COOPERATION
COOPERATION AGREEMENT FOR FORESTRY DEVELOPMENT

ENTENTE DE COOPÉRATION SUR LE DÉVELOPPEMENT FORESTIER

FOREST RESEARCH REPORT

No. 40 August, 1992

FROST HEAVING OF SOFTWOOD SEEDLINGS, PLANTED ON A SANDY CLAY LOAM SITE

INTRODUCTION

Frost heaving is one of the major causes of first year container seedling mortality (Michaud, 1973; Bailey, 1976). It is most severe on non-gravelly, moist, fine textured soils (Heidman, 1976). Heaving is caused by periodic freezing and thawing of the upper soil causing seedlings to be partially or completely pushed out of the ground (Boyce, 1961). Snow and organic cover, because of their insulating characteristics, reduce the number of freeze thaw cycles and hence the incidence of frost heaving.

In 1991, a one year old seasonal plantation trial was assessed in Cumberland County, Nova Scotia, to determine the extent of frost heaving in relation to microsite, planting date, and tree species.

SITE DESCRIPTION

The seasonal trial was conducted on a recent cutover, situated on a moderately exposed site near Thomson Station, in the lowlands of Cumberland County. The soil series is Queens/ Kingsville (Nowlan and MacDougall, 1973), a sandy clay loam with good to imperfect drainage. Previously, the site was covered by a jack pine (*Pinus Banksiana* Lamb.) stand that was whole-tree-harvested, with all trees skidded to roadside for processing. After harvest, the site was prepared with shark fin barrels and chains to break up a layer of ericaceous vegetation. The action of the barrels and chains also reduced the depth of the duff layer and exposed mineral soil over approximately 20% of the site. The duff layer, composed of leaf litter and decomposing organic matter, ranged from about 5 centimetres (cm) thick to a very thin layer covering the mineral soil.

The weather data used in this study was collected in the community of Middleboro and obtained from Environment Canada. Middleboro is 20 km north-east of the trial site and has similar weather patterns to Thomson Station (Dzikowski et al., 1984). The total precipitation for the period from May to No-

Canada

Nova Scotia

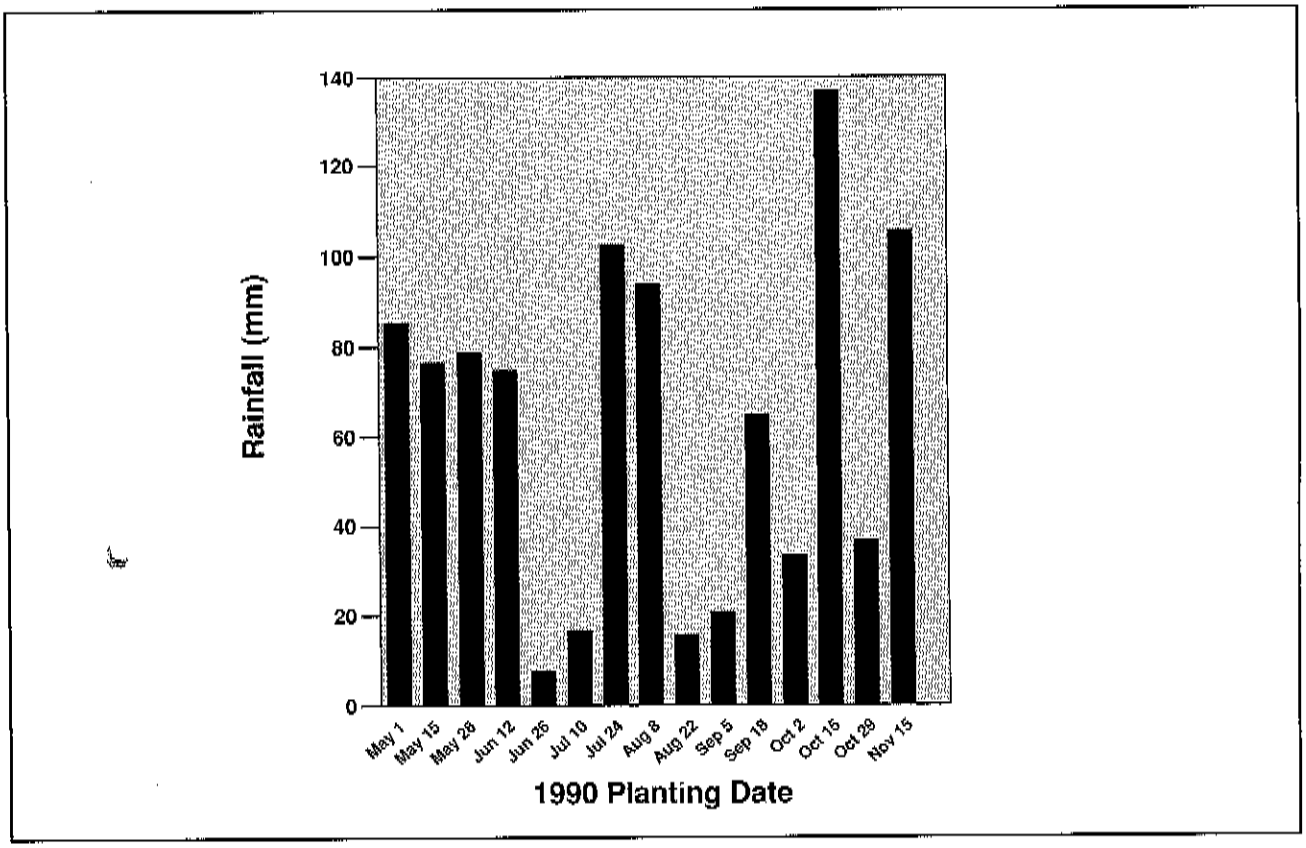


Figure 1: Precipitation during the 2 week period following each planting date.

vember, 1990 was 958 millimetres (mm), with a biweekly average of 68 mm (Figure 1). The corresponding 25 year averages for May to November are 609 mm and 44 mm (Environment Canada, 1982).

During the fall, winter, and spring of 1990-1991[1], approximately half the days had freeze thaw cycles [2] (95 days). Over this same time period, only 19 days had 10 cm or more of snow cover, and only 4 days had over 20 cm of snow cover. The previous 9 year average had 81 freeze thaw cycles, 54 days with 10 cm or more of snow cover, and 34 days with 20 cm or more of snow cover. These differences represent a 17% increase in freeze thaw cycles, a 65% decrease in days with 10 cm or more of snow cover, and an 88% decrease in days with 20 cm or more of snow cover.

METHODS

Establishment

A 1.5 hectare area was sectioned into 39 blocks, 27.5 metres (m) by 13.7 m, in April 1990. Blocks were randomly assigned to one of 13 biweekly planting dates, beginning May 1, 1990, and ending November 15, 1990, for all months except July. The spring planting session was from May 1 to June 26, the fall planting session was from August 8 to November 15. Each block was planted with 2 rows of 15 trees for each of 4 species: black spruce [*Picea mariana* (Mill.) B.S.P.], Norway spruce [*Picea abies* (L.) Karst.], red spruce [*Picea rubens* Sarg.], and white spruce [*Picea glauca* (Moench) Voss]. The trees were planted with dibbles at 1.8 m x 1.8 m spacing. An attempt was made to plant each seedling on a duff microsite.

The seedlings planted in this experiment

1 From November 1, 1990 to April 30, 1991, 181 days.

2 A freeze thaw cycle is defined as a day with a low temperature less than or equal to 0 Celsius (°C), and a high temperature greater than 0 °C. This does not mean that the soil necessarily froze or thawed, but the potential was there for this action to take place.

were multipots. Their stock quality characteristics at the time of planting are described in Appendix I.

Assessment

On June 3, 1991, every seedling in the experimental plantation was assessed. The trees were tallied as either live, dead or missing. If the seedling was not missing, it was assessed according to the microsite it was growing on (duff or mineral soil), and degree of frost heaving (nil, partial or completely heaved).

Seedlings were tallied as **live trees** if they had green foliage, even if they had been completely heaved and were lying flat on the ground. **Duff** microsites were defined as those with any amount of organic material covering the mineral soil: **mineral soil** microsites were defined as those with no organic layer. Seedlings were classified in the category: **nil heaving** when the top of the plug was even with ground level: **partial heaving** when the plug was raised above the ground surface with the roots still in contact with the soil: **complete heaving** when the plug was lying on its side such that the roots did not have contact with the soil.

Statistical Analysis

A stepwise linear discriminant analysis was performed to determine the factors contributing to seedlings being frost heaved.

RESULTS

Survival

Ninety-three percent of the seedlings survived the first winter after being planted; 6% were dead and less than 1% were missing. Black spruce had the greatest survival at 95% while red spruce had the least at 91%. Norway spruce was missing most often, 1.4% of the time. The highest mortality occurred in Norway spruce planted on August 8 (20%). Based on all species, the highest mortality for any of the planting dates occurred on September 18 (10%, Appendix II). Had the assessment been done later in the season, more of the completely heaved seedlings would likely have been dead.

Frost heaving versus microsite and planting date

Overall, 83% of the seedlings were planted on duff microsites, with only 17% planted on exposed mineral soil. The proportion of seedlings planted in duff ranged from 92% duff on the May 15 planting date, to 72% for October 29. Between species, the number of seedlings on duff microsites, varied from only 82% to 84%.

One half of the seedlings planted in this trial had some frost heaving; 21% were completely heaved, and 29% were partially heaved. Heaving was more severe on mineral soil microsites. In fact, 91% of the seedlings planted on mineral soil microsites were partially or completely heaved, compared to 41% on duff microsites. In addition, the degree of heaving on mineral sites was greater than on duff sites. On mineral sites, 63% of the planted seedlings were completely heaved compared to only 13% on duff sites (Table 1).

Heaving of seedlings also varied by planting date; heaving was least in the spring (38%) and greatest in the fall (57%) (Figure 2). In the

Table 1: Percent frost heaved by microsite.

Status of Seedlings	Duff Microsites	Mineral Soil Microsites	All Microsites
No heaving	58.6	9.3	50.2
Partial heaving	28.9	27.4	29.1
Complete heaving	12.5	63.3	20.7

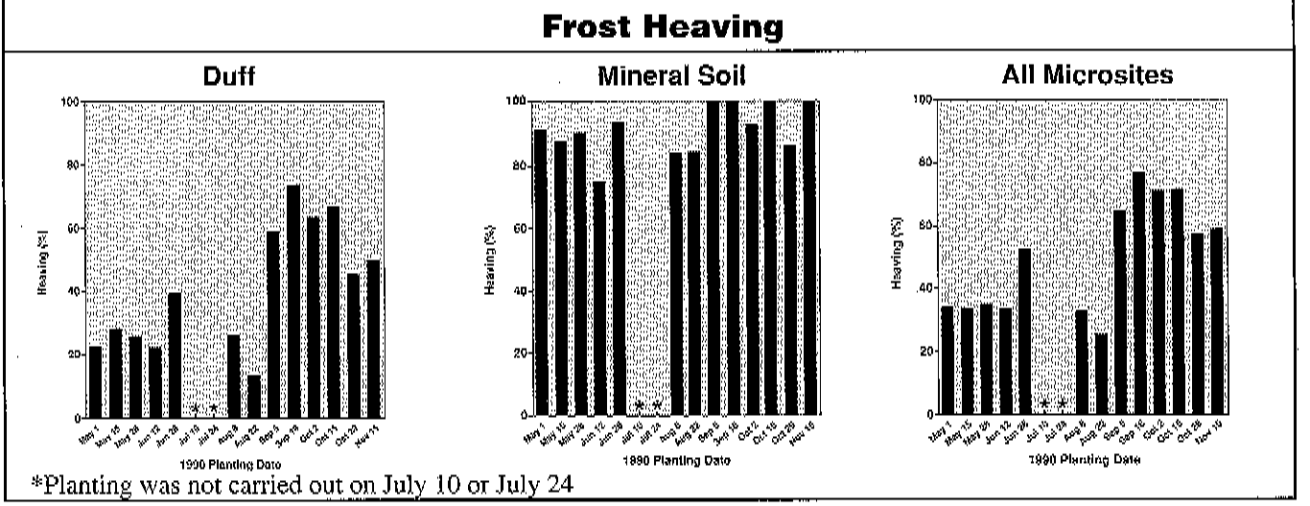


Figure 2: The percentage of seedlings frost heaved by planting date and microsite for all species. Both partially and completely heaved seedlings included.

spring, most frost heaving occurred on June 26 (52%). In the fall, frost heaving was least for seedlings planted on August 8 and 22 (averaging 29%). After August 22, heaving more than doubled to 67%.

For seedlings planted in the spring, heaving on mineral microsites was more than 3 times that on duff microsites (86% versus 28%). In the fall, heaving on duff sites increased substantially and the difference between microsites was less (50% versus 93%).

On mineral soil microsites, there was little difference in heaving between species, ranging from 89% for red and white spruce, to 93% for Norway spruce. On duff sites, over all planting dates, red spruce had the least heaving (36%), and black spruce had the most (48%). Each species showed similar patterns of heaving with microsite by planting date (Appendix III).

Discriminant Analysis

A stepwise discriminant analysis was utilised to determine the important factors contributing to frost heaving. The factors tested were: microsite, species, planting date, average tree height, root collar diameter, dry root weight, average high temperature and total precipitation for the 2 week period following planting.

The analysis resulted in functions correctly classifying the heaving status of the seedlings 73% of the time based on microsite, species, planting date, average seedling height and average temperature for the 2 week period after planting (Appendix IV). The two most significant factors in this analysis were microsite and date of planting. The functions classified all seedlings planted on a mineral soil site as frost heaved regardless of the other factors. In addition to microsite, planting date was also a significant indicator. Most seedlings planted on and after September 5, even on duff microsites, were classified as heaved by this analysis

SUMMARY

The following summarizes the results of a seasonal plantation trial on a sandy clay loam site, prepared with shark fin barrels and chains, and assessed for frost heaving in the first spring after planting. The seedlings were exposed to a winter with 17% more freeze thaw cycles, 65% fewer days with over 10 cm of snow cover, and 88% fewer days with over 20 cm of snow cover than the previous nine year average.

1) Ninety-one percent of the seedlings planted on mineral soil microsites were partially or completely heaved, averaging 86% in the spring and 93% in the fall planting session.

2) Forty-one percent of the seedlings planted on duff microsites were partially or completely heaved. Heaving was much greater starting on the September 5 planting date. Heaving increased from an average of 26% before September 5, to 60% for seedlings planted on and after September 5.

3) The degree of heaving was greater when seedlings were planted on mineral soil. Sixty-three percent of the seedlings planted in mineral soil were completely heaved compared to 13% for the duff sites.

4) The most significant factors leading to frost heaving, based on a discriminant analysis, were planting on a mineral soil microsite, and planting on and after September 5. The resulting classification based on the independent variables of: microsite, species, planting date, average seedling height, and average high temperature for the 2 week period after planting, correctly predicted the heaving status of 73% of the seedlings.

MANAGEMENT RECOMMENDATION

On sandy clay loam sites, extra care must be taken to ensure that seedlings are planted on a duff microsite to decrease the probability of frost heaving. On these types of sites, seedlings should not be planted after the last week of August, regardless of the microsite. It should be cautioned that different weather patterns, both during and after, any given growing season could lead to different results.

LITERATURE CITED

Bailey, R.E. 1976. *Survival of container stock on site prepared areas in Nova Scotia.* Nova Scotia Dept. of Lands and Forests, Internal Report. 20 pp.

Boyce, J.S. 1961. *Forest Pathology.* New York: McGraw Hill Book Company, Inc.. 572 pp.

Dzikowski, P.A., G. Kirby, G. Read and W.G. Richards. 1984. *The climate for agriculture in Atlantic Canada.* Atlantic Advisory Committee on Agrometeorology. Pub. No. ACA 84-2-500. 52 pp.

Environment Canada. 1982. *Canadian climate normals - temperature and precipitation - 1951-1980 - Atlantic provinces.* Canadian Climate Program, Environment Canada. 136 pp.

Heidman, L.J. 1976. *Frost heaving of tree seedlings: A literature review of causes and possible control.* USDA General Technical Report RM-21. 10 pp.

Michaud, R.P. 1973. *Frost heaving assessment of 1972 provincial container planting program.* Nova Scotia Dept. of Lands and Forests, Internal Report. 9 pp.

Nowlan, J.L. and J.I. MacDougall. 1973. *Soils of Cumberland County Nova Scotia.* Canada Department of Agriculture and Nova Scotia Department of Agriculture and Marketing, Report No. 17. 133 pp.

APPENDIX I

Stock quality characteristics at the time of planting.

Date		Average Root Collar Diameter[1] (mm)	Average Height[2] (cm)	Oven Dry Weight[3] (g)	Shoot/Root Ratio[4]
BLACK SPRUCE					
May	2	1.66	16.4	14.9	2.92
May	15	1.57	17.9	14.8	4.29
May	28	1.56	20.6	16.8	3.54
June	12	1.77	22.9	27.1	2.71
June	26	1.97	26.2	24.2	3.40
August	8	1.88	17.4	18.0	2.40
August	22	2.14	17.8	18.7	2.07
September	5	1.94	18.4	21.4	1.97
September	18	2.10	23.4	28.3	2.45
October	2	1.98	19.2	23.4	2.04
October	15	2.23	19.9	27.0	2.33
October	29	2.12	18.7	27.8	1.84
November	7	1.99	18.5	23.4	1.72
Average		1.92	19.8	22.0	2.59
NORWAY SPRUCE					
May	2	2.11	10.5	15.3	1.64
May	15	1.92	11.4	14.2	1.63
May	28	1.87	13.1	17.1	1.55
June	12	2.09	18.4	19.8	2.25
June	26	2.20	22.6	25.6	3.00
August	8	2.19	15.4	14.1	2.92
August	22	2.25	13.6	14.1	1.56
September	5	1.98	13.4	16.2	1.25
September	18	2.08	12.7	19.1	1.08
October	2	2.14	13.0	18.6	1.35
October	15	2.17	12.7	19.8	1.18
October	29	2.08	13.3	20.1	1.39
November	7	2.06	13.2	24.1	0.99
Average		2.09	14.1	18.3	1.68

[1] Average Root Collar Diameter -Root collar diameter measured at the junction of the roots and stem of the seedling.
[2] Average Height -Average seedling height measured from the root collar to the tip of the leader.
[3] Oven Dry Weight -Oven dry weight (g) of the shoot and roots of the seedling.
[4] Shoot/Root Ratio -Oven dry shoot weight divided by the oven dry root weight .

APPENDIX I (Con't.)
Stock quality characteristics at the time of planting.

Date		Average Root Collar Diameter[1] (mm)	Average Height[2] (cm)	Oven Dry Weight[3] (g)	Shoot/Root Ratio[4]
RED SPRUCE					
May	2	2.05	15.5	15.6	2.71
May	15	1.78	16.5	15.1	3.87
May	28	1.53	17.3	17.3	3.22
June	12	1.74	20.8	24.7	2.58
June	26	2.07	22.6	21.2	4.58
August	8	2.37	22.7	21.0	4.00
August	22	2.50	25.2	27.0	3.82
September	5	1.94	22.1	19.8	4.21
September	18	1.76	21.4	18.2	3.92
October	2	1.93	22.0	19.4	3.31
October	15	1.89	21.9	19.3	3.60
October	29	1.91	20.0	21.0	2.89
November	7	2.26	21.0	28.6	2.67
Average		1.98	20.7	20.6	3.49
WHITE SPRUCE					
May	2	2.57	23.6	34.5	3.73
May	15	2.05	24.0	28.7	4.86
May	28	2.15	23.3	33.3	3.76
June	12	2.44	29.9	40.0	3.76
June	26	2.51	32.6	42.9	5.04
August	8	2.24	16.6	14.8	2.79
August	22	2.26	17.7	18.5	2.36
September	5	2.20	17.2	20.9	2.12
September	18	2.14	17.5	22.1	2.03
October	2	2.04	17.0	22.4	2.15
October	15	2.14	17.9	23.6	2.06
October	29	2.15	16.2	24.8	1.73
November	7	2.12	16.4	26.0	1.60
Average		2.23	20.8	27.1	2.92

[1] Average Root Collar Diameter -Root collar diameter measured at the junction of the roots and stem of the seedling.
[2] Average Height -Average seedling height measured from the root collar to the tip of the leader.
[3] Oven Dry Weight -Oven dry weight (g) of the shoot and roots of the seedling.
[4] Shoot/Root Ratio -Oven dry shoot weight divided by the oven dry root weight.

APPENDIX II

Percent survival and frost heaving in relation to planting microsite, date, and species

Status of Seedlings	Planting Session													Average
	Spring					Fall								
	May 1	May 15	May 28	June 12	June 26	Aug. 8	Aug. 22	Sept. 5	Sept. 18	Oct. 2	Oct. 15	Oct. 29	Nov. 15	
All Species														
Live	93.6	93.3	97.2	92.8	92.8	90.0	92.8	95.6	90.0	95.8	91.4	91.4	96.7	93.3
Dead	4.7	6.7	1.9	6.9	6.7	8.3	7.2	4.4	9.7	4.2	8.6	8.6	3.1	6.2
Missing	1.7	0.0	0.8	0.3	0.6	1.7	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.4
All microsites														
No heaving	65.4	66.1	64.7	66.4	47.5	67.1	74.7	35.6	23.2	29.1	28.2	42.8	41.1	50.2
Partial heaving	21.7	25.3	26.6	22.2	20.3	21.3	17.5	41.5	35.2	38.8	36.8	35.3	36.1	29.1
Complete heaving	13.0	8.6	8.7	11.4	32.2	11.6	7.8	22.9	41.6	32.1	34.9	21.8	22.8	20.7
Planted in duff	83.1	91.9	86.1	78.1	76.2	88.4	82.8	87.0	88.0	80.2	86.6	72.1	81.1	83.2
No heaving	77.5	71.6	74.3	77.8	60.6	73.4	86.0	40.8	26.5	36.1	32.9	54.0	50.0	58.6
Partial heaving	15.5	23.0	21.5	18.3	21.0	19.3	12.7	43.8	38.5	41.8	41.8	38.6	39.8	28.9
Complete heaving	7.0	5.4	4.1	3.9	18.4	7.2	1.3	15.4	35.0	22.1	25.4	7.4	10.2	12.5
Planted in mineral soil	16.9	8.1	13.9	21.9	23.8	11.6	17.2	13.0	12.0	19.8	13.4	27.9	18.9	16.8
No heaving	8.4	16.7	10.3	30.2	6.2	15.8	15.4	0.0	0.0	6.8	0.0	12.4	2.1	9.3
Partial heaving	49.8	30.4	40.8	27.3	23.8	35.8	41.0	17.1	15.2	17.2	7.0	33.2	17.4	27.4
Complete heaving	41.8	53.0	49.0	42.5	70.1	48.3	43.6	82.9	84.8	76.0	93.0	54.4	80.6	63.3
Black Spruce														
Live	97.8	97.8	98.9	95.6	96.7	96.7	97.8	94.4	88.9	96.7	88.9	88.9	97.8	95.1
Dead	2.2	2.2	1.1	4.4	3.3	3.3	2.2	5.6	10.0	3.3	11.1	11.1	2.2	4.8
Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.1
All microsites														
No heaving	54.4	63.3	61.1	67.3	46.2	58.9	70.0	18.9	10.1	28.0	25.6	37.8	31.1	44.1
Partial heaving	31.1	22.2	32.2	22.5	18.7	26.7	18.9	55.6	49.6	38.4	41.1	38.9	40.0	33.5
Complete heaving	14.4	14.4	6.7	10.3	35.2	14.4	11.1	25.6	40.3	33.6	33.3	23.3	28.9	22.4
Planted in duff	86.7	86.7	85.6	84.2	72.5	86.7	76.7	84.4	89.8	81.1	84.4	68.9	82.2	82.3
No heaving	63.3	72.0	69.7	70.4	63.4	67.9	84.4	22.8	11.0	30.8	30.9	50.7	36.0	51.8
Partial heaving	27.9	19.2	29.1	19.4	13.3	25.6	14.4	60.2	55.6	42.7	46.6	43.7	46.2	34.1
Complete heaving	8.8	8.8	1.1	10.2	23.2	6.4	1.2	17.1	33.4	26.5	22.5	5.7	17.8	14.1
Planted in mineral soil	13.3	13.3	14.4	15.8	27.5	13.3	23.3	15.6	10.2	18.9	15.6	31.1	17.8	17.7
No heaving	0.0	8.3	16.7	57.1	0.0	0.0	23.8	0.0	0.0	14.8	0.0	5.6	4.8	8.8
Partial heaving	47.8	38.3	53.3	28.6	33.9	33.3	33.3	22.9	0.0	8.5	11.4	34.0	21.4	28.2
Complete heaving	52.2	53.3	30.0	14.3	66.1	66.7	42.9	77.1	100.0	76.7	88.6	60.5	73.8	63.0
Norway Spruce														
Live	86.7	94.4	93.3	96.7	87.8	73.3	96.7	98.9	93.3	97.8	94.4	95.6	98.9	92.9
Dead	7.8	5.6	3.3	2.2	11.1	20.0	3.3	1.1	6.7	2.2	5.6	4.4	1.1	5.7
Missing	5.6	0.0	3.3	1.1	1.1	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
All microsites														
No heaving	66.4	70.0	62.8	62.0	54.0	67.7	68.9	24.4	20.0	21.1	23.3	46.6	52.2	49.2
Partial heaving	19.8	25.6	27.0	24.8	23.4	14.8	28.9	51.1	32.2	40.0	37.8	33.8	30.0	29.9
Complete heaving	13.8	4.4	10.2	13.2	22.6	17.6	2.2	24.4	47.8	38.9	38.9	19.6	17.8	20.9

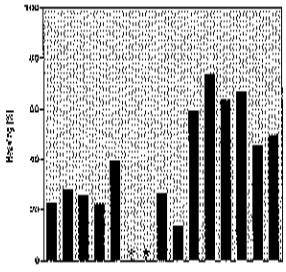
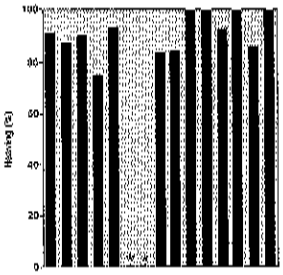
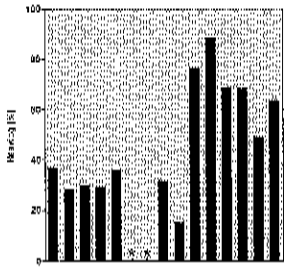
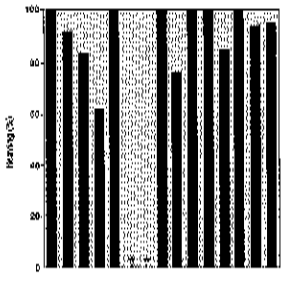
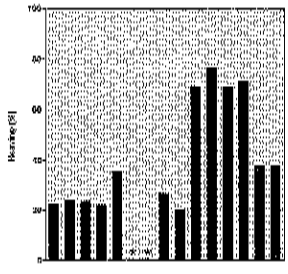
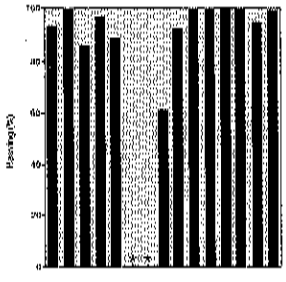
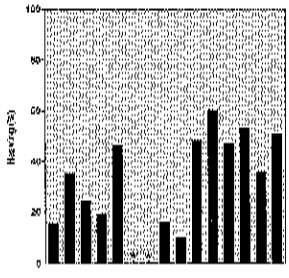
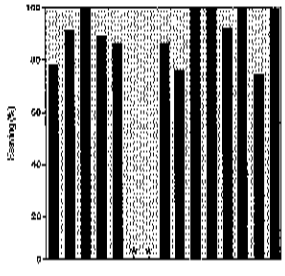
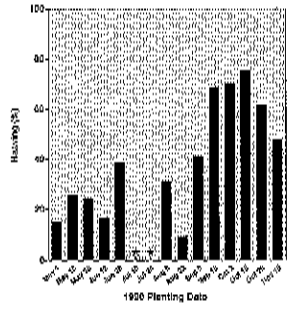
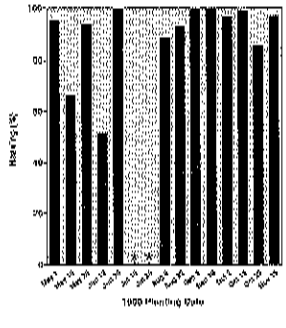
APPENDIX II (Con't.)

Percent survival and frost heaving in relation to planting microsite, date, and species.

Status of Seedlings	Planting Session													Average
	Spring					Fall								
	May 1	May 15	May 28	June 12	June 26	Aug. 8	Aug. 22	Sept. 5	Sept. 18	Oct. 2	Oct. 15	Oct. 29	Nov. 15	
Norway Spruce (Con't.)														
Planted in duff	83.7	93.3	80.0	79.2	83.2	84.8	84.4	83.3	86.7	77.8	85.6	72.7	82.2	82.8
No heaving	77.7	76.1	76.4	77.7	64.0	73.3	79.5	30.0	23.1	30.0	28.2	62.4	62.4	58.5
Partial heaving	15.3	20.6	18.8	21.1	23.0	12.7	19.4	52.9	35.1	46.2	43.4	32.1	36.4	29.0
Complete heaving	6.9	3.3	4.8	1.2	13.0	14.0	1.2	17.1	41.8	23.7	28.4	5.6	1.1	12.5
Planted in mineral soil	16.3	6.7	20.0	20.8	16.8	15.2	15.6	16.7	13.3	22.2	14.4	27.3	17.8	17.2
No heaving	6.7	0.0	14.3	2.8	11.1	38.9	7.4	0.0	0.0	0.0	0.0	4.8	0.0	7.0
Partial heaving	43.3	83.3	36.2	30.6	42.4	28.9	81.5	25.0	17.8	19.0	5.6	40.7	4.8	32.7
Complete heaving	50.0	16.7	49.5	66.7	46.5	32.2	11.1	75.0	82.2	81.0	94.4	54.5	95.2	60.3
Red Spruce														
Live	92.2	95.6	98.9	90.0	93.3	92.2	82.2	90.0	85.6	92.2	91.1	85.7	96.7	91.2
Dead	6.7	4.4	1.1	10.0	5.6	7.8	17.8	10.0	14.4	7.8	8.9	14.3	2.2	8.5
Missing	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.3
All microsites														
No heaving	72.9	61.1	66.7	64.2	41.1	77.8	78.9	44.4	35.0	42.5	41.1	54.7	42.2	55.6
Partial heaving	13.6	31.1	25.6	24.7	23.3	15.6	11.1	28.4	25.6	31.9	25.6	25.3	36.7	24.5
Complete heaving	13.6	7.8	7.8	11.1	35.6	6.7	10.0	27.2	39.4	25.6	33.3	20.0	21.1	19.9
Planted in duff	83.2	94.4	88.9	74.4	71.1	90.0	81.1	87.0	90.0	78.7	88.9	77.9	85.6	83.9
No heaving	84.4	64.1	75.8	80.4	53.5	84.1	90.0	51.6	39.2	52.8	46.4	63.7	48.9	64.2
Partial heaving	9.2	29.9	20.9	19.6	28.5	9.8	8.4	31.1	24.8	35.0	27.4	24.4	39.1	23.7
Complete heaving	6.4	5.9	3.3	0.0	18.1	6.1	1.6	17.3	36.0	12.2	26.3	11.9	12.1	12.1
Planted in mineral soil	16.8	5.6	11.1	25.6	28.9	10.0	18.9	13.0	10.0	21.3	11.1	22.1	14.4	16.1
No heaving	22.2	12.5	0.0	16.3	13.5	13.3	23.8	0.0	0.0	7.4	0.0	25.0	0.0	10.7
Partial heaving	33.3	25.0	33.3	38.1	12.7	70.0	14.8	8.3	42.9	13.2	11.1	36.1	18.8	27.3
Complete heaving	44.4	62.5	66.7	45.6	73.8	16.7	61.4	91.7	57.1	79.4	88.9	38.9	81.3	62.0
White Spruce														
Live	97.8	85.6	97.8	88.9	93.3	97.8	94.4	98.9	92.2	96.7	91.1	95.6	93.3	94.1
Dead	2.2	14.4	2.2	11.1	6.7	2.2	5.6	1.1	7.8	3.3	8.9	4.4	6.7	5.9
Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All microsites														
No heaving	67.8	70.0	68.4	72.2	48.9	64.1	81.1	54.4	27.8	24.8	22.9	32.2	38.9	51.8
Partial heaving	22.2	22.2	21.4	16.7	15.6	28.0	11.1	31.1	33.3	45.0	42.9	43.3	37.8	28.5
Complete heaving	10.0	7.8	10.2	11.1	35.6	7.9	7.8	14.4	38.9	30.3	34.2	24.4	23.3	19.7
Planted in duff	78.9	93.3	90.0	74.4	77.8	92.1	88.9	93.3	85.6	83.3	87.5	68.9	74.4	83.7
No heaving	84.7	74.3	75.4	82.8	61.3	68.4	90.1	59.0	32.6	30.8	26.0	39.3	52.5	59.8
Partial heaving	9.5	22.2	17.3	13.0	19.3	29.1	8.7	31.0	38.7	43.3	49.7	54.2	37.7	28.7
Complete heaving	5.8	3.4	7.2	4.1	19.4	2.5	1.2	10.0	28.7	25.9	24.3	6.5	9.8	11.5
Planted in mineral soil	21.1	6.7	10.0	25.6	22.2	7.9	11.1	6.7	14.4	16.7	12.5	31.1	25.6	16.3
No heaving	4.8	33.3	6.7	48.8	0.0	11.1	6.7	0.0	0.0	4.2	0.0	14.3	2.8	10.6
Partial heaving	74.9	8.3	37.8	16.1	6.1	11.1	34.4	10.0	0.0	33.3	0.0	22.2	25.0	21.5
Complete heaving	20.3	58.3	55.6	35.2	93.9	77.8	58.9	90.0	100.0	62.5	100.0	63.5	72.2	67.9

APPENDIX III

The percentage of seedlings frost heaved (both partially and completely heaved) by planting date, microsite and species. Planting was not carried out on July 10 and July 24 (*).

Duff Microsites		Mineral Soil Microsites
	All Species	
	Black Spruce	
	Norway Spruce	
	Red spruce	
	White Spruce	

APPENDIX IV
Results of stepwise linear discrininant analysis

Standardized canonical discriminant function coefficients and group means for seedlings not frost heaved and frost heaved.

Variable	Coefficient	Group Mean Value	
		Not Heaved	Heaved
Duff Microsite	-0.775	0.966	0.696
Black Spruce	0.192	0.220	0.281
White Spruce	0.068	0.259	0.241
Planting Date			
May 28	0.090	0.099	0.054
June 12	0.091	0.101	0.052
June 26	0.337	0.073	0.081
August 8	0.125	0.101	0.050
September 5	0.447	0.055	0.100
September 18	0.575	0.036	0.118
October 2	0.458	0.045	0.109
October 15	0.456	0.043	0.111
October 29	0.129	0.067	0.089
November 15	0.201	0.063	0.091
Average Seedling Height (cm)	-0.164	19.094	18.621
Average High Temperature for the 2 Week Period Following Planting (°C)	-0.231	17.927	16.186

Coefficients for Fisher's linear discriminant classification functions, for seedlings not frost heaved and frost heaved.

Variable	Not Heaved	Heaved
Duff Microsite	9.189	6.587
Black Spruce	-1.316	-0.795
White Spruce	-2.266	-2.083
Planting Date		
May 28	-2.836	-2.440
June 12	-12.354	-11.951
June 26	-16.242	-14.761
August 8	-12.364	-11.809
September 5	-3.710	-1.748
September 18	-0.144	2.419
October 2	0.911	2.943
October 15	9.460	11.485
October 29	23.099	23.665
November 15	22.907	23.789
Average Seedling Height (cm)	1.257	1.215
Average High Temperature for the 2 Week Period Following Planting (°C)	1.722	1.681
Constant	-31.765	-29.253

Frost heaving classification for planted seedlings using Fisher's classification functions.

Status	Number of Seedlings	Predicted Group Membership (%)	
		Not Heaved	Heaved
Not Heaved	2336	76.5	23.5
Heaved	2325	31.1	68.9

Overall, the function correctly classified 72.7% of the seedlings.

FOREST RESEARCH SECTION
FORESTRY BRANCH
N.S. DEPT. OF NATURAL RESOURCES
P.O. Box 68, Truro, Nova Scotia, Canada B2N 5B8

FOREST RESEARCH SECTION PERSONNEL

Technicians:	Dave Arseneau, Steve Brown, Sandy Chisholm, George Keddy, Randy McCarthy, Keith Moore, Bob Murray
Chief Technicians:	Laurie Peters, Cameron Sullivan
Data Processing:	Betty Chase, Eric Robeson, Ken Wilton
Foresters:	Peter Neily, Tim O'Brien, Peter Townsend, Carl Weatherhead
Editor/Forester	Tim McGrath
Supervisor:	Russ McNally
Director:	Ed Bailey
Secretary:	Angela Walker