A PROGRESS REPORT ON THE GROWTH OF JACK PINE AND BLACK SPRUCE TUBLINGS PLANTED IN HEAVY METAL CONTAMINATED SOILS NEAR THE INCO SMELTER AT THOMPSON, MANITOBA

Manitoba
Environment
and Workplace
Safety and Health

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D. C. Jones

Terrestrial Standards and Studies Section
Environmental Management Services Branch
Department of Environment and Workplace Safety and Health
Province of Manitoba

Report #86 – 5

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ABSTRACT

Jack pine and black spruce tublings were planted in nickel and copper contaminated soils near the Inco smelter at Thompson, Manitoba in 1984 and 1985. Seed of the same species were hand broadcast onto the undisturbed LFH to monitor germination success and survival. A control site was included in the study. A detailed tubling survival, growth and condition survey was done in October, 1985. Germination survival at direct seeding trial sites was also monitored in 1985. This report was prepared as a progress report in order to document objectives, methodology and data collected to date. Interpretation of growth data was not attempted at this early stage of seedling establishment.

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1. INTRODUCTION

Inco Metals Company has operated an integrated nickel mining, milling, smelting and refining operation at Thompson, Manitoba since 1961. Flue dust and gaseous emissions are discharged from a 150 meter stack to the surrounding environment.

One of the primary environmental concerns is the emission of heavy metal particulates contained in the flue dust. Nickel, copper, iron, lead, cadmium and zinc particulates are deposited to and subsequently incorporated into the surrounding forest soils. Recent studies of the boreal forest surrounding the smelter have indicated a sharp gradient of metal accumulation in the LFH soil horizons (Jones et al 1984, Phillips and Slaney Co. Ltd. 1981, Wotton and Hogan 1981, Hocking and Blauel 1977). LFH is defined, according to the Soil Classification System for Canada, as organic layers where in L the original structures are easily discernible, in F the original structures are difficult to recognize and in H the original structures are indiscernible (Canada Agriculture 1974).

Other studies have shown that plant physiological development can be severely inhibited by the uptake of heavy metals (Hogan and Wotton 1984, Ernst et al 1983, Lozano and Morrison 1982, Jenkins 1981, National Research Council Canada 1981, Malhotra and Blauel 1980, Fessendon and Sutherland 1979). A report, "The Growth of Jack Pine and Black Spruce Seedlings in Heavy Metal Contaminated Soils Collected Near the Inco Smelter at Thompson, Manitoba", was released by the Environmental Management Division in 1984 (Jones et al 1984). The study was carried out in a controlled environment using LFH collected near the Inco smelter as a growth medium for rearing of seedlings. The report concluded that the growth of jack pine (Pinus banksiana Lamb.) and black spruce (Picea mariana (Mill.) BSP) seedlings, reared in LFH collected within a 5 km radius of the smelter, was severely inhibited. In addition, the report concluded that the heavy metals Ni (nickel) and Cu (copper) appeared to concentrate in the seedling root tissue severely inhibiting root development. Previous studies of the forest soils near the Inco smelter at Thompson have indicated that elevated metal levels were confined, as yet, to the LFH horizons (Veldhuis 1985, Phillips and Slaney 1981, Wotton and Hogan 1981). In undisturbed soils the initial growing medium for new tree germinants is the LFH. It was uncertain if the growth inhibition demonstrated by Jones et al in 1984 would be as severe under natural field conditions. Also, it was not known if seedlings planted in metal contaminated LFH

would, after establishing roots in the uncontaminated underlying mineral soil, continue to grow uninhibited.

Experimentation in the field to observe the long-term growth response to elevated metal levels was initiated in 1983. The objectives of this study are;

1. To monitor the survival and growth of jack pine and black spruce tublings planted in LFH of varying heavy metal levels in a field plantation environment and
2. To monitor the establishment, growth and survival of jack pine and black spruce seed broadcast directly to the surface of undisturbed LFH of varying heavy metal levels.

The results of this study, to date, are presented herein.

2. METHODS

2.1 Site Selection

Three sites were located in July 1983, along the "Dam B" road on Inco property. In addition, a control site was located east of Moak Lake northeast of Thompson along the Split Lake road (Figure 1). The "Dam B" road location was chosen for the growth study because;

1. Considerable data on soil metal levels exists for the area.
2. The area is downwind of the smelter and directly in the path of the prevailing northwesterly winds.
3. A sharp gradient of metal loading in the LFH exists along the road.
4. The area is documented as an area of serious forest decline.
5. The road is easily accessible.

The Moak Lake control site was chosen as soil metal values had been previously documented as low background levels and because of its similarity in soil composition to the "Dam B" sites.

Specific site criteria used in the selection of all of the sites were;

1. Level terrain.
2. A well drained site.
3. A jack pine – black spruce – aspen stand composition.
4. Clay soils.
5. Undisturbed by fire or man.

6. That sites be located along a gradient of heavy metal loading in the soils.

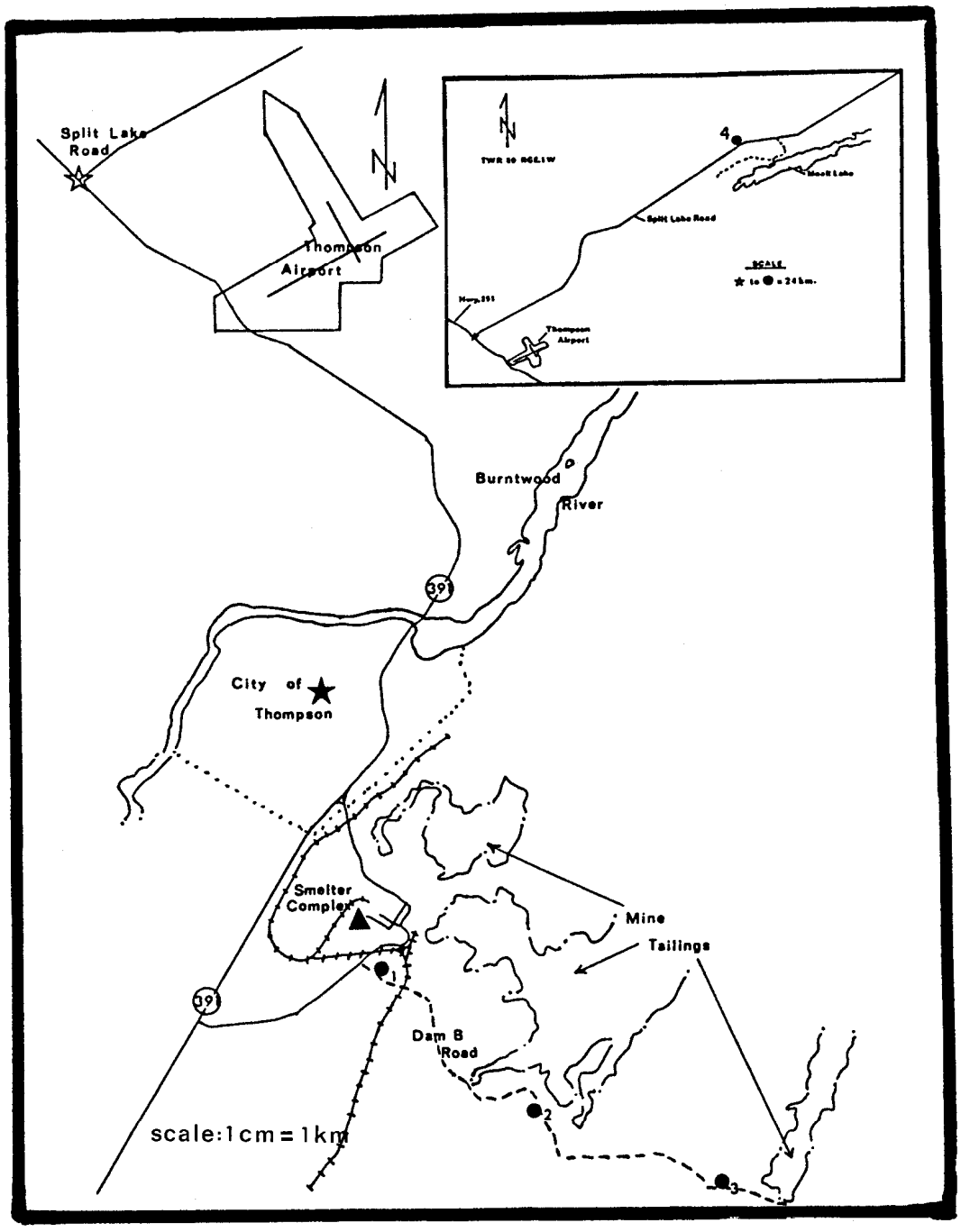

Figure 1. Map of study site locations

2.2 Site Preparation

Figure 2 illustrates study site design. A contract to clear the four sites was awarded on August 30, 1983 (Appendix 1). The contract was jointly funded and supervised by the Environmental Management Division and Inco. Under the terms of the contract all standing trees and shrubs were manually cut to ground level and removed from the site. Clearing of the overstorey and bush was carried out with a minimum of disturbance to the forest floor, in particular the LFH soil layers. Site clearing began September 5, 1983 and concluded December 11, 1983 at a cost of $3,525.71.

3. TUBLING ESTABLISHMENT, GROWTH AND SURVIVAL - 1984

3.1 Tubling Stock Rearing

In late August 1983, mature jack pine and black spruce cones were collected from each of five trees per species selected at random from the Pisew Falls area, a background location 100 km south of Thompson. Seed was extracted and during the February to June 1984 period, 1200-408 Japanese paperpot tublings of each species were reared at pineland Provincial Forest Nursery. The growing schedule is presented in Appendix 2.

3.2 Tubling Planting

In June 1984, two hundred jack pine tublings were planted at each study site. The black spruce tublings were discarded, as an unknown pathogen was causing severe dieback and wilt. The jack pine tublings were planted directly into the undisturbed LFH using a #408 Potoputki planting tube. Conventional tubling storage, transportation and establishment techniques were followed.

3.3 Direct Seeding Trial

Extra seed collected for the sowing and rearing of the tublings was used for the direct seeding trial. At each site, between the jack pine and black spruce transplant areas, five 0.5 m diameter seeding locations for each tree species were randomly located (Figure 2). A galvanized metal screen 1 m high (1.0 cm x 1.0 cm mesh) was erected around each location to keep rodents out but at the same time allow full sun exposure. The screen was anchored to the ground with tent pegs. The mesh screen was previously painted with latex paint to reduce metal

contamination of the site. Five hundred (500) black spruce seeds were broadcast sown onto the LFH inside of the mesh screen at 5 locations and jack pine were sown in the other five. Germination success and survival rate were recorded for each direct seeding location in June 1985. Early snowfall in the fall of 1984 prevented observations of germination success at that time.

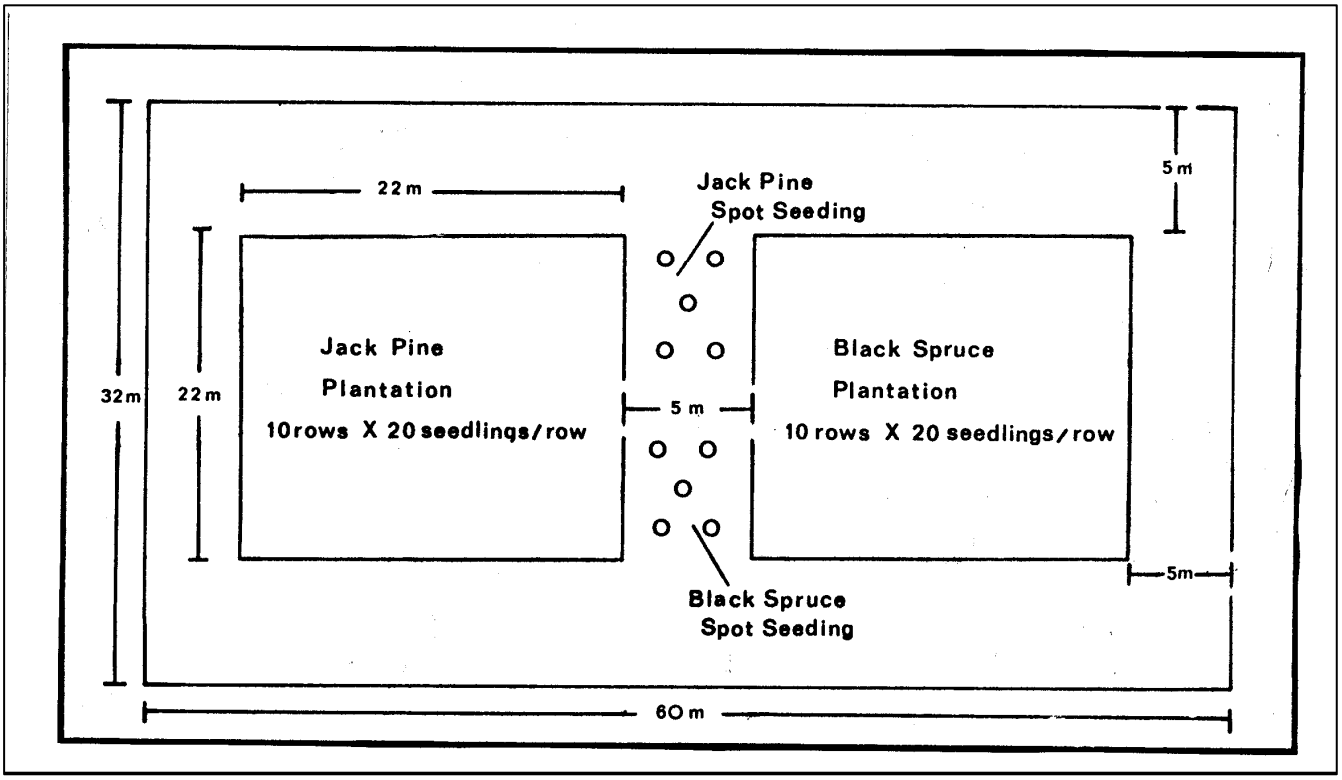

Figure 2. Map of study site design

3.4 Soils Monitoring and Analyses

A sample of LFH and the 0-5 cm underlying mineral soil layer were collected at the four corners and the center of each study site in June, 1984. A 10 cm x 10 cm wooden template was placed on the ground and by cutting around the edge with a sharp knife, a standardized 100 cm2 soil sample was collected. Samples were placed in clean plastic bags and returned to the W. M. Ward Technical Services Lab where they were placed in acid washed glass beakers. The samples were oven dried for 24 hours at 100 C. The dried mineral soil was ground, using a mortar and pestle, to pass through a #80 mesh Canadian Standard sieve. LFH samples were

ground in a Wiley mill to pass through a 2 mm mesh sieve. After each mineral soil sample was ground, the mortar and pestle were rinsed with tap water and wiped dry with clean paper towels. Compressed air was used to blow fine soil particles from the sieve after which it was wiped with clean gauze pads. Acetone and hexane solvents were used to rinse all mill surfaces and sieve parts after grinding each organic soil sample. The samples were analyzed for total Cu and Ni by atomic absorption spectroscopy.

3.5 Supplemental Soil Survey

During the summer of 1984, Mr. Hugo Veldhuis of CanadaManitoba Soil Survey conducted a detailed soil survey of all four sites. Information derived from this survey should help to assess the effects of site differences versus metal accumulations on seedling development.

3.6 Tubling and Seed Monitoring

In October 1984, four months after planting, jack pine tubling survival and condition were recorded for all tublings at each study site. No examination of direct seeding sites was possible during that visit because of excessive snowfall accumulation.

4. SITE ESTABLISHMENT, GROWTH AND SURVIVAL – 1985

4.1 Tubling Stock Rearing

In January 1984, mature black spruce cones were collected along the Joey Lake road, a background site 50km south of Thompson. This seed, along with the remaining jack pine seed collected in August 1983, was used to rear 1200-408 Japanese paperpot tublings of each species during the period February to June 1985. The growing schedule is presented in Appendix 3.

4.2 Tubling Planting

In June 1985, two hundred black spruce tublings were planted at each study site (Figure 2). Also, at each site, jack pine was replanted where any of the 1984 tublings were dead, missing, severely browsed and or generally appeared severely stressed. Refilling of the jack pine was done to ensure adequate stocking of the sites to fulfill future monitoring requirements. The same tubling storage, handling and planting techniques were followed as in 1983.

4.3 Direct Seeding Trial

No further direct seeding was carried out in 1985. Further examination of the sites is anticipated in 1986.

4.4 Soils Monitoring and Analyses

No further soils collection or analyses was carried out in 1985. The soil characterization and description report from the 1984 survey work has been prepared by the Canada Manitoba Soil Survey group.

4.5 Tubling and Seed Monitoring

In June 1985, the percentage of jack pine tubling survival was recorded for each site. In addition, the number of germinants in the direct seeding trial was recorded.

In October a formal survey of each tubling for each species at each study site was conducted. In addition to tubling height, tubling condition was recorded using the following classifications;

1. Healthy, no apparent stress.
2. Lightly stressed, no browsing, < 25% needle discoloration, needles fully retained.
3. Moderately stressed, light browsing, 25-50% needle discoloration and/or needle loss.
4. Severely stressed, heavily browsed, 75% needle discoloration and/or needle loss.
5. Dead.
6. Missing.

During this assessment any dead tublings were collected for total Ni and Cu analyses.

5. RESULTS AND DISCUSSION

5.1 Metals in Soils

Table 1 shows the mean and range of Ni and Cu concentrations in LFH and the 0-5 cm underlying mineral soil layer for each study site. Table 2 tabulates a more detailed analyses of soil fractions sampled by the Canada-Manitoba Soil Survey group.

It is evident that there is a steep gradient of metal levels between sites and also that the metals are still contained within the upper organic soil layers. Detailed soil descriptions for each

site are being prepared by the Canada-Manitoba Soil Survey group. This data will aid in assessing differences in seedling physiological development between sites, if they occur.

5.2 Tubling Survival. Growth and Condition

In October 1984, four months after initial planting of jack pine stock. a simplified survival count was taken. Tubling survival was 74%, 58%, 73% and 94% for Dam B sites 1, 2, 3 and Moak Lake (Control) respectively. Browsing incidence, apparently by rabbits, was 40% at site 1, 15% at site 2, 1% at site 3 and 0% at the control.

It was thought that the high incidence of browsed tublings was related to the increased deciduous cover near site 1. A wide fireguard a short distance south of site 1 has a variety of young deciduous vegetation. The increased ground cover and availability of browse is likely to attract more rabbits to this area. This may account for the incidence of browse on tublings at this site.

Table 1. Metal concentrations (µg/g) in LFH and mineral soil, 1984, Environmental Management

Site Location	LFH				Mineral Soil (0-5 cm)			
	Ni		Cu		Ni		Cu	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dam B - Site 1	4428	3100-5800	1524	805-2325	132	72-228	40	15-65
Dam B - Site 2	888	520-1260	167	115-220	79	50-114	20	15-25
Dam B - Site 3	720	520-840	123	85-165	72	58-82	20	15-25
Control (Moak Lake)	96	82-114	25	20-30	52	46-62	25	20-30

Table 2. Metal concentrations (µg/g) in LFH and mineral soil, 1984, Canada-Manitoba Soil Survey

Dam B - 1	L	FH	AHE	AC	AB	BTNJ	BT_2	CK_1	CK_2
Ni	4260	3320	58	34	42	56	72	40	34
Cu	4700	285	30	25	25	40	50	40	40

Dam B - 2	L	F	H	AE	AB	BTNJ	BCK	CK_1	CK_2	CK_3	CK_4
Ni	1100	680	260	52	58	56	58	22	56	56	34
Cu	375	65	25	25	40	40	40	20	40	50	30

Dam B - 3	L	F_1	F_2	AE	AB	BT_1	BT_2	BCK	CK_1	CK_2	CK_3
Ni	100	580	240	50	50	52	66	56	48	36	32
Cu	75	140	25	25	40	45	40	40	40	25	15

Control (Moak Lake)	L	FH	AE	AB	BTNJ	BT	BCK	CK_1	CK_2
Ni	52	94	50	50	56	66	72	56	56
Cu	15	25	25	25	25	40	40	40	30

In June 1985, one year after planting, jack pine survival was 49%, 61%, 70% and 76% for sites 1, 2, 3 and the control respectively. Browsing incidence by rabbits was considered severe at site 1, moderate at 2, light at 3 and very light at the control.

In October of 1985 the first formal survival, growth and tubling condition survey of jack pine (planted June 1984 and refilled June 1985) and black spruce tublings (planted in June 1985) was completed (Table 3). Jack pine survival ranged from 81% at the control site to 96% at site 1. The average height of jack pine tublings ranged from 6.8 cm at site 1 to 12.0 cm at the control. For black spruce mean tubling height ranged from 10.1 cm at site 3 to 14.3 cm at the control. Black spruce survival ranged from 83% at site 3 to 91% at the control.

Browsing of jack pine is still a problem. Browse percentages were 21, 10, 5 and 9 for sites 1, 2, 3 and the control respectively. The high browsing incidence, especially at site 1, may account for most of the suppression in growth and condition. There appears to be a good relationship between browsing incidence and tubling height in jack pine. Browsing of black

spruce tublings does not appear to be a problem as only site 1 had any browsing and that was only 8%.

Table 3. Tubling survival, growth and condition classification, October, 1985

Study Site	Survival %	Height (cm)	Browsing (%)	*Condition Classification %					
				1	2	3	4	5	6
Jack Pine									
Dam B - 1	96	6.8	21	53	7	6	28	4	2
- 2	94	11.1	10	35	6	9	44	6	0
- 3	95	10.6	5	38	5	18	34	4	1
Control (Moak Lake)	81	12.0	9	64	2	15	1	3	15
Black Spruce									
Dam B - 1	88	11.1	8	71	13	2	2	5	7
- 2	89	12.6	0	66	18	2	3	5	6
- 3	83	10.1	0	60	15	6	2	13	4
Control (Moak Lake)	91	14.3	0	72	12	7	0	5	4

* 1. Healthy, no apparent stress.

2. Lightly stressed, no browsing, < 25% need discoloration, needles fully retained.

3. Moderately stressed, light browsing, 25 - 50% needle discoloration and/or needle loss.

4. Severely stressed, heavily browsed, >50% needle discoloration and/or needle loss.

5. Dead.

6. Missing.

The Manitoba Forest Regeneration Survey Manual sets regeneration standards as follows (Manitoba Department of Natural Resources. 1980);

1. Established seedling: A live and undamaged seedling which exhibits vigour and health at the time of survey, and has grown for at least two years is said to be established. Seedlings that are dead or dying, or with disease incidence are not tallied.
2. Conditional seedling: A live and undamaged seedling which is healthy and vigorous at the time of tally and has grown for at least one year is said to be conditional.

Newly planted tub1ings must adapt to a number of environmental and physiological changes during the first two to three years after planting. Because the tub1ings were planted in the LFH soil layer (as opposed to the mineral soil in conventional planting programs) they are subjected to considerable plant stress due to wide fluctuations in organic soil moisture and temperature. Insects and pathogens are more numerous in the organic soil layers. The ratio of root surface area to leaf surface area is not yet optimum in newly planted tub1ings. Also. tub1ings having been reared on an optimum fertilizer schedule, despite a hardening off period prior to field planting, still may exhibit nutrient deficiency symptoms during the first few years after planting. Tub1ings are also small and succulent relative to bare root stock, and thus may succumb to considerable grazing by rodents and rabbits.

In this study the initial planting of jack pine took place in June 1984 with refilling in June 1985. The black spruce were also planted in 1985. Only the June 1984 jack pine plantings would qualify as established seedlings in 1986, at the earliest. As the planting stock in this study is still conditional and still greatly affected by those factors previously mentioned, no interpretation of differences between sites was attempted. Data collected after the 1986 growing season will be considered for interpretation. Data collected prior to the start of the 1987 growing season will be of value in aiding assessment of early establishment problems and the relationship to future growth problems.

Condition classification of tublings is presented in Table 3. Condition classification serves two major functions;

1. It gives a subjective description of the health of the seedlings and

2. Provides numerical data on the distribution of tublings within the condition classification description. This will enable statistical correlation with heavy metal levels in tubling tissue.

As previously discussed, tublings during the first two or three years after planting can not be considered as established. Interpretation of condition classification with relation to the metals Ni and Cu in the LFH is not reliable during this early stage of development. Growth and survival are more likely to be related to the various planting shock stresses during this initial growing period. For example, although "Dam B" site 1 has the highest levels of Ni and Cu in the LFH (Table 1 and 2) and the highest incidence of browsing (21%) and the lowest mean height growth (6.8 cm) of all the sites, the number of tublings in condition classifications 1, 2 and 3 combined is equal to the control site at Moak Lake. The same pattern is true for black spruce.

Interpretation of growth and condition data will develop as the data base is expanded. With time, definitive patterns of growth and condition suppression may develop which will relate to metals in soil and tissue.

Table 4. Numbers of one year old germinants on direct seeded sites, June, 1985

Study Site	Direct Seeded Sites									
	Jack Pine					Black Spruce				
	1	2	3	4	5	1	2	3	4	5
Dam "B" - 1	1	0	0	0	1	0	6	0	0	4
- 2	3	7	0	0	0	1	0	0	5	3
- 3	0	0	0	1	0	4	0	0	0	5
Control (Moak Lake)	102	35	71	54	90	8	54	9	24	3

5.3 Direct Seeding Trial

Direct seeding sites for each species at all four study sites were examined for germination success in June 1985, one year after broadcast sowing. Table 4 shows the numbers of germinants found for each species. It is evident that germination and germinant survival is being affected at the three "Dam B" sites. No remnants of dead germinants were found at the "Dam B" sites or the control. It is assumed that either very few seeds germinated and/or those that did germinate died at an early stage of development leaving no remnants. The direct seeded sites will be observed again at the beginning of the 1986 growing season.

6. CONCLUSIONS

1. Interpretation of surviyal, growth and condition data is not possible at this time because the tublings are not established. Initial planting stress for a period of up to three years after planting makes data interpretation questionable.
2. Tubling survival, growth and condition will continue to be monitored until a sufficient data base on established seedlings can be accumulated for interpretation. Also, germinant survival at seeding sites will continue to be monitored until a sufficient data base has been accumulated.

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APPENDIX 1 - Contract for clearing study sites,1983

THIS AGREEMENT made in duplicate this 26TH day of September 1983,

BETWEEN Her Majesty the Queen, in Right of the Province of Manitoba, as represented by the Honorable, the Minister of Environment and Workplace Safety and Health (hereinafter called "the Province")

of the first part

- and -

Mr. Brad Burki

of the second part.

WHEREAS the Province requires assistance to the Environmental Management Services, Environmental Standards and Studies Section to manually cut, clear and remove to ground level, standing trees, shrubs and other designated vegetation or debris from 4 (four) forest sites with approximate dimensions of 70 meters by 40 meters in the Thompson area.

AND WHEREAS Mr. Brad Burki has experience in the clearing and removal of forest land areas;

AND WHEREAS the Contractor is prepared to undertake these responsibilities;

NOW THEREFORE, the parties hereto agree as follows:

(1) the Contractor agrees to provide the services as described in Appendix "A" to this agreement.

(2) the services by the Contractor shall be performed under the direction and supervision of Dr. F. Phillips, of the Province or his designates.

(3) that the Province shall provide to the Contractor for the duration of the agreement, one (1) chain saw and other appropriate equipment and materials necessary for completion of the agreed work.

(4) that the Contractor shall be paid for his services hereunder by the Province or Inco Limited, not both at the rate of $500.00 per site, with the understanding that the total amount to be paid for these services shall not exceed the sum of Two Thousand Dollars ($2,000.00). Payment shall be initiated upon the completion of work to the satisfaction of the designated staff from the Department of the

APPENDIX 1 - Cont'd.

Environment, Workplace Safety and Health, and receipt of invoice from the Contractor for each site completed.

(5) that the Contractor agrees to hire the services of at least one (1) assistant to help conduct the clearing.

(6) that the Province shall not be liable for any injury or damage to the Contractor, or for the loss of or damage to the property of the Contractor in any manner based upon, occasioned by or in any way attributable to the Contractor's services under this Agreement unless the loss, injury or damage is caused by the negligence of an officer or servant of the Province while acting within the scope of his/her employment.

(7) that the Contractor shall provide services commencing upon the signing of this agreement by both parties and shall terminate when the site work has been completed, but no later than October 31, 1983.

(8) this Agreement is a contract for a service and the Contractor is not, nor are they deemed to be employees or agents of the Province.

(9) that this Contract may be terminated by either party upon two weeks written notice prior to the desired termination date.

(10) this Agreement is not assignable without the written consent of the Province.

IN WITNESS WHEREOF, the Honorable, the Minister of Environment and Workplace Safety and Health, for and on behalf of Her Majesty the Queen, in Right of the Province of Manitoba, has hereunto set his hand, and the Contractor has hereunto set his hand on the day and year first above written.

SIGNED, SEALED AND DELIVERED)

Witness

Her Majesty the Queen, in Right of the Province of Manitoba, as represented by the Honourable, the Minister of Environment and Workplace Safety and Health.

Witness

Aug 30/83

Contractor

cont'd.

APPENDIX "A"

1. To provide manual cutting and clearing of standing trees, shrubs and other designated vegetation or debris to ground level.

2. To provide services in each of 4 (four) forest sites, approximately 70 meters by 40 meters in the Thompson area as indicated by designated staff of the Environmental Management Services.

3. To manually haul or remove all designated material off the site with a minimum of disturbance to the forest floor, in particular the surface organic soil layer or litter layer.

4. To carry out other related duties as requested by the designated staff of the Environmental Management Services related to the successful clearing of each site.

5. To conduct the clearing in accordance with the terms of the work permit issued by the Department of Natural Resources, Thompson.

APPENDIX 2 - Growing schedule for tublings, 1984

Species: Black Spruce / Jack Pine Seedlot # N/A Lab Germination Sb-60% Pj-n/a %

Date Seeded: Jan. 26/84 Seeding Rate: Sb-broadcast / Pj-2/cav. / 4-Jack pine / 4-Black spruce In Greenhouse Date Jan. 26/84

Container Type: 408 No. Trays: Growing Medium: 50% peat, 50% verm.

Greenhouse # T.I. Seed Zone # N/A Grit Type: #2 Granite

NOTE: Dale Jones - Pollution test stock (notes below)

Procedure	Day	Date	Comments
*In greenhouse & poly cover	0	Jan.26/84	Seeded by D. Jones, G. Falk
Poly cover removed	5	Feb. 1/84	D. M. Gillis
[1]Fertilizer	Week 1	Feb. 6/84	12-0-44, 9-45-15 D. Gillis
Fertilizer	2	Feb. 9/84	Benlate 4 tsp./2 litre 12-0-44, 9-45-15 4 gal. D. Gillis
Fertilizer	3	Feb. 17/84	12-0-44 9-45-15 3 gal. G. Falk
Fertilizer	4	Feb.24/84	12-0-44 9-45-15 4 gal. G. Falk
Fertilizer	5	Mar. 1/84	15-15-30 7 gal. G. Falk
Fertilizer	6	Mar. 8/84	15-15-30 8 gal. G. Falk
Fertilizer	7	Mar.15/84	15-15-3- 2 gal. R. McDougall
Fertilizer	8	Mar.27/84	15-15-30 2 gal. R. McDougall
Fertilizer	9	Apr. 3/84	15-15-30 2 gal. R. McDougall
Fertilizer	10	Apr.10/84	H_2SO_4only 5 gal. R. McDougall
Fertilizer	11	Apr.17/84	H_2SO_4 only 10 gal. R. McDougall
Fertilizer	12	Apr.25/84	4-25-35 H_2SO_4 5 gal. E. Hodson
Fertilizer	13	May 1/84	4-25-35 H_2SO_4 7 gal. E. Hodson
Fertilizer	14	May 9/84	4-25-35 H_2SO_4 4 gal. Dana
Fertilizer	15	May16/84	4-25-35 H_2SO_4 6 gal. Lori
Fertilizer	16	May23/84	4-25-35 H_2SO_4 7 gal. E.Hodson
Fertilizer	17	June 1/84	20-5-30
Fertilizer	18		
Fertilizer	19		(notes)
Fertilizer	20	Feb.15/84	apply Truban 1/2 gal
Fertilizer	21	Feb.20/84	preliminary thinning D. Jones
Fertilizer	22	Feb.28/84	final thinning D. Jones
Fertilizer	23	Apr.19/84	Malathion 45 ml E.Hodson
Fertilizer	24	May29/84	moved to outside lathehouse
Ready for planting	25		

1. Wash fertilizer off needles after each fertilizer application.

APPENDIX 2 - Cont'd.

CONTAINER STOCK QUALITY RECORD

NO. T.I. SPECIES Jack Pine CROP Dale Jones Pollution Test ~~Smelter~~ Emissions DATE OF GERMINATION February 1, 1984

E June 6, 1984 AGE OF SEEDLING (WEEKS FROM GERMINATION) 18 weeks pH 4.9 E.C. 640

	H in cm R	S	T	D in mm	DMS in g	DMR in g	TDM in g	DMS/DMR RATIO	STURDINESS INDEX (H/D)	QUALITY INDEX (TDM÷(H+DMS)/D DMR)	VOLUME INDEX (HD²)
	2			3	4	5	6	7	8	9	10
	16.2	15.6	31.8	1.71	0.89	0.15	1.04	5.9	9.12	0.0692	45.62
	6.2	8.3	14.5	0.73	0.09	0.01	0.10	9.0	11.37	0.0049	4.42
	6.3	10.4	16.7	0.70	0.15	0.02	0.17	7.5	14.86	0.0076	5.10
	8.7	8.0	16.7	0.61	0.13	0.01	0.14	13.0	13.11	0.0054	2.98
	15.4	11.4	26.8	0.99	0.33	0.04	0.37	8.3	11.52	0.0187	11.17
	8.2	11.1	19.3	0.67	0.20	0.02	0.22	10.0	16.57	0.0083	4.98
	11.7	14.2	25.9	1.54	0.84	0.11	0.95	7.6	9.22	0.0565	33.68
	10.4	11.3	21.7	0.99	0.38	0.05	0.43	8.8	12.25	0.0244	15.42

ATE June 6, 1984 AGE OF SEEDLING (WEEKS FROM GERMINATION) 18 weeks BLACK SPRUCE pH 4.8 E.C. 520

	H in cm R	S	T	D in mm	DMS in g	DMR in g	TDM in g	DMS/DMR RATIO	STURDINESS INDEX (H/D)	QUALITY INDEX (TDM÷(H+DMS)/D DMR)	VOLUME INDEX (HD²)
	7.2	10.8	18.0	0.91	0.15	0.02	0.17	7.5	11.87	0.0088	8.94
	5.9	17.3	23.2	1.02	0.32	0.02	0.34	16.0	16.96	0.0103	18.00
	10.8	10.4	21.2	0.86	0.14	0.02	0.16	7.0	12.09	0.0084	7.69
	7.4	10.1	17.5	0.66	0.12	0.02	0.14	6.0	15.30	0.0066	4.40
	6.9	9.1	16.0	0.80	0.11	0.01	0.12	11.0	11.38	0.0054	5.82
	8.2	14.8	23.0	0.86	0.26	0.01	0.27	26.0	17.21	0.0064	10.95
	9.8	10.3	20.1	0.68	0.12	0.02	0.14	6.0	15.15	0.0066	4.76
	7.8	10.7	18.5	0.81	0.17	0.01	0.18	17.0	13.21	0.0060	7.02
	8.0	11.7	19.7	0.83	0.17	0.02	0.19	12.1	14.15	0.0073	8.45

R = Root S = Shoot T = Total

tion: Column 2 = Total seedling height. Column 3 : Stem diameter at root collar. Column 4 : DMS = dry mass of shoot & 1
Column 5 : DMR = dry mass of root. Column 6 = Column 4 + Column 5 : TDM = total dry mass
Column 7 = Column 4 ÷ Column 5 : dry mass ratio. Column 8 = Column 2 ÷ Column 3 L height/diameter ratio.
Column 9 = Column 6 ÷ $\frac{(\text{Column 2} + \text{Column 4})}{\text{Column 3} \quad \text{Column 5}}$ Column 10 = Column 2 x (Column 3)²

APPENDIX 3 - Growing schedule for tublings, 1985

Quality Monitoring - Container Stock

Crop # -1-

Species: Black Spruce Seedlot # Thompson Lab Germination ______ %

Date Seeded: Jan. 28-85 Seeding Rate: 1/cavity In Greenhouse Date Jan 28-85

Container Type: 1/08 No. Trays: -4- Growing Medium: Peat/lite

Greenhouse # T.J Seed Zone # [illegible] Grit Type: #2 Granite

Procedure	Day	Date	Comments
*In greenhouse & poly cover	0	Jan 29	(controlling 75%) [illegible]
Poly cover removed	5	FEB 05	- misting -
[1]Fertilizer	Week 1	FEB 26	7-40-17 : .714g; FC : .021g; H_2SO_4 : .101m / l — 10 litres applied CH
Fertilizer	2	MAR 5	see note on page #1 — 5 litres applied JT
Fertilizer	3	MAR 19	" " 10 litres applied CH
Fertilizer	4	MAR 26	" " 10 litres applied [illegible]
Fertilizer	5	APRIL 2	" " 10 litres applied CH
Fertilizer	6	APRIL 9	20-1-19 0.6g; H_2SO_4 [illegible] ml/l — 10 litres applied CH
Fertilizer	7	APRIL 16	" " 10 litres applied CH
Fertilizer	8	APRIL 23	" " 10 litres applied CH
Fertilizer	9	APRIL 30	H_2SO_4 .113ml/l — 10 litres applied J
Fertilizer	10	MAY 7	4-25-35 1.25g/l; H_2SO_4 0.05ml/l. — 10 litres applied CH
Fertilizer	11	May 14	" " 10 litres applied CH
Fertilizer Moved to [illegible]	12	MAY 21	" " 10 litres applied CH
Fertilizer	13	MAY 28	" " 10 litres applied CH
Fertilizer [illegible]	14	June 4	" " 10 litres applied CH
Fertilizer	15		— Complete —
Fertilizer	16		
Fertilizer	17		
Fertilizer	18		
Fertilizer	19		
Fertilizer	20		
Fertilizer	21		
Fertilizer	22		
Fertilizer	23		
Fertilizer	24		
Ready for planting	25		

APPENDIX 3 - Cont'd.

Species: Sb Seedlot # Thompson Lab Germination _____

Date Seeded: _____ Seeding Rate: 2/cav. In Greenhouse Date Jan 28-85

Container Type: 408 No. Trays: 4 Growing Medium: peat/lite

Greenhouse # TI Seed Zone # _____ Grit Type: GRANITE

FILE #85-11-3

CULTURAL PRACTICES	WEEK BEGINNING	RATE OF FERTILIZATION(F) IRRIGATION(W)	FERTILIZER # APPLIED	REMARKS
1	2	3	4	5
In greenhouse, seeded trays with poly cover	1 ✓	-	-	Maintain stringent sanitary practices, and optimum conditions for germination. Insect-proofing of greenhouses. Eliminate cull piles by June 1.
Removal of poly cover	2 ✓	-	-	Mist lightly to ensure complet germination and to prevent seed caps from sticking.
Irrigate incorporating Benlate.	3 ✓	W with 1032 g of Benlate in stock solution for injection ratio of 1:256 for 649 trays	-	90 percent of seedcoats must be completely shed.
Thin seedlings leaving one residual seedling in each cavity in the 4th week. Irrigate with Benlate and Truban.	4 ✓	W with774 g of Truban and 258 g of Benlate in stock solution for injection ratio of 1:256 for 649 trays	-	Majority of seedlings should show primary needle development.
Commence fertilizer #1 and continue weekly application for 5 weeks. Check for root-rot and damping-off.	5 ✓	F	1	Accuracy of the injector must be checked on a routine basis, by monitoring the concentration of the feed solution. Keep vigil for disease incidences. Monitor moisture content in seedlings root zones. EC & pH have to be monitored bi-weekly, preferably weekly. Day-time temperatures should not exceed 29°C. 16-18 hour photoperiod per day with 10 kilolux. Until April, supplementary lighting to 14 hours per day using cool-white fluorescent light. Soil temperature in the range 18-22°C. Relative humidity 60-80 during germination, 50-70 during growth, and should not exceed 80 percent.
	6 ✓	F	1	
	7 ✓	F	1	
Third application should contain only 1032 g of Truban in the stock solution.	8 ✓	F	1	
	9 ✓	F	1	
Commence fertilizer #2 and continue weekly application for four weeks.	10 ✓	F	2	
	11 ✓	F	2	
	12 ✓	F	2	
	13 - DC	F	2	
Irrigation only	14 ✓	W	-	
	15 - DC	W	-	
Commence fertilizer #3 and continue weekly application for five weeks.	16	F	3	
	17	F	3	
	18	F	3	
	19	F	3	
	20	F	3	

Fertilizer I (1:256 dilution factor)

	BS	WS	JP
7-40-17	1230g	1230g	1841g
10% iron chelate	3.4g	14g	27g

Fertilizer II (1:256 dilution factor)

	BS	WS	JP
20-7-19	1032g	1290g	1720g
10% iron chelate	27g	7g	-

Fertilizer III (1:256 dilution factor)

4-25-35	2150g (for 1/3 of BS, WS and JP)
93% H_2SO_4	87ml

APPENDIX 3 - Cont'd.

Quality Monitoring - Container Stock

Crop # -1-

Species: Jack Pine Seedlot # ________ Lab Germination ________ %

Date Seeded: JAN 28/85 Seeding Rate: 2/cav. In Greenhouse Date Jan 28/85

Container Type: 408 No. Trays: -4- Growing Medium: Peat/Lite

Greenhouse # T.1. Seed Zone # Thompson Grit Type: #2 Granite

Procedure	Day	Date	Comments
*In greenhouse & poly cover	0	JAN. 28	CAPTAN APPLIED TO SEED (GR-HOUSE 75%)
Poly cover removed	5	FEB. 05	MISTING
[1]Fertilizer	Week 1	FEB 26	7-40-17 : .07g; FE : .014g; H_2SO_4 : .082g /l — 10 liters applied EH
Fertilizer	2	MAR. 5	" " 5 liters applied JT
Fertilizer	3	MAR. 18	" " 10 liters applied EH
Fertilizer	4	MAR. 26	" " 10 liters applied D
Fertilizer	5	APRIL 2	" " 8 liters applied EH
Fertilizer	6	APRIL 9	20-7-19 : 1.0g; H_2SO_4 : .07ml /l — 10 liters applied EH
Fertilizer	7	APRIL 16	" " 10 liters applied EH
Fertilizer	8	APRIL 23	" " 10 liters applied EH
Fertilizer	9	APRIL 30	H_2SO_4 .113 ml/l — 10 liters applied JT
Fertilizer	10	MAY 7	4-25-35 : 1.25g; H_2SO_4 : .052ml /l — 10 liters applied EH
Fertilizer	11	MAY 14	" " 10 liters applied EH
Fertilizer moved to lath-house	12	MAY 21	" " 10 liters applied EH
Fertilizer	13	MAY 28	" " 10 liters applied EH
Fertilizer [illegible]	14	June 4	" " 10 liters applied EH
Fertilizer	15		- complete -
Fertilizer	16		
Fertilizer	17		
Fertilizer	18		
Fertilizer	19		
Fertilizer	20		
Fertilizer	21		
Fertilizer	22		
Fertilizer	23		
Fertilizer	24		
Ready for planting	25		

APPENDIX 3 - Cont'd.

Species: PJ Seedlot # Thompson Lab Germination _____

Date Seeded: _____ Seeding Rate: 2/cavity In Greenhouse Date Jan 28/85

Container Type: 408 No. Trays: 4 Growing Medium: Peat/Vermiculite

Greenhouse # T. I Seed Zone # _____ Grit Type: Granite

File # 85-044

CULTURAL PRACTICES	WEEK BEGINNING	RATE OF FERTILIZATION(F) IRRIGATION(W)	FERTILIZER # APPLIED	REMARKS
1	2	3	4	5
In greenhouse, seeded trays with poly cover	1	-	-	Maintain stringent sanitary practices, and optimum conditions for germination. Insect-proofing of greenhouses. Eliminate cull piles by June 1.
Removal of poly cover	2	-	-	Mist lightly to ensure comple germination and to prevent seed caps from sticking.
Irrigate incorporating Benlate.	3	W with 1032 g of Benlate in stock solution for injection ratio of 1:256 for 649 trays	-	90 percent of seedcoats must be completely shed.
Thin seedlings leaving one residual seedling in each cavity in the 4th week. Irrigate with Benlate and Truban.	4	W with774 g of Truban and 258 g of Benlate in stock solution for injection ratio of 1:256 for 649 trays	-	Majority of seedlings should show primary needle development.
Commence fertilizer #1 and continue weekly application for 5 weeks. Check for root-rot and damping-off. Third application should contain only 1032 g of Truban in the stock solution.	5 6 7 8 9	F F F F F	1 1 1 1 1	Accuracy of the injector must be checked on a routine basis, by monitoring the concentration of the feed solution. Keep vigil for disease incidences. Monitor moisture content in seedlings root zones. EC & pH have to be monitored bi-weekly, preferably weekly. Day-time temperatures should not exceed 29°C. 16-18 hour photoperiod per day with 10 kilolux. Until April, supplementary lighting to 14 hours per day using cool-white fluorescent light. Soil temperature in the range 18-22°C. Relative humidity 60-80 during germination, 50-70 during growth, and should not exceed 80 percent.
Commence fertilizer #2 and continue weekly application for four weeks.	10 11 12 13	F F F F	2 2 2 2	
Irrigation only	14 15	W W	- -	
Commence fertilizer #3 and continue weekly application for five weeks.	16 17 18 19 20	F F F F F	3 3 3 3 3	

Fertilizer I (1:256 dilution factor)

	BS	WS	JP
7-40-17	1230g	1230g	1845g
10% iron chelate	54g	54g	27g
93% H_2SO_4	175ml	175ml	151ml

Fertilizer II (1:256 dilution factor)

	BS	WS	JP
20-7-19	1032g	1290g	1720g
10% iron chelate	27g	7g	-
93% H_2SO_4	161ml	134ml	121ml

Fertilizer III (1:256 dilution factor)

4-25-35 2150g (for all of BS, WS and JP)
93% H_2SO_4 87ml

APPENDIX 3 - Cont'd.

February 12 Benlate 2.7g/4.5 L H_2O 0.25 L applied

February 19 Benlate 2.7g/4.5 L H_2O 2.25 L applied
Sulfur

March 4 Sulfur 1.25g/2.25 L.

March 5 7-49-7 1.07g
FE .014g /L Sulfur applied
H_2SO_4 .082g (wrong mixture)

March 28 Malathion 25 ml/6 L H_2O light misting applied for aphids.