METSÄNTUTKIMUSLAITOS

METSÄNVILJELYN KOEASEMAN TIEDONANTOJA 3

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KIM VON WEISSENBERG

EXPERIENCES OF LODGEPOLE PINE IN FINLAND

SUONENJOKI 1972

Til Max. Hagman
Med beste hilsninger av
forf.

Kim von Weissenberg

EXPERIENCES OF LODGEPOLE PINE IN FINLAND

Paper presented at the meeting
of the Nordic Working Group on Provenance
Research and Seed Procurement

Varparanta, Finland, aug. 15-19, 1972

Suonenjoki 1972

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to all persons who have contributed inspiration, councel, and assistance in the preparation of this study. The advice of professor Risto Sarvas, Head of the Dept. Silviculture of the Forest Research Institute, has been very constructive in the completion of this study. Appreciation is also extended to professors Veikko Koski and Veikko Hintikka for their valuable encouragement in the initial stages of this work. Dr. Erkki Annila has conducted the work on insect damage on cones of lodgepole pine, and Mrs. Marjatta Leikola has kindly made her data on cold damage in Kivalo available to me.

Special gratitude is expressed to Mr. Jyrki Raulo, M.Sc., Head of the experiment station, who has provided facilities and personell which greately has helped the author during the work. Miss Leena Suomela has typed the manuscript, Mr. Tuomas Huuskonen has prepared the graphs, and Miss Taina Pöysä has calculated the temperature sums and constructed the corresponding map as well as assisted in several other phases of the work. Miss Raija Eskelinen has done the printing.

Finally, I wish to thank Joann von Weissenberg for reading and correcting the English manuscript.

Suonenjoki, August 1972

Kim von Weissenberg

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1. INTRODUCTION

The lodgepole pine (Pinus contorta var. latifolia S. Wats.) from western North America was introduced to several European countries already in the beginning of the 20th century. Now, when many stands have matured and their performance has been examined, the lodgepole pine has obtained a large interest as a foreign species, possibly to be introduced on a large, commercial scale. The Scandinavian countries, especially, have been interested; and several recent publications both in Sweden and in Norway indicate increased research on lodgepole pine in these countries. The IUFRO Working Group on International Provenance Research has established a special Sub-Group on lodgepole pine Experiments to aid scientists of various countries in obtaining seed and establishing efficient experiments.

In Finland the oldest stands of lodgepole pine are now 62 years old. The total area of all stands of the species is well over 300 hectares. There are several reports on the performance of specific stands (TIGERSTEDT 1922, 1927, 1970, LINDFORS 1928, SCHULENBURG 1948, MIETTINEN 1952, HEIKINHEIMO 1956) and three reports on the technical properties of the wood(LINDFORS 1925, HAKKILA and PANHELAINEN 1970, KESKUSLABORATORIO, unpubl.). All accumulated experience and knowledge of the cultivation of the species have not, however, been fully exploited. More information could be extracted from the different sources of both published and stored records within the Finnish Forest Research Institute, the University of Helsinki, the State Board of Forestry, industry, private owners etc.

The objective of this study was to collect, organize, and analyze all available information on lodgepole pine grown in Finland. Subsequently, the necessity of additional field work can be estimated, and the specific areas of incomplete knowledge requiring further research can be identified.

2. PRESENTLY EXISTING CULTURES

In order to gain as complete information as possible about the performance and condition of the various cultures within the country, as well as about current research and field experiments, a thorough investigation of published and stored records on existing stands was undertaken. In addition, questionnaires requesting information about all known stands of lodgepole pine were sent out to the State Board of Forestry, the Central Association of the Finnish Woodworking Industries, and the Central Forestry Boards Tapio and Skogskultur. In the following sections a brief account of the existing cultures will be given. Subsequently, more complete analyses of growth and yield, performance of various provenances, seed production, breeding, and damage by biotic and abiotic agents will be given.

21. Stands

There are over 300 known stands of lodgepole pine in Finland, covering an area of about 250 hectares (Table 1). The stands are generally located in the southern part of the country with only a few in the central and northern

Table 1. Presently existing cultures of lodgepole pine in Finland

Type of cultures	Average size of stand or plot, ha	Year of planting	Number of units	Total area, ha	Number of provenances represented
Stands					
Forest Research Institute	0.30	1926-1969	65	29	13
State Board of Forestry	1.13	1927-1942	91	101	?
Industry land holdings	0.74	1925-1971	73	54	?
Other private land holdings	0.87	1911-1970	75	65	3
Totals			304	249	
Permanent experimental plots of Forest Research Institute					
Department of Silviculture	0.16	1927-1943	39	6.7	11
Department of Growth and Yield	0.25	1915-1930	6	1.5	4
Department of Peatland Forestry	0.23	1933	1	0.2	1
Totals			46	8.4	
Plus trees and year of selection					
City of Hämeenlinna (1971)		1931-1932	9		?
Kuru (1971)		1928	18		2

Table 1. Continued

Type of cultures	Average size of stand or plot, ha	Year of planting	Number of units	Total area, ha	Number of provenances represented
Mustila (1950, 1951, 1961, 1971)		1911-1927	50		8
Nuutajärvi (1971)		1931-1932	25		3
Punkaharju (1955, 1958)		1925-1938	17		6
Pälkäne (1971)		1930(?)	10		?
Riistavesi (1971)		1930(?)	16		?
Ruotsinkylä (1944...1971)		1927-1931	69		7
Ähtäri (1971)		1928-1930	22		1
Totals			236		
Progeny and provenance tests of the Department of Forest Genetics, Forest Research Institute					
Test no. 334/1 and 2 in Vesijako and Kolari (i.a. P.divaricata & P. banksiana)		1969	2	0.3	14 local
Test no. 373/1,2,3, and 4 in Pudasjärvi, Tiskivaara, Kittilä and Salla		1970-1972	4	46.4	7 IUFRO

Table 1. Continued

Type of cultures	Average size of stand or plot, ha	Year of planting	Number of units	Total area, ha	Number of provenances represented
Test no. 374/1, 2, and 3 in Rovaniemi, Kolari, and Kuusamo		1970	3	9.6	21 IUFRO
Totals			9	56.3	
Species trials on peatland					
University of Helsinki. Trial in Korkeakoski.		1969	1	15.7	local
For. Res. Inst. trials in Parkano, Haapavesi, and Muhos		1971	3	8.3	local
Totals			4	24.0	
The cultures of the Foundation for Forest Tree Breeding					
The Gene Bank		1972	1	8.0	110 IUFRO + local
The One-tree-plot experiment		1972	1	0.6	119 IUFRO + local
Seed Orchard *P. contorta* x *P. divaricata* (8 foreign prov.)		1972	1	1.2	14 IUFRO + local
Totals			3	9.8	
Over all totals			602	347,5	ca.120 foreign ca. 30 local

regions. The location of the stands of the Forest Research Institute and the woodworking industries is indicated on Figure 1. Most of the stands were planted in the late 1920's and early 1930's. Practically none were planted during the next two decades, but a few have been planted in the 1960's, and 1970's. The oldest stand, located in the arboretum in Mustila (N 60°44', E 26°29'), was planted in 1911.

The provenances of the stands are accurately known only for those of the Forest Research Institute and the arboretum in Mustila. For virtually all other stands data about the provenances used have been lost or have never been recorded. There are only 13 provenances represented in the older stands (Table 2). These provenances, with 2 exceptions, are from a relatively narrow region between N 49°-52°, W 112°-110°. The two other provenances are between N 55°-57°, W 119°-117°. Consequently, vast areas, especially in northern British Columbia and Yukon, are unrepresented in the older stands of Finland.

The average area of the stands is largest (1.13 hectares) on the State Board of Forestry land holdings. The stands on the land holdings of the private landowners are on an average 0.87 hectares while those of the woodworking industries are 0.74 hectares. The experimental Forest stands of the Finnish Forest Research Institute are generally small, only 0.30 hectares on an average.

The performance of the stands is best known and recorded within the Finnish Forest Research Institute. Information on

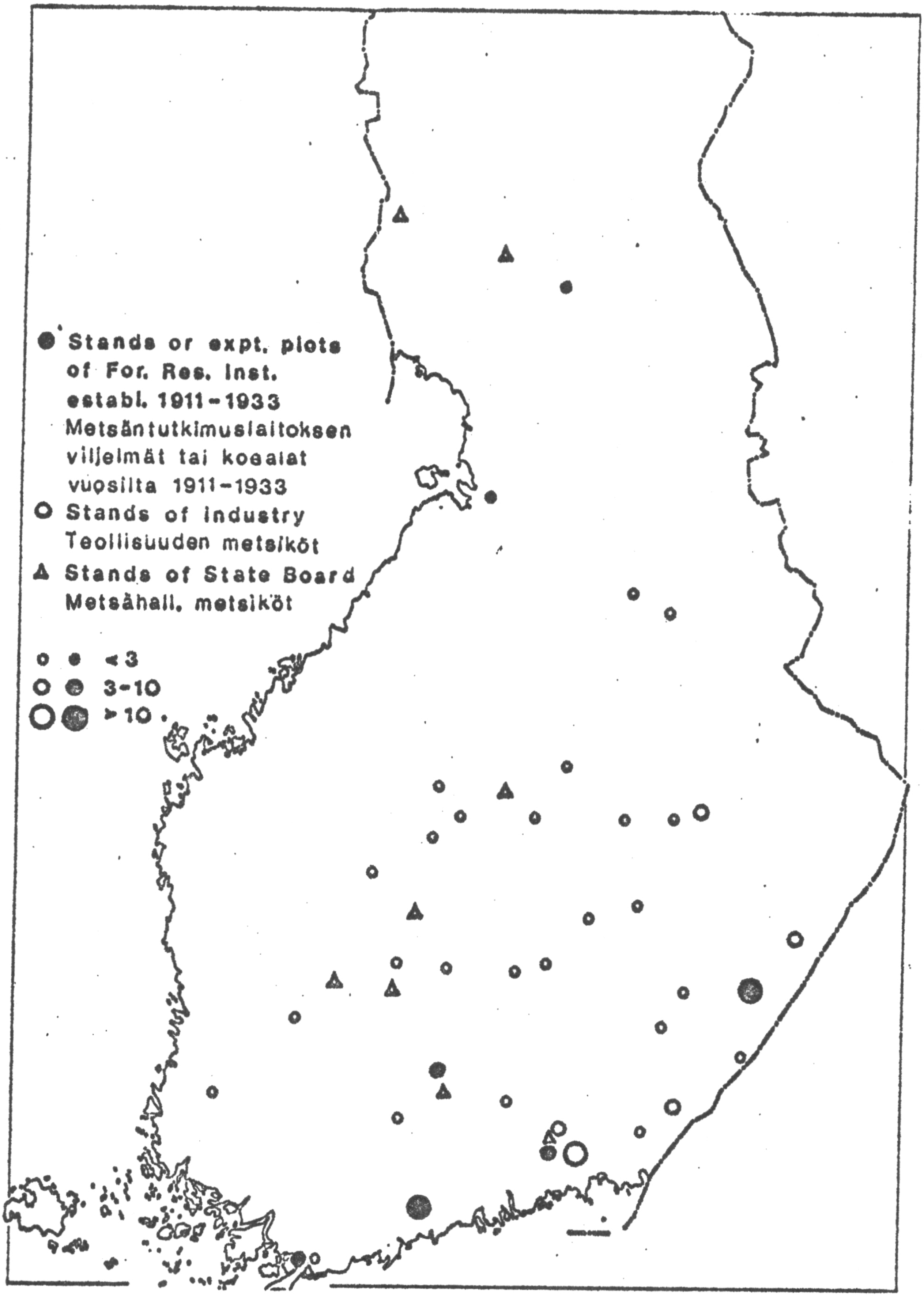

Figure 1. The location of older stands of lodgepole pine in Finland

Kuva 1. Vanhempien murraynmäntymetsiköiden sijainti Suomessa

Table 2. Provenances of *Pinus contorta* represented in the stands grown in Finland.

Prov. no.	N.Lat. 00°00'	W.Long. 00°00'	Elev. m	Temperature sum d.d.	Province (Canada), State (U.S.)	Location	Type of culture, number of: Stands	Perm. Expt. Plots	Plus Trees
1	49°40'	110°00'			Alberta	Cypress Hills	4	3	32
2	50°13'	121°00'	1260	1200	British Columbia	Nicola Forest Reserve	8	7	14
3	50°35'	121°35'	1500	900	-"-	Upper Hat Creek	4	2	5
4	50°42'	119°16'	400	2000	-"-	Salomon Arm and Shuswap Lake	3	1	-
5	50°50'	119°00'	900	1500	-"-	Mount Ida Forest Reserve	6	5	10
6	51°12'	115°25'	1200	1250	Alberta	Banff	4	3	8
7	51°45'	114°30'	1200	1300	-"-	Sundre	1	1	-
8	51°52'	114°00'	1050	1400	-"-	Olds + Calgary	10	6	46
9	55°47'	118°49'	500	1300	-"-	Spirit River	1	5	14
10	56°15'	117°15'	400	1300	-"-	Peace River	1	-	1
11	50°35'	117°25'	1260	1000	British Columbia	Long Lake, Trout Lake	13	10	12
12	-	-	-	-	Montana ?	-	1	-	2
13	49°58'	118°08'	500		British Columbia	Barnes Creek	5	1	-

the other stands has generally not been published. Some of the stands on the land holdings of the State Board of Forestry and the industries have been investigated in some detail in connection with selection of plus trees and for the needs of this study.

A list of all the known stands of the State Board of Forestry, the woodworking industries and other private landowners has been compiled and contains currently available information about location, history, area, provenance, performance, management, and condition of the stands. The list is available from the author on request.

22. Permanent Experimental Plots

Permanent experimental plots have been established by the Forest Research Institute on stands located on its land holdings and in the privately owned arboretum in Mustila. 39 plots were established by the Department of Silviculture, 6 by the Department of Growth and Yield, and one by the Department of Peatland Forestry (Table 1).

The locations of the experimental plots are mainly in the south in Solböle, Ruotsinkylä, Punkaharju, and Vesijako. Only two are located in the north, just below the Arctic Circle, in Kivalo (Figure 1). The experimental design is mostly single square plots without replications (exception: plots 85a-d). Controls of native pine or spruce are not generally available. In some cases a control plot has been established in a comparable Scots pine or Norway spruce stand in the vicinity of the lodgepole pine stand.

Only 11 provenances are represented among the permanent experimental plots. Several provenances are represented by only one plot in each experimental forest. Even though some additional provenances exist as stands in the experimental forests, no plots have been established in those stands. (e.g. two stands in Pyhäkoski experimental forest).

Results from most experimental plots are given in Tables 3-6. The stand number identifies the corresponding file of the Forest Research Institute. Provenance number refers to the numbers in Table 2. The forest site type has been identified at the time of planting according to the ground cover classification by CAJANDER (1909). No other methods for classifying the site quality have been used. Therefore, as pointed out by i.a. TIGERSTEDT (1970), within each site type, large variation may occur. Variation may also occur due to known or unknown damage by biotic and abiotic agents. Growing stock, total output, and total yield (= growing stock + total output) are given as total solid cubic meters over bark for the whole stem, not only to a certain minimum diameter. Growth, measured only in Mustila, is given as mean solid cu.m. under bark of the four years preceeding the last thinning.

The spacing used and the number of thinnings have generally not been included as variables in the experiments. Each thinning has removed 20-30 % of the growing stock. In stand no. 85a-d, 65/30a-b, and la-b, however, the intensity of thinnings has been either light or intensive. The thinnings have been purely silvicultural, usually

Table 3. Yield data from Permanent Experimental Plots (Dept. of Silviculture) of <u>Pinus contorta</u> in Finland, I

Stand no.	Provenance no.	Forest site type	Age at last measurement	Number of thinnings	Trees/ hectare	D 1.3, cm mean	D 1.3, cm dom.	Dom height, m	Growing stock	Output	Total yield
									Solid cu.m o.bark/ha		
In Solböle Experimental Forest, 60°2', 23°2'											
104	8	OMT stony	36	3	1114	15.8	21.8	15.6	185	111	296
105	8	OMT stony	36	3	1155	20.6	20.6	15.6	195	108	303
In Vesijako Experimental Forest, 61°30', 25°10'											
153	11	VT	28	1	1281	11.6	15.8	14.0	105	45	150
157	5	OMT	27	1	1185	12.8	17.7	16.0	144	83	227
In Kivalo and Kivalokumpu Experimental Forest, 66°23', 26°37'											
85d	9	HMT	25	1	1340	9.0	14.2	8.1	37	2	39
85c	9	HMT	25	1	972	9.6	13.9	8.0	29	3	32
85b	9	HMT	25	1	1220	13.8	13.8	8.1	34	1	35
85a	9	HMT	25	1	968	9.4	13.6	7.5	27	5	32
25	5	HMT	29	1	985	10.0	16.4	8.6	36	2	38

Table 4. Yield data from Permanent Experimental Plots (Dept. of Silviculture) of <u>Pinus contorta</u> in Finland, II

Stand no.	Prove-nance no.	Forest site type	Age at last measurement	Number of thinnings	Trees/hectare	D 1.3, cm mean	D 1.3, cm dom.	Dom. height, m	Growing stock	Output	Total yield
									Solid cu.m.o.bark/ha		
In Ruotsinkylä Experimental Forest 60°25', 25°10'											
115/31	5	VT	22	2	1900	9.9	14.2	12.0	92	41	133
119/31	4	VT	37	3	1820	12.9	17.0	14.3	99	57	156
121/31[b]	1	VT	35	4	1146	13.2	16.8	14.4	112	57	169
110/31	2	VT	36	5	1041	14.0	18.3	16.2	156	88	244
117/31	2	VT	36	3	1055	15.0	19.1	17.5	161	86	247
116/31	3	VT	36	3	1086	15.8	20.0	17.8	199	101	300
120/31	11	VT	36	4	953	15.3	19.1	18.0	171	101	272
65/30[a][b]	Alb.	VT	37	4	1092	14.6	20.0	16.4	151	73	224
65/30	Alb.	VT	37	3	1040	14.7	19.5	15.6	133	65	198
54/30	Alb.	VT and MT	36	4	1030	14.6	19.0	15.5	138	63	201
8/27	2	OMaT	40	4	735	18.3	23.0	20.4	202	166	368
7/27	5	OMaT and OMT	40	4	686	18.6	23.7	20.6	200	207	407
243/32	1	RKg, mu	28	1	1665	9.4	13.6	9.0	52	44	96

Table 5. Yield data from Permanent Experimental Plots (Dept.of Silviculture) of *Pinus contorta* in Finland, III

Stand no.	Provenance no.	Forest site type	Age at last measurement	Number of thinnings	Trees/hectare	D 1.3, cm mean	D 1.3, cm dom.	Dom. height, m	Growing stock (Solid cu.m.o.bark/ha)	Output (Solid cu.m.o.bark/ha)	Total yield (Solid cu.m.o.bark/ha)
In Punkaharju Experimental Forest, 61°46', 29°18'											
188	2	MT	35	4	886	16.0	20.7	18.8	164	112	276
196	2	MT	35	4	942	17.2	22.2	17.9	193	128	321
194	3	MT	35	2	960	15.5	21.6	17.5	152	54	206
189	8	MT	35	4	1000	16.5	21.7	18.8	204	135	339
192	8	MT	35	3	1050	15.1	19.0	17.5	161	141	302
193	8	MT	35	4	944	16.4	21.0	17.6	180	135	315
195	11	MT	35	4	900	17.3	22.0	18.3	198	131	329
319	1	OMT	30	4	1100	16.2	21.1	15.2	175	76	251
317	2	OMT	30	3	1036	17.0	23.2	17.1	193	89	272
318	2	OMT	30	3	908	17.9	22.8	16.3	188	84	272
320	9	OMT	30	3	1081	17.2	22.6	16.7	205	89	294
1/290	11	OMT	38	4	660	21.8	26.8	19.5	227	183	410*
97	11	OMT	38	5	427	21.1	24.6	20.7	142	151	293*
99	11	OMT	38	5	631	21.5	26.8	19.4	221	190	411
89	5	OMT	40	5	267	23.3	26.8	19.5	113	241	354*
2/290	5	OMT	40	4	477	23.9	30.3	21.4	212	200	412*
88	11	OMT	40	5	463	22.4	27.8	20.7	215	248	463

x) A few trees are either missing or extra on the plot

Table 6. Growth and Yield data from Permanent Experimental Plots (Dept.of Growth and Yield) in Mustila (N 60°44', E 26°29') of *Pinus contorta* in Finland

Plot no.	Provenance no.	Forest site type	Age at last meas.	Number of thinnings	Trees/ hectare	Mean D 1.3 cm	Basal area m^3	Height mean	Height dom.	Growth m^3	Growth %	Growing stock (Solid cu.m.o. bark)	Output (Solid cu.m.o. bark)	Total yield (Solid cu.m.o. bark)
19	8	VT	42	4	852	15.5	14.9	14.3	16.0	5.0	5.0	114	70	183
16	11	VT	44	5	643	19.3	17.5	17.2	19.0	6.1	4.4	158	93	250
15	11	VT-MT	44	5	504	21.1	16.2	18.7	20.0	9.8	6.9	157	153	309
12	7	PyT(?)	41	5	688	18.0	16.5	15.8	16.5	7.6	5.9	145	157	301
6 x)	6	PyT	44	3	740	18.5	18.9	18.4	19.0	15.0	-	179	243	422
1b x)	6	PyT	49	7	600	19.3	16.5	19.8	21.0	9.9	4.8	174	309	482
1a x)	6	PyT	59	7	610	22.5	22.5	23.3	25.0	11.3	4.1	268	416	683

x) Studies on the plot not continued

undertaken at about 5 year intervals. The last thinnings and measurements were generally made in 1967, and most stands are due for remeasurement in the fall of 1972.

Other data available, but not recorded in Tables 3-6, include soil type, number of measurements, number of trees with D 1.3 over 20 cm, branch diameter, crown height, etc.

23. Plus Trees

In order to establish seed orchards for lodgepole pine and provide phenotypically superior trees for breeding purposes, the Finnish Forest Research Institute has selected, measured, and registered plus trees during 1944-1971(Table 1). Scions were collected from many of the trees in the winter of 1972. A total of 236 plus trees have been selected, representing some eight known provenances. The trees were selected from stands which have had extremely good growth, little or no disease, good stem and crown form, and thin branches. The distribution of plus trees are indicated on Figure 2. The location of the planned seed orchard is also indicated on the same map.

24. Progeny and Provenance Tests

Since 1969 the Department of Genetics of the Finnish Forest Research Institute has established systematic progeny and provenance tests meeting modern requirements on experimental designs. The tests are mainly located in the northern parts of the country (Figure 2) covering

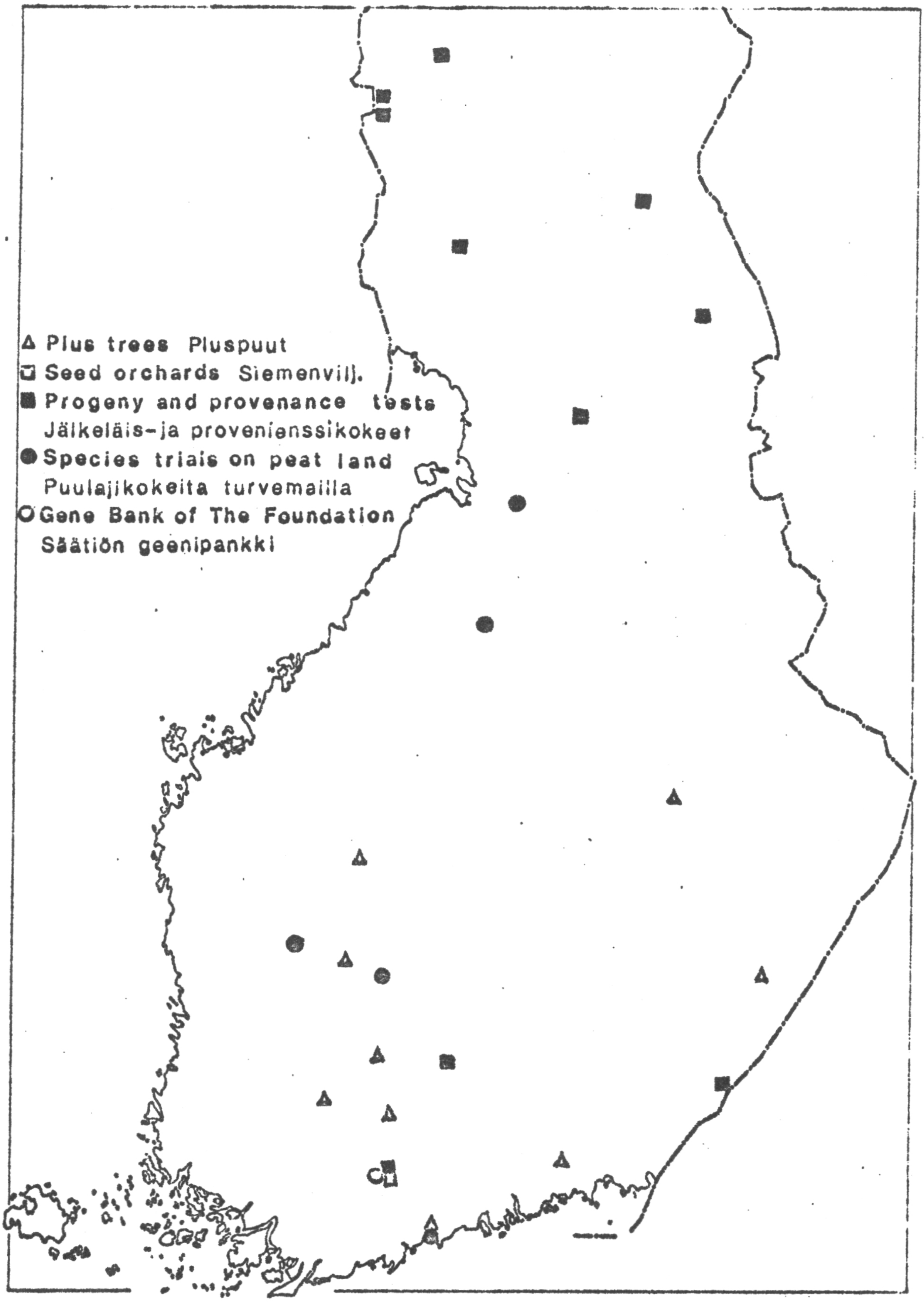

Figure 2. The location of plus trees, seed orchards, provenance- and progeny tests, species trials, and the gene bank of lodgepole pine in Finland

Kuva 2. Murraynmännyn pluspuiden, siemenviljelysten, proveniensssi- ja jälkeläiskokeiden, puulajikokeiden ja geenipankin sijainti Suomessa a total area of 56.3 hectares. 21 provenences, previously not tried in this country, are represented. 14 progenies of open-pollinated and cross-pollinated, as well as hybridized lodgepole pine and Jack pine (Pinus divaricata Ait.), grown in Finland are also included in these tests.

25. Species Trials on Peatland

Since 1969 both the University of Helsinki and the Finnish Forest Research Institute have established 24 hectares of species trials on peatlands in Southern and Central Finland (Figure 2). The trials of the University of Helsinki include one provenance from Wonowon, B.C. (N 56°40', W 21°38') which is compared to Pinus sylvestris L., Larix sibirica L., Populus tremula x tremuloides, and Betula verrucosa L. The trials by the Forest Research Institute contain 4 different provenances from stands grown in Finland which are compared to Picea abies L., Picea mariana L., Larix sibirica L., Pinus sylvestris L., and Populus tremula x tremuloides. In all trials on peatland various fertilizer treatments are studied by means of factorial designs.

26. Cultures of the Foundation for Forest Tree Breeding

In the spring of 1972 the Foundation established three different cultures of lodgepole pine. All are located close to the Foundation's main nursery, Haapastensyrjä, N 60°36', E 25°25' (Figure 2). Details about the used provenances and the experimental design can be obtained from the Foundation on request.

261. The Gene Bank. A gene bank, area 8 hectares, was established in order to furnish phenotypes of geographically separated provenances for future breeding of lodgepole pine. The bank contains a total of 110 provenances of the IUFRO international provenance experiment and from open-pollinated single trees or stands of lodgepole pine grown in Finland. 200-500 seedlings per provenance were planted without replication.

262. The One-tree-plot Experiment. 119 provenances of local stands and of the IUFRO international provenance experiment were planted, spacing 2 x 2 m, in a one-tree-plot experiment with 12 replications.

263. *Pinus contorta* x *Pinus divaricata* Seed Orchard. 14 provenances of Jack pine (*P. divaricata* Ait., syn *P. banksiana* Lamb.) were planted as 1 + 1 seedlings. To account for possible high mortality in some provenances a spacing of 1 x 3 m was used. There are 40 seedlings in each row. The rows of lodgepole and Jack pines are systematically alternated. There is a total of 4 x 40 = 160 seedlings of each lodgepole pine provenance and 7 x 40 = 280 seedlings of each Jack pine provenance.

3. GROWTH AND YIELD

The growth and yield of lodgepole pine in Finland have been studied in detail on a total of 46 permanent experimental plots (Table 1 , Figure 1). General information on most of the plots is given in the section on permanent experimental plots and the main results have been presented in Tables 3-6.

The main forest site types in southern Finland are Oxalis-myrtillus-type (OMT), Myrtillus-type (MT), and Vaccinium-type (VT). These forest site types cover 17 %, 44 %, and 34 % respectively of the forest land areas. Minor forest site types, such as Pyrola-type (PyT), cover only 5 % of the forest land area (ILVESSALO, 1956). There are eight experimental plots on OMT and seven plots on MT, all located in Punkaharju experimental forest. In Ruotsinkylä experimental forest there are seven plots on VT. Five different provenances are represented on OMT, five on MT, and four on VT. Figure 3 illustrates typical variation for one provenance growing on experimental plots on all three sites but in two different locations. The total yield at each time of measurement and subsequent thinning is plotted against

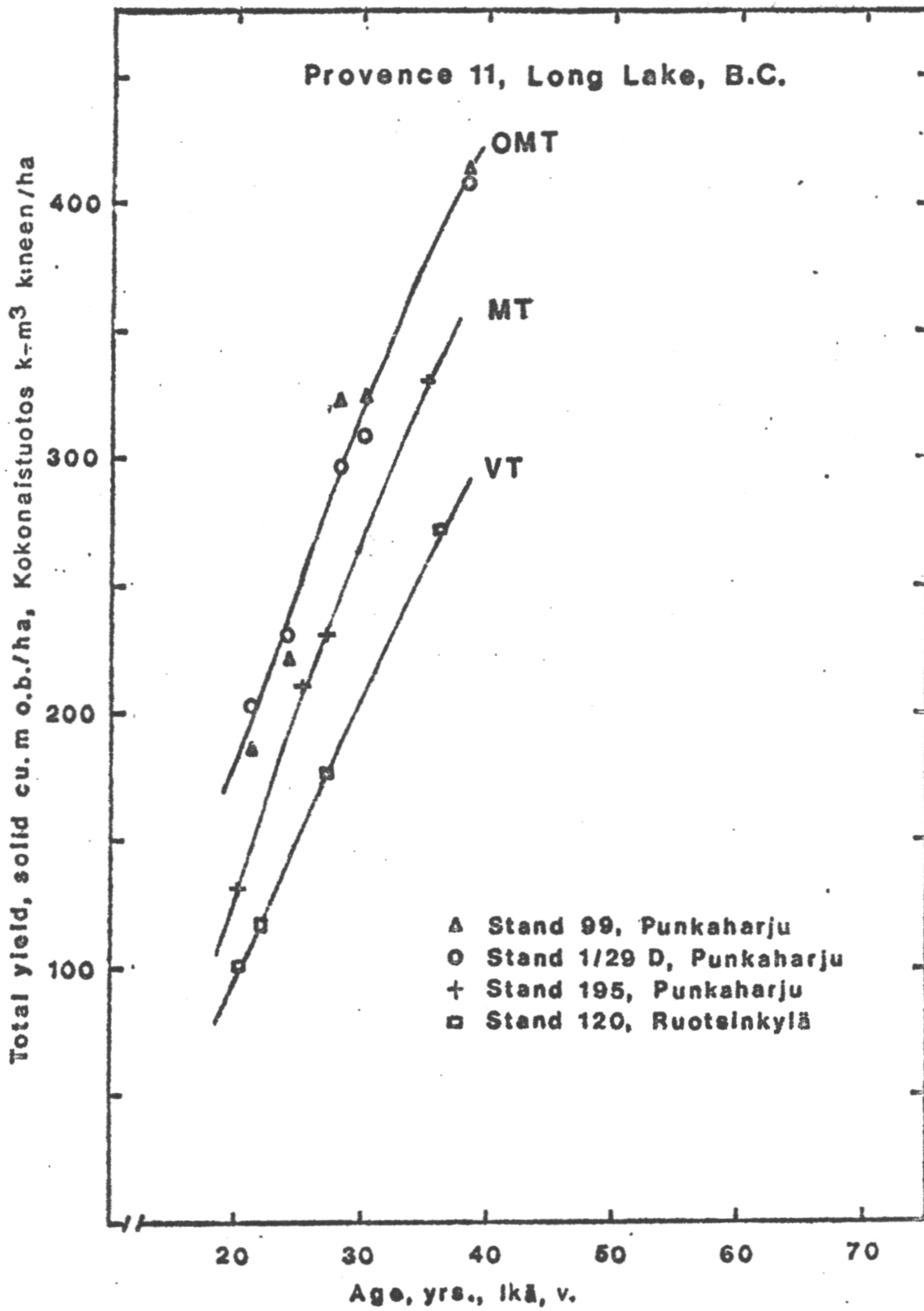

Figure 3. The total yield of provenance 11, Long Lake, B.C., on three forest site types at two geographic locations in southern Finland

Kuva 3. Provenienssi 11., Long Lake, B.C., kokonaistuotos kolmella metsätyypillä kahdella paikkakunnalla Etelä-Suomessa stand age. The same method has been used for the growth curves in Figures 4-6. The provenance of each stand is indicated at the end of the curve by a number referring to provenance number in Table 2.

31. Comparison with Native Species and Lodgepole Pine

The total yield for the permanent experimental plots in Punkaharju and Ruotsinkylä is compared (Figures 4-6) to the average performance of repeatedly thinned stands of Scots pine, Norway spruce, and silver birch on comparable forest site types in southern Finland (hereafter referred to as control curves and control stands). Control curves for stands regenerated naturally, by planting, and by sowing in patches have been used. The curves have been constructed on the basis of data extracted from tables published by KOIVISTO (1959) and KALLIO (1961). Information about the control stands is given below but for more details the reader is referred to the original papers KOIVISTO used for his publication.

Southern Finland is taken to be the area south of N 62°00'. Although the climate varies considerably within this region, most of the area has an annual temperature sum above 1 300 d.d. at sea level. On an average the area is colder and more continental than Ruotsinkylä experiment forest and somewhat colder than Punkaharju experiment forest. This should be considered when examining Figures 4-6.

The control curves for naturally regenerated pine stands 20-40 years old were originally constructed by

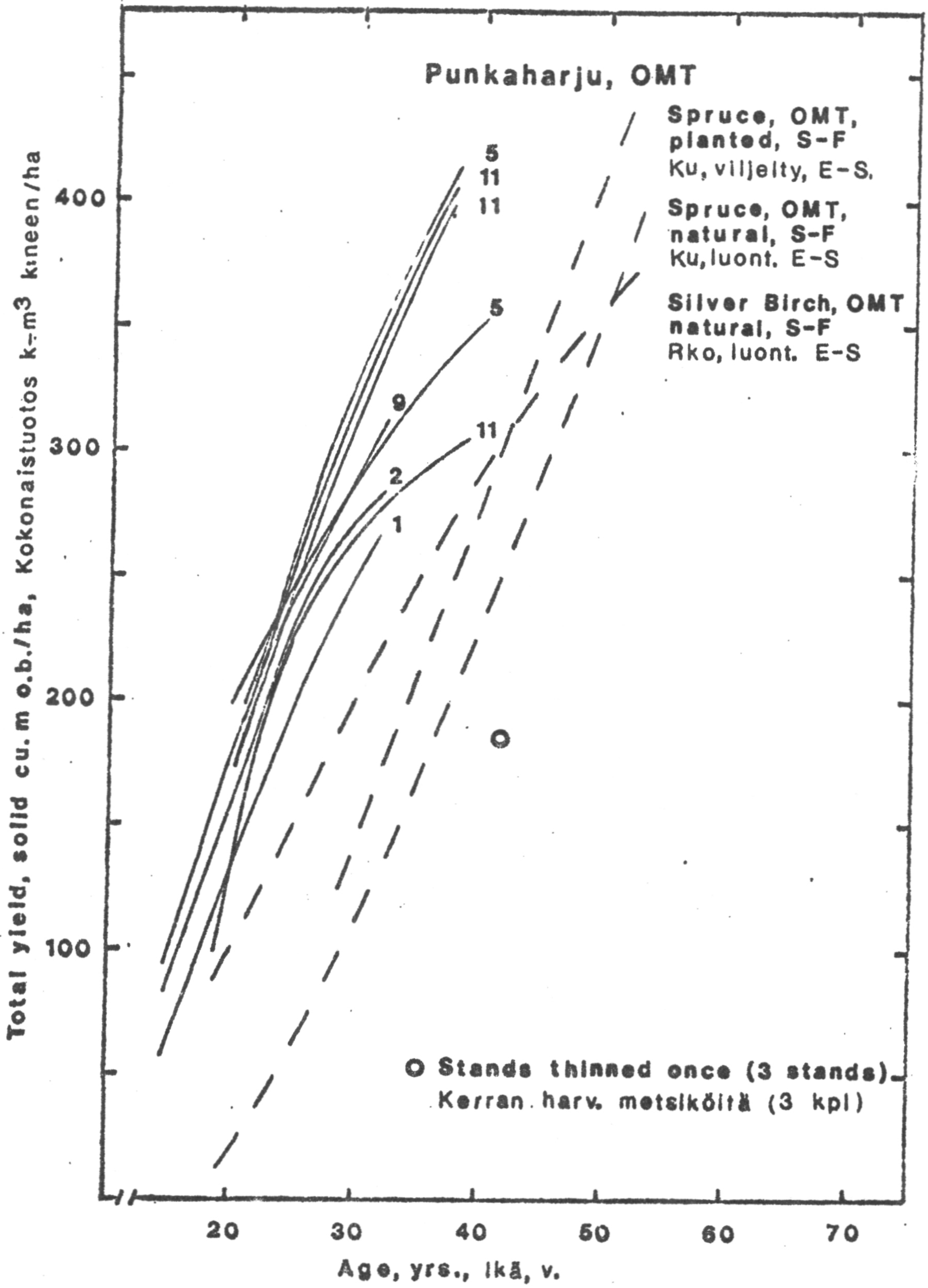

Figure 4. The total yield of lodgepole pine (full lines) on the site type OMT in Punkaharju compared to repeatedly thinned stands of Scots pine and Norway spruce (broken lines) in southern Finland

Kuva 4. Murraynmännyn kokonaistuotos (kokoviivat) Punkaharjun OMT:llä verrattuna Etelä-Suomen toistuvasti harvennettuihin OMT-kuusikoihin, -männiköihin ja -rauduskoivikoihin (katkoviivat)

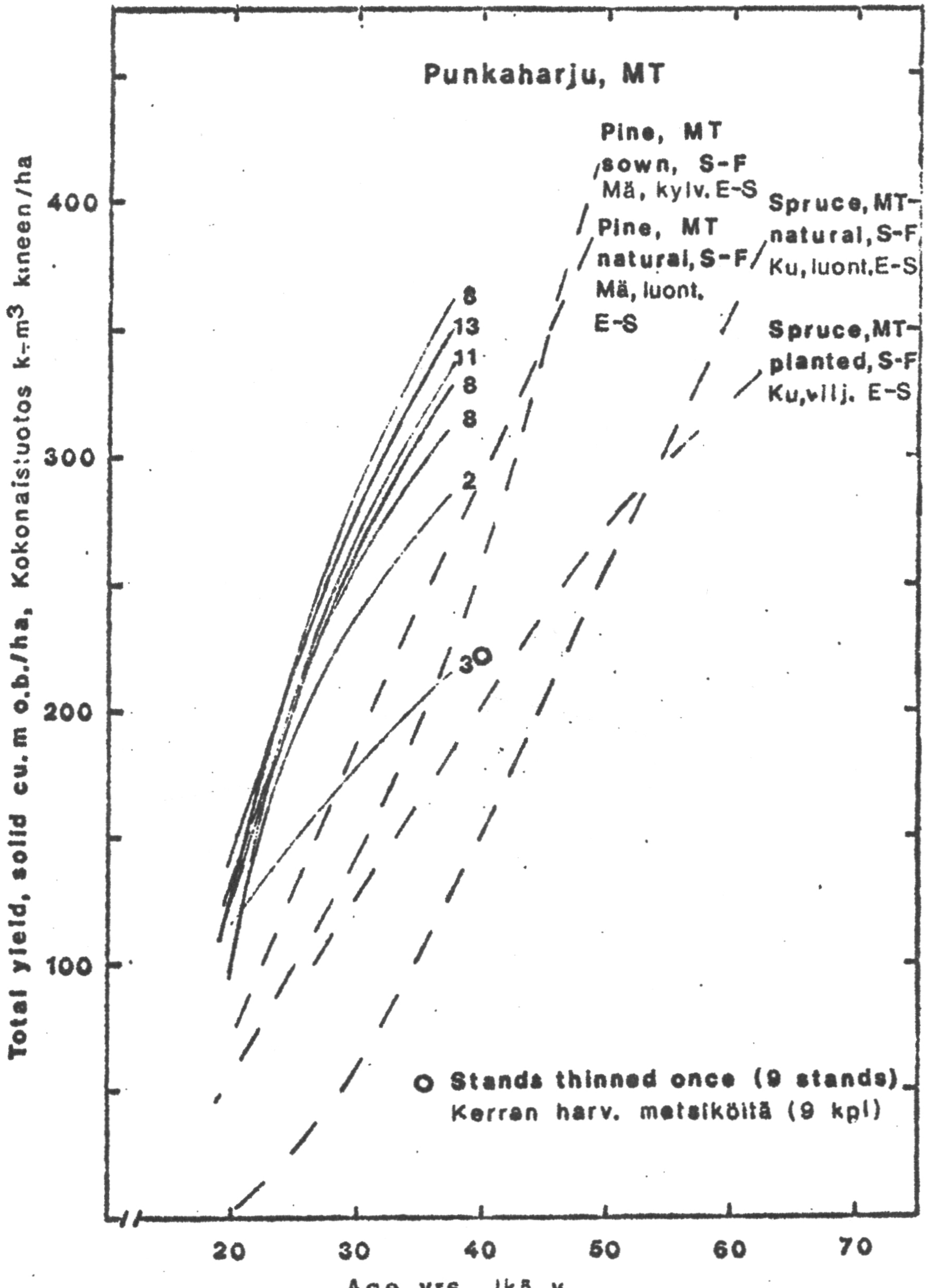

Figure 5. The total yield of lodgepole pine (full lines) on the site type MT in Punkaharju compared to repeatedly thinned stands of Scots pine and Norway spruce (broken lines) in southern Finland

Kuva 5. Murraynmännyn kokonaistuotos (kokoviivat) Punkaharjun MT:llä verrattuna Etelä-Suomen toistuvasti harvennettuihin MT-kuusikoihin ja -männiköihin (katkoviivat)

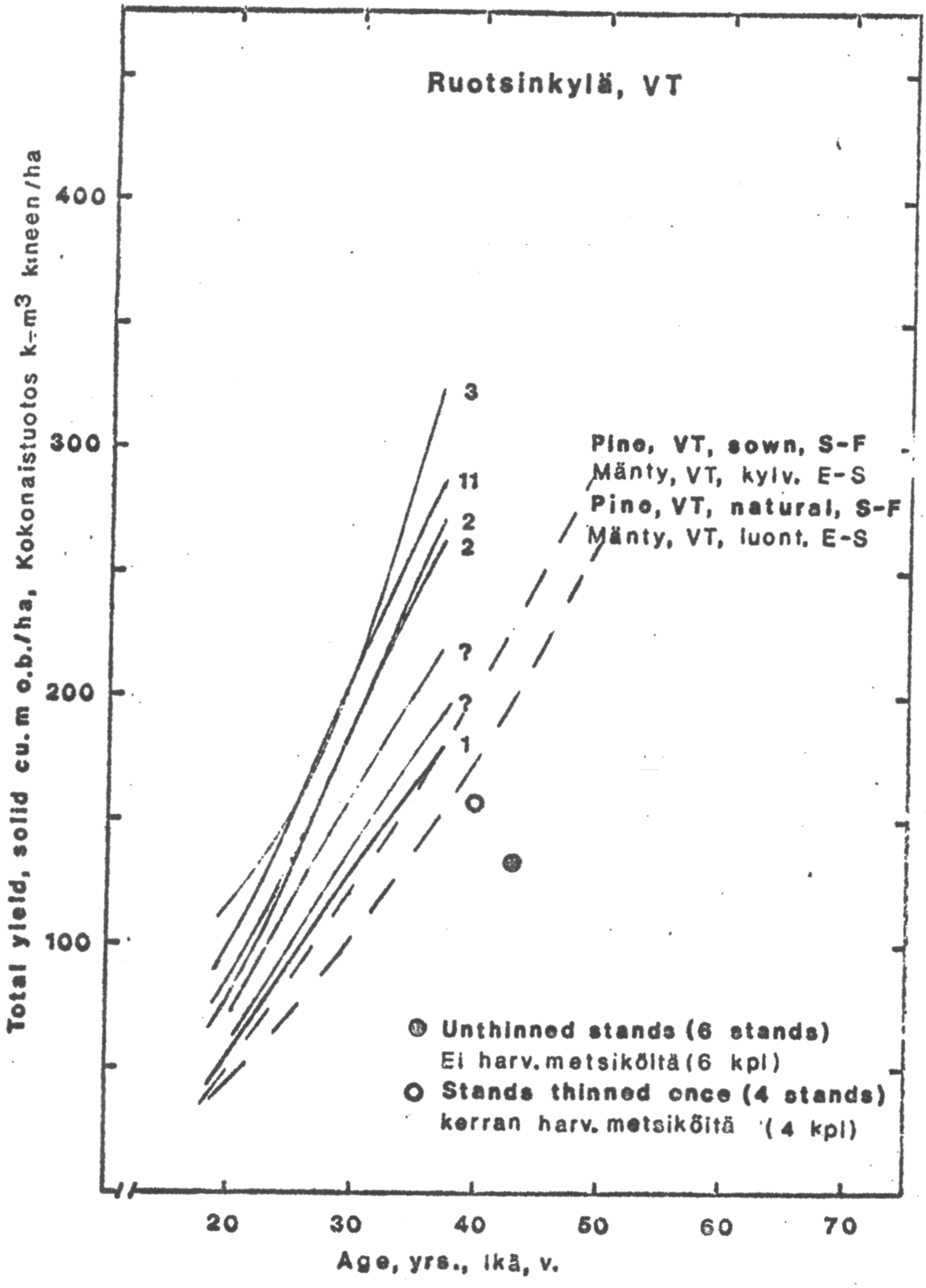

Figure 6. The total yield of lodgepole pine(full lines) on the site type VT in Ruotsinkylä compared to repeatedly thinned stands of Scots pine (broken lines) in southern Finland

Kuva 6. Murraynmännyn kokonaistuotos (kokoviivat) Ruotsinkylän VT:llä verrattuna Etelä-Suomen toistuvasti harvennettuihin VT-männiköihin (katkoviivat)

MÄKINEN (1958). The curve after age 40 is based on the publication by NYYSSÖNEN (1954) who used 15 experimental plots on MT and 19 plots on VT. The control curves for the sown pine stands 20-50 years old are based on the publication by KALLIO (1961) who used 19 plots on MT and 27 on VT, including a few north of N 62°00'.

The control curves for naturally regenerated spruce stands 20-60 years old are based on the publication by VUOKILA (1956) who used 29 experimental plots on OMT and 28 plots on MT. The control curves for planted spruce stands 20-53 years old are based on the publication by CAJANDER (1934) who used 36 plots on OMT and 28 plots on MT.

The control curve for silver birch (Betula verrucosa L.) is based on studies by KOIVISTO (1958).

In addition to the comparisons with these control curves the growth of lodgepole pine on the permanent experimental plots also has been compared to the total yield of the same species in the stands managed by the woodworking industries and the State Board of Forestry. The yield of these stands was estimated in the field by foresters in charge of their management in response to questionnaires sent out for a random sample of 55 stands out of a total of some 165 reported ones. Based on the returning information about site type, age, growing stock, and total output the average total yield, plotted on Figures 4-6, was calculated for each forest site type. It has to be pointed out that data obtained in such a manner contains considerable variation in total yield. Reasons for this include: inaccurate volume estimates, difficulties in forest site classification, and incomplete knowledge of the total output of the stand during its development. Also,the stands have in general been thinned only once or not at all. The stands reported to have been thinned two or more times were too few to provide even a remotely satisfactory sample.

The total yield of stands in Mustila (Figure 7) has been compared to the yield of comparable Scots pine stands measured on permanent experimental plots in Mustila and elsewhere (e.g. TIGERSTEDT 1922, 1927, 1970, SCHULENBURG 1948, MIETTINEN 1952).

32. Results

On the best forest site type OMT (Figure 4) lodgepole pine on the frequently-thinned permanent,experimental plots has produced a larger total yield until age 40 than both planted Norway spruce and naturally regenerated Norway spruce and silver birch. The only once-thinned stands of the State Board of Forestry and the woodworking industries (three observations only!) has produced a much smaller total yield than the controls and the frequently-thinned lodgepole pine. Some curves for lodgepole pine suggest a slight stagnation of growth at age 40 and may intercept more control curves before age 50.

On the intermediate forest site type MT (Figure 5) the lodgepole pine on the frequently-thinned experimental plots has produced a larger total yield until age 40 than Scots pine and Norway spruce regenerated both naturally, by sowing, and by planting. There is one experimental

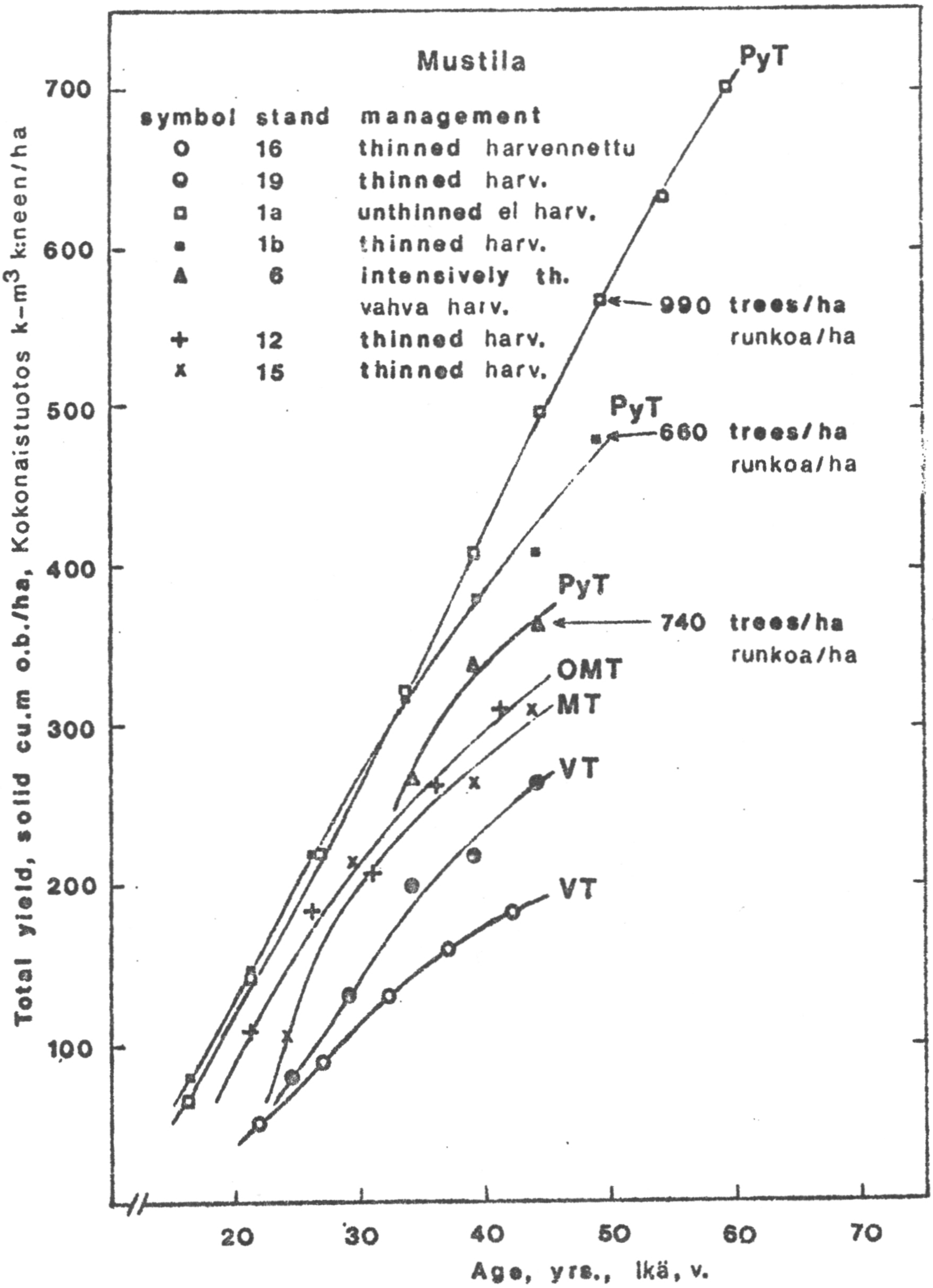

Figure 7. The total yield of lodgepole pine grown on various site types in the arboretum of Mustila. The degree of thinning is indicated by trees / hectare for three of the stands

Kuva 7. Murraynmännyn kokonaistuotos eri metsätyypeillä Mustilan arboretumissa. Harvennuksien voimakkuus on ilmaistu runkoluvulla kolmen metsikön kohdalta plot (provenance 3) which has been thinned only twice. By age 40 it has produced less than Scots pine regenerated naturally and by sowing. The only once-thinned stands of the State Board of Forestry and the woodworking industries (nine observations) has produced less than naturally regenerated and sown Scots pine and about the same as the twice-thinned permanent experimental plot. All curves for lodgepole pine suggest a trend of slight stagnation at age 40 and may intercept the curves for Scots pine at or before age 50.

On the poorest site type VT (Figure 6) the lodgepole pine on the frequently-thinned permanent experimental plots generally has produced a larger total yield until age 40 than Scots pine regenerated both naturally and by sowing. The unthinned (six observations) and once thinned stands (four observations) of the State Board of Forestry and the woodworking industries have produced less than both the controls and the permanent experimental plots. The curves do not indicate any stagnation of production until age 40.

The seven permanent experimental plots in the arboretum of Mustila (Figure 7) represent the oldest continuously measured stands of lodgepole pine in Finland. Detailed comparisons of their performance with native tree species in Mustila and elsewhere have been published by TIGERSTEDT (1922, 1927, 1970), SCHULENBURGER (1948), MIETTINEn (1952). Their data indicate that at sites better than VT lodgepole pine outgrows native species. TIGERSTEDT (1970) points out that on VT in Mustila lodgepole pine does not outgrow native species. He also emphatically concludes that the economical rotation of lodgepole pine is not more than 50 years. The curves in Figure 7 suggest slight stagnation of growth at age 45 on most sites except on plots 1a and 1b. Measurements on 1b have been discontinued at age 49, on 1a at age 59, and on 6 at age 44 (on 6 due to snow damage, on 1a-b reason not stated).

33. Discussion and Conclusions

The control curves used in this preliminary report may not be the best available data for acceptable comparison of the growth of lodgepole pine with native species. Efforts should be made to find continuously measured comparable stands of native species on VT in Ruotsinkylä and on MT and OMT in Punkaharju.

The comparisons of growth of lodgepole pine with that of native species which have been made in this paper have to be viewed with the following in mind. Factors that may increase the advantage of lodgepole pine in a manner not acceptable when forming a basis for firm conclusions include:

- Intensive, purely silvicultural management of the lodgepole pine experimental plots
- On an average colder climate for the control stands
- The lack of control stands established in exactly the same way i.e. stands planted with spacing less or equal to 1.5 x 1.5.

Factors that may increase the advantage of lodgepole pine in a manner that is acceptable when forming a basis for firm conclusions include:

- Lodgepole pine has a lower bark percentage than native softwood species (MIETTINEN 1952, HAKKILA and PANHELAINEN 1970)
- Lodgepole pine has a higher basic density (HAKKILA and PANHELAINEN 1970) and consequently a higher yield of pulp (KESKUSLABORATORIO, unpublished) than Scots pine.

Keeping these factors in mind it may be concluded that until age 40 intensively managed lodgepole pine, of most provenances indicated on Figures 4-6, on sites in southern Finland comparable to those of Ruotsinkylä and Punkaharju may outgrow many kinds of cultures established by genetically unimproved seed of native tree species in the same area. TIGERSTEDT's (1970) conclusion regarding low productivity on site type VT of Mustila may be in contradiction with the results obtained from VT of Ruotsinkylä. A more appropriate choice of control stands from Ruotsinkylä may elucidate this question.

Stands of lodgepole pine, which have been thinned only once or not at all until age 40 may not produce more than regularly thinned stands of native species.

4. PROVENANCE

The question of selecting the most suitable provenance of a tree species to be grown outside its natural range is of extreme importance. When A.F. T i g e r s t e d t in the early 1900's and Olli H e i k i n h e i m o in the 1920's selected the provenances of lodgepole pine now growing in Finland, they were guided by previous research but not by any experience of previous performance of the species in its new environment. Thanks to their bold efforts at that time, we today have valuable experience to guide our further attempts to improve the selection of provenances. Further, new research data continue to furnish additional information.

In the present study the temperature sum (threshold/value +5^{o}C) at the origin of the provenance was investigated in order to gain understanding of the importance of this factor for correct choice of provenance. The published temperature records over the last 40 years of nearly 70 climate stations of Alaska, Yukon, British Columbia, Alberta, and Washington were used to construct a map (to be published later) indicating the temperature sum at sea level in the northern part of the natural range of lodgepole pine. The temperature sum for each climate station was calculated and subsequently increased to that of the sea level by applying four different gradients for each of four zones between N 49° and N 66° (Figure 8). The gradients observed were obtained by regression analysis of temperature sum on elevation for 11-15 stations within each zone. Using the constructed map, the approximate temperature sum was determined at the origin of each provenance represented in older stands grown in Finland (Table 2).

When comparing the relative performance of some provenances grown on different sites and locations in Finland the total yield at age 35 was taken as a reference point (Table 7). Provenances 2 and 11 have produced a high total yield on all sites at both locations. It is interesting to note that the temperature sum at the origin of the provenance is lower than at the new, warmer locations where the provenances presently are growing in Finland. The same is true for provenance 6 from 1 200 d.d., presently growing in Mustila in 1 300 d.d. on plot 1a and 1b. Provenance 3 from 900 d.d. has performed extremely well on VT in Ruotsinkylä at 1 350 d.d. Unfortunately, on MT the stand of this provenance has been thinned only twice and does not therefore provide comparable information. All provenances listed in Table 2 have suffered badly in the north (Kivalo, N 66°23', E 26°37', elev. 220-240 m) at temperature sums of about 760 d.d. On the other hand, provenances 5 and 8 represented only at OMT and MT respectively, have performed well in locations colder than their original provenance.

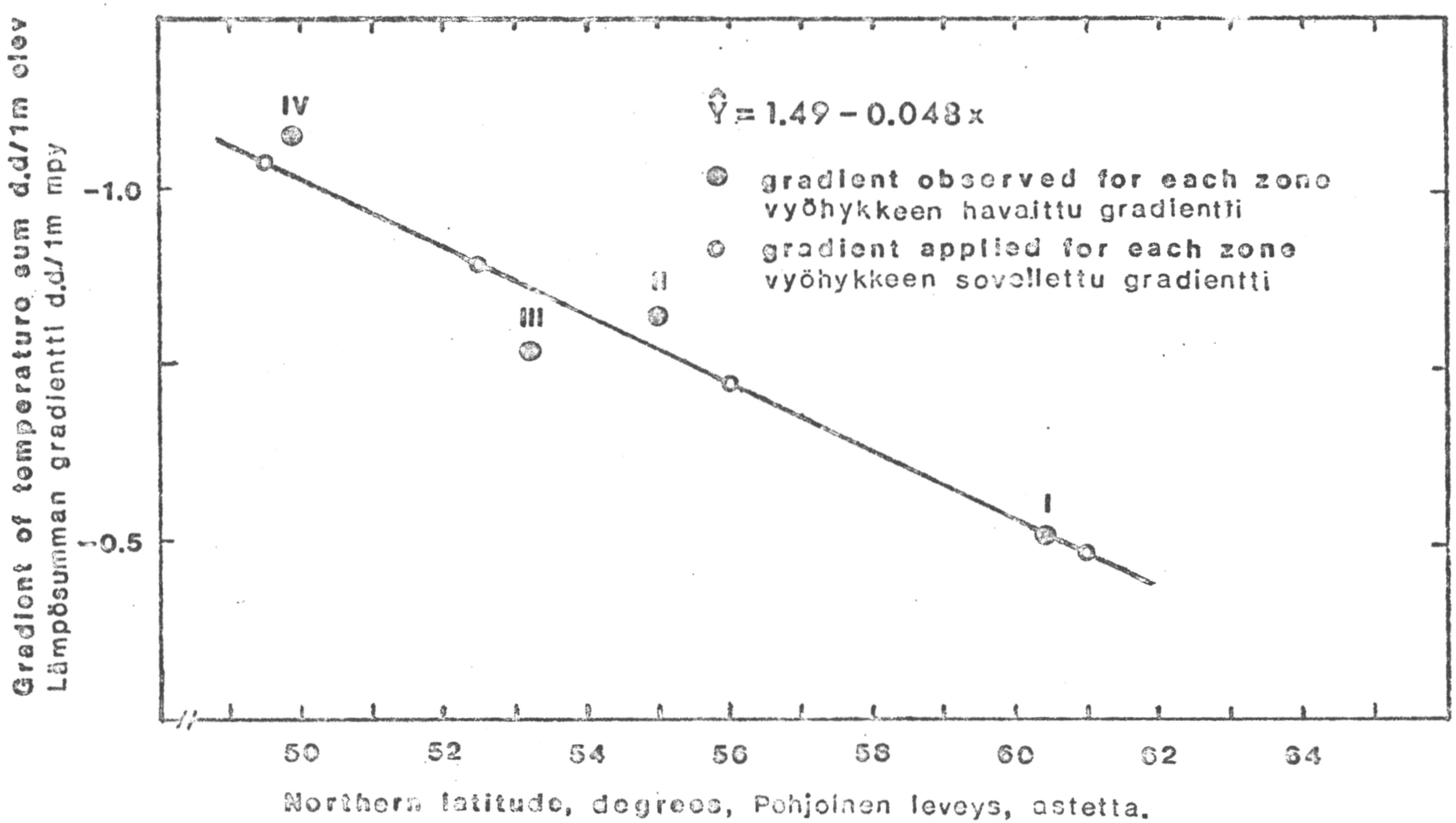

Figure 8. The regression of the gradient of the temperature sum for four regions of the northern range of lodgepole pine on the northern latitude. Observed and applied values of the gradient

Kuva 8. Neljän alueen lämpösummagradientin ja pohjoisen leveysasteen välinen regressiosuora murraynmännyn luontaisen levinneisyysalueen pohjoisosissa. Lämpösummagradientin havaitut ja sovelletut arvot

Table 7. Total yield at age 35 for some provenances of lodgepole pine grown in Finland on three forest site types at two locations

Provenance no.	Northern latitude	Temp. sum, d.d.	Punkaharju, 1 300 d.d. OMT	Punkaharju, 1 300 d.d. MT	Ruotsinkylä 1 350 d.d. VT	Average over locations and sites
			Solid cu. m. o. b./ha			
1	49°40'	-	285	-	165	225
2	50°13'	1200	290	265	245	267
3	50°35'	900	-	205 x)	295	250
5	50°50'	1500	350	-	-	350
8	51°52'	1400	-	313	-	313
9	55°47'	1300	330	-	-	330
11	50°40'	1000	345	310	265	307
Average over provenances			320	273	208	-

x) Thinned only twice, others thinned several times

Newly-established provenance trials include a total of about 100 IUFRO provenances, of which 20 are growing on several locations north of N 65° in well-designed field experiments. No data on their relative performance are yet available.

In the early spring of 1972 96 kg seed of lodgepole pine representing eight provenances of a previously not tested region of British Columbia (N 54°-57°, W 125°-121°) was distributed to 15 public and private land owners. Providing that careful records are kept of the provenance and that controls of native species, represented by genetically improved seed, are planted at the same time as lodgepole pine, these cultures will give extremely valuable information in the future. The Forest Research Institute has reserved a sufficient amount of each provenance for establishing provenance trials with this material.

Presently-available data do not provide a satisfactory basis for firm conclusions on suitable provenances. In general, provenances from regions of 900-1500 d.d. north of N 50° have performed satisfactorily in the southern parts of Finland (see provenance 1, Figure 6 and Table 7). It may be that even well-designed field experiments may not detect differences in total yield between a variety of provenances if they represent marginal populations with limited genetic variation. Extensive studies in Norway (DIETRICHSON 1970) and Sweden (HAGNER 1970) on young material raised from seed of several provenances do suggest, however, that several morphological and physiological traits show large variation at a young age.

5. SEED PRODUCTION AND BREEDING

51. Seed Production

Information about seed production of lodgepole pine grown in Finland has not been published or recorded. Therefore, a limited study of the seed production of 10 dominant trees in one stand in Punkaharju (stand 99, age 49, site OMT, provenance 11) was undertaken. All cones from each tree were collected. Each tree had produced an average of 404 cones corresponding to 1.41 kg and 3.7 liters. Due to serotiny, the trees contained an average of only 20 % 2 year-old cones. rom all the cones of each tree an average total of 0.9 g of full seed could be extracted, having a 1 000-seed weight of 2.4 g. This weight varied from 2.1-2.7 g for individual trees. The unsorted seed contained 12 % (6.0 %-19.5%) empty seed when sorted by blowing. From each cone an average of about one full seed was obtained (0.2-2.4 seeds per cone). The germination of the seed was determined using two methods: the Jacobsen apparatus and plastic-covered moist peat in plastic greenhouse. The seed was not stratified. The unsorted seed from 2 year-old cones had a germinability of 34 % with both methods, while the seed from old cones had only 7 % and 5 % with the two methods respectively.

Taking full seed from both old and new cones together, the average germination per tree was 43 % and 35 % with the two methods respectively. The germination varied from 75 %-16 % per tree.

Pissodes validirostris Gyll. had damaged 78 % of the cones, varying from 48 % - 97 % for the 10 trees investigated. Although these cones were found to contain 40 % undamaged seed, they did not release their seed when extracted. This explains the very small full-seed crop per cone and tree. Also, the fact that a tree contained some 80 % old cones with low germinability of their seed, contributed to the unsatisfactory seed crop. This problem may be further elucidated by the results from the Röntgen analysis of the seed that was undertaken. The results of this analysis will be published later.

The results from this limited special study on the seed crop suggest that much attention has to be paid to the damage caused by Pissodes validirostris. In the future, the control of this insect in the established and planned seed orchards, as well as in breeding experiments, may present a serious problem to be solved at possibly high costs. The large variation between trees and clones (ANNILA, pers. comm.) suggests possible genetic differences in resistance. Further information about Pissodes validirostris is given in the section on biotic and abiotic damage and ANNILA has undertaken a comprihensive study on the biology of the insect as well as on its effect on seed crops.

52. Breeding

Breeding experiments with lodgepole pine have been undertaken in Finland, and one seedling seed orchard has been established in 1972. Scions for a clonal seed orchard were collected in the winter of 1972 from plus trees selected from older stands in Finland.

Results, except for first year mortality, from the breeding, experiments (progeny tests) are not yet available. Experiment 334/1 in Vesijako (Table 1) contains i.a.four crosses of P.contorta x P. divaricata grown in Ruotsinkylä. Each progeny contained 36-48 seedlings in six-tree plots with eight replications. First year mortality was 1.0 %. Experiment 334/2 in Kolari (Table 1) contains two progenies of P. contorta x P. contorta, two of P.contorta x P.divaricata, and eight open-pollinsted P.contorta. All seed was collected from stands grown in Ruotsinkylä. Each progeny contains 1-72 seedlings in six-tree plots with 12 replications. First year mortality was 2.3 %.

Some of the selected plus trees (Table 1) have a selection differential (s) for height varying from 5.4%-10.0 % and for volume from 24.5 % - 33.1 % when compared to 20 dominant trees in the stands. Trees selected from provenance 1 have an avegare selection differential of 10.1 % for height and 27.6 % for volume, while trees from provenance 8 have 7.8 % for height and 30.0 % for volume. Note that provenance 1 had not produced a very high total yield on VT in Ruotsinkylä and on OMT in Punkaharju (Figures 4 and 6, Table 7). Plus trees selected before 1971 were compared to only four adjacent dominant trees. The selection differential has not been calculated for these trees.

In connection with selecting plus trees in 1971, the growing stock of seven stands, from which several plus trees were selected, was measured by a 2 x 1 000 m line mensuration. The data obtained will provide the possibility for an accurate estimate of the selection intensity (i) for height and volume (to be published later) of the plus trees as compared to the trees of the present growing stock. Unfortunately, the total output of these stands is not known. Therefore, the volume of growing stock alone cannot be used for comparing total yield of lodgepole pine with that of native species, as has been done in Figures 4-6.

In connection with the present study, information has been obtained about several stands previously not known to the Forest Research Institute. A large number of new plus trees may be selected from these stands providing that the unusually bad storms of July 1972 have not caused too much damage to these stands.

The gene bank of the Foundation for Forest Tree Breeding (Table 1), containing about 200-500 individuals of about 100 different lodgepole pine provenances, will provide material for future breeding work. The one-tree-plot experiment (Table 1) with 12 replications, containing about the same provenances as the gene bank, will provide some guidance in selecting provenances in the gene bank for breeding. Some 20 of these provenances are also represented in the provenance tests 373 and 374 located north of N 65^{o}. These tests will provide additional aid for selecting provenances to be bred in the gene bank. The southern location of the gene bank, in addition to intensive fertilizing, will stimulate flowering at an early age.

In general, the possibilities for breeding lodgepole pine in Finland appears good, providing that damage by Pissodes validirostris can be controlled and that the lodgepole pine contains large genetic variation.

6. DAMAGE CAUSED BY BIOTIC AND ABIOTIC AGENTS

61. Mortality in Young Plantations

An early report on mortality in young plantations of lodgepole pine in Finland has been published by KATAINEN (1939). While his report usually does not give information about specific causal agents, such as fungi or insects, it is of value as general information on regeneration difficulties encountered. KATAINEN's observations on mortality, site factors, and seedlings have been compiled in Table 8. The condition of the stands 25 years later is also given according to KARPPINEN and SIIRILÄ (1963). The data in Table 8 clearly indicate the high mortality in the young plantations. Ground cover competition and small seedling size has affected the early development of the plantations. If more attention had been paid to fungi and insects other explanations for the mortality may have been given as well. The fact that many of the plantations 25 years later have developed into fairly good stands in spite of high early mortality is mostly due to the originally very high planting density (3640-8800 seedlings/hectare) that had been used.

Table 8 . Mortality of seedlings of lodgepole pine in 1938 in young plantations in Korkeakoski Forest District (N 61°50', E 24°13') and their condition in 1963

Stand identification according to: KATAINEN 1938	KARPPINEN and SIIRILÄ 1963 (map of 1962)	Forest site type	Data on seedlings in 1938: Type of seedling	Age	Average height, cm	Mortality %	Probable reason for mortality according to KATAINEN 1938	Condition x) of remaining stand in 1963
Lakukivi I	76 b	OMT	2 + 0	7	100	44	Ground cover competition	Excellent
Lakukivi II	72 b	MT	2 + 0	7	80	50	" " "	Good
Jokihaara	647 a	MT	2 + 0	8	-	98	Spring Frost in first season	Fair
Susimäen th.	820 b	MT	4 + 0	3	70	0	No ground cover competition	Good
Karhujärvi	-	MT	1 + 2	9	55	57	Ground cover competition	No information
Lapinkangas	675, 678 a	CT	3 + 0	4	27	72	Seedlings too weak	Good
Siikakangas, A	284 a	CT	1 + 2	10	18	62	Mostly *Evetria resinella*	Good
-"- , B	284 b	CT	3 + 0	6	16	25	Day of planting very dry	Fair
-"- , C		CT	1 + 0	8	18	75	Seedlings too small	Cut for air strip

x) Subjective grading into four classes based on information given by KARPPINEN and SIIRILÄ in 1963: Excellent, Good, Fair, Poor.

In more recently planted (1969-1971) field experiments the mortality of lodgepole pine has been small compared to the data of the 1930's. In a field experiment, containing 7 500 Pinus contorta seedlings, planted on a drained peat bog in Korkeakoski Forest District in 1969, PÄIVÄNEN (unpublished data from Viheriäisenneva species trial) reported that the cumulated mortality after the third growing season was 1.0-3.2 % compared to 10.8-17.1 % for Scots pine. The 1 + 1 seedlings used in the experiment were raised from open pollinated seed collected from stands grown in Finland.

Another field experiment (no. 334/2, Forest Res. Inst.) containing 340 Pinus contorta seedlings, planted in Kolari (N 67°10', E 23°8') in 1969, showed an average mortality of 2.3 % after the first growing season. The 1 + 2 seedlings used in this experiment were raised from open pollinated seed collected from plus trees grown in Ruotsinkylä.

Parts of the international IUFRO provenance experiment have been planted in northern Finland as Forest Research Institute field experiments no:s 374 and 373. In Experiment 374/1 20 provenances from Alaska, Yukon and northern British Columbia, as well as one provenance from southern California, no. 2109, were used. The provenance 2109 suffered 100 % mortality after the first winter in the nursery of Imari due to damage by hares. After the first growing season in the field (Hirvas, N 66°28', E 25°33'), the 20 remaining provenances showed an average mortality of 3.8 %. In experiment no. 373/1 and 373/4 only 7 of the northernmost lodgepole pine provenances were compared to Scots pine. In Pudasjärvi (expt. no. 373/1) the average mortality for both lodgepole and Scots pine was 0.4 % after the first growing season. The 8 400 seedlings used in the experiment were planted as 1 + 1. In Salla (expt. no. 373/4, N 66°45', E 28°10') the same provenances showed an average mortality of 9.6 % compared to 2.8 % for Scots pine. The 11 500 seedlings used in this experiment were also planted as 1 + 1.

Information on the specific biotic and abiotic agents causing damage to lodgepole pine is extremely limited. In the following an attempt has been made to compile all available information on such insects, fungi, mammals, and abiotic agents that have been observed to cause damage on lodgepole pine grown in Finland.

62. Damage Caused by Insects

The literature on damage caused by insects on lodgepole pine in Finland is reviewed. The insects and damage caused by them are reported in the order of their importance, judged on the basis of the available literature.

Pissodes validirostris Gyll. occurred in all cones of 31 year old lodgepole pines in a 0.25 hectare sample plot in Siikakangas, Korkeakoski Forest District (N 61° 50', E 24°13'). By opening a sample of cones it was found that some 40 % of the seeds had been eaten by the larvae. Since damaged cones do not release the remaining seed, seed loss was complete. Up to 5 insects were found in each cone (KARVINEN and RIKKONEN, 1959). In studying the 1972 cone crop of 10 dominant trees in one stand at Punkaharju, it was found that 48.0-96.6 % (mean 77.5 %) of the cones of each tree had been damaged by the insect. On Pinus sylvestris the damage caused by P. validirostris usually is very insignificant (TRÄGÅRDH 1939, SAALAS 1949). The importance of this insect is further discussed in the section on seed production.

Hylobius abietis L. had caused high mortality in 1927 in four 1-3 year old plantations of lodgepole pine located in Punkaharju and Ruotsinkylä Experimental Forests (HEIKINHEIMO 1956). The same insect also caused damage on some 30 year old lodgepole pines on Siikakangas in Korkeakoski Forest District; but the damage was of little or no importance, occurring only on smaller branches and on the upper thin-barked sections of the stems. Only 2 % of the investigated stems had evidence of damage by this insect. No difference in frequency was found between adjacent lodgepole and Scots pines (KARVONEN and RIKKONEN 1959).

Evetria resinella L. had caused damage on several 3-10 year old plantations in Korkeakoski Forest District. The damage caused by this insect was considered the main reason for a 62 % cumulative mortality in one 10 year old plantation (Table 8)(KATAINEN 1938). Studying the same stands as KATAINEN did, KARPPINEN and SIIRILÄ (1963) reported that the insect also caused damage on the stands 25 years later. Due to the larger size of the trees, the damage was not considered very serious. Comparing two adjacent 0.25 hectare sample plots of 31 year old lodgepole and Scots pines on Siikakangas, Evetria resinella was found to occur very frequently. The frequency on lodgepole pine was, however, smaller than on Scots pine. The attacks had caused changes of leaders and branching on smaller trees, while the damage was of little consequence on larger ones. In general lodgepole pine had recovered from damage better than Scots pine (KARVINEN and RIKKONEN 1959).

Pissodes notatus F. was also found on the sample plots. Damage caused by adults was more frequently found on Scots pine than on lodgepole pine probably due to the more suitable size of the Scots pines. The damage on this species was severe. No damage caused by larvae was observed on either species.

Luperus pinicola Duft. was observed on the same pines. The frequency on lodgepole pine was smaller than on Scots pine, and the damage was of little or no importance. Brachyderes incanus L. had occurred on both species with approximately the same frequency but causing little damage.

Blastophagus sp. had caused insignificant damage to shoots of lodgepole pine while some adjacent Scots pines were severely damaged. The authors (KARVINEN and RIKKONEN 1959) doubted that any damage would occur in a pure lodgepole pine stand due to absence of suitable breeding material for adults.

Evetria buoliana Schiff. was found sparsely in both lodgepole and Scots pine.

Evetria turionana Hb. attacked the terminal bud of lodgepole pine approximately 4 times more frequently than the buds of Scots pine but caused little damage in either species. The reason for the markedly higher frequency on lodgepole pine may have been the more vigorous condition of the species (KARVINEN and RIKKONEN 1959).

Although Lachnus pineti Koch. was found on Scots pines some 300-400 meters from the lodgepole pines, no evidence of damage caused by this insect was found on the latter species (KARVINEN and RIKKONEN 1959).

Diprion sertifer Geoffr. was found to do little damage on lodgepole pine in 31 year old stands in Korkeakoski Forest District.

In one 28 year old stand the insect occurred more frequently on lodgepole pines than on adjacent Scots pines. The damage was insignificant. In four 25 year old stands the insect had caused some damage (KARPPINEN and SIIRILÄ 1963). During the serious 1961 attack in Punkaharju, lodgepole pines were much more severely damaged than Scots pines (Mr. HÄYRYNEN, pers. comm., SARVAS 1964).

The importance of insect damage on lodgdpole pine in Finland may be summarized as follows: Pissodes validirostris appears to be a severe threat to satisfactory seed crops. Hylobius abietis may cause severe mortality in plantations, while Evetria resinella may retard the development of young plantations. Several other insects do attack the species, but usually the damage has been of little or no importance and not much more severe than on comparable Scots pines. An apparent exception from this rule is Evetria turionana which had occurred much more frequently on lodgepole pine, although the damage had been of little or no consequence.

The above conclusions have to be viewed cautiously since they are based on only four publications, three of which have been graduate theses. More detailed and rigorous studies on insect damage, especially to young plantations, are desirable in order to make reliable conclusions.

63. Damage Caused by Fungi

The literature on damage caused by fungi in lodgepole pine grown in Finland is reviewed. The damage caused by the various pathogens is reported in order of importance, judged on the basis of the available literature. Currently accepted scientific names are used while the names used in the original papers are given in parentheses.

Fomitopsis annosa (Fr.) Karst. (Trametes radiciperda Hart.) and Armillaria mellea (Vahl. ex Fr.) Quel. (Agaricus melleus Fr.) were reported to cause severe damage in young stands (less than 30 years old) of lodgepole pine in Veikkola (N 60°17', E 24°25') and Ruotsinkylä (HEIKINHEIMO 1956). Already KUJALA (1948) noted that Fomitopsis annosa (Fomes annosus (Fr.) Cke.) caused rapid death in clusters of young lodgepole pines (about 10-15 years old) both in Punkaharju and Ruotsinkylä. LAINE (1970) observed damage by this pathogen in the same stands as did KUJALA; but he also found the pathogen in adjacent, previously uninfected, stands. Especially in Ruotsinkylä, living and green-needled trees with decayed roots had been falling to the ground. Also in Mäntyharju (N 61°24', E E 26°50') in a 35 year old stand, large numbers of trees had died due to the pathogen. On the other hand, LAINE had not been able to find the fungus in several other stands, and he suggested the possibility that differences in resistance between provenances may be a partial explanation for the absence of the pathogen in many stands.

Scleroderris lagerbergii Gremmen (Crumenula abietina Lagerb., Bruchorstia pinea (Karst.) v. Höhn) appears to be a serious threat to young stands of lodgepole pine. In Punkaharju Experiment Forest KUJALA (1948, 1950) observed large numbers of apothecia of Scleroderris lagerbergii and pycnidia of Brunchorstia pinea on 15 year old lodgepole pines bent, broken, or dead by snow damage. Scots pines of the same age in the stand or at its edges were also attacked but appeared less susceptible. The attack on lodgepole pines was much lighter on lower, already dead branches. He also studied some lodgepole stands (age 19-22 years) in Nuutajärvi (N 61°01', E 23°18') where the pathogen had attacked the leaders and killed the whole shoot and all needles. In other cases the stem was healthy but the apical parts of the branches were devoid of needles. In other trees with most branches dead, there were a few live branches left, indicating very rapid progress by the pathogen. Large parts of the planted area (several thousand trees) were dead due to attacks during the last few years (Photograph on p.15 in KUJALA 1950).

As a probable and partial reason for the intensive and disastrous attack of the pathogen, KUJALA (1950) suggests the overly-dense stands with high humidity and poor ventilation as well as the very good forest site type (OMT). He concludes, supported by observations on several lodgepole pine plantations in Finland, that stands on good sites are more predisposed to the pathogen than stands on poor sites. KUJALA considers Scleroderris lagerbergii Gremmen as the most devastating pathogen of lodgepole pine and a serious threat to successful cultivation of the species in Finland. If the stands, however, are planted on dry, less fertile sites (VT), and thinnings are performed in an early stage, the attacks by the pathogen may be reduced. Also HEIKINHEIMO (1956) found Scleroderris lagerbergii on lodgepole pines in both Punkaharju and Ruotsinkylä, but the damage was probably not serious since the author does not put any particular emphasis on this pathogen in his report. There are detailed studies on other young stands of lodgepole pine in Finland, but serious damage by Scleroderris lagerbergii was not found in any of the stands. In the report made by KARVINEN and RIKKONEN (1959) on a 31 year old plantation at Siikakangas much attention was paid to the fact that Scleroderris lagerbergii could not be found. Referring to KUJALA (1950), the authors suggested that the less fertile forest site type (VT) may have contributed larger resistance to the pines. The pathogen did not occur on adjacent Scots pines. Also, the pathogen was not observed in any of the more than 10 stands of lodgepole pine investigated in 1938 and 1963 by KATAINEN (1938) and KARPPINEN and SIIRILÄ (1963). On the other hand, the authors, being mostly interested in growth and yield studies, may have overlooked the pathogen.

On the basis of the available report on Scleroderris lagerbergii on lodgepole pine in Finland it appears that this pathogen poses a real threat to young stands under certain conditions favourable for the pathogen. The true role of this disease in the early stage of stand development is, however, very difficult to assess due to complete lack of observations in numreous stands that may have perished leaving no records of the reason for their death.

Crumenula sororia Karst. has been reported on lodgepole pine by KUJALA (1948, 1950) and HEIKINHEIMO (1956). In Nuutajärvi, Punkaharju, and Ruotsinkylä KUJALA observed resin flow on branches and stems of 19-22 year old lodgepole pines and identified apothecia of Crumenula sororia. The pathogen attacked the bark and the cambium causing blue staining and bark necrosis, finally killing the whole tree. In Mustila (N 60°44', E 26°29') and Punkaharju the damage was much less frequent. KUJALA (1950) is of the opinion that the pathogen spreads from branches and twigs of Scots pine to branches and stems of lodgepole pine, causing serious damage in the latter species. HEIKINHEIMO (1956) found the pathogen in connection with resin flow both in Ruotsinkylä and Punkaharju, but there is no record on the consequences of the damage. There are no other records of this pathogen on lodgepole pine in Finland.

Lachnellula subtilissima (Cke) Dennis (Dasyscypha subtilissima (Cke) Sacc.) was found on wounds together with Crumenula sororia.The pines were 20 years old and in a stage of vigorous growth, but the two fungi together had caused the death of several trees. Whether the fungus was a primary or secondary pathogen could not be determined. Lachnellula subtilissima does not cause any serious damage on native tree species of Finland. There are no other reports on attacks by this fungus on lodgepole pine in Finland.

Sclerophoma pityophila (Corda) v. Höhn. is reported by KUAJLA (1950) as a fairly strong parasite on lodgepole pine, and HEIKINHEIMO (1956) has also made observations about it. The fungus attacks the young expanding shoots and destroys their xylem to such an extent that the shoots assume a drooping position.(Photograph on p. 80 in KUJALA 1950). Finally they die. KUJALA considers this pathogen very disastrous to lodgepole pine.

Lophodermella sulcigena (Rostr.) v. Höhn. (Hypodermella sulcigena (Rostr.)Tub) was reported by KUJALA as occuring more frequently on the lodgepole than on the Scots pine, but details on the severity of the attacks were not reported.

Lophodermium pinastri (Fuck.)v. Höhn. was reported by KUJALA (1950) as occuring more frequently on the lodgepole than on the Scots pine, but details on the severity of the attacks were lacking. HEIKINHEIMO (1956) does not report on this pathogen. KARVINEN and RIKKONEN (1959) did not find this needle cast on lodgepole pines although the pathogen occured quite frequently on adjacent Scots pines.

Nectria cinnabarina (Tode) Fr. was reported by KUJALA (1950) as occuring more frequently on lodgepole than on Scots pine, but details on the severity of the attacks were not reported.

Cronartium flaccidum (Alb. et Schw.) Wint. (Peridermium pini (Pers.) Lèv.) was observed by neither KUJALA nor HEI-KINHEIMO. KUJALA makes the conclusion that rusts known in Finland do not appear to attack the lodgepole pine. KARPPINEN and SIIRILÄ (1963), however, observed Scots pine blister rust on one individual in a 35 year old stand, dominant height 12.8 m. KARVINEN and RIKKONEN (1959) found blister rust on Scots pines but not on adjacent lodgepole pines of the same age (31 years old).

KUJALA (1950) has observed on lodgepole pine a number of saprophytic fungi on dead branches, twigs, bark, pieces of wood on the ground etc. These fungi are listed by their scientific names as used by KUJALA:

Biatorella resinae Fr.
Cenangium abietis (Pers.) Duby
Crumenula pinicola (Rebent.)Karst.
Dasyscypha calycina Fuck. (non. Schum)
Dothoria pinacea Velem.
Hysterium acuminatum Fr.
Pezicula livida (B. et Br.) Rehm
Propolis faginea (Schrad.) Karst.
Therrya pini (Rehm)
Tympanis pinastri Tul.
Nectria episphaeria (Tode) Fr.
Ophionectria cylindrospora (Sollm) Berl. et Vogl.
Rosellinia abietina Fuck.
Valsa pini Fr.

The importance of damage caused by fungi on lodgepole pine grown in Finland may be summarized as follows: *Fomitopsis annosa* appears to be a severe pathogen on some stands while other stands are not infected at all. The role of various provenances as sources of resistance should be investigated. Infection by Scleroderris lagerbergii may occur more frequently in overly dense stands on very good forest site types. The risk of attacks by this fungus may force the forester to plant the species on less fertile sites using wide spacing. Dasyscypha subtilissima and Crumenula sororia as well as Sclerophoma pityophila seem to be able to attack even vigorously growing young trees although, as a whole, these species have not occurred very frequently. Rusts, except for one observed case of Cronartiums flaccidium, do not seem to be of any importance. Numerous other parasitic fungi do occur, but their effect on development of the stands appears to be of little or no consequence. In the survey of 55 stands conducted for the present study 10 % of the professional foresters (a total of 32 persons) reported that damage due to insects and fungi had been the most serious damage in the stands of lodgepole pine they have managed.

The fact that a number of planted stands may have perished leaving no record of reasons for their death, makes it difficult to make a more relaible and general statement of the importance of fungi for successful cultivation of this tree species in Finland. No information is available on nursery diseases and diseases in very young plantations.

It has to be noted that experiments to determine the true pathogenicity, virulence, and aggressiveness of the pathogenes have not been conducted in Finland.

64. Damage Caused by Mammals

HEIKINHEIMO (1956) does not report any damage caused by mammals on lodgepole pine. KARVINEN and RIKKONEN (1959) gave detailed description of moose (Alces alces L.) damage on 31 year old lodgepole and Scots pine, comparing two 0.25 hectare adjacent sample plots of the two species. On each plot 3 % of the trees were damaged. The moose had been browsing on shoots and needles of Scots pine, while the bark had been peeled off the lodgepole pines (Photographs on p. 37, KARVINEN and RIKKONEN 1959). Shoots and needles were not damaged on lodgepole pine. The wounds, a couple of years old had resulted in intensive resin flow. The authors did not consider the damage to be of any serious consequence for the development of the stand. KARPPINEN and SIIRILÄ found browsing by moose in one stand out of 20 investigated. The damaged stand was 28 years old with a dominant height of 12.8 meters. The damage was not described in detail. BRANDER (1961) observed damage by moose and white tail deer (Odocoileus virginianus L.) on several foreign tree species in Nuutajärvi arboretum but did not particularly mention damage on lodgepole pine. In personal communication with the author (14.7.1972) he reported that neither animal had caused damage on any of the stands of lodgepole pine (total area 9.98 ha) in the arboretum. The lack of damage was assumed to be partly due to the large size of the trees at the time of observation.

Damage caused by reindeer (Rangifer tarandus L.) cleaning their antlers, was observed by this author in 1972 in Kivalo. The trees, about 0.8-1.5 meters high, had the bark damaged on small areas at a height of 0.3-0.7 meters. The importance of such damage was hard to assess since only a few trees were found damaged by reindeer of those less than 50 trees remaining of stands sown in patches in 1935.

Damage caused by hares (Lepus timidus L.) caused 100 % mortality in IUFRO provenance 2109 (N 34°13', E 25°31'). The other 20 provenances were completely undamaged. The southernmost of those provenances was from Cypress Hills, Alb. (N 49°37', W 110°18').

65. Damage Caused by Abiotic Agents

Damage caused by accumulation of snow in the crown is the most frequently reported damage on lodgepole pine grown in Finland. Such damage was reported by KUJALA (1950). HEIKINHEIMO (1956) reported that of all foreign tree species grown in Finland, *Pinus contorta* is most susceptible to snow damage and especially so in the Experiment Forests of Kivalo and Vesijako. Well-managed stands have suffered less than poorly-managed stands. KARPPINEN and SIIRILÄ (1963) reported snow damage in three out of some 20 stands of lodgepole pine studied in the Korkeakoski Forest District. In the survey of 55 stands conducted for the present study 25 % of the professional foresters (a total of 32 persons) reported that snow damage has been the most serious damage in the stands of lodgepole pine they have managed. One permanent experiment plot in Mustila was discontinued due to snow damage when the stand was 49 years old. The provenance was Banff, Alb. (N 51°12', W 115°25', elev. 1 200 m, 1 250 d.d.).

The poor self-pruning ability of lodgepole pines grown in Finland suggests that the pliable, strong, and slowly decaying branches tend to accumulate more snow than the stem is able to endure.

The role of snow damage in providing suitable conditions for parasitic fungi is mentioned in connection with reports on *Scleroderris lagerbergii*. Overly dense stands, susceptible to snow damage, may provide conditions favouring attacks by the fungus.

Damage due to extremely cold temperature has been studied by HEIKINHEIMO (1956) and LEIKOLA (in prep.). The extremely cold winter of 1939-1940 caused damage even to native tree species (HEIKINHEIMO 1940). According to a subjective grading scheme, lodgepole pine was rated among the hardy species together with such species as *i.a.* *Abies balsamea* (L.) Mill., *Larix decidua* Mill., *Picea Engelmanni* (Parry) Engelm., *Picea mariana* (Mill.) B.S.P., *Pinus Cembra* (L.), *Betula papyrifera* Marsh., and *Populus suaveolens* (Fisch). Consequently, lodgepole pine belongs to a group of species that traditionally are known to endure the winter climate of southern Finland at least. Most of the stands were at that time some 5-15 years old, and all of them were located in southern Finland. Five stands in northern Finland in Kivalo (N 66°19', E 26°40', elev. 240 m, d.d. ca 760) were not investigated at that time. One of the stands is probably of provenance Spirit River, Alb. (N 55°47', W 118°49', elev. 500 m(?), d.d. ca 1 300). At the age of 38 years this stand was severely damaged by the cold summer and exceptional fall of 1968[1].

In the fall of 1969 all trees were classified (LEIKOLA, in prep.) into four subjective damage classes (Table 9), indicating that the dominated trees had suffered much more than the dominant trees (14.8 % vs. 0.7 % and 16.9 % vs. 0.3 % of the trees were classified

[1] The winter of 1967-68 was long and the summer started late. Warm weather occured only during a few days around the 1st of July, in the end of August, and at the beginning of September. 20 days after the warm days in September, a record low temperature occurred, and October was exceptionally cold. The rapid beginning of winter left green leaves in several hardwoods, and the conifers may not have hardened off as during normal autumns. The summer of 1969 was extremely dry (VALTANEN 1971).

Table 9. 1968 cold damage to lodgepole pine, provenance 9(?) grown in Kivalo (N 66°19', E 26°41', elev. 240 m d.d. ca 760).

Damage[1)] class	Four light thinnings (1036 trees/ha, age 36)	
	Dominant trees	Dominated trees
	% of trees within each class	
I	32.0	19.2
II	57.3	30.4
III	10.0	35.6
IV	0.7	14.8
Totals, %	100.0	100.0
Total no. of trees	391	135
	Four intensive thinnings (740 trees/ha, age 38)	
I	34.9	20.0
II	58.9	40.0
III	5.9	23.1
IV	0.3	16.9
Totals, %	100.0	100.0
Total no. of trees	304	65

1) Classification:
- I = No damage
- II = Slight damage; foliage damaged only on the current and immediately preceeding shoots
- III = Severe damage; braches damaged on more than the current and immediately preceeding shoots
- IV = Dead or dying; more than 1/4 of the foliage damaged

as IV). The degrees of thinning hardly effected the cold resistance of the dominant trees, while the dominated trees had suffered somewhat more in the lightly thinned stand. The foliage and shoots of comparable Scots pines had not been visibly damaged as a result of these climatic conditions.

Consequently, the results suggest that a well-managed stand with wide spacing and even canopy may endure exceptional climatic conditions better than a more dense stand with uneven canopy. A provenance hardier than that of Spirit River (?) may have suffered less. When inspecting the stand in the spring of 1972 this author found most of the trees in a vigorous condition. The severely damaged trees had recently been salvaged.

Of the four other stands in Kivalo, one of provenance Mount Ida (N 50°50', W 119°00', elev. 900 m, d.d. 1500) suffered so badly that much of the stand was cut down in 1969-70. In the summer of 1972 this author found the stand in a poor condition with large openings and only forked trees left. At the present time the three other stands consist of only a few individuals unsuccessfully competing with naturally regenerated Scots pine. The provenances Long Lake, Barnes Creek, Cypress Hill, Nicola Forest, and Spirit River (Table 2) are represented in these stands established by sowing in patches.

KARVINEN and RIKKONEN (1959) found only slight damage due to cold in the 31 year old stand at Siikakangas in Korkeakoski Forest District. They did not consider the damage to be of any consequence for growth of the trees.

With one exception[1)] there are no published reports on the spring and autumn frost tolerance of young seedlings. The low mortality of lodgepole pines planted on peatland in southern Finland and on mineral soils in northern Finland suggests that the frost tolerance may be comparable to Scots pine.

Damage due to wind throw has been reported in a few cases(e.g.YKSPUU, pers. comm. 1972). It has to be noted that the lodgepole pine has no taproot and consequently it is not as firmly rooted as e.g. Scots pine. In the survey of 55 stands conducted in the present study no professional foresters (a total of 32 persons), however, reported damage due to wind throw.

66. Discussion and Conclusions

The total role of damage by abiotic and biotic agents is extremely difficult to assess. Some guidance is found in the fact that in the survey of 55 randomly selected stands out of some 165, 40 % of the 32 professional foresters reported that no serious damage had been observed in the stands while 20 % reported that no such damage was known to have occurred. The remaining foresters had reported snow damage (25 %) and damage due to insects or diseases (10 %) while 5 % reported competition with other species. Fiftynine percent considered the species to be more susceptible to damage than Scots pine, while 28 % considered the two species equally susceptible. Thirteen percent considered lodgepole pine less susceptible than Scots pine.

1) For the exception, see Table 8.

Of all the 46 permanent experiment plots managed by the Forest Research Institute, only one has so far been discontinued due to snow damage. Two other ones have been discontinued due to reason not stated in available records. One of the two stands in Kivalo may be discontinued because of its presently very poor condition due to the cold damage of 1968.

Of the known damage due to specific biotic agents, that of Fomitopsis annosa, Hylobius abietis, Evetria resinella, Scleroderris lagerbergii, and Pissodes validirostris may be the most serious ones. It has to be kept in mind that the sceltered and small populations of lodgepole pine presently growing in Finland may not have provided sufficiently large breeding material for insects to cause their populations to increase. The same may be true for fungi; susceptible tissue may not have been present in sufficient amount to allow for rapid growth of pathogen populations. The cultivation of a new species on large areas may change the situations in favor of pathogenes or insects, introduced or endemic.

In general it appears that well-managed stands, frequently thinned, well-spaced, and with even canopy, may be able to reach the age of 40-50 years without serious natural mortality. The choice of more suitable provenances may improve the condition of future stands.

7. OVERALL CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to collect, organize, and analyze all available information on lodgepole pine grown in Finland, thus providing a basis for estimating the necessity of additional field work and identifying specific areas of incomplete knowledge requiring further research.

All available information has hardly been collected. While this is true especially for field work presently conducted or very recently completed, it is, however, felt that the most important information with respect to the other objectives of this study has been collected and organized.

The most important conclusion from the present study are briefly summarized as follows:

1. There are over 300 stands of lodgepole pine in Finland. Most of them are fairly evenly spread out over the country south of N 65°. There are 46 continuously measured experimental plots, 44 of which are located south of N 62°. Although most of the stands are of about the same age, the existing stands provide material for further measurement of growth and yield as well as for selection of plus trees, studies of damage by biotic and abiotic agents etc. Very few stands are on organic soils. The few stands established after

1968 are rather large and provide good possibilities for studying the development of young stands.

2. On the sites MT and OMT in Punkaharju and on MT, OMT, and PyT in Mustila most provenances in densly-planted, frequently-thinned stands have, until age 40, outgrown several kinds of stands of native species established in southern Finland with genetically unimproved seed. Some uncertainty exists with respect to the performance on VT. Stands thinned only once or not at all until age 40 do not appear to have outgrown, with a few exceptions, repeatedly thinned stands of native species. At about age 50 many lodgepole pine stands on MT appear to produce less than Scots pine on that site, and on OMT less than Norway spruce on that site. It is very dicficult to predict, based on the present information, the total yield of genetically unimproved, not to mention improved, lodgepole pine compared to the predicted total yield of genetically improved native species of Finland.
3. There are no preserved records of the provenance of approximately 70 % of the older stands in Finland. The few known provenances represented in older stands do not provide a basis for judgement on their relative performance. In general, the tested provenances from 900 d.d.-1 500 d.d. north of N 50^{o} in western Canada have preduced satisfactory total yields in Finland south of N 62^{o}. At elevations of 160-240 m located north of N 65^{o} none of the provenances have grown satisfactorily. The relative performance of about 110-120 newly introduced provenances is not yet known.
4. The production of lodgepole pine seed in Finland is severely reduced by damage due to Pissodes validirostris Gyll.
5. Providing that the damage by Pissodes validirostris is controlled and that lodgepole pine has sufficient genetic variation, there appears to be a satisfactory

supply of breeding material for cultures in northern Finland when the recently-established seedling seed orchard and gene bank start flowering. The clonal seed orchard to be established will provide seed and breeding material for cultures in southern Finland. The selected plus trees to be included in the orchard have a selection differential for volume of 25 %-30 %. There are possibilities for accurately measuring selection intensity for a number of these plus trees.

6. It appears that most densly-planted, well managed, and frequently-thinned stands in southern Finland are able to reach the age of 40-50 years without serious mortality due to biotic and abiotic agents. Some damage by e.g. Hylobius abietis, Evetria resinella, Scleroderris lagerbergii, and Fomitopsis annosa may occur during various stages of the stand development. Larger, even-aged monocultures of lodgepole pine may, however, in the future provide sufficient breeding material and susceptible tissue for rapid increase of populations of introduced or endemic insects and pathogens.

In order to increase our knowledge of the cultivation and breeding of lodgepole pine the following measures are recommended:

1. A satisfacotry sample of the existing, over 300 young and old cultures of lodgepole pine should be investigated in order to:
   - measure the yield of only once or not all thinned stands
   - measure the yield of stands on VT, MT, and OMT on other, more northern locations than Ruotsinkylä, Punkaharju, and Mustila, especially the performance on VT should be investigated
   - the few stands established after 1968 should be continuously measured (growth and yield) and observed

(damage by biotic and abiotic agents) by establishing permanent experimental plots both in them and in adjacent stands of native species on comparable sites.

2. Acceptable control curves for total yield of native species should be constructed in Ruotsinkylä for VT, and in Punkaharju for MT and OMT. The total yield of lodgepole pine should subsequently be compared to such curves.
3. When establishing stands in the near future using newly imported seed (in the spring of 1972) the following should be considered:
   - absolutely relaible records should be maintained of origin of seed and planting material
   - several replications of various provenances on each major mineral- and organic-soil site type, especially north of N 62^{o}, should be established
   - controls of native species raised from genetically superior material should be established at the same time. Preferably the controls should consist of standards used in the other genetic experiments
   - comparisons between planting and sowing, various spacing, and various thinning programs should be made. Nursery techniques should be developed
4. In order to facilitate possible future breeding of the species the following should be considered:
   - control measures for Pissodes validirostris should be investigated
   - to obtain good breeding material for cultures for the southern part of the country the provenancs including in the gene bank should preferably be tested on a few more locations and sites in southern Finland (including areas south of N 65^{o}).

areas south of N 65^{o})

- when selecting plus trees attention should be paid to wood quality and needle dry weight
- in genetic experiments the controls of native species should consist of best available genetically improved material and/or standards included in genetic experiments with the native species.

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