ESTABLISHMENT OF JACK PINE FAMILY-TEST PLANTATIONS IN EASTERN SASKATCHEWAN AND WESTERN MANITOBA, 1976

J. I. KLEIN AND A. M. NANKA

NOR-12-051 FILE REPORT
FEBRUARY, 1981

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CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA
5320-122 STREET
EDMONTON, ALBERTA, CANADA
T6H 3S5

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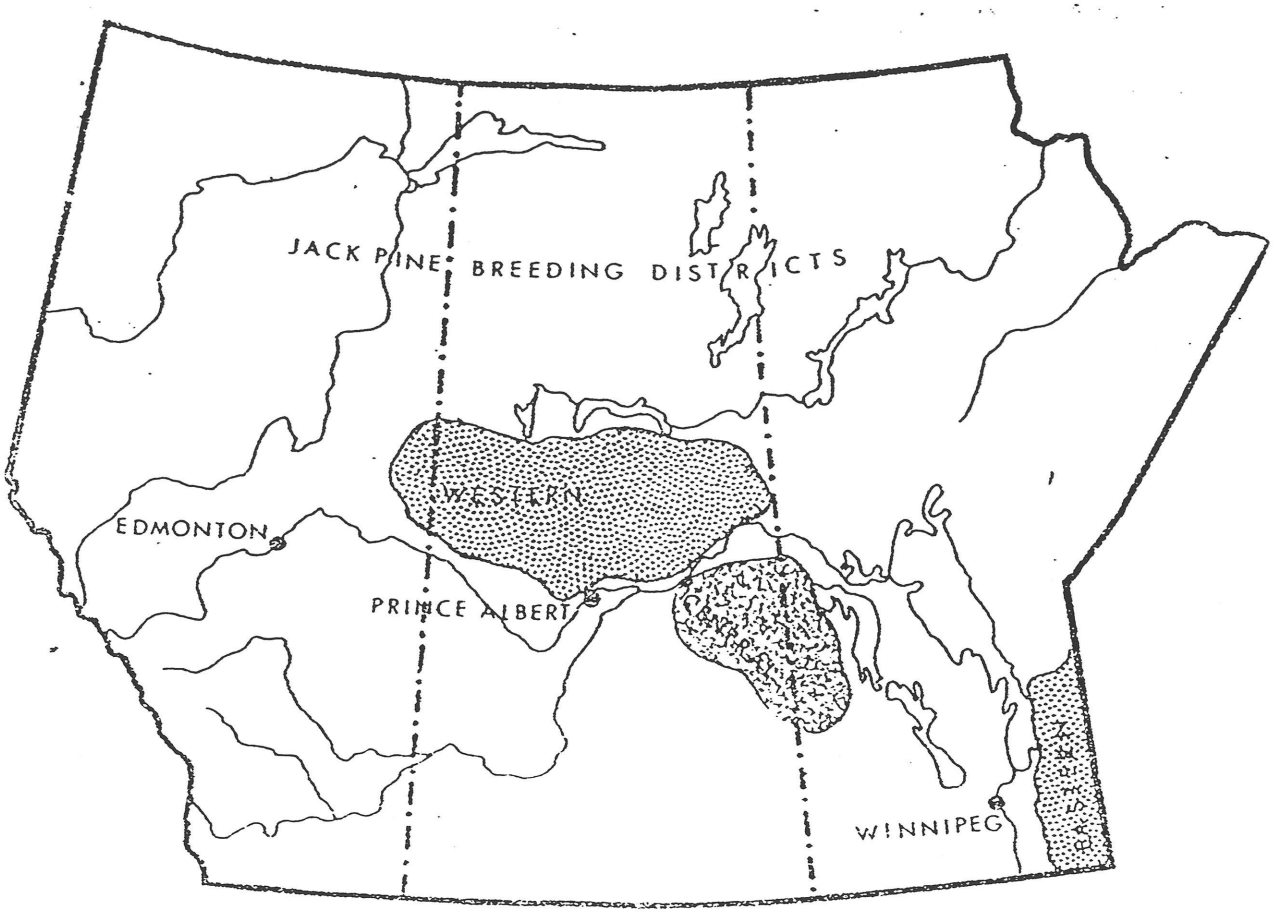

BY

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CONTENTS

FIGURES

Page

TABLES

Klein, J.I. and A.M. Nanka. 1981. Establishment of jack pine family-test plantations in eastern Saskatchewan and western Manitoba, 1976. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. File Rep. NOR 051.

ABSTRACT

Open-pollinated seed was collected from 244 selected parent trees and two stands, mainly from 51°26' to 53°33' north latitude and from 100°37' to 103°30' west longitude, in 1970, 1971, and 1975. Rearing was done in 40 x 40 x 120 mm containers filled with peat, from June 1975 to March 1976. During the rearing period, 214 progenies were selected to be included in the test, along with the two stand collections, and the seedlings selected for planting were arranged according to the cubic lattic design of the plantations. In the summer of 1975, four planting sites in eastern Saskatchewan and western Manitoba were cleared, then were scarified with shark-finned barrels and anchor chain, or with anchor chain alone. The scarified sites were staked out at a spacing of 2.5 x 2.5 m. Planting was accomplished in May and June of 1976. The test has 12 replicates (3 in each plantation) and four-tree row plots. Progeny source information, plantation maps, and detailed planting site descriptions are presented in Appendixes.

INTRODUCTION

In 1967 a program was initiated for genetic improvement of jack pine (Pinus banksiana Lamb.) for forest plantations in the Prairie Provinces. In the first selection cycle of this program, improvement of growth rate, stem quality, and other traits will be pursued by means of performance comparisons among trees grown in family-test plantations. Each family comprises progeny trees grown from open-pollinated seed collected from a single selected parent tree, and any surviving grafted ramets of that parent tree. The mean performance of a progeny, relative to other progenies in the test, provides information on the genetic merit of the parent genotype, maintained by planting grafted ramets of parent-tree scions, and of each progeny tree in that family, growing in the test plantations.

A more detailed account of the objectives and strategy of the first selection cycle, will be presented in an Information Report in preparation.

The program for the first selection cycle is carried out concurrently in three breeding districts (see front cover). Breeding district boundaries enclose areas of anticipated forest planting activity within which one set of selected genotypes can be expected to be adapted.

This report describes the establishment of family test plantations for the central breeding district, planted in May and June, 1976. This district comprises the uplands of the Manitoba escarpment, and adjacent forested lowlands, from the southern slopes of Duck Mountain Provincial Forest in western Manitoba, north and west to the northern slopes of the Pasquia Hills in eastern Saskatchewan. Cubic lattice design was used for this test, as for the eastern and western breeding district tests, because of its potential efficiency in controlling site variation effects in tests having large numbers of progenies. The number of treatments (progenies) must be the cube of an integer, and the number of replicates must be three or a multiple of three. This test has 216 progenies, four plantations of three replicates each, and four-tree row plots. Two of the progenies are stand progenies, included to serve as controls for assessing the effect of parent-tree selection. Collection and rearing were done for a larger number of progenies to ensure that 216 would still be available for the test plantations in the event that some were unusable. As it turned out, all progenies produced enough seedlings,

and progenies were selected for use primarily on the basis of parent-tree and source considerations.

THE TESTED POPULATION

Acquisition

Cones were collected in 1970, 1971, and 1975 from 244 selected trees and two stands within and near the central breeding district. Selection locations were chosen with the objective of obtaining a representative distribution of progeny sources throughout the portion of the district accessible by road. From one to six parent trees were selected at each chosen location. The collection area within the district extended from $51^{o}26'$ to $53^{o}33'$ north latitude, and from $100^{o}37'$ to $103^{o}30'$ west longitude. Twenty-four parent trees were selected north and southeast of the district, including six from a plantation of unknown origin. About 60% of the single-parent progenies were collected in Manitoba. The stand progenies are from the Porcupine Hills upland in Saskatchewan and the Duck Mountain upland in Manitoba.

Parent trees were selected by ocular inspection and subjective judgement, for above-average stem quality and satisfactory vigor. Up to an hour was spent on examination and comparison of candidates for each tree selected. All but a few selected trees were felled for collection of cones and of scions for grafting. Accession numbers beginning with 1301 were assigned to all families, in order of collection. The stand progenies are numbered 2040 and 2042, from a different collection series. They were obtained from crowns of more than 20 trees felled for timber sales.

Source stand locations were recorded in the field as road distances from mapped intersections with other roads, or river crossings, then described in terms of latitude and longitude, and public land survey, by reference to 1:250,000 topographic maps. Tree cover and stocking were described for all source stands, landform for some. Height, diameter, stump age, branch angle, and stem straightness were recorded for all selected trees, except that age was not determined on trees that were not felled. Source stand and parent tree information for the 214 families and two stand progenies used in the test plantations, is presented in Appendix A. Distribution of source locations and of test sites is presented in Figure 1.

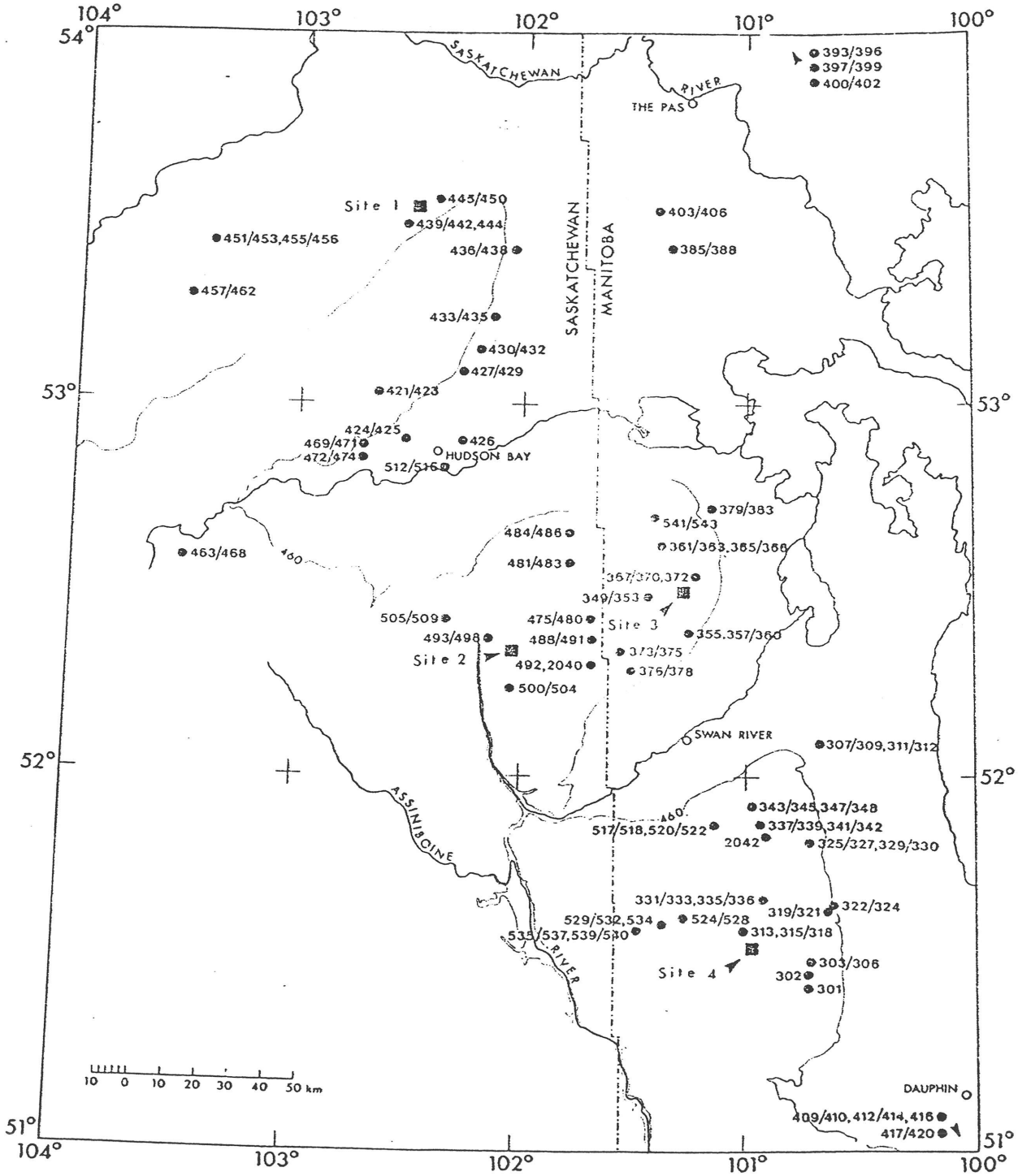

Figure 1. Distribution of source stands. Numbers referring to dots are family accession numbers, with the common leading digit 1 omitted, or stand progeny accession numbers.

Seed extraction and processing were done at the Northern Forest Research Centre. Cones were opened in a walk-in drier, at 45°C for 12 to 16 hours. The opened cones were tumbled for extraction of seeds in an apparatus having a rectangular drum 30 x 30 cm in cross-section and 60 cm long, covered with wire mesh having 1 cm openings. Seed wings were separated from the seeds by wetting the winged seeds while holding them between two sieves in a stream of warm air from a heated aspirator. The wings were then manually removed. Removal of empty seeds and broken wings was done in an aspirator. The cleaned seed lots were brought to a moisture content of about 5% by leaving them for several hours in an incubation cabinet providing forced air circulation at electronically controlled humidity and temperature. The seed lots were then stored at -10°C in 5 mL screw-capped glass vials.

Rearing

Planting stock for the family test was reared from June 1975 to March 1976 in greenhouses at the Northern Forest Research Centre, in Spencer-Lemaire "Hillson" Rootrainer book planters. One of these planters, when folded, forms a line of four cavities, each 40 x 40 x 120 mm in size. Two sides of the cavities are corrugated to prevent spiralling of roots, and taper at the bottom 20 mm to a 10 x 20 mm opening. The folded planters are held in trays which accommodate eight planters, or 32 cavities. A randomized block design with three replicates and one-tray plots was used for the rearing period. Replication during rearing was intended to prevent rearing environment variation from causing genetically inferior progenies to outperform genetically superior progenies after planting; that is, to prevent confounding of rearing environment effects with progeny effects.

Filling of 738 trays containing 5,904 planters with moist sphagnum peat was done at the (Alberta) Provincial Tree Nursery near Edmonton from June 6 to 13. An electrically-powered apparatus moistened the peat, dispensed the moistened peat into trays, and vibrated the trays. Loading of peat, metering of water, loading of trays on the vibrator, and packing of the dispensed peat in the cavities to the desired density, were done manually.

Seeding was done from June 12 to 20. Trays were watered shortly before they were seeded. In each rearing replicate, 64 seeds of each progeny were dispensed on to the peat surface of the 32 cavities of one tray. Seeded trays were arranged on wood lath above greenhouse benches, then covered with polythene vapor barrier.

In the first rearing replicate, germination was prompt, with hypocotyls extending straight up and primary roots penetrating straight down. In the second and third rearing replicates, some trays were visibly drying under the polythene cover by June 25. Germination appeared to be delayed in some trays. Germinates in these replicates had roots that extended along the peat surface before penetrating downward, or that had not penetrated at all. Apparently, the watering of trays before seeding of part of the second replicate and all of the third replicate had been insufficient to saturate the peat, and this moisture insufficiency inhibited germination and initial seedling development. The covers were removed on June 25, and the trays in the second and third replicates were watered frequently during the following week to allow completion of germination. Seedlings having roots partly or wholly on the surface of the peat were manually planted in their peat plugs, in a position and orientation as near normal as was feasible, from June 25 to July 30. Transplanting of doubles into blank cavities was also done during this period. More than two-thirds of the seedlots showed germination of better than 95%, while fewer than 10% were below 90%.

When germination was recorded from June 30 to July 4, it was discovered that some progeny numbers were missing in certain replicates and some numbers appeared twice in a replicate. These errors could have been due either to omissions and duplications in drawing sowing lots from the seed storage vials, or to errors in copying progeny numbers from the seed vials to the sowing lot envelopes and to the trays. New sowing lots were drawn for the missing and duplicated rearing plots, and were sown in manually-filled trays on July 24 and 25. Duplicated plots were discarded.

Family accession number was written on every planter in every tray during July and August.

Application of mineral nutrients was begun on July 2 for the June seeding and on August 5 for the July seeding. The nutrient solution described by Hocking (1971) was used in most instances. Two stock solutions were diluted and combined to produce a solution that provided N, P, K, and Mg at 112, 31, 156, and 48 mg/L, plus Ca, S, and minor nutrients. Additional iron chelate was applied on two occasions. A commercial soluble fertilizer (Plant-Prod 10-52-10) supplemented by potassium sulfate, was applied to the June seedling in late January 1976, but the concentration was not recorded. Nutrients were applied at intervals of about two weeks through mid-September. Thereafter, the June seeding received single applications in October, November and January, while the July

seeding was fertilized four times in November and twice in December. The amount applied was sometimes sufficient to saturate the plugs, but at other times application had to be discontinued short of this goal. Watering was done between nutrient applications, as frequently as twice weekly.

Supplementary illumination from cool white fluorescent tubes provided a light intensity of 600-650 foot candles. Photoperiod was 18 hours from seeding to October 31 for the June seeding, and to March 12, 1976 for the July seeding. Photoperiod for the June seeding was reduced to 16 hours on October 31, and to 12 hours on December 5. Daily minimum and maximum temperatures in ^{o}C for the June seeding were 15 to 20 and 25 to 30 from July to September, 20 to 25 and 25 to 33 in October, 8 to 18 and 15 to 22 after November 6, and gradually decreasing thereafter to daily lows of around 10 and highs of 10 to 18 by early February. Summer temperatures were maintained until March 12 for the July seeding, when those trays were moved to one of the compartments occupied by the June seeding.

Despite the maintenance of nutrition, photoperiod, and temperature conditions suitable for rapid growth through the fall and winter, the seedlings sown in July were slightly shorter than the others at the end of the rearing period. Shoots that extended during fall and winter were characterized by close spacing of needles and persistent succulence. This abnormal morphology has been observed repeatedly among jack pine seedlings grown in the N.F.R.C. greenhouses during winter, and may be due to deficiency of red and far-red light components in the output of the cool white fluorescent tubes.

Planting of seedlings into the peat plugs in June and July did not solve the problem of instability. At the end of July, it was observed that most seedlings, including those that had germinated normally, were leaning away from the walks, and that the leaning started during watering. Despite modification of the watering technique, and periodic reversal of tray orientation, leaning and bending of the seedlings under the weight of wet foliage persisted and worsened. Alleviation of leaning was achieved only by adding wet peat at the top of the cavities, and packing the added peat to support the hypocotyl in a vertical position. This procedure required about a half hour per tray. All trays seeded in June were treated from July 31 to September 18. Removal of duplicate seedlings to leave one seedling per cavity was also done during this period. Further propping of leaning seedlings was required and was done

from October 22 to December 12, on January 26 for one family and on February 2 for trays seeded in July.

An infestation of grey mold (Botrytis cinerea Pers. ex Fr.), first observed on November 4, caused the death of some lower branches and a minor amount of seedling mortality. A fungicide spray was applied on November 7 and on January 30. Other control measures were separation of adjacent trays and pruning of lower branches on seedlings selected for planting, to improve air circulation; and reduction of watering frequency.

STATISTICAL DESIGN

The expectation of enhanced precision from the cubic lattice design is based on the use of a six-plot block, rather than the plantation replicate, for statistical control of site variation effects. Although the small block size allows efficient adjustment for site variation over short distances, the small number of progenies in a block results in the confounding of this adjustment with an excessive amount of sampling error due to progeny effects. Partitioning of this sampling error from the block adjustments is made possible in a set of three replicates, by the design construction procedure which ensures that progenies occurring in the same block in one replication of the set, will be in different blocks in both of the other replicates of the same set.

Design Plan Construction

Three basic replicate plans were first constructed as described by Cochran and Cox (1960), using 216 three-digit code numbers to represent progenies. These code numbers specify "dummy" treatments at six levels of three factors, which provide the key to block formation and adjustment of block effects for progeny sampling error effects. Within each of the 36 blocks of a replicate, two digits (factors) are fixed, while the third takes all six levels. The two factors that are fixed within blocks vary among blocks. The three basic replicate plans differ in regard to which of the three factors varies within blocks.

Four randomizations of each of the three replicate plans produced block sequences for four sets of three replicates, corresponding to the four plantations in the test. The 36 factor combinations fixed within blocks were represented by the club ace to spade nine in a pack of playing cards, which was shuffled several times to produce a random block sequence for each replicate. Plot

sequence was randomized in each of the 432 blocks of the 12 replicates. The replicate sets were numbered 10 to 13, following on the nine replicate sets for the eastern and western breeding district family tests. Within sets, replicate 1 has the right-hand factor varying within blocks, replicate 2 the middle factor, and replicate 3 the left-hand factor. Replicate numbers 10-1 to 13-3 were written accordingly at the top of the 12 randomized replicate design plans.

The four sets of design plans were used to set up permanent observation record forms and plantation layout diagrams for the four plantations. The forms are on 40 line by 80 column sheets, with a separate line for identification and performance observations of each tree. Replicate, block, progeny code, and tree-in-plot numbers were entered in columns 1 through 12, in accordance with the replicate design plans, for the 10,368 trees required by the design. The sheets were folded in half vertically for convenience in handling, then punched and bound in four replicate set books. Format of the observation record is described in Table 1. The record books are kept in the study leader's office, except when taken to the field for a measurement or when key punching is in progress. The plantation layout diagrams are presented in Appendix B, and are bound, along with access maps, in the record books.

Selection and Arrangement of Seedlings for Planting

Of the 30 progenies chosen to be omitted from the family test, 16 were from selected trees that had the poorest height-over-age relationship among the six trees selected in their source stands within the breeding district. Six progenies had relatively short parents selected in stands outside the breeding district, four lacked a parent clone, and four were omitted for other reasons. The 216 remaining progenies, including both stand progenies, were thus selected to be included in the family test plantations. Vial caps labelled with the 216 code numbers were drawn at random, and their code numbers assigned to the selected progenies in order of accession number.

For each progeny, the test design requires 12 four-tree plots, whereas the rearing design provided 24 four-tree planters in three trays. By growing twice as many seedlings of each progeny as required, we ensured availability of ample reserves for culling substandard seedlings while maintaining full stocking at the time of planting. Seedlings grown in Spencer-Lemaire Rootrainers can be transferred from one planter to another without harm to the seedlings, provided

Table 1. Format for the permanent observation record

Column no.	Entry
76-80	Deck identification: 051-5 on all cards, fifth deck for study NOR-051.
1-12	Card identification
1-2	Replicate set: 10, 11, 12, 13; randomly assigned to four plantation locations.
3	Replicate in set: 1 - right-hand progeny code digit varies in blocks 2 - middle progeny code digit varies in blocks 3 - left-hand progeny code digit varies in blocks
5-6	Block in replicate: 1, 2, ..., 36
8-10	Progeny code number for 6 x 6 x 6 cubic lattice design. Source and parent-tree data for progenies are in Appendix A, in sequence of code number.
12	Tree in plot: 1, 2, 3, 4
14-74	Space for performance observation data

that their roots are sufficiently developed to maintain the integrity of the peat plug during the transfer. This capability was used by transferring seedlings within each selected progeny tray so that 16 seedlings selected for planting filled four of the tray's planters. Each of these four planters then held the stock for one plantation plot.

Preparation of plantation planters for selected progenies in the trays seeded in June was done in November and December 1975. For the trays seeded in July, this procedure was carried out on February 2, 1976. Seedlings to be planted were selected for superior size, vigor, and stem straightness. After the selected seedlings were transferred as required, their four planters were placed together at one end of the tray. The selected seedlings were then propped up with added peat, and their lower branches were pruned for control of grey mold.

Planters containing selected seedlings were allocated to plantation replicates according to a scheme that provided appropriate partitioning of variances due to rearing replicates and to randomized rearing treatment sequence and greenhouse position effects on rearing plots within replicates. One planter from every progeny tray in all three rearing replicates was assigned to each plantation. Every one of the four plantations thus has one planter from each of the 648 trays in which the 216 planted progenies were reared. All plantations have seedlings from the same set of trays. For any specified progeny, its trees were reared in the same three trays, in every one of the four plantations. Performance differences among plantations will consequently measure response to differences in plantation environment, free of contributions from response to environmental differences among rearing replicates, and among trays within rearing replicates.

Because replicates within a plantation contain trees from different rearing replicates, rearing environment variation will contribute to performance differences among replicates within plantations. These performance differences are interpreted as measures of experimental erorr, not as responses to differences in plantation environment. Rearing environment effects are also experimental error. Confounding of rearing replicate and rearing plot effects with plantation replicate and progeny by replicate effects within plantations, amounts to addition of pre-planting and post-planting experimental error. This summing of experimental error will not in any way weaken or complicate interpretation of plantation performance results.

Planters were randomly assigned to plantation replicates, within the constraints described above. The four plantation planters in all trays of each rearing replicate were first randomly matched with the four replicate sets. The three planters of every progeny thus assigned to each set, one from each of the three rearing replicates, were then matched at random with the three plantation replicates of the set. When this matching was completed, the assigned rearing replicate number and planter number were written on the design plan for each plantation replicate, as illustrated in Figure 2. Finally, replicate sets were randomly matched with plantation locations. The resulting assignment of planters to plantation replicates is presented in Table 2.

Plantation planters in trays seeded in June were marked and arranged in January 1976 to facilitate their arrangement according to the plantation replicate design plans. Every plantation planter was marked with the appropriate progeny code number and all were numbered from 1 to 4 within trays. Trays containing a progeny with an odd right-hand progeny code digit were labelled with the progeny code number on the left half of the tray, the letter "S" to designate selected seedlings, and the next higher code number on the right half of the tray. Trays containing a progeny with an even code number were labelled with the next lower code number on the left half of the tray, the letters "NS" for non-selected seedlings, and the code number for the tray's progeny on the right half of the tray. Empty trays were marked to take the place of July-seeded trays. Trays were arranged in order of progeny code number within rearing replicates. Planters containing non-selected seedlings of each odd-numbered progeny were transferred to the left half of the tray in which the next higher-numbered progeny had been reared, and their place was taken by the selected seedlings of that progeny. After the planters were transferred to match the tray markings, the trays containing non-selected seedlings were moved to a separate greenhouse location.

With the non-selected seedlings out of the way, and planters of selected seedlings arranged in order of code number within rearing replicates, arrangement of the plantation planters according to the design plan was begun on February 2. Fifty-four empty trays were first marked with replicate and block numbers. The 27 trays required for the first plantation replicate to be formed, were marked with the number of the plantation replicate to which planter 1 of the first rearing replicate had been assigned. The other 27 empty trays were marked with the plantation replicate number for planter 2. Because each tray holds

site 1, Rice River

Replicate 11-1

sowing rep 3 strip 3

		8D		4S		7S		AC		AS		3S	
Block 1	56x		Block 7	34x	Block 13	54x	Block 19	11x	Block 25	14x	Block 31	26x	
563	566		342	346	546	542	111	112	145	146	264	265	
561	562		341	344	545	543	115	114	142	144	266	262	
564	565		343	345	544	541	116	113	143	141	263	261	
		8S		5H		4C		8S		4H		2D	
Block 2	42x		Block 8	41x	Block 14	31x	Block 20	62x	Block 26	33x	Block 32	16x	
422	425		412	416	312	313	622	624	336	331	162	164	
424	423		414	411	316	315	621	623	333	332	163	165	
421	426		415	413	314	311	626	625	334	335	166	161	
		2H		5C		5D		9H		2S		7H	
Block 3	21x		Block 9	35x	Block 15	36x	Block 21	65x	Block 27	22x	Block 33	53x	
211	212		353	352	364	362	653	655	225	226	531	535	
213	216		356	355	365	366	651	654	224	221	536	533	
215	214		351	354	361	363	656	652	223	222	534	532	
		AH		6H		8H		6C		4D		3H	
Block 4	13x		Block 10	45x	Block 16	61x	Block 22	43x	Block 28	32x	Block 34	25x	
136	134		454	453	615	616	434	433	321	324	256	253	
131	133		455	451	613	612	431	435	322	323	252	251	
132	135		452	456	611	614	432	436	325	326	254	255	
		9D		7D		9S		2C		7C		6D	
Block 5	64x		Block 11	52x	Block 17	66x	Block 23	15x	Block 29	51x	Block 35	44x	
644	643		526	521	664	662	153	155	516	515	445	442	
645	642		522	524	663	661	154	152	512	513	444	443	
646	641		525	523	666	665	156	151	511	514	441	446	
		3C		AO		9C		8C		6S		3D	
Block 6	23x		Block 12	12x	Block 18	63x	Block 24	55x	Block 30	46x	Block 36	24x	
133	231		123	125	633	634	553	556	461	465	241	243	
235	232		126	124	631	632	555	552	464	463	242	244	
234	236		121	122	635	636	554	551	462	466	245	246	

Figure 2. Randomized design plan for plantation replicate 11-1 with assigned planter and plantation location identified at the top. Plot sequence in a block is from top left to bottom left to top right to bottom right.

Table 2. Assignment of planter books to plantation replicates

Plantation location	Plantation replicate	Assigned planter	
		Rearing rep.	Planter in rep.
Twin Moose Creek, Sask.	10-1	3	4
	10-2	2	4
	10-3	1	2
Rice River, Sask.	11-1	3	3
	11-2	1	4
	11-3	2	3
Harte Mtn., Man.	12-1	1	1
	12-2	3	2
	12-3	2	1
Shallow Lake, Man.	13-1	3	1
	13-2	1	3
	13-3	2	3

eight planters, while a plantation block contains six plots, three trays accommodated planters for four blocks. Hence every tray was to hold planters for two consecutive blocks, and was marked with the two block numbers and a line between the planter positions for the sixth plot of the lower block and the first plot of the upper block, in addition to the plantation replicate number. When the 54 trays were so marked, each tray was filled with planters. The planters were located within the rearing replicate by reference to the block number on the plantation tray, the progeny code numbers for the same block on the design plan for that plantation replicate, and the progeny code numbers on the rearing trays containing selected seedlings. Sequencing of the planters within the plantation trays was accomplished and verified by comparison of the progeny code numbers on the planters with the same numbers on the design plan.

After two plantation replicates had been arranged in this manner into the 54 trays marked at the outset, planters 3 and 4 for all progenies in the first rearing replicate were consolidated from 108 trays into 54 trays. Another 54 trays were thus released to hold the next two plantation replicates. The progeny code number and "S" markings were erased from these, and they were marked with plantation replicate and block numbers. The two plantation replicates utilizing planters 3 and 4 of each progeny were formed as for the first two replicates, except that progenies had to be located by reference to the code numbers on the planters, as the numbers on the rearing trays were no longer applicable. The last 54 trays from the first rearing replicate were used for the first two plantation replicates from the second rearing replicate, and so on, until arrangement of the planters according to the design plans for the 12 plantation replicates was completed on February 5.

Dead and unhealthy seedlings in the plantation trays were replaced on February 23 with the best available non-selected seedlings of the corresponding progenies and rearing replicates. Plantation planters from the trays seeded in July were inserted into the appropriate positions in the plantation trays on March 15. Four plantation planters had to be prepared on March 15 from eight planters of non-selected seedlings, for one progreny which ought to have had a tray seeded in July. These March 15 insertions were noted at the left margin of the appropriate lines in the observation record.

MEASUREMENT AND CHILLING OF PLANTING STOCK

Height of seedlings arranged for planting was measured to the nearest cm, from February 23 to 25. Seedlings in planters inserted on March 15 were measured on that date. This measurement was recorded in columns 14 and 15 in the observation record.

All trays were transferred from the greenhouse to wire shelf units in a cold room on March 16 to 18. Unselected seedlings and progenies were placed against the walls, on the top shelves, and next to an open aisle left in the middle of the room. Temperature in the cold room was set at 5°C. Humidity was not controlled, but the border of seedling-filled trays was intended to provide protection from drying for the plantation trays. Fluorescent light fixtures were set up in the cold room and timed to provide eight hours of light per day. Light intensity was not recorded, but would have been quite low, especially for seedlings on the lower shelves.

THE TEST ENVIRONMENT

Location, Climate and Soils

Four test sites were selected in summer 1975 on recently harvested areas within the breeding district. Two were chosen on the Porcupine Hills Upland; on Parr Hill in Saskatchewan and on Harte Mountain in Manitoba. The others are on the Pasquia Beaches of the Carrot River Lowland, below the north slope of the Pasquia Hills Upland in Saskatchewan (Ayres et al. 1978) and in Duck Mountain Provincial Forest in Manitoba. Only the Pasquia Beaches location lies slightly below the boundary of the upland which it represents and is probably typical of the relatively productive sites near the base of the Pasquia Hills Upland. Site locations were shown in relation to family sources in Figure 1, and are specified in Table 3. The sites were numbered 1 to 4 from west to east, to allow concise identification.

Climate of the planting sites can only be roughly inferred from the climate of the nearest lowland stations, as there are no reliable weather records from any of the three uplands. The three upland planting sites may be assumed to have frost-free seasons of 70 to 80 days, mean temperature of about 17°C in July and -20°C in January, annual precipitation of about 480 mm and May to September precipitation of about 300 mm. At the Pasquia Beaches site,

Table 3. Location of test plantation sites

Location Mode	Planting site 1 assigned to replicate set 11	2 assigned to replicate set 10	3 assigned to replicate set 12	4 assigned to replicate set 13
Province	Saskatchewan	Saskatchewan	Manitoba	Manitoba
Physiographic area	Pasquia Beaches subsection of Carrot River Lowland[1]	Porcupine Hills	Porcupine Hills	Duck Mountain
Landscape feature	Rice River	Twin Moose Creek	Harte Mtn.	Shallow Lake
Nearest settlement or town	Smoky Burn	Swan Plain	Birch River	Boggy Creek
North latitude	53°31'	52°18'	52°28'	51°33'
West longitude	102°25'	102°05'	101°17'	100°58'
Elevation, m	350	550	690	700
Section-township range-meridian	30-52-3-W2	24-38-1-W2	28-40-27-WPM	6-30-25-WPM
1:250,000 map sheet	Pasquia Hills 63E	Hudson Bay 63D	Swan Lake 63C	Duck Mountain 62N

[1] Ayres et al. (1978)

the frost-free season is probably longer (90 to 100 days) and warmer, and precipitation is probably lower, perhaps 430 mm annually.

Soils are predominantly medium- to fine-textured on the planting sites. Habitats having coarse-textured soils were not favored as test sites, because such soils cover only a small proportion of the area within this breeding district. Native jack pine occurs and grows well on medium- and fine-textured soils in the district. As a group, the test sites are probably less sloping and less stony than the average habitat here. A soil survey report is available only for the Pasquia Beaches site, which is mapped within the Nitenai complex of predominantly regosolic soils developed on variable colluvial deposits (Ayres et al. 1978).

A soil pit was dug at each planting site in summer 1977. Observations on depth, moist color, structure type, moist consistence, root occurence, clay films, carbonates, stoniness, horizon boundary, and horizon thickness, were recorded in the field for each horizon. Color and consistence of dry horizon samples were recorded at the Northern Forest Research Centre. Physical and chemical analysis of horizon samples were performed by the N.F.R.C. Soils Service Laboratory. Site description and morphological description of soil horizon samples, results of physical and chemical analysis, and classification of soil profiles are presented in Appendix C. Soil profile description follows the terminology of Canada Soil Survey Committee, Subcommittee on Soil Classification (1978).

The Duck Mountain site, and part of the Harte Mountain site, have heavy clay horizons of significant thickness. The other Harte Mountain pit and the Pasquia Beaches pit, indicated moderately fine-textured soils on these sites. At Twin Moose Creek, horizon texture varied from clay loam to silt loam and loam, indicating a predominantly medium-textured profile. There may be considerable soil variability within each test site.

Site Preparation and Protection

Clearing, scarification, fireguard installation, and fence erection were done on all planting sites during summer and fall of 1975.

At each location, site boundaries were placed so as to avoid abrupt changes of slope, drainage, or soil within sites. Flagging tape was tied to trees to mark out areas to be cleared that were slightly larger than required to accommodate the plantations. Residual trees that uprooted without causing major soil disturbance

were bulldozed down. Large, heavy-rooted trees were felled. Trees, deadfalls, shallow-rooted stumps, and other woody debris were bladed off the sites.

The exact position of each planting site was determined within its cleared area, and sighting lines were established to control furrow orientation. Five flagged poles were first set to serve as the sighting line for an outer furrow. Two of the five poles were separated by the prescribed furrow length, one was midway between these two, and the other two were about 25 m beyond the two ends of the intended furrow, to ensure that furrow straightness would be maintained for the entire prescribed length. A second sighting line of five poles was set for a centre furrow. The positions of the poles marking the two ends of the centre furrow were determined by turning right angles from the first sighting line at the furrow-end poles and measuring the prescribed distance (20 furrows x 2.5 m) from them. The angles were checked from the centre line back to the outer corners, and the distance was measured between the projected outer corners on the opposite side of the planting site, as a further check. Three additional poles were then placed at the middle and beyond the ends of the centre furrow.

The first round trip of the scarifying equipment formed furrows along the two flagged lines. The furrow-end poles were removed just before the equipment reached them, and were replaced when it passed. On each subsequent trip, the operator sighted along a marker on the appropriate end of the tractor blade to the previous furrow, to maintain a 2.5 m spacing between furrows, and to keep the furrows parallel. The forest genetics research technician kept track of the remaining space and of the number of furrows remaining to be formed, instructing the operator to adjust the space between furrows as required, so that the final furrow from the marked outer furrow was positioned 2.5 m from the marked centre furrow.

At sites 1, 2, and 4, 40 furrows 200 m long were formed by shark-finned barrels, then smoothed by a length of anchor chain attached to the second barrel. These implements were drawn by a Timberjack 550 skidder on site 1, a Caterpillar D8 crawler tractor on site 2, and a Caterpillar D6 crawler tractor on site 4. At site 3, 40 furrows 130 m long accommodate two replicates (site 3a), while the third replicate is a few hundred metres away on 40 other furrows 70 m long (site 3b). Scarification on site 3 was done by a Timberjack

360 skidder pulling anchor chain alone. Equipment time for scarification was 12, 14, 15, and 16 hr for sites 1, 2, 3, and 4.

A fireguard 4 m wide was scraped to mineral soil around the perimeter of each plantation, by a straight blade on a Caterpillar D6 crawler tractor. A fence was erected within each fireguard for protection against browsing by rodents and inadvertent trespass by motor vehicles. Each was constructed using 110 treated fence posts 2 m in length and spaced at 6 m intervals. Smooth wire 4 mm in diameter was stretched horizontally 1.4 m above the ground and at ground level, secured to the posts with staples. Poultry netting, 1.5 m in width with 5 x 5 cm mesh, was stapled to the smooth wire. The bottom 10 cm of the poultry netting was buried or held down with earth or logs.

PLANTATION ESTABLISHMENT

Plantation Layout

Immediately before planting commenced at a plantation, wire pins were set in the centre of the furrows, at every position where a tree was to be planted. Every plot was labelled with a pin bearing the progeny code number, in accordance with the plantation layout design plans. Pins marking positions in different furrows, at the same number of positions from the same end of the furrows, were set in a straight line perpendicular to the furrows.

The location of one end of a plantation was determined by extending the line from a corner post through the centre-furrow post to the outer furrow. These posts had been set so that they were aligned perpendicular to the furrows, in preparation for furrow formation. A post or pin was then set in the other outer furrow to mark the other corner for that end of the plantation. A cord was pulled taut between the corners, and pins were set at the cord in the remaining furrows. The cord was pulled to positions at 2.5 m measured intervals in the two outer furrows, and pins were set in the furrows at the cord, until the prescribed number of positions had been marked. For the Manitoba plantations (sites 3 and 4), all of the outer-furrow positions were measured and marked before staking of the inner furrows was begun. For the Saskatchewan plantations, all furrows were marked as each successive interval was measured. The outer-furrow positions were sometimes offset from the nominal spacing to avoid stumps. When offsetting was done in the Saskatchewan plantations, the next outer-furrow position was set 2.5 m from the offset position. Consequently,

conformance to or deviation from the nominal spacing is independent for successive intervals at sites 1 and 2, whereas at sites 3 and 4, a smaller interval is likely to be followed by a larger interval.

When the planting positions were marked, labelled 60-cm pins were used for the first-tree position of every plot, 20-cm blue and red pins were used for the remaining positions of odd and even-numbered plots, and 20-cm yellow pins were set in border row positions.

The first and last two planting positions in every furrow, and all planting positions in the four outer furrows (two on each side), were marked with yellow pins, to indicate where border row trees were to be planted. The inner 36 furrows, which are the plot furrows, were marked in their third position with the 60-cm pins bearing the code numbers for the progenies assigned by the design plan to blocks 1, 7, 13, 19, 25, and 31 of the replicate randomly assigned to the starting end of that plantation. The labelled pins, or plot stakes, had been packed by plantation replicates and bundled by blocks in accordance with the replicate design plans. Block bundles bore disposable block-number labels. Facing the far end of the planting-site furrows, block 1 plot stakes were placed in the six furrows adjacent to the right-hand border furrows, block 7 plot stakes in the next six furrows to the left, and so on. The design plan for the replicate being laid out was used to set the plot stakes for the progenies assigned to plots 1 to 6 in sequence from right to left in the six furrows for each block (Figure 3). The next three positions in the plot furrows were marked with unlabelled 20-cm pins. Blue pins were placed in odd-numbered plots, red pins in even-numbered plots. Each plot occupies four consecutive positions in one furrow, and each block the same four consecutive positions in six adjacent furrows, beginning with the plot-stake position.

In the fourth planting position after the first set of plot stakes, the furrows were marked with the plot stakes for blocks 2, 8, 14, 20, 26 and 32 of the same replicate, from right to left, and the design plan used to sequence plot stakes within blocks, as for the first labelled position. Unlabelled blue and red pins were set in alternating plot furrows at the next three positions. The sequence of one labelled position followed by three unlabelled positions was repeated until layout at each site was completed by setting yellow pins at the last two positions in all 40 furrows. Block numbers increased by one at successive labelled positions along furrows within replicates. Where a second or third replicate began at a site, plot stakes for blocks 1, 7, 13, 19, 25, and 31 of the new replicate

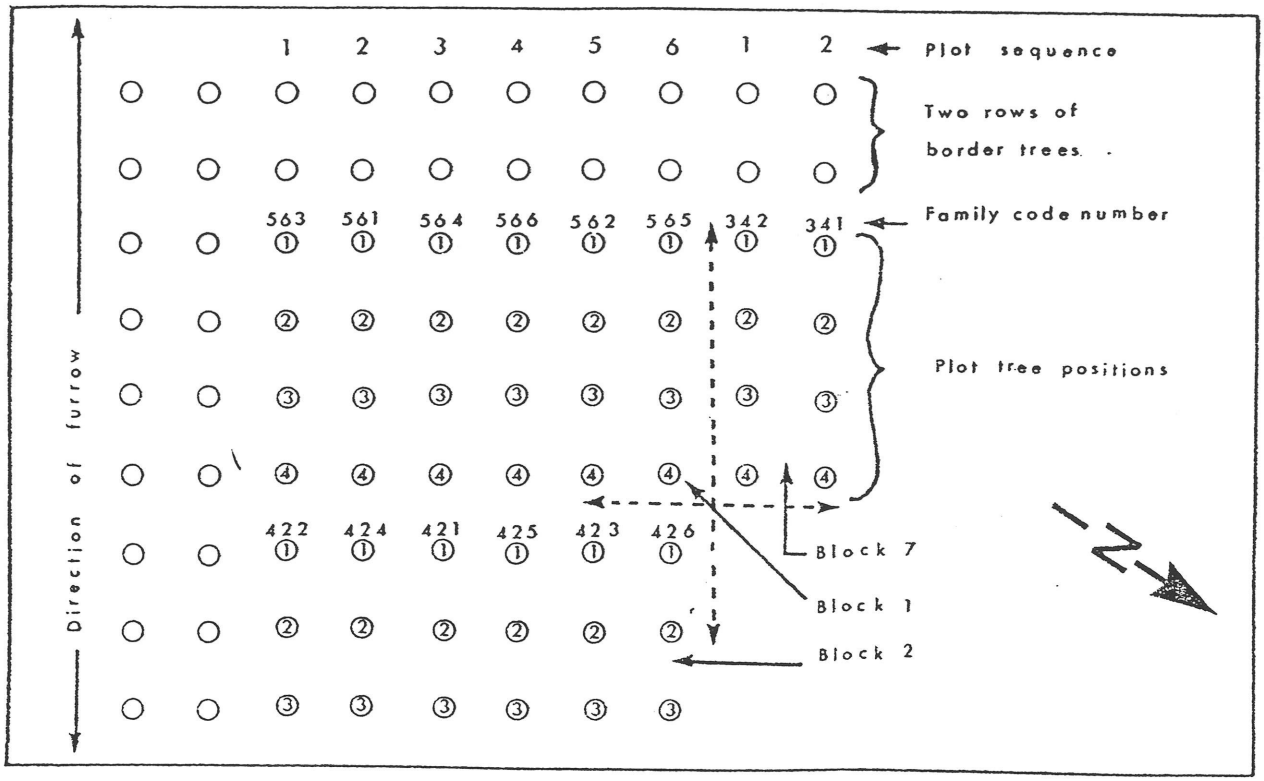

Figure 3. Plot sequence and tree position within blocks, illustrated for replicate 11-1, block 1. Plot 1 would be to the right for an observer looking toward block 2 from block 1.

were set in the next position after the third unlabelled position of blocks 6, 12, 18, 24, 30, and 36 of the previous replicate. Plot stakes were set for second and third replicates according to the same block numbering arrangement, and with the same right-to-left sequence of plot numbers in blocks, as was followed in the first replicate at each site. Blocks and replicates are not explicitly labelled in the plantations, but can be identified by reference to the plantation layout diagrams and the plot stakes.

Use of wire pins to mark the unlabelled planting positions was intended to aid in discriminating between planted and volunteer jack pines in early examinations, so that the former will be measured and the latter removed. Color-coding of odd- and even-numbered plots was intended to reduce the likelihood of incorrect progeny identification during measurement, of trees at unlabelled positions.

Plantation layout diagrams for all plantations are presented in Appendix B.

Transport and Distribution of Planting Stock

Trays containing plot seedlings for the four plantations were removed from the cold room to an unshaded outdoor location on April 26-28. They were loaded in an enclosed trailer on April 30, transported the following day to a Fire Suppression Depot operated by the Manitoba Forest Service at Boggy Creek, and unloaded on May 2. Apparent frost injury was observed when the trays were unloaded, on seedlings in the 15 trays sown in July 1975. The trays were arranged outdoors on shaded ground, grouped by assigned planting site, and watered as required. Trays containing seedlings of progenies not used in the family test, and non-selected seedlings of other progenies, were transferred from the cold room to a lath house on April 28, and transported to the Boggy Creek facility on May 14. Seedlings planted in the border rows of all plantations were taken from these latter trays, and were not identified in the plantations.

Stock was transported from Boggy Creek to the planting sites under cover, in a pickup box or trailer. The trays of seedlings were unloaded at their planting sites under a forest canopy, and were at the sites for not more than 30 hours before the seedlings were planted. Stock for the Saskatchewan plantations was transferred in one trip to a shaded outdoor storage location in eastern Saskatchewan. A thorough watering en route kept the plugs moist for the remaining nine days until planting was completed.

Trays were distributed to the assigned plantation block positions, marked on the trays, as planting progressed, and not longer than two hours before their seedlings were planted. About 10 to 30 minutes before a block was planted, its book planters were removed from the trays, and each planter was placed at the plot stake bearing the progeny number written on the planter. Distribution of trays and planters on the planting sites was done by a forest research technician seconded from another N.F.R.C. program.

Planting

The planting crew consisted of six residents of the general area in which the planting sites are located. The same crew carried out plantation layout and planting at all four sites. For the planting operation, three crew members were designated to dig holes, while the three planters placed the seedlings in the assigned holes and backfilled. Each planter was assigned a pair of plot numbers (1 and 2, 3 and 4, 5 and 6) to plant in every block of the test. Planters were instructed to verify the match of progeny code numbers between plot

stake and book planter, to plant their odd-numbered plot before their even-numbered plot, and to maintain in the plantation plots the order of seedlings in the book planters. The seedling in the cavity marked with the progeny code number was to be planted in the first tree position of its plot, marked by the plot stake. The forest genetics research technician did a final check on the match of progeny code numbers between plot stake and book planter.

Demonstration, instruction, and supervision of planting techniques were provided by the forest genetics research technician. Crew members gained familiarity with the prescribed techniques while planting the border rows for the first plantation to be planted. Planting shovels were used to dig holes with one vertical wall against which the plugs were held during backfilling. The top of the peat plug was positioned 1-3 cm below the top of the hole, which was backfilled by hand. The soil was heel-tamped on three sides of the seedling when the hole was partly filled, then more soil was added and tamped until the hole was filled to slightly below grade level.

Layout and planting took place on May 18-20 at site 4, May 23-25 at site 3, May 26-29 at site 2, and May 31-June 4 at site 1. Normal weather prevailed during this period. A casual examination of the plantations in August 1977 provided an impression that survival was not less than 97%, with height growth of 30-70 cm at all four sites.

Replacement Trees

Seedlings were sown in 1978 and planted in 1979 to replace mortality among trees grown in trays seeded in July 1975. In anticipation of moratlity in plots from those trays, one tray was seeded in February 1978, with each of the 15 progenies that included a July-seeded tray. The replacement seedlings were reared in the greenhouse until placed outside for chilling in September and October 1978. Examination of the plantations in summer 1978 indicated that survival in the plots of concern was satisfactory, despite the apparent frost injury noted when the seedlings were unloaded at Boggy Creek. The replacement plan was nonetheless followed. For each dead planted tree, two seedlings of the same progeny were selected and potted up in 20 x 20 cm round pots in November, 1978. The potted replacement trees were grown in the greenhouse under an 18 hour photoperiod through January 1979. They were chilled on the greenhouse floor until May, then moved outside again for a final growth period. Commercial soluble fertilzers were applied as required during the three growth

periods. During the winter growth period, some trees showed normal extension only on branch shoots, and most trees required some staking. Stakes were removed before planting. The better of the two replacement trees was planted in each appropriate plantation position, in July 1979. Replacement trees will be identified on the observation record. They were about two years behind the other trees when they were planted.

ACKNOWLEDGMENTS

The authors express sincere thanks to the Alberta Provincial Tree Nursery at Oliver for providing facilities for filling book planters with peat, to Mr. Frank Flavelle, Section Head, Silviculture, Saskatchewan Department of Tourism and Renewable Resources, for providing funds for scarification of site 1; to Mr. Gordon McColm, Western Regional Forester, Manitoba Forest Service for underwriting scarification of site 3 and for the use of facilities of Boggy Creek Fire Suppression Depot for lodging and for storage of plantation materials, to Mr. Harvey Johnsone for tendering on the planting and fencing contract, and to the planting crew for adherence to rigorous standards while carrying out contract work; to Mr. N.R. Walker, Forest Research Technician, N.F.R.C. for assistance in the planting operation and to Belmont Rehabilitation Centre for unremunerated assistance in fabricating labelled plot markers.

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Table 1. Continued

Code	Nor[1]	N Lat.	W. Long.	Elev. m	Source Stand Stocking	Age yr.	Ht. m	Dia. cm	Stem[2] Class	Crown[3] Class
316	1428	53°05'	102°16'	390	moderate	23	10	14	2	d
321	1497	52°22'	102°08'	530	open-grown	43	13	18	3	d
322	1536	51°35'	101°28'	570	open-grown	66	17	36	3	d
323	1367	52°32'	101°13'	670	full	46	18	20	1	d
324	1441	53°29'	102°32'	350	full	27	9	12	1	d
325	1438	53°25'	102°03'	420	full	79	16	17	1	d
326	1332	51°40'	100°55'	700	full	78	20	21	2	d
331	1532	51°36'	101°21'	670	moderate	29	12	14	1	d
332	1450	53°33'	102°24'	320	open-grown	29	9	12	1	d
333	1477	52°25'	101°41'	640	full	29	10	13	1	d
334	1309	52°05'	100°40'	360	full	77	22	28	1	d
335	1470	52°53'	102°43'	440	irregular	28	10	14	2	d
336	1351	52°29'	101°26'	760	full	73	18	20	1	d
341	1456	53°26'	103°24'	350	moderate	34	12	14	1	c
342	2042	51°50'	100°54'	765	moderate	stand collection			1	d
343	1520	51°52'	101°08'	640	moderate	78	18	22	1	d
344	1435	53°14'	102°07'	410	full	38	17	15	2	d
345	1535	51°35'	101°28'	570	open-grown	38	9	17	3	d
346	1434	53°14'	102°07'	410	full	40	16	17	2	d
351	1447	53°33'	102°24'	320	open-grown	28	8	11	1	d
352	1522	51°52'	101°08'	640	moderate	77	16	18	1	d
353	1467	52°35'	103°30'	480	full	27	13	14	1	d
354	1466	52°35'	103°30'	480	full	36	14	14	1	d
355	1396	54°32'	101°03'	300	full	125	17	22	1	d
356	1480	52°25'	101°41'	640	full	28	10	16	1	d
361	1348	51°55'	100°58'	670	full	79	18	25	1	d
362	1375	52°20'	101°33'	640	open-grown	28	8	15	2	c
363	1335	51°40'	100°55'	700	full	79	21	20	1	d
364	1402	54°35'	101°23'	300	moderate	36	15	19	1	d
365	1321	51°38'	100°38'	570	moderate	68	21	29	1	d
366	1506	52°25'	102°20'	560	open-grown	121	28	46	1	d
411	1416	49°50'	99°35'	360	full	27	14	15	2	d
412	1481	52°34'	101°47'	730	full	76	18	14	1	d
413	1388	53°25'	101°20'	300	open-grown	27	9	16	2	c
414	1452	53°26'	103°24'	350	full	26	10	15	1	d
415	1331	51°40'	100°55'	700	full	73	20	23	1	d
416	1543	52°42'	101°24'	760	full	77	17	32	1	d
421	1528	51°37'	101°16'	570	open-grown	-	12	36	3	d
422	1512	52°49'	102°21'	640	moderate	67	14	20	1	d
423	1359	52°23'	101°15'	670	full	45	9	16	1	d
424	1306	51°30'	100°42'	710	open-grown	72	18	19	1	d

[1] Northern Region permanent number
[2] 1 - Straight, 2 - Fairly, 3 - Crooked
[3] d = dominant, c - codominant
[4] (pltn) = plantation

Table 1. Continued

Code	Nor[1]	N Lat.	W. Long.	Elev. m	Source Stand Stocking	Age yr.	Ht. m	Dia. cm	Stem[2] Class	Crown[3] Class
425	1350	52°29'	101°26'	760	full	74	20	20	1	d
426	1368	52°32'	101°13'	670	full	49	17	20	1	d
431	1460	53°17'	103°30'	360	full	25	11	13	1	c
432	1476	52°25'	101°41'	640	full	27	10	11	1	d
433	1403	53°31'	101°24'	300	open-groun	78	16	16	2	d
434	1360	52°23'	101°15'	670	full	48	13	18	1	d
435	1401	54°35'	101°23'	300	open-grown	38	19	16	1	d
436	1366	52°37'	101°22'	730	full	82	20	21	1	d
441	1333	51°40'	100°55'	700	full	77	21	27	1	d
442	1479	52°25'	101°41'	640	full	30	10	14	1	d
443	1485	52°39'	101°47'	760	moderate	105	19	17	1	d
444	1464	52°35'	103°30'	480	moderate	27	10	13	1	d
445	1473	52°51'	102°43'	440	full	45	17	18	1	d
446	1382	52°43'	101°09'	360	open	46	10	13	2	d
451	1534	51°36'	101°21'	670	moderate	29	14	18	2	d
452	1338	51°52'	100°56'	700	full	79	22	26	1	d
453	1531	51°36'	101°21'	670	moderate	29	12	14	2	d
454	1394	54°32'	101°03'	300	full	121	16	22	1	d
455	1459	53°18'	103°30'	360	moderate	28	10	17	1	d
456	1529	51°36'	101°21'	670	moderate	37	13	18	2	d
461	1339	51°52'	100°56'	700	full	78	18	22	1	d
462	1444	53°29'	102°32'	350	full	30	8	13	1	d
463	1413	50°40'	99°48'	650	open-grown	22	6	13	2	d
464	1440	53°29'	102°32'	350	full	28	10	14	1	d
465	1347	51°55'	100°58'	670	full	76	21	11	1	d
466	1502	52°14'	102°02'	560	moderate	27	14	28	1	d
511	1385	53°25'	101°20'	300	open-grown	28	10	19	2	d
512	1525	51°37'	101°16'	570	open-grown	-	8	36	3	d
513	1489	52°22'	101°41'	640	full	75	18	16	1	c
514	1312	52°05'	100°40'	360	full	78	19	20	1	d
515	1395	54°32'	101°03'	300	full	119	16	17	1	d
516	1430	53°09'	102°12'	390	full	24	9	13	2	d
521	1424	52°54'	102°31'	420	moderate	43	16	19	2	d
522	1319	51°38'	100°38'	570	moderate	68	17	19	1	d
523	1377	52°17'	101°30'	610	moderate	25	9	16	2	d
524	1304	51°30'	100°43'	730	full	74	20	20	2	d
525	1357	52°23'	101°15'	670	full	46	9	16	1	d
526	1330	51°49'	100°43'	540	full	75	19	21	1	d
531	1484	52°39'	101°47'	760	moderate	103	19	18	1	d
532	1445	53°33'	102°24'	320	open-grown	27	8	14	1	d
533	1326	51°49'	100°43'	540	full	74	20	23	1	d

[1] Northern Region permanent number
[2] 1 - Straight, 2 - Fairly, 3 - Crooked
[3] d = dominant, c - codominant
[4] (pltn) = plantation

Table 1. Continued

Code	Nor[1]	N Lat.	W. Long.	Elev. m	Source Stand Stocking	Age yr.	Ht. m	Dia. cm	Stem[2] Class	Crown[3] Class
534	1386	53°25'	101°20'	300	open-grown	29	9	18	2	d
535	1417	49°50'	99°35'	360	full(pltn)[4]	27	14	16	2	d
536	1370	52°32'	101°13'	670	full	46	18	19	1	d
541	1316	51°35'	101°00'	700	full	77	22	21	1	d
542	1431	53°09'	102°12'	390	full	25	9	11	2	d
543	1369	52°32'	101°13'	670	full	48	18	18	1	d
544	1383	52°43'	101°09'	360	open-grown	47	7	20	2	d
545	1419	49°50'	99°35'	360	full(pltn)[4]	26	14	17	2	d
546	1343	51°55'	100°58'	670	full	78	20	26	1	d
551	1515	52°49'	102°21'	640	moderate	61	14	18	1	d
552	1451	53°26'	103°24'	350	full	34	11	18	1	d
553	1491	52°22'	101°41'	640	full	75	18	18	1	c
554	1469	52°53'	102°43'	440	open-grown	27	10	17	2	d
555	1427	53°05'	102°16'	390	moderate	24	8	13	2	d
556	1373	52°20'	101°33'	640	open-grown	32	11	18	2	d
561	1537	51°35'	101°28'	570	open-grown	40	14	23	3	d
562	1305	51°30'	100°42'	710	open-grown	75	21	23	2	d
563	1327	51°49'	100°43'	540	full	74	21	21	1	d
564	1362	52°37'	101°22'	730	full	82	18	20	1	d
565	1336	51°40'	100°55'	700	full	82	20	20	1	d
566	1352	52°29'	101°26'	760	full	73	18	20	1	d
611	1453	53°26'	103°24'	350	full	26	11	17	1	d
612	1317	51°35'	101°00'	700	full	76	20	24	1	d
613	1301	51°26'	100°43'	700	moderate	76	18	20	2	d
614	1423	53°02'	102°39'	540	full	51	16	17	1	d
615	1503	52°14'	102°02'	560	moderate	28	15	18	1	d
616	1429	53°05'	102°16'	390	moderate	23	10	14	2	d
621	1442	53°29'	102°32'	350	full	25	11	13	2	d
622	1414	50°40'	99°48'	650	open-grown	17	6	15	2	d
623	2040	52°22'	101°41'	640	full	stand collection			1	d-c
624	1353	52°29'	101°26'	760	full	74	19	22	1	d
625	1492	52°22'	101°41'	640	full	74	18	23	1	d
626	1433	53°14'	102°07'	410	full	38	10	17	2	d
631	1344	51°55'	100°58'	670	full	77	18	20	1	d
632	1463	52°35'	103°30'	480	moderate	24	8	10	1	d
633	1412	50°40'	99°48'	650	open-grown	17	7	11	2	d
634	1379	52°43'	101°09'	360	open-grown	40	10	19	2	d
635	1475	52°25'	101°41'	640	full	29	10	14	1	d
636	1307	52°05'	100°40'	360	full	80	21	25	1	d
641	1524	51°37'	101°16'	570	open-grown	-	13	41	3	d
642	1494	52°22'	102°08'	530	full	46	16	18	3	d
643	1504	52°14'	102°02'	560	moderate	39	16	17	1	d

[1] Northern Region permanent number
[2] [3] 1 - Straight, 2 - Fairly, 3 - Crooked
d = dominant, c - codominant
[4] (pltn) = plantation

Table 1. Continued

Code	Nor[1]	N Lat.	W. Long.	Elev. m	Source Stand Stocking	Age yr.	Ht. m	Dia. cm	Stem[2] Class	Crown[3] Class
644	1526	51°37'	101°16'	570	open-grown	-	20	24	3	d
645	1513	52°49'	102°21'	640	moderate	39	12	15	1	d
646	1410	50°40'	99°48'	650	open-grown	21	6	13	2	d
651	1418	49°50'	99°35'	360	moderate (pltn)[4]	27	16	19	1	d
652	1482	52°34'	101°47'	730	full	74	18	16	1	d
653	1381	52°43'	101°09'	360	open-grown	39	12	17	2	d
654	1329	51°49'	100°43'	540	full	75	20	23	1	d
655	1358	52°23'	101°15'	670	full	47	11	19	1	d
656	1363	52°37'	101°22'	730	full	82	18	20	1	d
661	1337	51°52'	100°56'	700	full	79	21	24	1	d
662	1474	52°51'	102°43'	440	full	37	19	20	1	d
663	1471	52°53'	102°43'	440	open-grown	29	10	15	2	d
664	1541	52°42'	101°24'	760	full	83	20	25	1	d
665	1308	52°05'	100°40'	360	full	75	18	20	1	d
666	1320	51°38'	100°38'	570	moderate	66	20	28	2	d

[1] Northern Region permanent number
[2] 1 - Straight, 2 - Fairly, 3 - Crooked
[3] d = dominant, c - codominant
[4] (pltn) = plantation

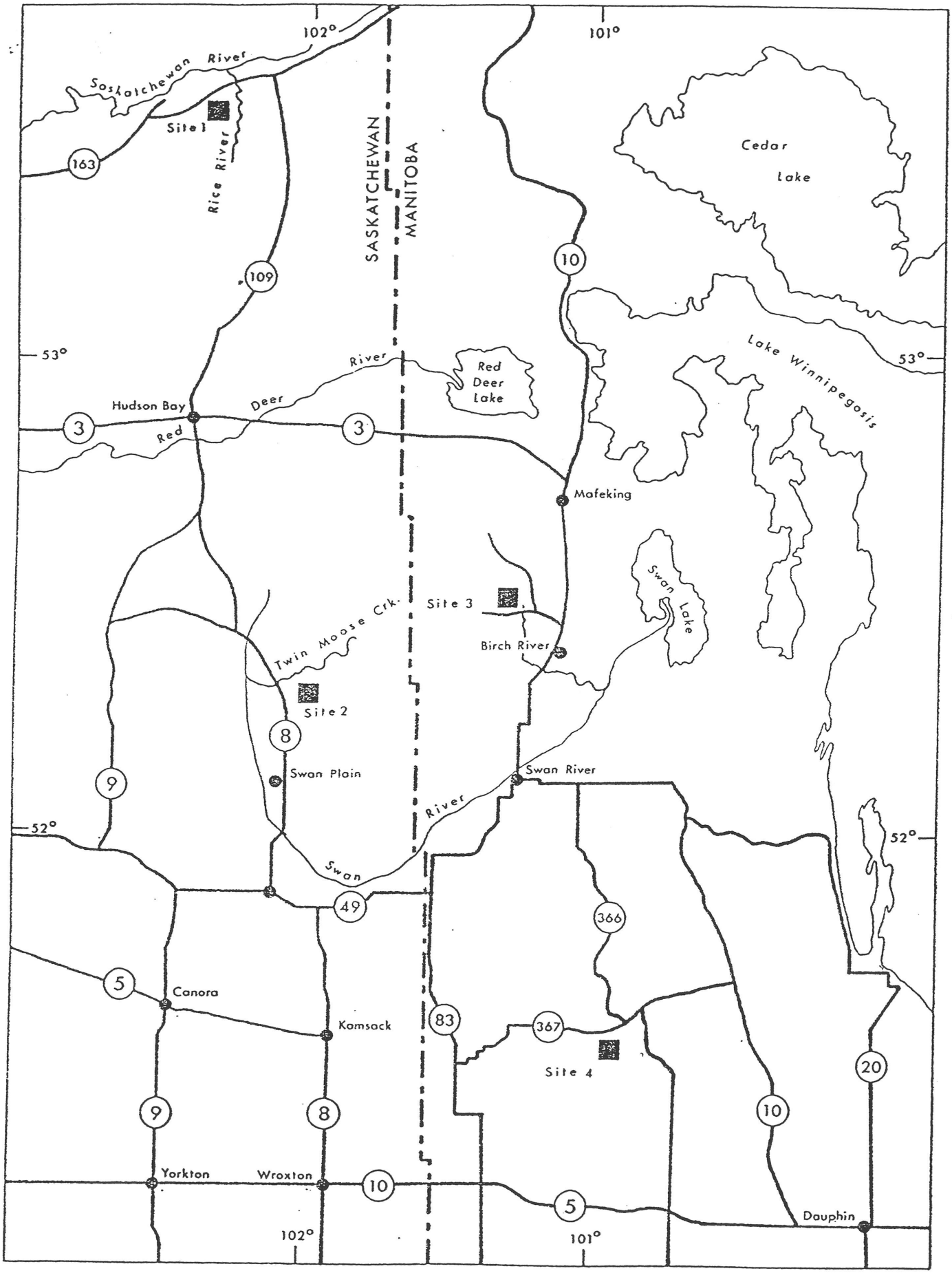
APPENDIX A (continued)

Table 2. List of families in test, by accession number

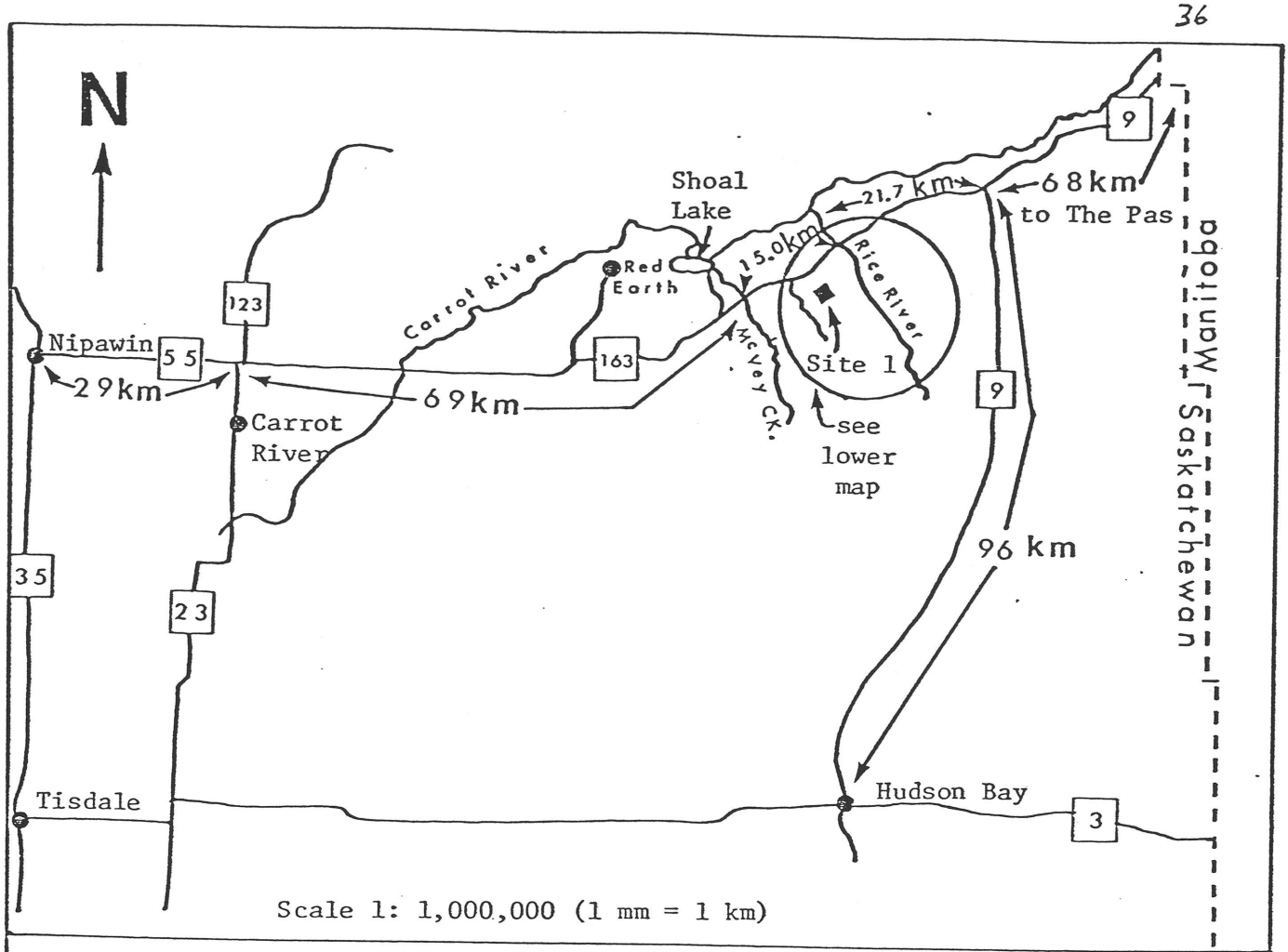
Family no.		Family no.		Family no.		Family no.		Family no.		Family no.	
acc.	code	acc.	code	acc.	code	acc.	code	acc.	code	acc.	code
1301	613	1342	224	1383	544	1428	316	1466	354	1504	643
1302	166	1343	546	1385	511	1429	616	1467	353	1505	222
1303	263	1344	631	1386	534	1430	516	1468	246	1506	366
1304	524	1345	241	1387	124	1431	542	1469	554	1507	214
1405	562	1347	465	1388	413	1432	156	1470	335	1508	164
1306	424	1348	361	1393	216	1433	626	1471	663	1509	145
1307	636	1349	211	1394	454	1434	346	1472	233	1512	422
1308	665	1350	425	1395	515	1435	344	1473	445	1513	645
1309	334	1351	336	1396	355	1436	256	1474	662	1514	212
1311	266	1352	566	1397	135	1437	245	1475	635	1515	551
1312	514	1353	624	1398	123	1438	325	1476	432	1516	146
1313	262	1355	163	1399	141	1439	116	1477	333	1517	132
1315	143	1357	525	1400	126	1440	464	1478	312	1518	125
1316	541	1358	655	1401	435	1441	324	1479	442	1520	343
1317	612	1359	423	1402	364	1442	621	1480	356	1521	155
1318	153	1360	434	1403	433	1444	462	1481	412	1522	352
1319	522	1361	122	1404	226	4145	532	1482	652	1524	641
1320	666	1362	564	1405	242	1446	313	1483	311	1525	512
1321	365	1363	656	1406	215	1447	351	1484	531	1526	644
1322	235	1365	252	1409	131	1448	134	1485	443	1527	244
1323	234	1366	436	1410	646	1449	232	1486	136	1528	421
1324	223	1367	323	1412	633	1450	332	1488	161	1529	456
1325	162	1368	426	1413	463	1451	552	1489	513	1530	243
1326	533	1369	543	1414	622	1452	414	1490	231	1531	453
1327	563	1370	536	1416	411	1453	611	1491	553	1532	331
1329	654	1372	112	1417	535	1455	113	1492	625	1534	451
1330	526	1373	556	1418	651	1456	341	1493	314	1535	345
1331	415	1374	254	1419	545	1457	253	1494	642	1536	322
1322	326	1375	362	1420	264	1458	115	1495	261	1537	561
1333	441	1376	236	1421	315	1459	455	1496	213	1539	265
1335	363	1377	523	1422	121	1460	431	1497	321	1540	154
1336	565	1378	165	1423	614	1461	114	1498	221	1541	664
1337	661	1379	634	1424	521	1462	133	1500	142	1542	151
1338	452	1380	251	1425	111	1463	632	1501	255	1543	416
1339	461	1381	653	1426	225	1464	444	1502	466	2040	623
1341	144	1382	446	1427	555	1465	152	1503	615	2042	342

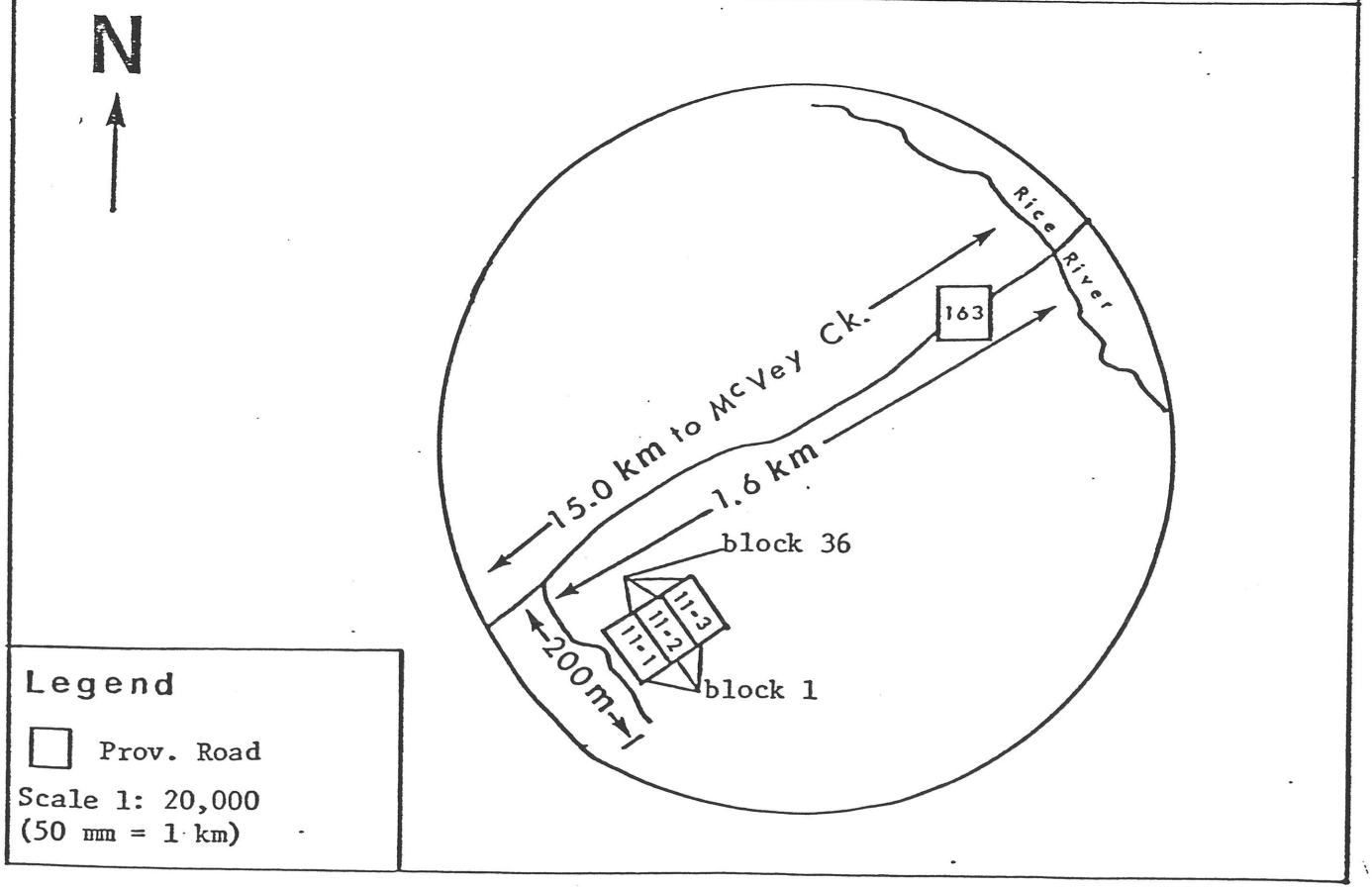
APPENDIX B

Plantation Access Maps and Layout Diagrams



Map 1. Location of Central breeding district family test plantations.





Central Breeding District, Access map, Site 1, Rice River

11-1

Block 1: 563 561 564 566 562 565	Block 7: 342 341 343 346 344 345	Block 13: 546 545 544 542 543 541	Block 19: 111 115 116 112 114 113	Block 25: 145 142 143 146 144 141	Block 31: 264 266 263 265 262 261
Block 2: 422 424 421 425 423 426	Block 8: 412 414 415 416 411 413	Block 14: 312 316 314 313 315 311	Block 20: 622 621 626 624 623 625	Block 26: 336 333 334 331 332 335	Block 32: 162 163 166 164 165 161
Block 3: 211 213 215 212 216 214	Block 9: 353 356 351 352 355 354	Block 15: 364 365 361 362 366 363	Block 21: 653 651 656 655 654 652	Block 27: 225 224 223 226 221 222	Block 33: 531 536 534 535 533 532
Block 4: 136 131 132 134 133 135	Block 10: 454 455 452 453 451 456	Block 16: 615 613 611 616 612 614	Block 22: 434 431 432 433 435 436	Block 28: 321 322 325 324 323 326	Block 34: 256 252 254 253 251 255
Block 5: 644 645 646 643 642 641	Block 11: 526 522 525 521 524 523	Block 17: 664 663 666 662 661 665	Block 23: 153 154 156 155 152 151	Block 29: 516 512 511 515 513 514	Block 35: 445 444 441 442 443 446
Block 6: 233 235 234 231 232 236	Block 12: 123 126 121 125 124 122	Block 18: 633 631 635 634 632 636	Block 24: 553 555 554 556 552 551	Block 30: 461 464 462 465 463 466	Block 36: 241 242 245 243 244 246

11-2

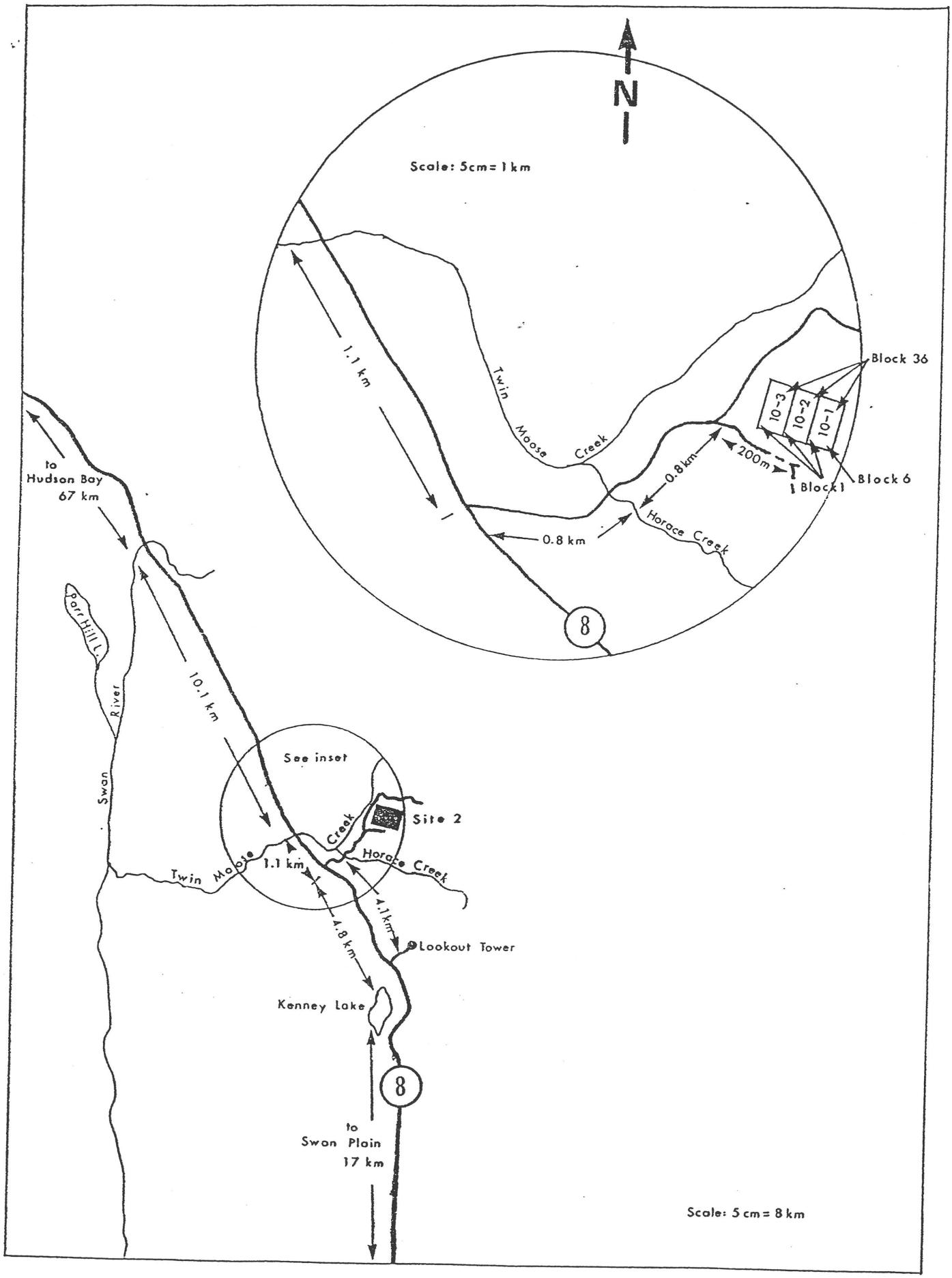
Block 1: 111 131 151 121 141 161	Block 7: 521 551 541 531 511 561	Block 13: 213 243 253 233 263 223	Block 19: 516 536 526 566 556 546	Block 25: 426 416 456 436 466 446	Block 31: 664 644 624 634 614 654
Block 2: 316 346 366 336 326 356	Block 8: 555 515 535 565 525 545	Block 14: 514 524 544 564 554 534	Block 20: 651 611 631 621 641 661	Block 26: 215 265 255 245 235 225	Block 32: 136 166 156 126 116 146
Block 3: 422 462 442 452 412 432	Block 9: 444 454 424 434 414 464	Block 15: 522 512 552 532 562 542	Block 21: 613 633 653 643 623 663	Block 27: 632 652 622 542 612 662	Block 33: 364 354 334 314 344 324
Block 4: 465 435 425 415 455 445	Block 10: 142 152 122 112 132 162	Block 16: 463 453 413 433 443 423	Block 22: 266 216 226 236 256 246	Block 28: 214 264 234 254 244 224	Block 34: 232 222 262 242 252 212
Block 5: 341 351 361 331 311 321	Block 11: 421 431 461 451 411 441	Block 17: 523 563 543 533 553 513	Block 23: 362 342 312 322 332 352	Block 29: 135 125 165 145 115 155	Block 35: 325 335 365 315 355 345
Block 6: 616 656 666 626 646 636	Block 12: 363 333 313 343 353 323	Block 18: 645 635 625 655 665 615	Block 24: 134 114 164 144 154 124	Block 30: 123 163 153 133 113 143	Block 36: 251 221 241 211 231 261

11-3

Block 1: 313 113 613 413 213 513	Block 7: 351 551 251 651 151 451	Block 13: 126 226 626 426 526 326	Block 19: 444 644 344 544 244 144	Block 25: 315 115 415 615 515 215	Block 31: 525 325 225 625 425 125
Block 2: 523 223 423 123 323 623	Block 8: 556 356 456 156 656 256	Block 14: 165 365 265 565 465 665	Block 20: 255 455 555 355 155 655	Block 26: 662 362 162 262 562 462	Block 32: 441 141 641 541 341 241
Block 3: 124 424 224 624 524 324	Block 9: 436 636 336 136 236 536	Block 15: 335 635 535 135 435 235	Block 21: 161 361 661 561 461 261	Block 27: 242 642 542 342 442 142	Block 33: 512 212 412 112 612 312
Block 4: 646 146 346 446 246 546	Block 10: 522 422 622 222 122 322	Block 16: 545 445 645 345 145 245	Block 22: 364 164 664 564 264 464	Block 28: 254 454 654 554 154 354	Block 34: 332 432 532 632 232 132
Block 5: 234 434 134 534 634 334	Block 11: 643 243 443 543 343 143	Block 17: 531 631 331 231 431 131	Block 23: 414 214 514 314 614 114	Block 29: 221 421 521 121 321 621	Block 35: 266 466 166 666 366 566
Block 6: 453 353 653 553 153 253	Block 12: 411 611 511 311 111 211	Block 18: 316 516 216 416 616 116	Block 24: 633 533 133 233 333 433	Block 30: 363 163 663 563 463 263	Block 36: 652 352 252 422 552 152

N

Diagram 1. Plantation layout, site 1, replicate set 11



Map 3. Access to site 2.

10-3

Block 1	Block 7	Block 13	Block 19	Block 25	Block 31
424 124 624 224 524 324	154 354 454 554 654 254	442 342 642 142 242 542	511 411 111 611 311 211	166 566 366 266 466 666	126 526 226 426 626 326
Block 2	**Block 8**	**Block 14**	**Block 20**	**Block 26**	**Block 32**
534 434 634 334 234 134	451 551 251 151 651 351	512 112 612 212 312 412	645 245 445 345 145 545	356 556 456 256 156 656	136 536 331 636 436 236
Block 3	**Block 9**	**Block 15**	**Block 21**	**Block 27**	**Block 33**
315 515 415 615 115 215	225 525 425 325 125 625	321 221 121 621 521 421	453 353 553 253 653 153	413 313 513 213 613 113	231 531 431 331 131 631
Block 4	**Block 10**	**Block 16**	**Block 22**	**Block 28**	**Block 34**
622 222 122 422 322 522	255 455 655 555 355 155	163 463 363 563 263 663	146 646 246 446 546 346	661 361 261 161 561 461	352 652 252 552 452 152
Block 5	**Block 11**	**Block 17**	**Block 23**	**Block 29**	**Block 35**
135 535 335 435 635 235	243 143 643 343 543 443	164 264 464 364 564 664	216 316 516 416 116 616	123 223 623 423 523 323	232 332 432 532 632 132
Block 6	**Block 12**	**Block 18**	**Block 24**	**Block 30**	**Block 36**
462 562 262 162 662 362	433 133 633 233 333 533	244 144 544 444 344 644	641 141 441 541 341 241	214 414 514 114 614 314	165 465 665 365 565 265

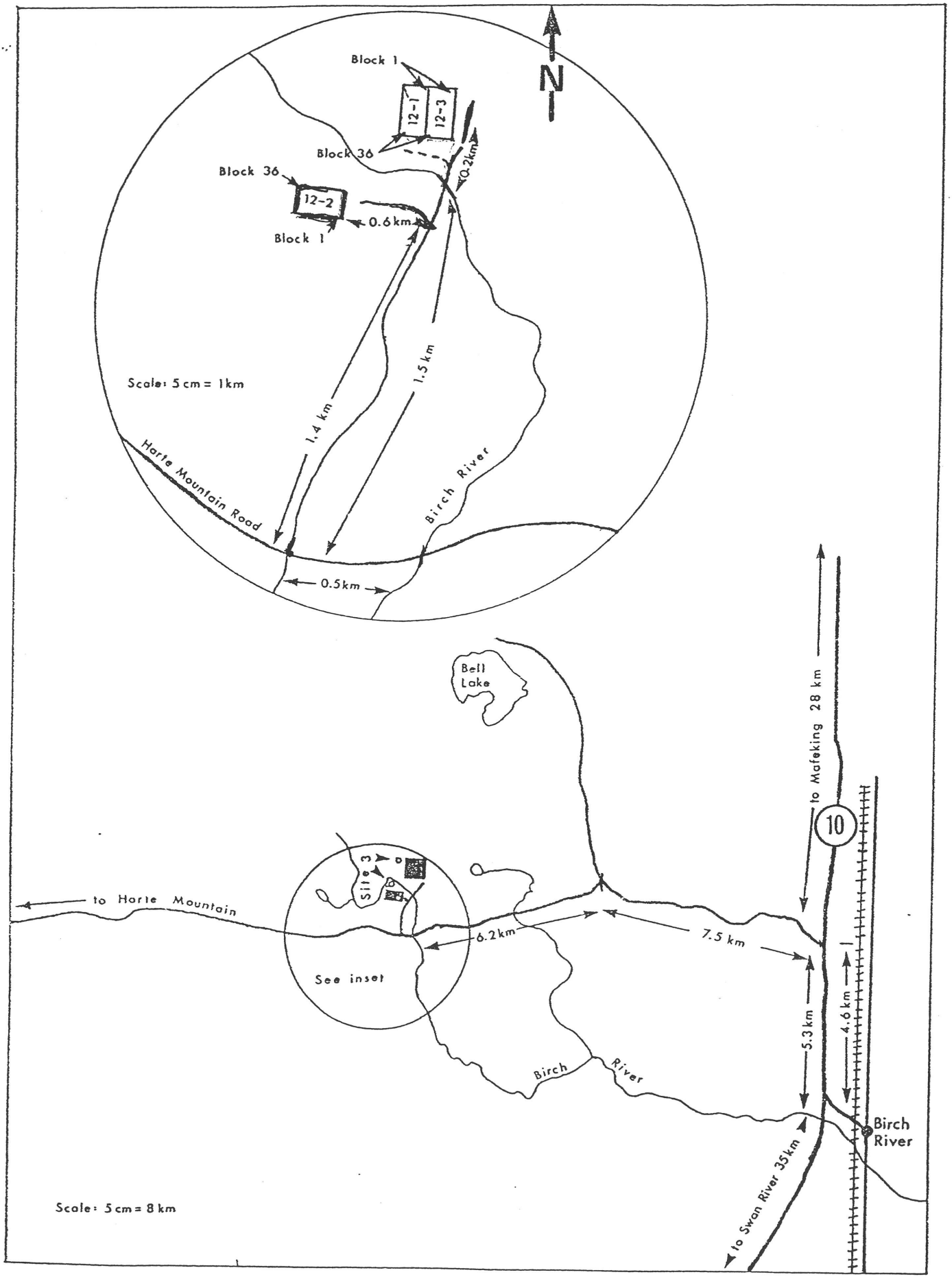
10-2

Block 1	Block 7	Block 13	Block 19	Block 25	Block 31
525 515 535 545 555 565	653 613 663 633 623 643	241 211 251 231 261 221	125 145 155 165 135 115	523 533 513 553 543 563	131 111 141 161 121 151
Block 2	**Block 8**	**Block 14**	**Block 20**	**Block 26**	**Block 32**
664 634 624 614 654 644	514 554 544 534 524 564	645 625 655 635 615 665	154 134 124 144 114 164	366 326 316 356 336 346	265 235 225 255 245 215
Block 3	**Block 9**	**Block 15**	**Block 21**	**Block 27**	**Block 33**
443 453 423 463 433 413	425 455 435 445 465 415	123 163 113 143 153 133	656 636 616 666 626 646	436 446 466 456 426 416	252 212 242 232 262 222
Block 4	**Block 10**	**Block 16**	**Block 22**	**Block 28**	**Block 34**
311 341 331 351 321 361	424 464 414 444 434 454	516 546 566 556 526 536	542 532 562 552 512 522	431 421 451 461 411 441	325 355 345 335 315 365
Block 5	**Block 11**	**Block 17**	**Block 23**	**Block 29**	**Block 35**
363 353 313 333 323 343	132 162 122 142 152 112	332 312 352 342 322 362	641 621 661 611 651 631	344 314 324 364 354 334	224 254 244 264 214 234
Block 6	**Block 12**	**Block 18**	**Block 24**	**Block 30**	**Block 36**
253 263 213 243 223 233	452 412 432 462 422 442	521 561 541 551 511 531	622 642 612 652 662 632	266 216 226 256 246 236	126 156 166 116 136 146

10-1

Block 1	Block 7	Block 13	Block 19	Block 25	Block 31
634 631 636 632 633 635	223 221 222 224 226 225	546 542 545 541 544 543	465 462 463 464 461 466	443 442 441 445 446 444	526 525 523 524 521 522
Block 2	**Block 8**	**Block 14**	**Block 20**	**Block 26**	**Block 32**
154 155 153 156 152 151	424 425 421 423 426 442	333 331 336 335 332 334	256 253 252 251 255 254	661 665 662 666 663 664	165 162 161 166 164 163
Block 3	**Block 9**	**Block 15**	**Block 21**	**Block 27**	**Block 33**
116 111 115 114 112 113	626 622 621 624 623 625	551 554 552 556 555 553	345 343 342 341 346 344	654 656 652 653 651 655	433 435 436 434 432 431
Block 4	**Block 10**	**Block 16**	**Block 22**	**Block 28**	**Block 34**
352 353 355 354 351 356	325 326 323 324 322 321	265 261 262 266 264 263	246 243 244 242 245 241	454 453 451 455 452 456	561 565 566 562 563 564
Block 5	**Block 11**	**Block 17**	**Block 23**	**Block 29**	**Block 35**
312 311 315 316 314 313	145 146 143 142 141 144	646 642 643 644 645 641	236 234 235 233 231 232	531 535 533 536 534 532	612 613 611 615 614 616
Block 6	**Block 12**	**Block 18**	**Block 24**	**Block 30**	**Block 36**
211 213 214 215 216 212	361 364 362 363 365 366	135 134 136 131 133 132	511 515 514 516 513 512	416 413 414 411 412 415	124 121 122 126 125 123

Diagram 2. Plantation layout, site 2, replicate set 10.



Map 4. Access to site 3a and 3b.

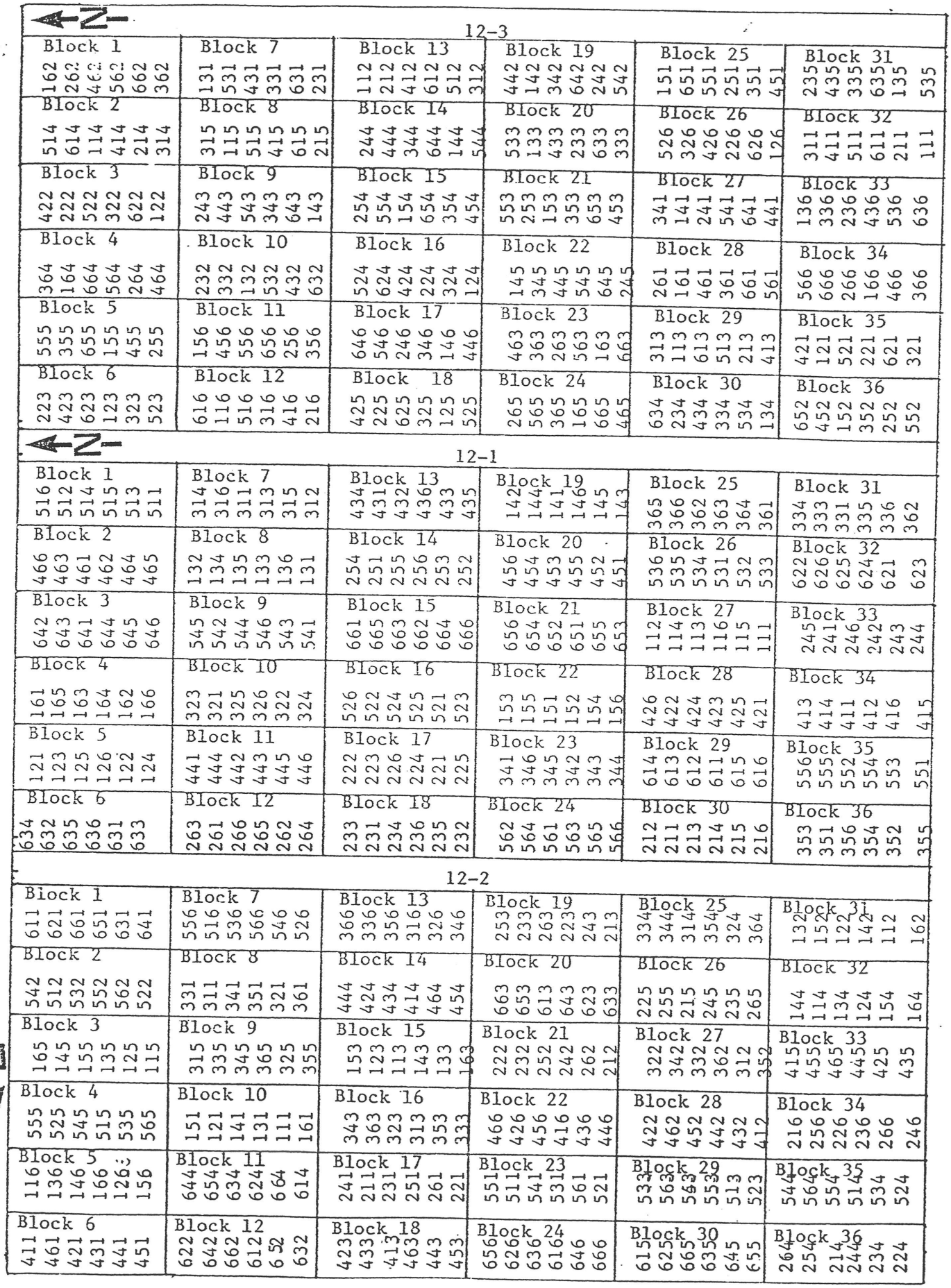
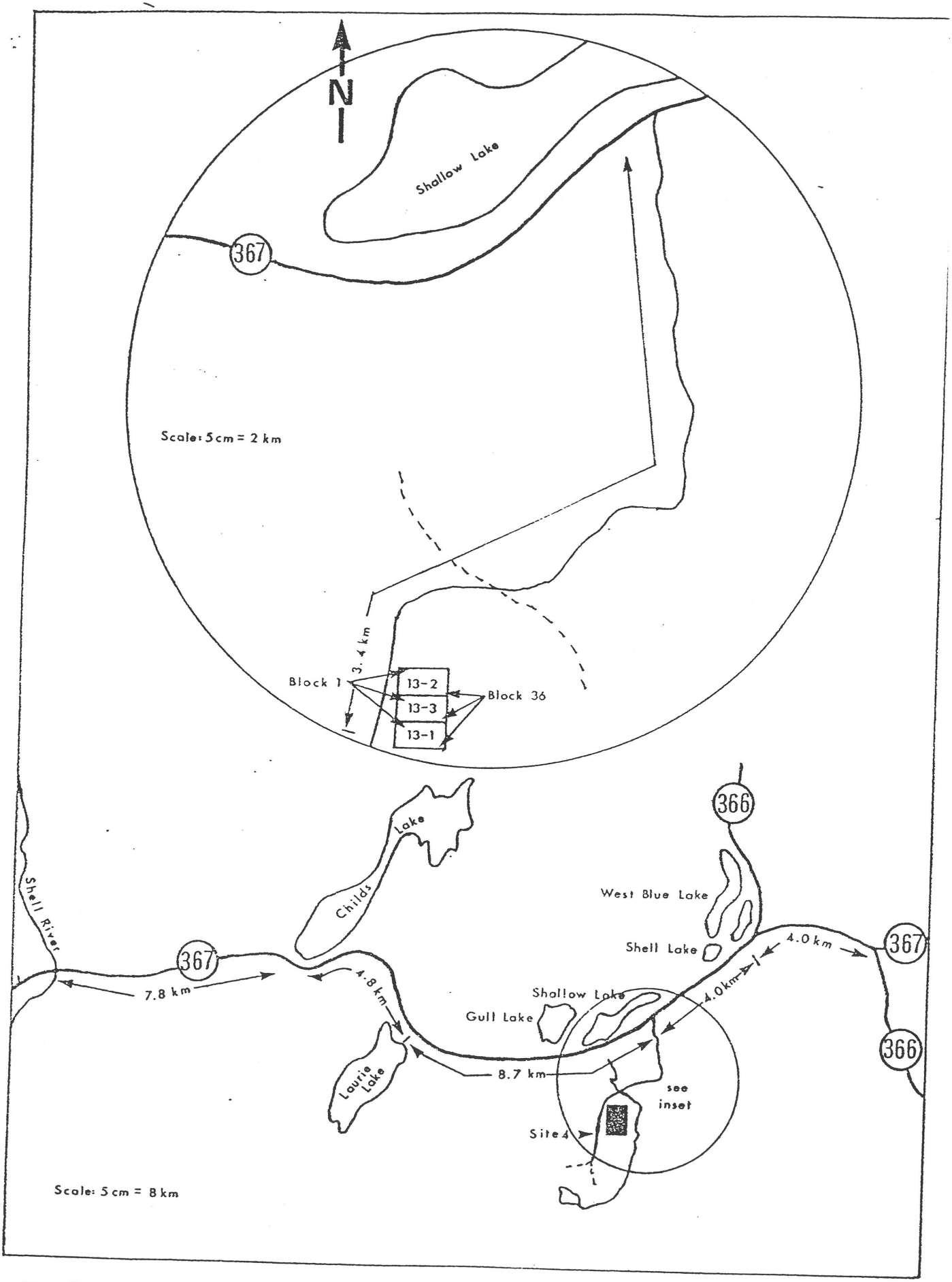


Diagram 3. Plantation layout, site 3, replicate set 12.



Map 5. Access to site 4.

13-2

Block 1	Block 7	Block 13	Block 19	Block 25	Block 31
113	226	344	245	151	413
153	266	314	215	161	463
133	256	354	265	131	433
143	246	364	255	121	453
163	216	324	235	141	423
123	236	334	225	111	443
Block 2	**Block 8**	**Block 14**	**Block 20**	**Block 26**	**Block 32**
644	455	562	352	454	341
654	445	552	312	434	361
634	425	522	362	414	351
624	435	512	342	444	331
614	465	532	322	424	321
664	415	542	332	464	311
Block 3	**Block 9**	**Block 15**	**Block 21**	**Block 27**	**Block 33**
643	144	421	333	162	412
633	164	461	323	142	442
613	124	441	363	112	452
653	114	431	353	132	432
663	134	451	343	152	422
623	154	411	313	122	462
Block 4	**Block 10**	**Block 16**	**Block 22**	**Block 28**	**Block 34**
646	166	534	563	232	526
626	126	514	553	222	566
616	116	544	523	262	546
666	156	554	513	212	516
656	136	524	533	252	556
636	146	564	543	242	536
Block 5	**Block 11**	**Block 17**	**Block 23**	**Block 29**	**Block 35**
316	241	213	545	214	416
356	251	263	515	254	466
336	231	243	525	224	436
346	211	233	535	244	456
366	221	253	565	264	446
326	261	223	555	234	426
Block 6	**Block 12**	**Block 18**	**Block 24**	**Block 30**	**Block 36**
531	335	631	155	645	632
521	365	641	125	665	642
561	325	621	135	655	662
541	315	651	145	615	622
551	355	661	165	635	612
511	345	611	115	625	652

13-3

Block 1	Block 7	Block 13	Block 19	Block 25	Block 31
643	545	634	536	553	111
543	645	234	436	253	311
243	245	334	236	153	511
443	445	534	636	653	611
343	345	134	136	353	411
143	145	434	336	453	211
Block 2	**Block 8**	**Block 14**	**Block 20**	**Block 26**	**Block 32**
213	616	515	444	165	514
413	316	315	544	565	214
313	516	115	644	665	414
113	116	415	344	465	114
613	216	615	144	365	614
513	416	215	244	265	314
Block 3	**Block 9**	**Block 15**	**Block 21**	**Block 27**	**Block 33**
241	461	655	651	235	146
441	661	255	551	435	646
541	261	355	151	635	546
641	361	555	351	535	246
341	161	455	451	135	346
141	561	155	251	335	446
Block 4	**Block 10**	**Block 16**	**Block 22**	**Block 28**	**Block 34**
232	526	425	423	431	363
632	126	625	623	331	163
132	626	225	223	231	263
332	226	125	323	631	563
532	426	325	523	131	663
432	326	525	123	531	463
Block 5	**Block 11**	**Block 17**	**Block 23**	**Block 29**	**Block 35**
124	321	533	312	352	166
624	521	233	112	652	466
324	121	633	612	252	666
524	421	133	412	152	266
424	621	333	212	552	366
224	221	433	512	452	566
Block 6	**Block 12**	**Block 18**	**Block 24**	**Block 30**	**Block 36**
542	254	556	262	464	522
442	154	156	362	364	322
142	654	456	162	264	622
342	554	356	562	564	422
642	354	256	662	664	122
242	454	656	462	164	222

13-1

Block 1	Block 7	Block 13	Block 19	Block 25	Block 31
622	316	436	612	422	215
624	313	432	611	423	216
623	314	434	613	424	214
625	312	435	614	425	212
626	311	433	615	421	213
621	315	431	616	426	211
Block 2	**Block 8**	**Block 14**	**Block 20**	**Block 26**	**Block 32**
234	265	556	465	446	146
233	263	552	461	442	145
231	264	551	563	443	143
235	266	553	466	444	142
236	262	555	464	441	141
232	261	554	462	445	144
Block 3	**Block 9**	**Block 15**	**Block 21**	**Block 27**	**Block 33**
151	334	162	412	346	223
152	335	166	414	343	222
155	333	161	415	342	224
153	332	163	416	344	226
156	331	165	411	341	225
154	336	164	413	345	221
Block 4	**Block 10**	**Block 16**	**Block 22**	**Block 28**	**Block 34**
512	545	453	666	643	124
513	543	455	663	645	123
511	541	452	661	641	126
515	546	454	662	642	122
514	542	456	664	644	121
516	544	451	665	646	125
Block 5	**Block 11**	**Block 17**	**Block 23**	**Block 29**	**Block 35**
113	252	361	531	355	634
115	255	365	533	356	631
111	251	364	534	353	633
116	254	362	535	354	632
114	256	366	532	352	636
112	253	363	536	351	635
Block 6	**Block 12**	**Block 18**	**Block 24**	**Block 30**	**Block 36**
245	561	654	525	321	136
246	565	656	521	322	135
244	563	653	523	323	133
241	564	652	524	324	134
242	562	655	522	325	131
243	566	651	526	326	132

Diagram 4. Plantation layout, site 4, replicate set 13.

N

APPENDIX C

Description and Analysis of Planting sites

SITE AND SOIL DESCRIPTION, SITE 1

Site description

Date 1977-9-10

Described by: A.M. Nanka

Location: Rice River, 121 km east of Nipawin, Sask. on Saskatchewan Hwy. 163.

Vegetation: Moderately stocked stand prior to 1974-75 logging. Picea glauca(white spruce) 45%; Betula papyrifera (Paper birch) 40%; Populus tremuloides (aspen) 10%; Pinus banksiana (jack pine) 5%; Acer spicatum (mountain maple) moderate; Corylus cornuta (beaked hazelnut) moderate; and Alnus crilspa (green alder) sparse cover.

Elevation: 350 m

Parent material: weathered shale bedrock, mainly colluvial shales, clays, variable textured colluvial intermixed with gravelly beach deposits.

Landform: Colluvial slope

Surface expression: gently sloping. Site: nearly level

Estimated drainage: moderately well drained

Classification[1]: Orthic Regosol to Rego Dark Gray

Association[2]: Nitenai

Pedon Description

L-H 3-0 cm; Black (10 YR 2/1 m[3]), black (5 YR 2.5/1 d[3]); semi-decomposed organic matter; abundant, fine and medium roots; clear, wavy boundary, 3-8 cm thick.

Ah1 0-4 cm; Black (2.5 Y 2/0 m), gray (10 YR 5/1 d); clay loam; fine massive; very friable m, hard d; abundant, fine and medium roots; clear, wavy boundary; 4-10 cm thick, neutral.

Ah2 4-11 cm; Grayish brown (10 YR 5/2 m) light gray (10 YR 7/2 d); clay loam; fine massive and weak fine subangular blocky, friable m, very hard d; few, fine roots; abrupt, smooth boundary, 5-14 cm thick; neutral.

[1] Canada Soil Survey Committee, Subcommittee on Soil Classification, 1978
[2] Ayres et al (1978)
[3] In Pedon description m = moist, d = dry

C1 11-24 cm; Brown (10 YR 5/3 m), light gray (2.5 Y 7/2 d); clay loam, weak fine prismatic; firm m, very hard d; very few, fine roots; abrupt, smooth boundary; 12-20 cm thick; neutral.

C2 24-42 cm; Grayish brown (10 YR 5/2 m), light gray (2.5 Y 7/2 d); clay loam; weak medium prismatic and moderate subangular blocky; firm m, very hard d; very few, fine roots; gradual, wavy boundary; 15-25 cm thick; acid.

IIBtb 42-86 cm; Dark grayish brown (2.5 Y 4/2 m), light brownish gray (2.5 Y 6/2 d); clay loam; weak medium prismatic and weak coarse subangular blocky; friable m, hard d; stratified seams of shale, clay and sand; very few roots; gradual, smooth boundary; 40-45 cm thick; neutral.

IIBCb 86-120 cm; Grayish brown (2.5 Y 5/2 m), light brownish gray (2.5 Y 6/2 d); clay loam; weak prismatic and subangular blocky; very friable m, hard d; few pores, pockets of chalky paste; few, medium roots; alkaline.

SITE AND SOIL DESCRIPTION, SITE 2

Site description

Date 1977-9-7

Described by: A.M. Nanka

Location: Parr Hill, Sask. 77 km south of Hudson Bay, Sask. on Hwy. 8.

Vegetation: Moderately stocked stand prior to 1974-75 logging. Picea glauca(white spruce) 65%; Populus tremuloides (aspen) 25%; Populus balsamifera (balsam poplar) 5%; Corylus cornuta (beaked hazelnut) moderate cover; Salix spp. (willow) sparse.

Elevation: 550 m

Parent material: medium to moderately fine textured, strongly calcareous silty glacio-lacustrine deposits over ground moraine

Landform: dissected lacustrine plain

Surface expression: ridge and swale. Site: nearly level

Estimated drainage: moderately well drained

Classification: Dark Gray Luvisol

Association: not mapped

Pedon Description

L-H 4-0 cm; Black (5 YR 2.5/1 m), very dark gray (5 YR 3/1 d); well to semi-decomposed organic matter; abundant, fine roots; clear, wavy boundary, 4-10 cm thick.

Ahe 0-7 cm; Black (2.5 Y 2/0 m), dark gray (10 YR 4/1 d); silt loam; fine massive; very friable m, hard d; abundant, fine and medium roots; clear, wavy boundary; 5-15 cm thick, neutral.

Ae 7-14 cm; Grayish brown (10 YR 5/2 m, d) silt loam; weak fine platy; very friable m, very hard d; abundant, fine roots; clear, wavy boundary, 5-15 cm thick; neutral.

Bt 14-51 cm; Very dark grayish brown (10 YR 3/2 m), light brownish gray (10 YR 6/2 d); clay loam; weak fine subangular blocky; very friable m, extremely hard d; few, fine roots; thin streaks of lime, clay film on peds; texture progressively finer with depth; clear, wavy boundary; 20-40 cm thick; alkaline.

Ck — 51-86 cm; Grayish brown (10 YR 5/2 m), light grayish brown (2.5 Y 6/2 d); loam; fine platy; very friable m, hard d; few, fine roots; clear, wavy boundary; 30-40 cm thick; alkaline.

IICk — 86-104 cm; Dark grayish brown (10 YR 4/2 m) light brownish gray (2.5 Y 6/2 d); silty clay loam; fine blocky; very friable m, slightly hard d; very few, fine roots; streaks of lime; alkaline.

SITE AND SOIL DESCRIPTION, SITE 3a

Replicates 12-1 and 12-3

Site description

Date 1977-8-27

Described by: A.M. Nanka

Location: Harte Mtn., 14 km west of Birch River, Manitoba.

Vegetation: Fully stocked stand prior to 1974-75 logging. Pinus banksiana (jack pine) 60%; Picea mariana (black spruce) 35%; Picea glauca (white spruce) 5%; no shrubs.

Elevation: 690 m

Parent material: coarse to fine textured, strongly calcareous glacio-fluvial deposits over glacial till.

Landform: dissected ridge and swale over rolling morainic till

Surface expression: hummocky Site: level ridge

Estimated drainage: moderately well drained

Classification: Orthic Gray Luvisol

Association: not mapped

Pedon Description

L-H 2-0 cm; Very dark grayish brown (10 YR 3/2 m, 3/3 d); slightly decomposed feather mosses and conifer litter; very few, fine roots; abrupt, wavy boundary; 2-10 cm thick.

Ae1 0-3 cm; Grayish brown (10 YR 5/2 m), light brownish gray (10 YR 6/2 d); sandy loam; fine massive; very friable m, hard d; abundant, medium to coarse roots; clear, wavy boundary; 3-7 cm thick, acid.

Ae2 3-16 cm; Brown (10 YR 5/3 m) light gray (10 YR 7/2 d); sandy clay loam; fine massive; very friable m, slightly hard d; few, fine roots; clear, wavy boundary; 5-20 cm thick; acid.

Bt 16-46 cm; Dark brown (10 YR 4/3 m), brown (10 YR 5/3 d); clay; fine subangular blocky with clay film on peds; very friable m, very hard d; abundant, fine and few, medium roots; clear, wavy boundary; 20-30 cm thick; neutral.

BC 46-74 cm; Yellowish brown (10 YR 5/4 m), light yellowish brown (2.5 Y 6/4 d); clay loam; fine to medium subangular blocky; very friable m, very hard d; very few, fine and medium roots; streaks of lime; moderately cobbly; clear, wavy boundary; 25-35 cm thick; alkaline.

Ck 74-100 cm; Light yellowish brown (10 YR 6/4 m), light reddish brown (5 Y 6/3 d); clay loam; fine prismatic; very friable m, very hard d; few streaks of lime; cobbly; alkaline.

SITE AND SOIL DESCRIPTION, SITE 3b

Replicates 12-2

Site description

Date 1977-8-24

Described by: A.M. Nanka

Location: Harte Mtn., 14 km west of Birch River, Manitoba.

Vegetation: Fully stocked stand prior to 1974-75 logging. Pinus banksiana (jack pine) 95%; Picea glauca (white spruce) 3%; Picea mariana (black spruce) 2%; no shrubs.

Elevation: 690 m

Parent material: coarse to fine textured, weakly to strongly calcareous glacio-fluvial deposits over glacial till.

Landform: dissected ridge and swale over rolling morainic till

Surface expression: hummocky Site: on hummock

Estimated drainage: moderately well drained

Classification: Orthic Gray Luvisol

Association: not mapped

Pedon Description

L-H 3-0 cm; Very dark brown (10 YR 2/2 m and d), slightly decomposed feather mosses and conifer litter; very few, fine roots; abrupt, wavy boundary; 3-10 cm thick.

Ae 0-34 cm; Brown (10 YR 5/3 m), light gray (10 YR 7/1 d); sandy clay loam; fine massive; firm m, hard d; abundant, fine roots; gradual, wavy boundary; 20-35 cm thick; acid.

Bt1 34-54 cm; Dark grayish brown (10 YR 4/2 m), gray (10 YR 5/1 d); heavy clay; fine prismatic with clay film; friable m, extremely hard d; few, fine roots; clear, smooth boundary; 20-25 cm thick; acid.

Bt2 54-71 cm; Dark gray (10 YR 4/1 m and d); heavy clay; fine prismatic with clay film; friable m, extremely hard d; gradual, smooth boundary; 20 cm thick; neutral.

Ck 71-96 cm; Yellowish brown (10 YR 5/4 m), light reddish brown (5 YR 6/3 d); clay loam; fine subangular blocky; friable m, extremely hard d; cobbles to gravel with sand pockets; alkaline.

SITE AND SOIL DESCRIPTION, SITE 4

Site description

Date 1977-8-23

Described by: A.M. Nanka

Location: Duck Mtn., 33 km east of Boggy Creek, Manitoba.

Vegetation: Fully stocked stand prior to 1974-75 logging. Pinus banksiana (jack pine) 45%; Populus tremuloides (aspen) 45%; Picea glauca (white spruce)10%; Salix spp. (willow) sparse.

Elevation: 700 m

Parent material: Polymorphic; fine textured till over fine to very coarse textured calcareous till.

Landform: hummocky morainic hills

Surface expression: dissected knob and kettle

Estimated drainage: moderately well drained

Classification: Orthic Gray Luvisol

Association: Duck Mountain

Pedon Description

L-H 8-0 cm; Black (5 YR 2.5/1 m) very dark gray (10 YR 3/1 d); semi-decomposed forest litter; abundant, fine roots; abrupt, wavy boundary; 5-10 cm thick.

Ae 0-12 cm; Dark grayish brown (10 YR 4/2 m), gray (10 YR 6/1 d); clay loam; weak, fine, massive; very friable m, slightly hard d; abundant, fine roots; clear, wavy boundary; 8-12 cm thick; neutral.

Bt 12-39 cm; Very dark gray (10 YR 3/1 m), dark grayish brown (10 YR 4/2 d); heavy clay; moderate, fine subangular blocky; firm m, extremely hard d; abundant, fine roots; clear, smooth boundary; 27 cm thick, neutral.

Ck 39-64 cm; Yellowish brown (10 YR 5/4 m), light brownish gray (2.5 Y 6/2 d); clay; moderate, fine blocky and fine granular; friable m, extremely hard d; abundant, fine roots; 2 cm seam of granular lime, light gray (10 YR 7/2 m), along abrupt, wavy boundary; 25-40 cm thick; alkaline.

Physical and Chemical Analysis of Soil Horizon Samples[1]

Hor.	Depth cm	Particle size distribution, % Sand	Silt	Clay	Texture Class[2]	% CaCo[3]	pH[3]	Organic Matter %	Ca	K ppm	P
Site 1 - Orthic Regosol to Rego Dark Gray											
L-H	3-0										
Ah1	0-4	37	32	31	CL		6.2	8.6	4250	508	51
Ah2	4-11	44	21	35	CL		6.0	1.9	2438	480	43
C1	11-24	46	19	35	CL		5.8	1.0	3438	578	45
C2	24-42	45	20	35	CL		5.0	6.0	2563	293	28
IIBtb	42-86	43	20	37	CL	1	7.3	1.1	3938	278	7
IIBCb	86-120	40	27	33	CL	10	7.5	0.8	9375	398	2
Site 2 - Dark Gray Luvisol											
L-H	4-0										
Ahe	0-7	24	55	21	SiL		5.5	12.7	3488	380	10
Ae	7-14	26	51	23	SiL		5.5	2.1	1463	228	6
Bt	14-51	22	40	38	CL		5.8	0.9	2725	273	12
Ck	51-86	30	49	21	L	11	7.6	0.7	4438	130	8
IICk	86-104	16	55	29	SiCL	18	7.7	0.7	5938	140	2
Site 3(a) - replicate 1 & 3 - Orthic Gray Luvisol											
L-H	2-0										
Ae1	0-3	53	31	16	SL		4.9	1.9	338	105	11
Ae2	3-16	53	27	20	SCL		5.3	0.8	713	108	3
Bt	16-46	21	33	46	C		6.0	1.0	2838	113	19
BC	46-74	43	29	28	CL	24	7.5	0.6	4188	103	2
Ck	74-102	37	33	30	CL	29	7.6	0.6	4375	98	2
Site 3(b) replicate 2 - Orthic Gray Luvisol											
L-H	3-0										
Ae	0-34	59	27	24	SCL		5.3	1.1	975	135	5
Bt1	34-54	20	9	81	HC		4.5	1.6	4750	328	7
Bt2	54-71	11	20	79	HC		5.6	1.4	5750	278	6
Ck	71-96	30	32	38	CL	18	7.6	0.7	4813	133	1

Physical and Chemical Analysis of Soil Horizon Samples - continued

Hor.	Depth cm	Particle size distribution, % Sand	Silt	Clay	Texture Class[2]	% $CaCO_3$[3]	pH[3]	Organic Matter %	Ca	K ppm	P
Site 4 - Orthic Gray Luvisol											
L-H	1-0										
Ae	0-12	28	38	34	CL		5.9	3.6	2188	130	4
Bt	12-39	15	23	62	HC		6.0	1.4	4313	248	4
Ck	39-64	25	34	41	C	35	7.5	0.9	4938	118	1
IIBmbk	64-100	61	16	23	SCL	28	7.8	0.4	3638	70	1
IIBCb	100-125	48	22	30	SCL	28	8.0	0.6	3900	68	1

1 Physical and chemical analysis were carried out according to procedures used by the Soils Laboratory at the Northern Forest Research Centre. Analytical procedures are available on request.

2 Soil texture classes: CL = clay loam, SiL = silt loam, L = loam, SiCL = silty clay loam, SL = sandy loam, SCL = sandy clay loam, C = clay, HC = heavy clay

3 Saturated paste method