FOREST MANAGEMENT NOTE

Note 53 Northwest Region

BLACK SPRUCE GROWTH ON DRAINED, FORESTED PEATLAND IN NORTHERN ALBERTA

In recent years, several forest drainage projects have been implemented in Alberta to study how trees respond to drainage (Hillman 1987; Tóth and Gillard 1988), but the time span since drainage has been too short to obtain meaningful tree growth response data. However, in 1975 a drainage trial was established near Fort McMurray in northern Alberta by the Alberta Forest Service (AFS), and black spruce (*Picea mariana* [Mill.] B.S.P.) growth data from this trial were used to obtain estimates of tree growth response to drainage. This note (condensed from Hillman et al. 1990) reports the responses resulting from the AFS trial, and draws some conclusions.

SITE DESCRIPTION AND TREATMENTS

The study area, a coniferous swamp in the mixedwood Boreal Forest Region of Alberta (Rowe 1972), was located 11 km south of Fort McMurray (Fig. 1), at an elevation of 400 m.

The study area was contained within a level glaciolacustrine plain, which had slopes of 0–0.7%. Lateral movement of water from the area was restricted by a clay lip along the adjacent creeks. Soil development consisted of an impermeable Rego Gleysol overlying glaciolacustrine sediments and a Terric Fibric Mesisol organic layer (0.5–1.2 m thick) on top of the Rego Gleysol. Vegetation, which had established itself after a wildfire in 1953, consisted of a dense cover of black spruce, in association with Labrador tea (*Ledum groenlandicum*), peat mosses (*Sphagnum* spp.), and feather mosses (*Hylocomium* spp., *Pleurozium* spp., and *Ptilium* spp.).

Establishment of Treated and Control Areas

Between 1975 and 1981, the AFS imposed a number of different treatments on the area to remove excess soil water and enhance forest growth. For the purpose of this report, data from two areas were used: a drained 25-ha area that was intensively cleared and ditched (Figs. 1 and 2), and the adjacent, undrained, 16-ha control area to the south (Fig. 1). It was essential to measure trees on the undrained area to determine if changes in tree growth resulted primarily from drainage or from changes in climatic conditions.

The 25-ha area was first treated in May 1975. During the initial treatment, vegetation and the upper layer of peat were cleared by angle blading, in 7-m wide strips, leaving windrows on either side, and 3.5-m wide, treed strips between the windrows. Where ponding occurred, lines were cut through the windrows and treed strips to facilitate drainage. The blading/clearing treatment was prescribed to reduce existing permafrost (which was believed to be contributing to poor tree growth) by decreasing the ground surface albedo. Because this treatment resulted in minimal drainage and growth response, it was decided to resort to ditching. A main ditch,

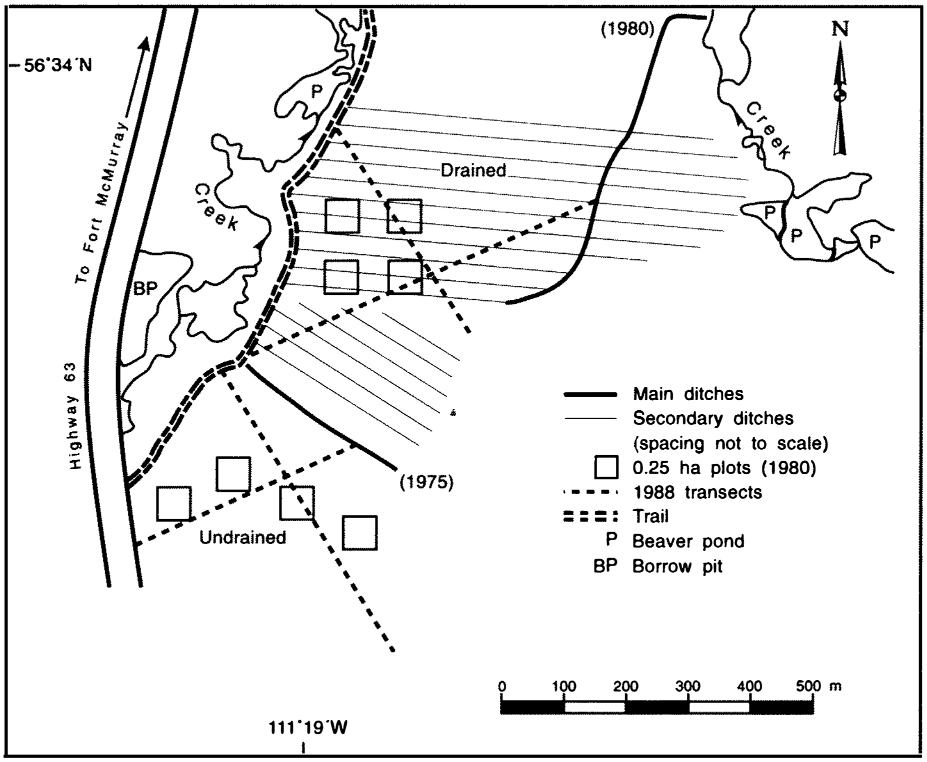

Figure 1. Study drainage area, located near Fort McMurray, Alberta.

Figure 2. Oblique aerial photo (looking east) of drained area, containing alternating cleared strips (7 m wide) with ditches in the middle, and treed strips (3.5 m wide).

305 m long, 2.1 m wide, and 0.9–1.5 m deep, was dynamited at the boundary between the drained and undrained areas to carry water away from the site (Fig. 1). No secondary ditches were constructed during this phase.

In work completed in September 1979, a Marttiini plow was used to dig secondary ditches (0.76 m deep) in the drained area; average ditch spacing was about 10 m. By December 1980 an additional main drainage ditch (650 m long, 1.07 m deep, and 1.06–1.22 m wide) had been dug by large tracked excavators in this area (Fig. 1).

In 1980, eight 0.25-ha plots were established in the drained and undrained areas, four in each area (Fig. 1); one plot in each area was then thinned to 1730 stems ha^{-1}. In May 1981 a second plot in each area was fertilized with nitrogen (ammonium nitrate, 34-0-0, 359 kg ha^{-1}) and a third with phosphorus (triple superphosphate, 0-45-0, 269 kg ha^{-1}). The fourth plot, which was neither thinned nor fertilized, served as a control plot. Because treatment took place over a six-year period (1975–81), for the purpose of analysis the postdrainage period was arbitrarily defined as 1979–88.

MEASUREMENT AND ANALYSIS

Each spring from 1981–85, growth measurements were taken for about 20–30 trees in each of the 0.25-ha, fertilized, thinned, or control plots established in 1980 (Fig. 1). These trees were located on a 5-m wide strip centered a 5-m wide strip centered along one diagonal in each plot, and they were measured each year for total height and leader growth. Stem diameter at the root collar was included in 1984 and 1985 measurements.

In August 1988, four new transects were established for destructive sampling purposes across both drained and undrained areas (Fig. 1). After excluding trees ≤1.1 cm dbh and trees located in the 0.25-ha plots, 42 trees on the transects were chosen at random. Of these, 22 trees were destructively sampled on the drained area and 20 on the undrained area. They were sectioned and measured according to procedures described by Alberta Energy and Natural Resources (1986).

A Holman digimicrometer and television camera were used to measure age and ring widths. The resulting data sets were processed by using the computer programs DUFFNO and STEM, which were developed by Kavanagh (1983). The STEM program carried out stem analyses and provided tables that showed average annual increment and periodic annual increment for height, dbh, basal area, and volume.

Paired and nonpaired *t*-tests were run to test two hypotheses: 1) there are no differences between growth averages for the drained and undrained areas; and 2) there are no differences between growth averages for the predrainage and postdrainage periods.

RESULTS

For the period 6–9 years after treatment began, data in Table 1 shows that the average annual leader growth for black spruce on 0.25-ha plots in the drained area was 3.8 times the growth on the undrained area. Although there may have been some effects due to the fertilizer and thinning treatments, the effect of the drainage appears to have been very much the dominant factor.

In 1981, on the same 0.25-ha plots, the average tree height on the drained area was 18 cm greater than on the undrained area; four years later, it was 121 cm greater. Figure 3 shows these differences in height growth for 1981 and 1985, reflected in their respective tree height frequency distributions.

Root Collar Diameter

In 1984 the average tree diameter growth at root collar for each treatment was greater on the drained area than the undrained; overall, the growth on the drained area was four times greater (Table 1). In 1985 the average root collar diameter increased to 5.9 cm on the drained area, and to 3.7 cm on the undrained. More than 60% of the trees on the drained area exceeded 5 cm in diameter, compared with only 8% on the undrained area (Fig. 4).

Table 1. Average annual growth of black spruce on the 0.25-ha plots in drained and undrained areas, based on data available for the period 1981–84

Site	Treatment				Average annual growth
	Phosphorus	Nitrogen	Thinned	Control[a]	
Drained site					
Number of samples per treatment	29	29	25	30	
Leader growth[b] (cm)	36.3	33.1	32.2	35.0	34.2
Root collar diameter[c] (cm)	0.70	0.89	1.19	1.03	0.95
Undrained site					
Number of samples per treatment	28	21	24	26	
Leader growth[b] (cm)	5.8	17.3	8.8	6.3	9.1
Root collar diameter[c] (cm)	0.06	0.34	0.29	0.23	0.22

[a] No fertilizer, no thinning.
[b] Average annual growth in period 1981–84.
[c] Growth in 1984.

Ingrowth Exclusion and Age, Height, Dbh, and Volume

Data from the 42 black spruce trees destructively sampled in 1988 showed that the average tree age was less on the drained area (17.9 years) than on the undrained area (26.4 years). On the drained area, two age groups related to treatment history were identified: 50% of the trees were 10–14 years old; the remainder were 20–27 years old. The corresponding averages for these groups were 11.8 and 24.0 years, respectively. It appears that trees belonging to the younger age group grew in after the two-blade-wide clearing treatment; the others evidently predated this treatment.

On the drained area, *t*-tests showed that average tree height, dbh, and volume were significantly lower ($p \leq 0.05$) in the age 10–14 class than in the age 20–27 class. Consequently, when this ingrowth after treatment was excluded (Table 2), the averages for each of these variables on the drained area increased significantly, and the difference between the average ages on the drained and undrained areas was much less. The number of degrees of freedom is reduced to 29 in Tables 2 and 3 because data from the 11 ingrowth trees were excluded from the analyses.

Leader growth measurements were taken from 23 of the 42 trees sampled in 1988 (leaders of the remaining 19 were unavailable for measurement). The measurements obtained showed that the ratio of drained to undrained leader growth was being maintained at the same ratio (3.8:1) as for the 1981–85 period. The average leader growth in 1988 on the drained area was 45 cm—an impressive increase for black spruce.

Ring Width and Periodic Annual Height and Volume Increments

For the periods 1969–78 (predrainage) and 1979–88 (postdrainage), a comparison of data for trees within the undrained area showed that there were no significant differences in average ring width at the 0.3-m height or in periodic annual height increment (pahi) (Fig. 5a; Table 3). The periodic annual volume increment (pavi), on the other hand, was significantly greater ($p \leq 0.001$) during the period 1979–88 (Table 3).

On the drained area, ring width, pahi, and pavi were all significantly higher for the postdrainage period (1979–88) than for the predrainage period (1969–78) (Fig. 5b; Table 3). As before, sample sizes for drained and undrained areas were different for this analysis because 50% of the trees sampled on the drained area grew in after treatment (precluding pretreatment measurements).

Comparisons of ring width, pahi, and pavi were made between drained and undrained areas for the 1969–78 predrainage period, with no significant differences found in ring width or pahi during this period (Fig. 5; Table 3). Before drainage, pavi for the undrained area was significantly greater ($p \leq 0.05$)—more than twice that of the drained area (after drainage, pavi was significantly greater for the drained area).

A similar comparison for the 1979–88 postdrainage period showed that the differences in tree ring width, pahi, and pavi were significant between the drained and undrained areas (Fig. 5; Table 3).

Other Drainage Effects

The preceding results are related entirely to black spruce, but it is important to note that drainage also had a noticeable effect on the growth of deciduous species. No attempt was made to quantify the growth of green alder (*Alnus crispa* [Ait.] Pursh), willow (*Salix* spp.), aspen (*Populus tremuloides* Michx.), balsam poplar (*P. balsamifera* L.), and birch (*Betula pumila* L.), but it was evident that these species grew densely between the spruce.

DISCUSSION

Water Table

Treatment that lowered the water table on the peatland near Fort McMurray resulted in significant increases in the height, diameter, and volume of black spruce. Although no groundwater table measurements were taken, drainage probably caused the average water table level to drop 50 cm.

Reduced Stocking

Although site treatment was imposed specifically to lower the water table, it also greatly reduced stocking, which allowed considerably more light than usual into the residual stand. Some of the resulting improved growth response must be attributed to this factor.

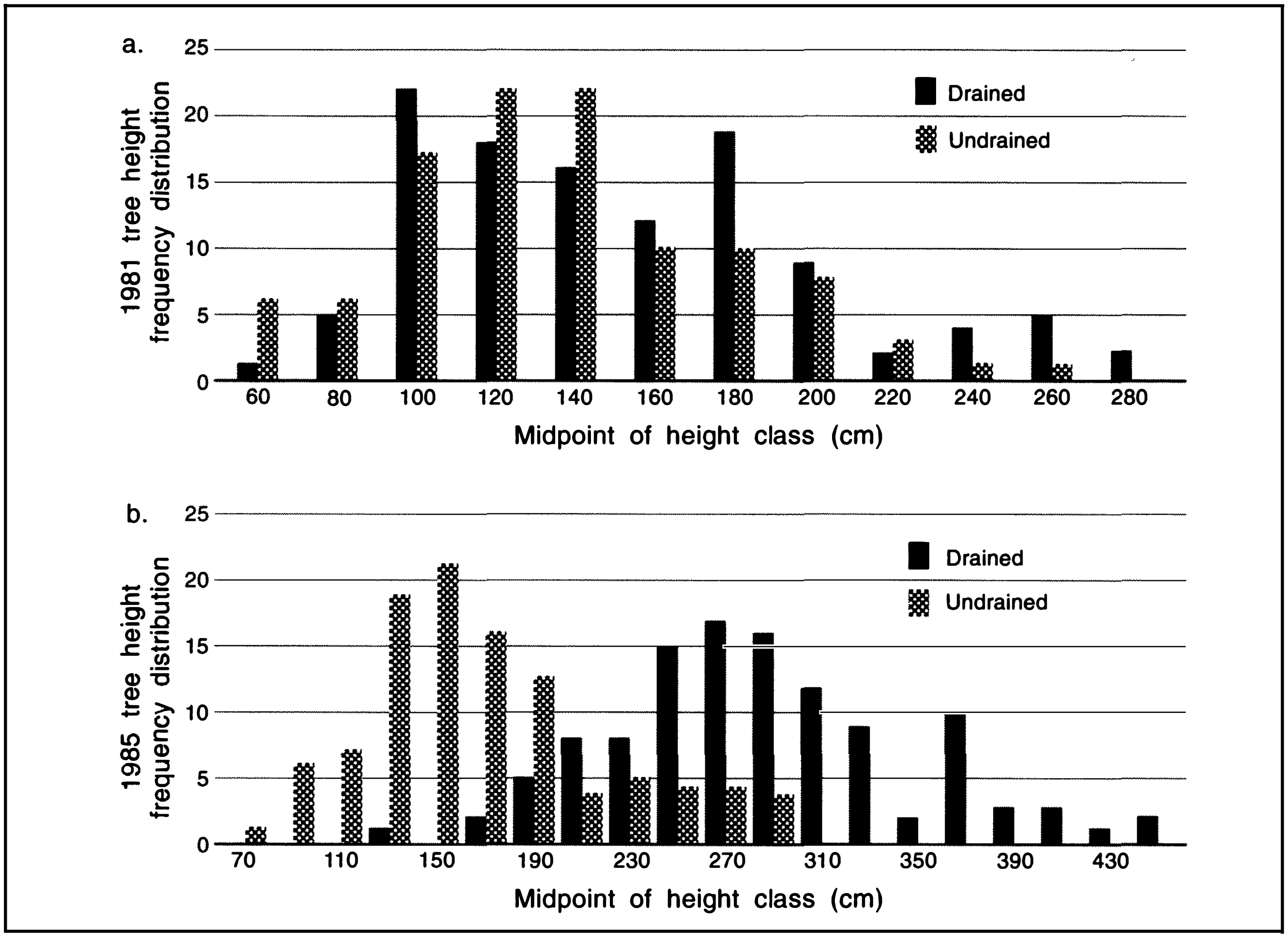

Figure 3. Tree height frequency distribution of black spruce on two sites, drained and undrained, in 1981 and in 1985.

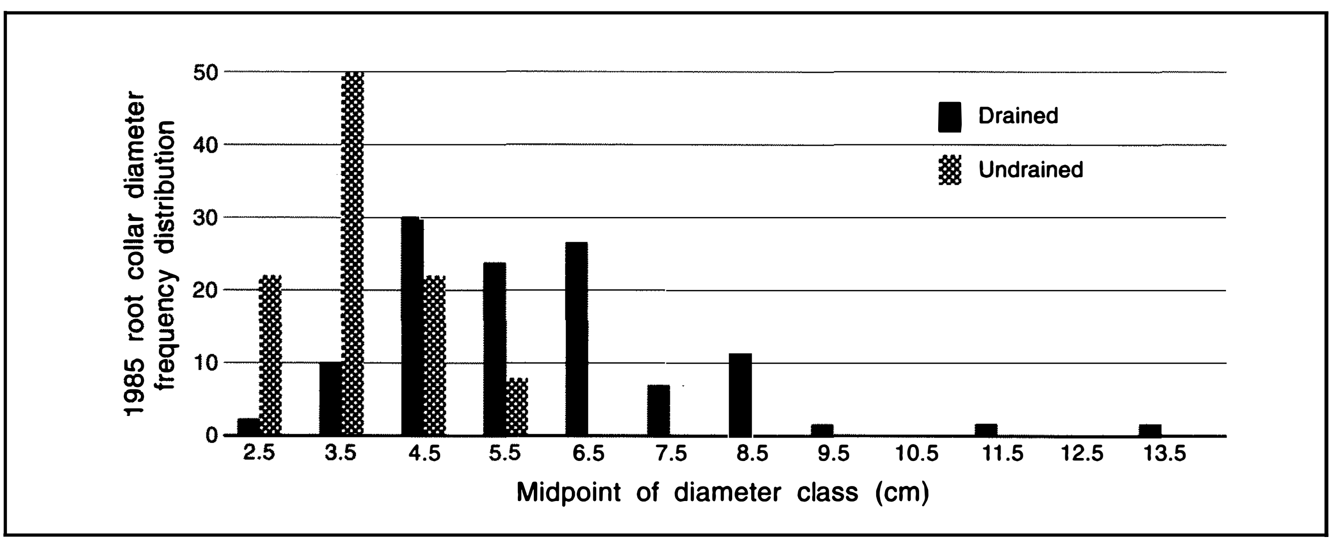

Figure 4. Root collar diameter frequency distribution of black spruce on two sites, drained and undrained, in 1985.

Table 2. Significant differences in growth between drained and undrained black spruce destructively sampled in 1988 (ingrowth[a] excluded)

	Drained average (± SD)[b]	Undrained average (± SD)	Drained average/ undrained average	df[c]	*t*-test[d]
Age (a)	24.0 ± 2.5	26.4 ± 2.3	0.9	29	−2.72*
Height (m)	3.89 ± 0.84	2.13 ± 0.34	1.8	29	8.36**
Dbh (cm)	4.1 ± 1.7	1.8 ± 0.5	2.3	29	5.57**
Volume (dm^3)	3.4885 ± 2.7982	0.6947 ± 0.3700	5.0	29	4.46**

[a] Ingrowth is the entrance of trees into the measurable stand.
[b] Average (± standard deviation).
[c] Degrees of freedom.
[d] *t*-test results have the following degrees of probability: * = $p \le 0.05$, and ** = $p \le 0.001$.

Table 3. Comparison of ring widths, periodic annual height increments, and periodic annual volume increments for black spruce on drained and undrained sites, for the periods 1969–78 and 1979–88 (ingrowth excluded)

	Ring width[a] (mm)		Periodic annual height increments (m)		Periodic annual volume increments (dm^3)	
	1969–78	1979–88	1969–78	1979–88	1969–78	1979–88
Drained average	0.40	1.70	0.082	0.255	0.0086	0.3392
Undrained average	0.49	0.51	0.064	0.067	0.0182	0.0469
Drained average/ undrained average	0.8	3.3	1.3	3.8	0.5	7.2
t-test[b]	−1.35	6.5**	1.39	12.20**	−2.30*	4.77*
df[c]	29	29	29	29	29	29

[a] Ring width was measured at 0.3 m height.
[b] *t*-test results have the following degrees of probability: ** = $p \le 0.001$, and * = $p \le 0.05$.
[c] Degrees of freedom.

Comparative Data

Comparative data on the effects of drainage on black spruce of similar age in Alberta and elsewhere in Canada is sparse. Lieffers and Rothwell (1987) conducted studies on 35-year-old black spruce growing on a drained fen in the Saulteaux River drainage, near Slave Lake, Alberta. They reported a reduction in leader elongation for the postdrainage period (1984–85) compared with predrainage (1979–83) elongation. The postdrainage leader reduction was evident on both drained and undrained sites, as well as on adjacent undisturbed areas. There was, in fact, less leader elongation on the drained site than on the undrained. This depressed growth was attributed to the shock imposed by drainage and drought during the two years of postdrainage measurement (1984–85).

On the drained site near Fort McMurray, recovery seemed to be faster and leader growth was clearly superior during the arbitrarily defined postdrainage period (1979–88). The difference in results obtained from the two Alberta sites can be related to 1) the difference in wetland types (the Fort McMurray study area was a treed swamp, the Saulteaux River site was a treed fen), 2) the difference in stand ages (15 years at Fort McMurray versus 35 years at Saulteaux River) at the time they were drained, 3) the length of the postdrainage measurement period, 4) site characteristics such as peat depth and peat hydraulic conductivity, and 5)

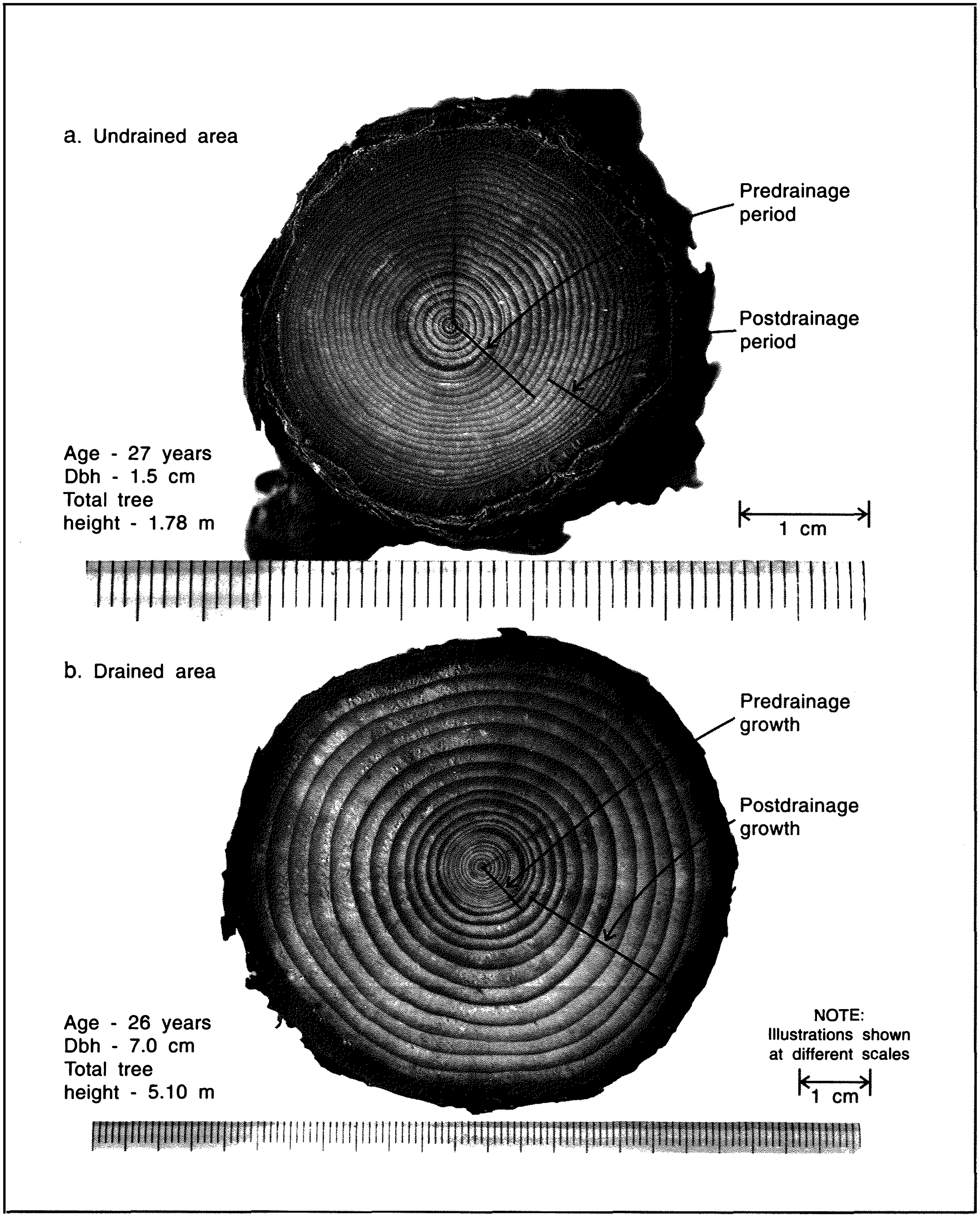

Figure 5. Disks cut from black spruce stumps (0.3-m height) on both undrained and drained areas.

the treatments imposed, particularly as they affected stand stocking.

CONCLUSIONS

The black spruce trees sampled in this study were young, and therefore it was expected that they would respond quickly to drainage. A significant increase in height, diameter, and volume growth of the 15-year-old black spruce was achieved by lowering the water table of their location (a treed swamp with 0.5- to 1.2-m-deep peat), through drainage, using approximately 10-m ditch spacings. The increase was evident from the comparison of annual growth rings of trees on the drained area, measured before (1969–78) and after (1979–88) drainage. The increase was also evident from comparison of annual growth rings of trees on the drained and undrained areas for the same time periods.

Because the trees were growing on shallow peat, the effect of lowered water tables on tree root development in this environment and the possible penetration of roots into mineral soil warrant further investigation.

Site treatment resulted in greatly reduced stand stocking that improved light conditions within the stand, and this, in turn, contributed to the increased growth response.

The increase in growth of black spruce was accompanied by an equally impressive growth of alder, willow, birch, aspen, and poplar—a development both positive and negative. As well as enhancing coniferous growth, peatland drainage may benefit considerably the wildlife that take advantage of the increased ungulate food supply (deciduous species) and improved shelter (black spruce). The significance of the increased growth of deciduous species on black spruce productivity, however, merits further study: it may be necessary to develop methods for controlling the deciduous competition.

ACKNOWLEDGMENTS

The author is indebted to the staff of the Alberta Forest Service, Alberta Forestry, Lands and Wildlife, in the Athabasca Forest for providing support services, data, and reports used in this study. Valuable suggestions for improving the manuscript were provided by D.J. Morgan, D.J. Patterson, and S.K. Takyi, all members of the Alberta Forest Service. The Forestry Canada component of this study was made possible through funding provided under the Canada–Alberta Forest Resource Development Agreement.

G.R. Hillman
November 1991

REFERENCES

Alberta Energy and Natural Resoruces. 1986. Alberta phase 3 forest inventory: tree sectioning manual. Alberta For. Serv., Resour. Eval. Plann. Div., Edmonton, Alberta. ENR Rep. 56.

Hillman, G.R.; Johnson, J.D.; Takyi, S.K. 1990. The Canada–Alberta wetlands drainage and improvement for forestry program. For. Can. and Alberta. For. Serv., Edmonton, Alberta. Canada–Alberta For. Resour. Dev. Agreement Rep. 86.

Hillman, G.R. 1987. Improving wetlands for forestry in Canada. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-288.

Kavanagh, J. 1983. Stem analysis: sampling techniques and data processing. M.Sc. thesis, Lakehead Univ., Thunder Bay, Ontario.

Lieffers, V.J.; Rothwell, R.L. 1987. Effects of drainage on substrate temperature and phenology of some trees and shrubs in an Alberta peatland. Can. J. For. Res. 17:97-104.

Rowe, J.S. 1972. Forest regions of Canada. Environ. Can., Can. For. Serv., Ottawa, Ontario. Publ. 1300.

Tóth, J.; Gillard, D. 1988. Experimental design and evaluation of a peatland drainage system for forestry by optimization of synthetic hydrographs. Can. J. For. Res. 18:353-373.

Forestry Canada, Northwest Region
Northern Forestry Centre
5320 – 122 Street
Edmonton, Alberta T6H 3S5
(403) 435-7210

Cat. No. Fo29-2/53-1991E
ISBN 0-662-19229-X
ISSN 0714-1181