.

Early frosts also caused major losses in fall-planted black spruce seedlings because they had not been sufficiently hardened. The seedlings had been cultivated at Sainte-Foy, then, before undergoing acclimatization treatment, shipped to the sites, which were either further north or at higher elevations and thus frosts there were earlier and harsher. Losses caused by early frosts are now practically a thing of the past in Quebec since planting is no longer done as late as September. Moreover, planting seedlings produced by nurseries located closer to reforestation areas considerably reduces problems due to early frosts because seedlings are better adapted to regional conditions.

DISCUSSION AND RECOMMENDATIONS

In this study, we obtained growth and survival responses for four conifer species planted on different sites in Quebec. The results clearly show that survival and growth are directly influenced by a great many environmental factors, some of which can be more easily identified by the forester than others, such as competing vegetation, animals, climate and drainage. The various problems that arose during these tests occurred differently depending on site location, ground preparation method, species planted, location of microsite and planting period.

Competing vegetation, which was clearly the worst problem for the survival of plants, was very dense on most sites with the exception of those at Lac Bean and Lac Trenche. These two sites, which were the northernmost of our eight test sites, were part of the spruce forest with lichens, considered a poor site. In addition, as the result of a fire the year before planting, there was a delay in re-establishment of plant cover. It was not until several years following planting that blueberries (*Vaccinium* sp.) began to grow sparsely, along with a few isolated aspens (*Populus tremuloïdes*).

On richer sites, the problems with competing vegetation are of another order. The Thurso, Lac-Drolet and Lac Métis sites, following deep scarification using the TTS device or barrels and chains performed early in the spring, had much denser growback of vegetation than the unscarified parts. The competition on these sites was mainly herbaceous plants, and this was the main cause of mortality in seedlings. Microsite was also a determining factor in plant survival. Seedlings planted in the lower part of furrows were crushed by vegetation at the end of the summer. A mulch several centimetres thick then covered the plants, many of which bent to the ground and smothered to death. Others were eaten by voles which had dug tunnels through the mulch to reach the seedlings during the winter.

In the lower parts of the sites, where drainage was slower, a number of seedlings planted in the bottom of a furrow became waterlogged and died due to prolonged accumulation of water in the spring. Seedlings planted on the crest of a ridge generally survived the excess water and plant competition. Rather than crushing the seedlings in the fall, these plants fell down on either side of the ridge, leaving the seedling free of vegetation.

At Grand-Mère, preparation of microsites using a Bräcke scarifier failed to prevent growth of aspen. Clearing using mechanical brush cutters with a view to eliminating this species failed to produce the anticipated results. This action instead resulted in a five-fold increase in the number of aspen stems because of the many stump sprouts. The next year, glyphosate spraying was carried out on part of the area with a view to again eliminating aspen shoots. Clearing was successful, but the untreated part where vegetation was several metres high provided shelter for deer and hare. Although mortality due to these animals was lower for Scots pine than for jack pine, damage was nevertheless considerable. In addition to loss of the terminal shoot, a number of plants lost almost all of their branches. Our results were similar to those obtained by Krefting and Arend (1960), who have observed a reduction in height growth and the development of many apical shoots.

The same phenomenon occurred at Lac-Drolet where an entire block of jack pine and Scots pine was destroyed by deer over the winter. Here again, this block had not been sprayed with chemicals and had served as a refuge for deer.

At Saint-Martin, we once again found a significant link between damage caused by animals and the importance of plant cover. In this case, the fast regrowth of shrubs and scrub in the experimental plots provided a habitat for hare, which was responsible for considerable damage.

Jack pine and black spruce, which are two of the conifers most preferred by hare (Parker 1986; Bergeron 1988), should be planted with moderation in areas where hare populations are high.

On the four sites where the ground was prepared only once for several consecutive years of planting, losses due to plant competition increased with the time elapsed between site preparation and planting.

Before undertaking any regeneration effort, it is necessary to prepare the site to ensure the success of the new stand. Clearcut sites should first be cleared and the site prepared manually or mechanically to make it ready for seedling planting. Scarification is an operation that makes the ground warmer, improves oxygenation, and increases water penetration. This measure should be taken as soon as possible after cutting.

The best period for this operation is at the most crucial time for competing plants, that is during that time of year when plants produce leaves, stems and flowers. At that time, there is a net loss of energy (nutrients) from the root system to the plant (Oswald 1990). Although the majority of plants would not be destroyed by this disturbance, they would be weakened for an extended period of time. This would allow seedlings to develop for a longer time in an environment free from too much plant competition.

Before proceeding with planting, an evaluation must also be made of soil conditions, for they directly influence the choice of reforestation species. Thus, soil drainage has a major influence on the success of planting, as a well-drained soil always gives better results. In general, pines do well on dry, sandy soil, while spruces prefer richer silty and clayey soils. A spring visit to the site would provide a better picture of poorly drained areas, so that they could be omitted from the reforestation program.

Planting should be done soon after ground preparation without leaving time for competitive plants to grow back. When replanting, care must be taken to ensure that there are no growths of competing vegetation around the seedlings. The ideal choice of a microsite varies with the reforestation site. In dry areas, seedlings should be planted at the bottom of the furrow, while in damper areas, they should be planted more on the shoulder. However, the latter has the disadvantage of increasing the risk of frost heaving (Örlander *et al.* 1990).

Weeds mainly cause problems on abandoned farmland. Competition by underbrush, on the other hand, is more common on former logging sites. Control of this vegetation is essential for the survival of plants. This does not mean exterminating it. If this plant cover is not too dense, it gives the seedlings some protection against sun scald, frost, drought, or frost heaving. If it is too abundant, however, it will be in competition with plants for light, nutrients and water in the soil.

When the outplanting has become well established, it is important that seedlings be given the best chance to grow and develop into a healthy, productive stand. To do so, the forester removes all the encroaching vegetation which, if left to grow freely, would choke seedlings.

Another major problem seedlings had to face was early frosts. This occurred mainly in spruce planted in late summer. Producing seedlings in a more southerly location than the planting area and too short a period in the shade house with a view to obtaining better lignification of seedlings were the main factors linked to mortality of seedlings due to early fall frosts.

Other problems related to cold can also occur, such as winter drying of the stem and late freezing of buds. The first problem arose during the winter in plants exposed to cold and dry wind, while the second occurred in the spring after budbreak. This phenomenon occurred mainly at night when the cooler and denser air from the top of the slope flows down towards the lower slope. An effective way of preventing these two phenomena would be to leave windbreaks placed so as to reduce the speed of prevailing winds and block cold air masses coming down the mountainside (Spittlehouse and Stathers 1990).

CONCLUSION

This report has presented the results obtained in reforestation tests carried out between 1981 and 1984 with small seedlings produced in containers and aged from 12 to 21 weeks at the time of planting. Intensive monitoring for five years following planting enabled us to better understand the dynamics of spring and fall planting for the four species used, namely: white spruce, black spruce, jack pine and Scots pine.

The results of this monitoring enabled us to arrive at the following conclusions:

1- The highest mortality rate is found in fall plantings.
2- Competing vegetation is the major cause of mortality.
3- Animals are responsible for major losses and damage in plantations.
4- Black spruce planted in the fall is more vulnerable to early frosts.
5- Height growth was the same for the spring and fall plantings.
6- The type of container, in over 75% of cases, does not significantly influence the growth and survival of plants.

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REFERENCES

Ackerman, R.F.; Johnson, H.J. 1962. Continuous planting of white spruce throughout the frost-free period. Canada, Dep. For., For. Res. Br., Tech. Note 117.

Arnott, J.T. 1971. Progress report on field performance of Douglas-fir and Western hemlock container seedlings on Vancouver Island, British Columbia. Dept. Environ., Can. For. Serv., Victoria, B.C. Inf. Rep. BC-X-63.

Arnott, J.T. 1972. Influences affecting container seedling performance on Vancouver Island, British Columbia. Pages 84-91 *in* Waldron ed. Proceedings of a workshop on container planting in Canada. Can. For. Serv., Ottawa, Ont. Inf. Rep. DPC-X-2.

Bergeron, J.-M.; Tardif, J. 1988. Winter browsing preferences of snowshoe hares for coniferous seedlings and its implication in large-scale reforestation programs. Can. J. For. Res. 18:280-282.

Bigras, F.J.; D'Aoust, A.L. 1992. Hardening and dehardening of shoots and roots of containerized black and white spruce seedlings under short and long days. Can. J. For. Res. 22:388-396.

Burgar, R.J.; Lyon, N.F. 1968. Survival and growth of stored and unstored white spruce planted through the frost-free period. Ont. Dep. Lands and Forests, Res. Branch. Res. Rep. 84.

Carlson, L.W. 1983. Guidelines for rearing containerized conifer seedlings in the Prairie provinces. Can. For. Serv., Northern For. Res. Cent., Edmonton, Alta. Inf. Rep. NOR-X-214E.

Cauboue, M. 1988. Le reboisement au Québec : Choix des essences résineuses. Énerg. et Ressour. Qué. Québec, Qué.

Cochran, W.G. 1963. Sampling Techniques, 2nd ed. John Wiley & Sons, Inc., New York.

Commission canadienne de pédologie, Comité de la classification des sols. 1978. Le système canadien de classification des sols. Minist. Agric. Can., Ottawa, Ont. Publ. 1646.

Conway, J.M. 1964. On the rentability of the Grand-Mère plantations. Communication CPPA. Montréal, Qué. W.S. Index n° 2321 (F-1).

Conway, J.M. 1980. La culture des semis en récipients chez Consolidated-Bathurst Inc. Pages 104-113 *in* Atelier de travail sur la culture des semis en récipients. 18-20 mars 1980. Québec, Qué. Pêches et Environ. Can., Énerg. Ressourc. Qué., Ordre ing. for. Qué. (éd.).

Côté, F. 1991. La forêt d'Hydro-Québec à Drummonville : historique. MERQ, Rapp. int. non publié.

Cousin, J.-Y.; Lanier, L. 1976. Techniques modernes de production de plants forestiers. Rev. for. fr. XXVIII-2:115-131.

Crossley, D.I. 1956. The possibility of continuous planting of white spruce throughout the frost-free period. Can. Dep. of North. Af., Nat. Resour. For. Res. Div. Tech. Note 32.

Cunningham, G.C. 1953. Growth and development of coniferous plantations at Grand-Mère, (Qc). Minist. Ressour. et Dév., section for., Div. rech. for., Ottawa, Ont. Note rech. for. n° 103.

Dancause, A. 1977. La régénération artificielle du pin gris au ministère des Terres et Forêts. Pages 119-149 *in* Atelier de travail sur l'aménagement du pin gris, Val d'Or (Qué.). Pêches et Environ. Can. et Terres et For. Qué. (éd.).

D'Aoust, A.L.; Trudel, D. 1985. L'endurcissement au gel et au stress du milieu, par des traitements photo-thermo périodiques, chez des semis d'épinette noire en conteneurs. Pages 76-85 *in* Deuxième atelier de travail sur la culture des semis en récipients. 24-30 nov. 1985. Gouv. du Canada, Serv. can. des forêts, gouv. du Québec, Ordre ing. for. Québec, Sainte-Foy, Qué.

Delisle, C. 1989. Programme informatique interactif pour le suivi des plantations (Version 1.0). For. Can., Région du Québec, Sainte-Foy, Qué. Rapp. inf. LAU-X-87.

Delisle, C. 1990. Résultats après trois ans d'un dégagement au glyphosate de semis de pin gris et de pin sylvestre en plantation. Pages 329-341 *in* Troisième atelier québécois sur la culture des plants forestiers en récipients, Chicoutimi (Qué.). Nov. 1988. Énerg. et Ressour. Qué. (Forêts), Serv. transfert tech. Québec, Qué.

Dorais, P. 1991. Performance des plantations établies dans des forêts publiques du Québec entre 1980 et 1989. Gouv. du Québec, min. des Forêts Qué. Québec, Qué.

Edlun, L. 1980. Mineral mound and humus mound methods: two alternative soil scarification methods applied in forest land in northern Sweden. Pages 427-436 *in* Symposium on Stand Establishment Techniques and Technology, Proc. IUFRO Subject Group S3.02-00, Moscow.

Fletcher, R. 1990. Ponderosa pine regeneration: the last scoop. Pages 11-15. USDA For. Serv. For. Res. West. Fort Collins, Col. January 1990.

Gagnon, J.D. 1972. Les plantations de Grand-Mère: modèle de reboisement pour l'avenir. Serv. can. for., Cent. rech. for. Laurentides, Sainte-Foy, Qué. Rapp. inf. Q-X-30F.

Gonzalez, A.; D'Aoust, A.L. 1987. Observations et mesures concernant la culture en serre de semis d'épinette noire en conteneurs. Serv. can. for., Cent. for. Laurentides, Sainte-Foy, Qué. Rapp. inf. LAU-X-79.

Hawey, R. 1980. La politique de reboisement au Québec. Pages 70-83 *in* Atelier de travail sur la culture des semis en récipients, Québec. Environ. Canada, Énerg. et Ressour. Qué. et Ordre ing. for. Qué. (éd.).

Hatcher, R.J. 1981. Survival and growth of some Paperpot seedling plantations in Quebec. Pages 367-371 *in* J.B. Scarrat, C. Glerum and C.A. Plexman ed. Proceedings of the Canadian Containerized Tree Seedling Symposium, 14-16 sept. 1981. Toronto, Ont. Pub. O-P-10.

Krefting, L.W.; Arend, J.L. 1960. Effect of Deer Browsing on a Young Jack Pine Plantation in Northern Lower Michigan. Lake States For. Exp. Station. USDA For. Serv. Tech. Note 586.

MacKinnon, G.E. 1970. Container planting in Ontario. For. Chron. 46:470-472.

McLean, M. M. 1959. Experimental planting of tubed seedlings 1958. Ont. Dep. Lands For., Div. Res., Tech. Series Res. Rep. No. 39.

McMinn, R.G. 1980. Root growth capacity and field performance of various types and sizes of white spruce stock following outplanting in the central interior of British Columbia. Pages 37-41 *in* H. Schmidt-Vogt ed. Characterization of Plant Material, Proc. IUFRO Working Group S1.05-04 Meeting, Waldbau-Institut der Univ., Freiburg, Germany.

Ministère de l'Environnement. 1978 à 1988. Normales des précipitations pour le Canada. Environ. atmosph. Downsview, Ont.

Mullin, R.E. 1968. Comparison betweeen seddlings and transplants in fall and spring plantings. Ont. Dep. Lands For., Res. Br., Res. Rep. No. 85.

Mullin, R.E. 1979. Plantation Performance Averages for Jack Pine. Ont. Minist. Nat. Res. For. Res. Note No. 20.

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

Mullin, R.E.; Howard, C.P. 1973. Transplants do better than seedlings. For. Chron. 49:213-218.

O'Donnel, W.A. 1977. Applied Techniques in Site Preparation for Forest Plantation Establishment. Pages 48-51 *in* R.F. Sutton ed. Proceedings of plantation establishment symposium. 21-23 sept. 1976. Kirkland Lake, Ont. Pub. O-P-5.

Örlander, G.; Gemmel, P.; Hunt, J. 1990. Site Preparation: A Swedish Overview. B.C. Minist. For. FRDA Rep. 105.

Oswald, E.T. 1990. Theoritical overview of successional considerations in vegetation management. For. Chron. 66: 361-365.

Parent, B. 1990. Ressources et industrie forestières : portrait statistique. Éd. 1990. Gouv. Qué., minist. For., Serv. comm. Publ. n° 91-3010.

Parker, G.R. 1986. The importance of cover on use of conifer plantations by snowshoe hares in northern New Brunswick. For. Chron. 62:159-163.

Pohtila, E. 1977. Reforestation of ploughed sites in Finnish Lapland. Comm. Inst. For. Fenn. 91(4).

Rahkonen, J. 1983. Paperpot reforestation chain, introduction of latest developments. Pages 1(4)-10(4) *in* Finnish technology for forest renewal. 25 mars 1983. Québec, Qué. Symposium sponsored by the Finnish Trade Association.

Scarratt, J.B. 1973. Japanese Paperpots for containerized planting of tree seedlings. I. Tools and equipment. Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ont. Inf. Rep. O-X-188.

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

Scarratt, J.B.; Ketcheson, D.E. 1974. Japanese Paperpots for containerized planting of tree seedlings. II. Preliminary evaluation of planting tools. Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ont. Inf. Rep. O-X-204.

Sheedy, G. 1984. Mesures et observations du pin gris (*Pinus banksiana* Lamb.) en contenant et à racines nues, trois ans après la plantation. Énerg. et Ressour. Qué., Serv. rech. for., Note n° 21.

Sinclair, A.R.E.; Smith, J.N.M. 1984. Do plant secondary compounds determine feeding preferences of snowshoe hares? Oecologia (Berlin) 61:403-410.

Smyth, J.H. 1980. A directory of forest tree nurseries in Canada. Can. For. Serv., Great Lakes For. Res. Cent., Sault Ste. Marie, Ont. Inf. Rep. O-X-305.

Spittlehouse, D.L.; Stathers, R.J. 1990. Seedling Microclimate. B.C. Minist. For. Land Manag. Rep. 65.

Stiell, W.M. 1981. L'épinette blanche : régénération artificielle au Canada. Min. Environ., Serv. can. for., Inst. for. nat. Petawawa, Chalk River, Ont. Rapp. inf. FMR-X-85F.

Sutherland, D.C. 1984. Effects of container volume and shape on the growth of black spruce (*Picea mariana* (Mill.) B.S.P.) seedlings. M.Sc.F. thesis, Lakehead Univ. Thunder Bay, Ont.

Sutton, R.F. 1991. Mounding site preparation for jack pine and black spruce in boreal Ontario: five-year results. For. Can., Great Lakes For. Cent., Sault Ste. Marie, Ont. COFRDA Rep. 3311.

Thibault, M. 1985. Les régions écologiques du Québec méridional (seconde approximation). Carte à l'échelle de 1:1 250 000. Minist. For., Serv. rech. for., 90 cm x 140 cm.

Van Eerden, E. 1972. Influences affecting container seedling performance near Prince George, British Columbia. Pages 92-100 *in* Waldron ed. Proceedings of a workshop on container planting in Canada, Ottawa, Ont. Inf. Rep. DPC-X-2.

Veilleux, J.-M. 1979. Taux de survie et accroissement en hauteur obtenus après cinq ans à la suite d'essais de reboisement continu. Énerg. et Ressour. Qué., Mém. rech. n° 58.

Veilleux, J.-M. 1983. Taux de survie et accroissement en hauteur obtenus après dix ans à la suite d'essais de reboisement d'automne. Énerg. et Ressour. Qué., Mém. rech. for. n° 84.

Walter, N.R.; Johnson, H.J. 1980. Containerized conifer seedling field performance in Alberta and Northwest Territories. Dep. Environ., Can. For. Serv., Edmonton, Alta. Inf. Rep. NOR-X-218.

Walters, J. 1969. Container planting of Douglas-fir. For. Prod. J. 19(10):10-14.