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GREMMENIELLA DISEASE AND SITE FACTORS AFFECTING THE CONDITION AND GROWTH OF SCOTS PINE

TUOVI AALTO-KALLONEN AND
TIMO KURKELA

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HELSINKI 1985

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Cover (front & back): Scots pine (*Pinus sylvestris* L.) is the most important tree species in Finland. Pine dominated forest covers about 60 per cent of forest land and its total volume is nearly 700 mil. cu.m. The front cover shows a young Scots pine and the back cover a 30-metre-high, 140-year-old tree.

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The development of the epidemics caused by *Gremmeniella abietina* (Lagerb.) Morelet was studied in six young Scots pine stands. The age of the cankers and the changes of leader shoot were observed; and the size and increment in height and radius in the trees were measured. The trees were classified according to their condition. The disease intensity on the sample plots was compared to some site characteristics.

The stands were surveyed in 1979, although the epidemics did not culminate until 1982. The trees in the worst condition were at the bottom of topographic depressions where the microclimate could be more favourable for the causal fungus than for the pines. A water drainage channel passing through the area and increasing relative humidity was characteristic of the disease centers.

Some of the cankers which are the earliest signs of the disease were already established at the beginning of the 1970s. A great many changes of the leader shoot occurred in 1975 and later.

Radial increment in the trees culminated in 1972—1973 and height increment one or two years later. The main reason for this culmination could be the poor climate situation at the same time as the canopy closed and competition among trees became harder: the growth curves of the trees which were dead in 1979 separated from the other trees at that time. The growth respons to the disease according to the disease incidence in living trees was generally obvious two or four years later (in 1975—1977). Losses in growth in the studied stands depended on the average condition of the trees. The losses in radial increment varied between 7.4—54 %, and in height increment between 11—58 % in 1978.

Versosyöpäepidemian kehitystä tutkittiin kuudessa riukuasteen männikössä. Inventoinnissa koepuista mitattiin pituus- ja sädekasvu sekä määritettiin suurimpien korojen syntymäaika ja latvanvaihtojen ajankohta. Puut luokiteltiin kunnon mukaisesti. Koealojen puuston kuntoa verrattiin kasvupaikan ominaisuuksiin.

Inventointi tehtiin kesällä 1979, mutta epidemia saavutti huippunsa vasta 1982. Tauti oli heikentänyt puita ankarimmin painanteiden pohjalla, missä mikroilmasto todennäköisesti suosi enemmän sienen (taudin aiheuttajan) kuin männyn (isäntäkasvin) kehitystä. Tautikeskukselle oli tyypillistä alueen läpi tai ohi virtaava joki tai oja, mikä lisäsi paikallisesti suhteellista kosteutta.

Varhaisimpina merkkeinä taudista todettiin rungoissa koroja joita oli alkanut muodostua jo 1970-luvun alkupuolella. Latvanvaihtoja oli tapahtunut pääasiassa vasta vuonna 1975 ja sen jälkeen.

Puiden sädekasvu saavutti huippunsa vuosina 1972—1973 ja pituuskasvu vuoden tai kaksi myöhemmin. Kasvun heikentymiseen lienee pääsyynä kasvukausien sääsuhteiden heikkeneminen sekä samanaikaisesti tapahtunut latvuston sulkeutuminen ja puiden keskinäisen kilpailun lisääntyminen. Jo kasvun kulminoitumisvaiheessa heikkeni vuonna 1979 kuolleeksi todettujen puiden kasvu voimakkaimmin erottuen selvästi toisista puista. Elävinä säilyneiden puiden kasvussa taudin vaikutus alkoi näkyä muutamia vuosia myöhemmin, 1975—1977. Kokonaiskasvutappiot tautipesäkkeissä riippuivat taudin ankaruudesta. Keskimääräinen sädekasvutappio oli vuonna 1979 7,4—54 % ja pituuskasvutappio 11—58 %.

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CONTENTS

1. INTRODUCTION

During the later half of 1970s the fungus *Gremmeniella abietina* (Lagerb.) Morelet (= *Ascocalyx abietina* (Lagerb.) Schläpfer) caused serious damage in young Scots pine *(Pinus sylvestris* L.) stands in several places in Southern Finland (Kurkela 1981). Previously the fungus had been more important in Scots pine forests in Northern Finland. The fungus is commonly present on the weakest trees and branches in connection with a low rate of assimilation. The fungus is a pathogen which needs favorable weather and predisposed hosts to reach epidemic proportions (Björkman 1961). As factors favoring the onset of epidemics, Read (1967, 1968) mentions: low average temperature, shade, and high relative humidity during a growing period, which predispose the host for infection and favor the development of the pathogen. In healthy pine stands, the fungus may promote natural pruning (Siepmann 1975).

Read (1968) compared healthy and diseased Corsican pines and observed a clear dependence of poor growth on disease severity. Butin and Hackelberg (1978) classified trees in a diseased stand of *Pinus nigra* according to the annual rate of radial increment. By comparing the growth rate of healthy and diseased trees, they determined the year of infection: the intensity of the attack was characterized by the number of dead or living branch whorls and internodal lengths. Gibbs (1984) also described the decreasing growth pattern caused by the disease. The value of lost transplants, reforestation costs in damaged sites, and quality losses in diseased trees have been discussed by Teich (1972) and Dorworth (1979).

In the present work, factors favoring the outbreak of epidemics in Scots pine stands were investigated. Growth losses of trees, classified according to disease severity, were calculated. The value of the stands for further growth and silvicultural measures are also discussed. A preliminary report of this work was presented as a thesis for the degree of M. F. Sci (University of Helsinki, Department of Forest Management) by Tuovi Aalto-Kallonen (Aalto 1980). Another brief report was given by Kurkela (1984) at the International Symposium on Scleroderris Canker of Conifers, Syracuse, USA, June 21—24, 1983.

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2. MATERIAL AND METHODS

21. Stands investigated

Six young Scots pine stands suffering from Gremmeniella canker and die-back were surveyed in 1979 (Table 1 and 2). The stands were located in Southern Finland (Fig. 1). Five of them had been established by sowing and one by planting. The sowed stands had been thinned once. Two of the stands were fertilized (Table 1). Due to artificial reforestation, the trees in the stands were of the same age. In Palojärvi, the stand consisted of two groups of trees of differing ages. Site classification of the sample plots was made according to the floristic, forest-type system (Cajander 1949). The plots fell mainly into Myrtillus (MT) or Vaccinium (VT) -types (Table 2). Although the earlier type of forest in the studied areas was not known for certain, in most cases it probably was by spruce.

The documentation of the seed origin for the studied stands was inadequate. For Multia, seed was most likely collected in the area 70—150 km to the west of Multia. The seed used in Kuru, Itä-Aure was obtained from a local seed extractory, but it was not known where the cones were collected. Pines in Palojärvi probably had their origin in Rautavaara, 30—60 km to the west. The origin of pines in Koiravaara could not be traced. The stand in Hyytiälä was of exceptional origin: the pines were the free pollinated progeny of a single tree, E 627, selected for breeding purposes. The mother tree is located in Sulkava, about 200 km to the east of Hyytiälä. In any case, the elevation difference between the sites of the seed origin and the studied sites could hardly exceed 50 m.

Thus, any possible inadequate frost hardiness of pines in the studied stands could not be derived from a wrong geographical origin. Scots pine originating from southern countries, e.g. from Poland, will definitely suffer from serious frost damage and Gremmeniella cankers if grown in Finland. Due to their narrow genetic base, the pines in Hyytiälä might have a high inherited susceptibility to *Gremmeniella abietina.*

Each stand was thinned or cleared except the planted one in Hyytiälä. Thus overstocking or too high density cannot be considered as a predisposing factor. Fertilization is often thought to make forest trees susceptible to pathogens. Of the studied stands, two were fertilized, Palojärvi once and Hyytiälä three times. However, the size of the material did not allow us to make any conclusions as to the effect of fertilization on the disease.

22. Methods for survey and measuring of trees

In the sowed pine stands, the sample plots were delineated by the line circular plot survey method. In Multia, Kuru, and Palojärvi, topographic maps with a scale of 1:4000 with 2 m contour lines were drawn (by Kaavakartta Oy) using aerial stereo photographs. In Koiravaara, an ordinary topographic map with a scale of 1:10000 was used in

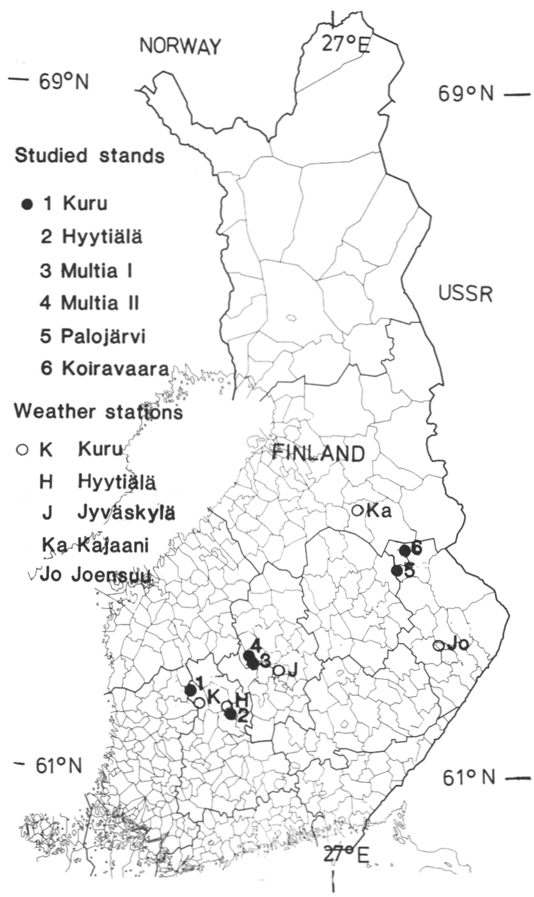

Figure 1. The locations of the studied stands and the weather stations where the data for temperature and precipitation, used in this study, were obtained.

Kuva 1. Tutkittujen metsiköiden sijainti sekä sääasemat, joiden lämpötila- ja sadehavaintoja käytettiin tässä tutkimuksessa.

Table 1. The surveyed stands and their management history.
Taulukko 1. Tutkitut metsiköt ja niiden aiempi käsittely.

Stand *Metsikkö*	Altitude *Korkeus mpy* m	Silvicultural management — *Metsänhoitotoimet* Sowing *Kylvö*	Planting *Istutus*	Clearing/thinning *Perkaus/harvennus*	Fertilization *Lannoitus*
Kuru	166—180	1954		1970	
Hyytiälä	140		1960		1963 and late 60s and 70s *1963 sekä 1960- ja 1970-luvun lopulla*
Multia I	138—152	1948		1956	
Multia II	146—158	1958		1966	
Palojärvi	160—178	1937 (1) 1954 (2)		1975 (1) 1961 (2)	1970
Koiravaara	150—165	1954		1977	

Table 2. Some characteristics of the surveyed stands.
Taulukko 2. Tietoja tutkituista metsiköistä.

Stand *Metsikkö*	Forest type[1]) (fertility) *Metsätyyppi*	Size *Koko* ha	Number of sample plots *Koealoja*	Number of trees on plots *Puita koealoilla*	Average stocking *Keskitiheys*	$D_{1,3}$, cm
Kuru	MT-VT-KgK	22,5	114	1708	1500	8,1
Hyytiälä	MT	0,7	—	1024	1460	12,3
Multia I	MT[2]) -VT[2])	9,5	66	1504	2280	3,6
Multia II	VT -VT[2])	13,0	30	525	1750	7,1
Palojärvi	MT -VT[2])	9,5	59	687	1160	11,6
Koiravaara	MT -VT[2])	28,0	64	959	1500	9,3

[1]) see e.g. Cajander (1949), Heikurainen (1960)
[2]) stony — *kivinen*

the survey. The sample plots were located on the maps (Appendixes 1—3). For the survey, a line direction was chosen which seemed to give the most representative result in each area. This line was in the main perpendicular to the contour lines. In each case, those parts of the stands which were suffering from the disease were surveyed. For the sudy areas in Multia I and Palojärvi, a sample plot net of 30×40 m was measured. In Kuru the plot net was correspondingly 30×60 m. In Multia II, the survey was begun using a plot net of 40×50 m. During the survey, it became evident that the damaged area was larger than previously expected. This additional area was surveyed with a 40×60 m sample plot net. For the same reason, the distances used in Koiravaara were 30×60 m and 60×60 m.

The radius of the sample plots was 5.64 m, giving an area of 100 m². The trees on the plots were counted clockwise starting from the arrival direction. Breast height diameter (d) was measured for every tree. The average growing stock in the stands varied from 1160 to 2280 trees/ha, and the average diameter (d) of the trees from 7.1 to 11.6 cm (Table 2). The trees were also classified according to disease severity. Every tenth tree was chosen for more detailed examination. If there were not enough trees in the plots to follow this sample interval, the last tree counted in the plot was taken. In Hyytiälä, pines were planted in 50 straight rows; each tree was examined, and every seventh tree was taken as a sample tree for further studies.

The sample trees were cut with a stump height of 10—15 cm. From the base of each stem, a disc was cut for later measurement of radial increment with a stereomicroscope. Radial increment was thus measured at the stem base rather than e.g. the level of breast height. The growth response to environmental changes at the stem base is usually much stronger than in other parts of the stem (see Vuokila 1960). In addition to $d_{1,3}$, diameters were measured at the base and at the heights of 0.5, 2.0, and 4.0 m in the stems. The total length of the felled stems, and the increment in heigth for the last 12 years, were also measured. The last measured annual shoot was from 1978, since the shoot elongation in 1979 had not yet terminated at the time of the survey. Changes in the main top shoots were also observed in the sample trees. A change, recorded e.g. for the year 1975, means that the leader could have been killed at any time from late 1974 up to the beginning of the growing period in 1975. The year of the establishment of the largest cankers in the tree was determined in the sample trees, using a stereomicroscope.

The disease incidence (DI) classification was based on the condition of the crown of the trees.

The following scale was used:

DI-Class 1) healthy tree
„ 2) only occluded cankers in the stem; the top, branches, and needles in good condition without disease symptoms
„ 3) stem cankers, the last top shoot healthy, dead shoots in lateral branches with brown needles
„ 4) stem cankers, numerous dead shoots in the crown, top shoot dead, lateral branches still mainly living
„ 5) several internodes from the top dead, only a few living branches left
„ 6) dead tree

The trees up to condition class 4 were expected to have some ability to recover. The number of trees in the poorest DI-Classes was higher in the material than that of trees in better condition, since the surveys were restricted to epidemic centers (Tables 3 and 4). The number of sample trees varied by area from 53 to 189. The average breast diameter was between 7.8 and 12.3 cm, and average height between 5.05 and 9.20 m (Table 4).

23. Comparison of environmental factors and condition of pines

An effort was made to deduce the suitability of the growing seasons for the development of pine and the pathogen, using data on the deviations of the monthly mean temperature, amount of precipitation during May to September and the number of frost days during that period.

The temperature and precipitation data were obtained from the Finnish Meteorological Institute. The data from the observation station nearest to each study area were used. Average monthly precipitation from May to September in 1964 to 1978 was compared to the long term average from the period 1931—1960 (see Helimäki 1967). The monthly mean temperatures from the period 1961—1975 were used as reference values for studying the effect of the deviation of temperatures on the outbreak of the disease (see Heino 1976). Data on the number of frost days were obtained from the Finnish Meteorological Institute.

Table 3. The percentages of pines by DI (Diesease Incidence) class in the total material obtained from the sample plots in each stand.
Taulukko 3. Kuntoluokkien %-osuudet koealoilla luetuista männyistä metsiköittäin.

Stand *Metsikkö*	DI class — *Kuntoluokat* 1	2	3	4	5	6
Kuru	2,2	34,8	21,9	10,6	8,3	22,2
Hyytiälä		5,3	35,7	17,2	16,4	25,4
Multia I	3,9	21,5	31,4	9,1	12,8	21,3
Multia II	0,4	11,8	29,3	14,9	15,8	27,8
Palojärvi		24,9	44,4	16,2	8,2	6,3
Koiravaara	2,1	57,7	27,0	7,7	2,9	2,6

The elevation of the sample plots was determined from maps with contour line intervals of 2 m. The year of death (Class 6) was obtained by comparing the annual radial growth of dead and healthy trees.

The effect of the disease on the growth of pines was determined by comparing the growth of diseased trees to that of healthy ones, and to the growth rate before the outbreak of the epidemic. In those cases in which the number of healthy trees was inadequate or there were no healthy trees in the stand, reference growth data was obtained from trees in the DI-Class 2.

The sample tree material was divided into three diameter classes by areas. The first group consisted of trees with a diameter < 85 % of the average d, the second group with a diameter of 86—115 %, and those with d > 115 %. In Palojärvi the higher threshold value was 110 % (Table 5). The growth in these size classes during the epidemic was examined by comparing it to the growth in the beginning of the study period.

Table 4. The number of sample trees, their breast height diameter (d), and percentages of the trees in different disease incidence (DI) classes according to the tree size (diameter) classification. A = small trees, B = medium-sized trees, C = tall trees, and D = the total sample tree material, for which also the average height (H) is presented.

Taulukko 4. Puuluku, rinnankorkeusläpimitta d ja tautisuusluokkien (DI) suhteelliset osuudet, kun puut on jaettu rinnankorkeusläpimitan mukaan kolmeen kokoluokkaan. A = pienet, B = keskikokoiset, C = suuret puut ja D = kaikki koepuut yhteensä. = koepuiden keskimääräinen pituus.

Tree size class *Kokoluokka*	DI (%)	Kuru	Hyytiälä	Multia I	Multia II	Palojärvi	Koiravaara
	Number of trees (No.) — *Puuluku, kpl*	70	47	42	11	16	30
	d (cm)	6,1	7,3	6,2	5,6	8,5	6,8
A	1			2,4			3,3
	2	20,0	2,1	2,4		26,3	50,0
	3	24,3	10,6	42,9	18,2	31,6	33,3
	4	15,7	8,5	19,1	18,2	31,6	3,3
	5	12,9	14,9	16,7	45,5	10,5	6,7
	6	27,1	63,8	16,7	18,2		3,3
	No. — *kpl*	65	60	60	26	18	41
	d	8,5	11,0	8,9	7,4	11,7	9,9
B	1			5,0			2,4
	2	41,5	8,3	26,7	19,2	22,2	63,4
	3	24,6	61,7	36,7	19,2	66,7	22,0
	4	6,2	13,3	11,7	27,0	11,1	4,8
	5	9,2	11,7	11,7	27,0		4,8
	6	18,5	5,0	8,3	7,7		2,1
	No. — *kpl*	54	39	55	16	36	24
	d	11,2	14,4	12,2	9,9	14,6	12,8
C	1			9,1			4,2
	2	50,0	48,7	47,3	31,3	41,7	58,3
	3	16,7	33,3	23,6	50,0	36,1	37,5
	4	11,1	15,4	9,1	12,5	14,0	
	5	7,4		9,1	6,3	8,3	
	6	14,8	2,6	1,8			
	No. — *kpl*	189	146	157	53	73	95
	d	8,4	10,7	9,3	7,8	12,3	9,7
	H, m	6,10	6,95	8,05	5,05	9,20	6,40
D	1			5,7			3,2
	2	36,0	17,1	27,4	18,9	32,9	57,9
	3	22,2	37,7	33,8	28,3	42,5	29,5
	4	11,1	12,3	12,7	20,8	17,8	3,2
	5	10,1	9,6	12,1	24,5	6,9	4,2
	6	20,6	23,3	8,3	7,6		2,0

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Table 5. The number of frost days in June, July, August, and September at the weather stations during the period from 1964 to 1978.
Taulukko 5. Hallapäivien määrä kesä-, heinä-, elo- ja syyskuussa vuosina 1964—1978.

Weather station *Sääasema*	Month *Kuukausi*	Year — *Vuosi* 64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Kuru	VI	3	3		1	4	2	3	5	2	6	6	15	9	8	5
	VII				2	1							7	1		3
	VIII			5		2	2	1	3	2	6	1	2	6	7	5
	IX	4		4		1	4	1	8	6	9	3	3	7	4	2
Hyytiälä	VI	7	3	2	1	3	4	2	7	2	2	7	12	9	7	6
	VII	5	3		2				2				4		1	
	VIII	5	1	5		4	5	1	4	2	2		4	4	9	4
	IX	5		4		1	4	4	8	5	8	2	4	6	4	1
Jyväskylä	VI	1					2	1	1			2	7	9	7	4
	VII								1				3			1
	VIII	2	2	2			2	1	1	1	1		5	3	5	1
	IX	4	1	3			3	1	6	5	6	2	3	6	6	1
Joensuu	VI	1	1	1				2	1			2	2	2	6	2
	VII												1			
	VIII	1		2						1	2		2	2	4	1
	IX	1	1	1				1	3	4	5	2	1	6	3	1
Kajaani	VI	3	5	2	4	3	3	3	3		1	5	3	5	2	3
	VII	1				1			3				1			2
	VIII	3	1	5		3	3	1	1	2	1		3	4	7	2
	IX	3	2	4	1	1	6	2	7	4	7	2	2	6	1	3

3. RESULTS

31. Climatic conditions and the outbreak of disease

The amount of precipitation varied greatly both under and above the long-term average. The rainiest seasons did not necessarily occur at different stations in the same years. In Jyväskylä, the years 1967, 1973, 1975 and 1977 were clearly distinguished with heavy rainfall during the growing seasons. In the east, in Joensuu, the growing seasons seemed often to be dryer than normal, seasons of heavy rainfall occurred e.g. in 1973 and 1974. The rainy seasons in Kuru were in 1966, 1975, 1977; and in Hyytiälä in 1967, 1972, 1974, 1977, and 1978. In Kuru, much of the rain fell in August and September. As a consequence of heavy precipitation, high relative humidity was available for the development and dissemination of the pathogen. However, exceptionally high precipitation alone could hardly predispose pines to the disease; but the average light intensity is usually decreased during a rainy season, which may increase the effect on the host. The occurrence of long cloudy periods during the growing season is known to be a strong predisposing factor, regardless of the amount of precipitation. The late summer and autumn of 1974 were exceptionally rainy with poor light intensity for photosynthesis. The relative number of killed trees was higher in the groups of short than of tall trees (Table 4). The reason for this could be a combination of factors, including competition within the stands and more effective shading (cloudiness combined with the presence of taller trees), as predisposing factors for the disease.

High precipitation during the summer months is often connected with lower temperatures. This tendence was also found in the climatic data used in this study. In Jyväskylä, cold seasons occurred in 1964, 1969, 1976, 1977, and 1978. In Joensuu, the monthly averages were mostly above the reference level, but the coldest summers there were also in 1977 and 1978. Low averages were recorded in Kuru in 1965 and 1968, and continuously beginning in 1973. In Hyytiälä, the three coldest seasons were in 1965, 1971, and 1976. Long cool periods and low minimum temperatures during the 1970s lowered the average temperature of the summer months. The number of frost days was exceptionally high in 1971 and even more so in 1975—1977 (Table 5). The deviation below the average was relatively more serious in the southwestern stations than in others. However, it has to be remembered that with these climatic data it is possible to demonstrate only the general weather conditions of the area but not to give information on the extreme fluctuation of climatic factors on a particular site.

The number of cankers initiated in the sample trees seemed to correlate with cool growing seasons and the number of frost days (Fig. 2). Only a few cankers initiated in 1978 were detected, possibly due to the fact that the time from the infection to the survey was too short for the development of detectable cankers. Heavy sporulation of *G. abietina* was observed in the late summer of 1978 and 1979, which was followed by the extention of diseased areas until 1980. Then the spread stopped for one year, beginning again in 1981, with the highest degree of damage observed in 1982.

The number of changes in the leading shoot in the sample trees since 1975 has been relatively abundant (Fig. 3).

32. Topogarphy and disease incidence

Topographic variation as a site factor in forest pathology phenomena is closely related to the local micro-climate, especially to variation in temperature and relative humidity. The effect of the elevation of the site on disease intensity was studied in Multia I and II, Kuru, and Palojärvi. In each of these areas, the condition of pines was worst

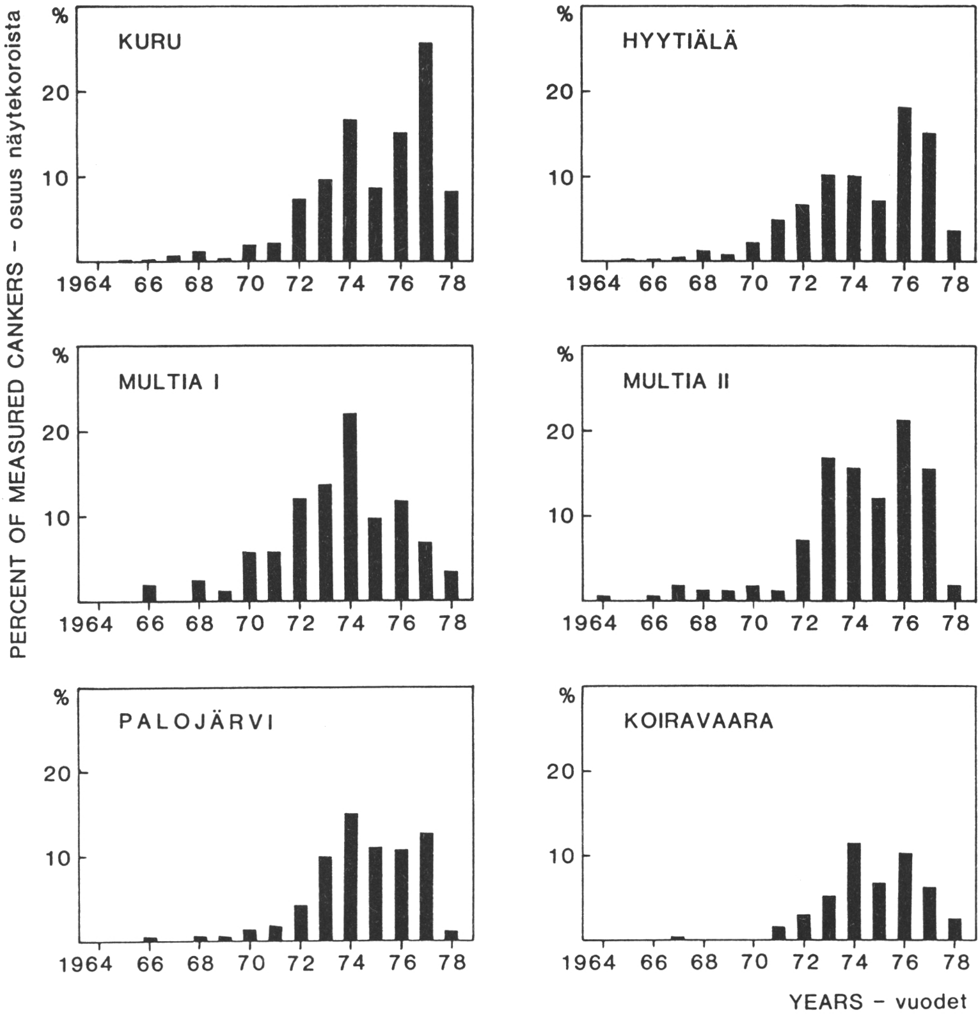

Figure 2. Relative number of the cankers initiated in the stems of sample trees in each year. The three largest cankers were examined in each tree.
Kuva 2. Eri vuosina koepuissa alkunsa saaneiden korojen suhteellinen määrä. Kustakin koepuusta tarkastettiin kolme suurinta koroa.

at the lowest elevations (Appendixes 1—3). The differences were more pronounced when the downward flow of cold air from the depression was blocked by e.g. older forest or terrain. The affected area was most sharply limited in Kuru, where the studied area formed a nearly 1 km long and 100 or 300 m broad frost kettle. In the other areas, the blockage of the depressions was less complete. In Multia I, cool air flowed continuously through a narrow, deep channel to a stream bed at the end of a depression. In Palojärvi, the topographic situation was reversed. The central part of the stand was on the top of a hill and the terrain descended deeply to the west, north, and east.

In addition to temperature gradient, there was also an apparent humidity gradient in each study area, from the highest elevation to the bottom. The stands in Multia, Palojärvi, and Hyytiälä were situated close to a stream. These streams, some smaller water drainages, and adjacent swamps could provide occasionally high relative humidity associated with cool air at the bottom of each study area. The disease was often most intensive along the water drainages.

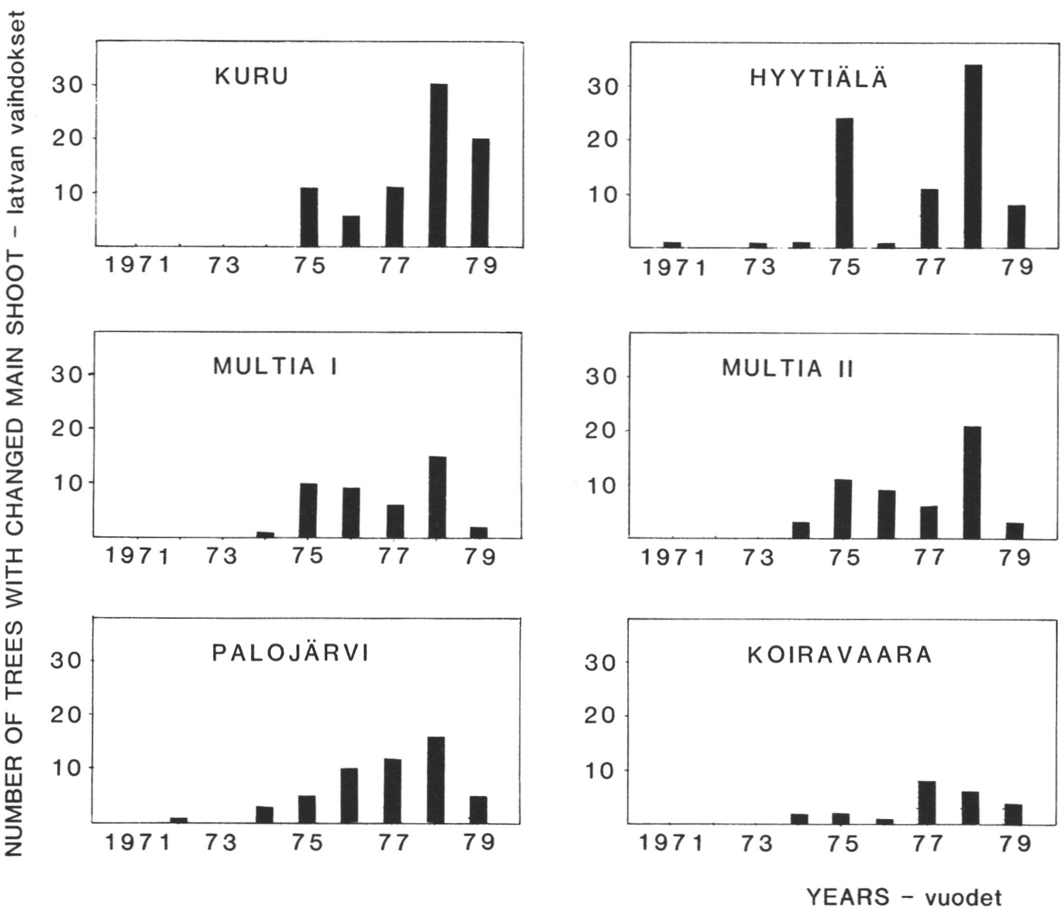

Figure 3. Annual number of the sample trees with changed leader shoot.
Kuva 3. Eri vuosina pääversoa vaihtaneiden koepuiden määrät.

In Multia I the difference between the bottom and the highest elevation was 12 m; and the average disease intensity (calculated from the average DI-classes of individual trees) was 5.3 for the bottom and 2.8 at the highest point. In Kuru the maximum elevation difference was 14 m; and the corresponding difference in the average disease intensity was 3.9 (Fig. 4).

33. Growth response of pines to disease

331. Increment in height

Site fertility had a significant effect on the growth rate in Multia II, Palojärvi, Koiravaara, and Kuru. There was also a significant interaction between the disease intensity and site fertility in Multia II, Koiravaara, and Kuru. In this connection, an interaction between fertility and disease can be better explained in terms of topographic variation: site fertility often varied according to topography. On the other hand, elevation of the site and disease intensity apparently had a close relation with climatic factors.

In 1967—1969 when no Gremmeniella epidemics were observed in southern Finland (in Lapland during the same period, Gremmeniella destroyed thousands of hectars of young pine reforestations [Norokorpi 1971]), statistically significant differences in the height growth between DI-classes

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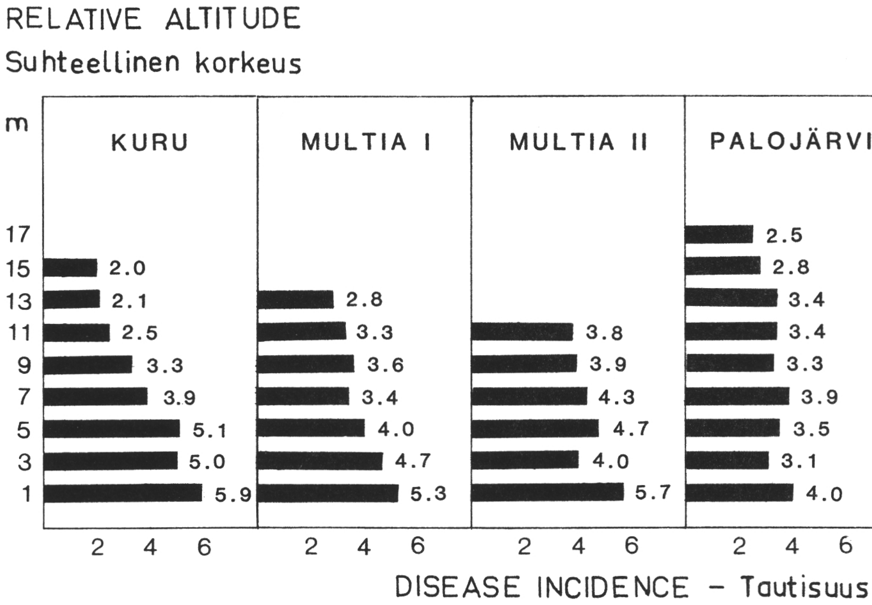

Figure 4. Average disease condition of pines at different elevations in the stands in Kuru, Multia and Palojärvi.
Kuva 4. Mäntyjen keskimääräinen tautisuus eri korkeustasoilla Kurun, Multian ja Palojärven tutkimusmetsiköissä.

were found only in Multia I and Hyytiälä (Fig. 5). If Gremmeniella was not affecting the area at that time, these differences could be explained by the theory that slowly growing trees on unfertile sites at the bottoms of the depressions had been heavily attacked previously. In other places site fertility was distributed differently.

A pattern of increase in the height growth of all stands has been evident since 1969 or 1970. The maximum rate of growth occurred in 1973 or 1974. This increase was obviously a result of favorable weather conditions connected with vigorous juvenile growth. After 1974, the weather became more unfavorable, and the height growth declined in each stand. The most pronounced general drop in the growth rate occurred in 1975, due to both disease and bad weather conditions in interaction, coupled with competition between trees as the canopies closed. In 1975 a remarkable number of trees also changed their leading shoot (Fig. 3).

After 1974, a clear separation of the trees according to disease intensity, DI, was observed in each stand (Figs. 5—6). Statistically significant differences ($P < 0.1$ %) between DI-classes were found in all stands in

Table 6. Increment in height by DI-classes as % of expected value in 1978.
Taulukko 6. Pituuskasvu tautisuusluokittain %:a odotusarvosta vuonna 1978.

Stand — *Metsikkö*	DI class — *Tautisuusluokka* 1	2	3	4	5	6
Kuru		100.0	77.8	58.0	46.7	1.8
Hyytiälä		100.0	99.5	72.3	63.5	9.6
Multia I		100.0	82.5	47.5	32.3	0.0
Multia II		100.0	78.9	60.5	36.1	16.9
Palojärvi		100.0	95.0	63.8	61.5	
Koiravaara		100.0	54.6	31.7	24.6	0.0

1978 (Table 6), which also means that there was a significant interaction between disease intensity and years, except in Palojärvi. The almost parallel growth pattern of different DI-classes has been disturbed since the onset of the epidemic during 1972—1974.

Some differentiation between DI-classes began after 1970 in Multia II, 1972 in Kuru, Hyytiälä, and Koiravaara, 1974 in Multia I, and 1976 in Palojärvi. This fact has some relation to the time of canker initiation (see Fig. 2), although there must also be other factors affecting the growth in addition

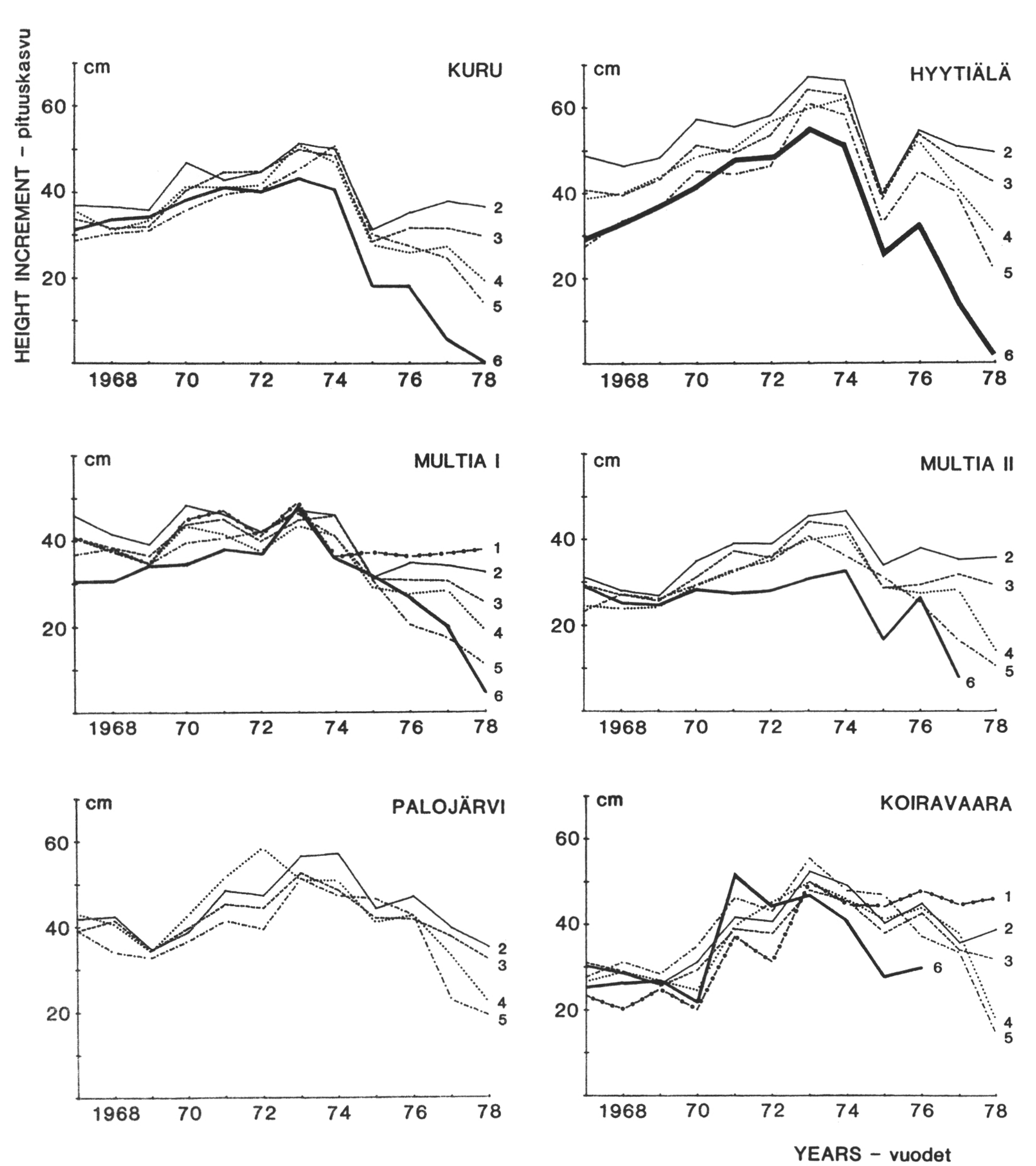

Figure 5. Actual height increment of pines according to disease incidence classes.
Kuva 5. Mäntyjen pituuskasvu tutkimusmetsiköissä kuntoluokittain.

to canker development. It is also difficult to draw correct conclusions because the rate of height growth is primarily determined by the weather conditions of the previous growing season. The disease does not much affect growth in the year of infection, but that of one or more years later, if conditions are favorable for fungal growth in pine bark tissue.

The material from Kuru and Hyytiälä was divided into three size classes according to the diameter of the trees. There was a strong increase in the growth from the level of 1967—1969 until 1974, relatively more in

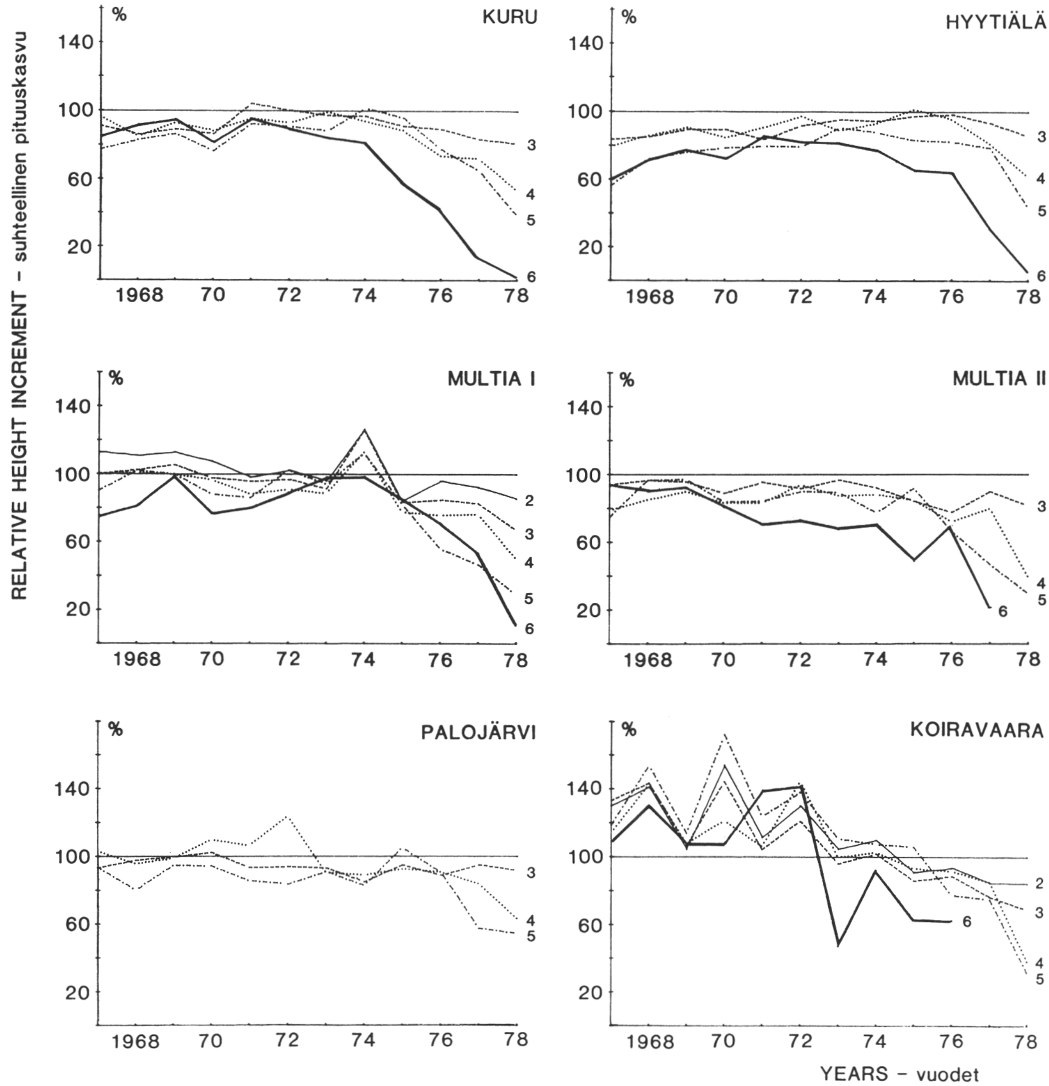

Figure 6. Relative height increment of pines according to disease incidence classes.
Kuva 6. Mäntyjen suhteellinen pituuskasvu tutkimusmetsiköissä tautisuusluokittain.

small trees than in large trees (Fig. 7). After that time the growth of small trees was very seriously affected by the disease, which can be concluded from the clearly different growth rate in different DI-classes (Fig. 7).

Taking the growth of trees in DI-class 1 and 2 to represent the growth trend during the whole study period from 1967 to 1978, and the growth before the epidemics in 1967—1969 to represent the relative growth in different DI-classes, an expected value for normal growth for each DI-classes was computed. The ratio of actual growth to the expected growth gave a percentage indicating the level how much the growth was decreased by the disease (Table 6).

In each stand these percentages for DI-classes varied widely, especially those computed for the period of 1974—1978. That was to be expected, because the time

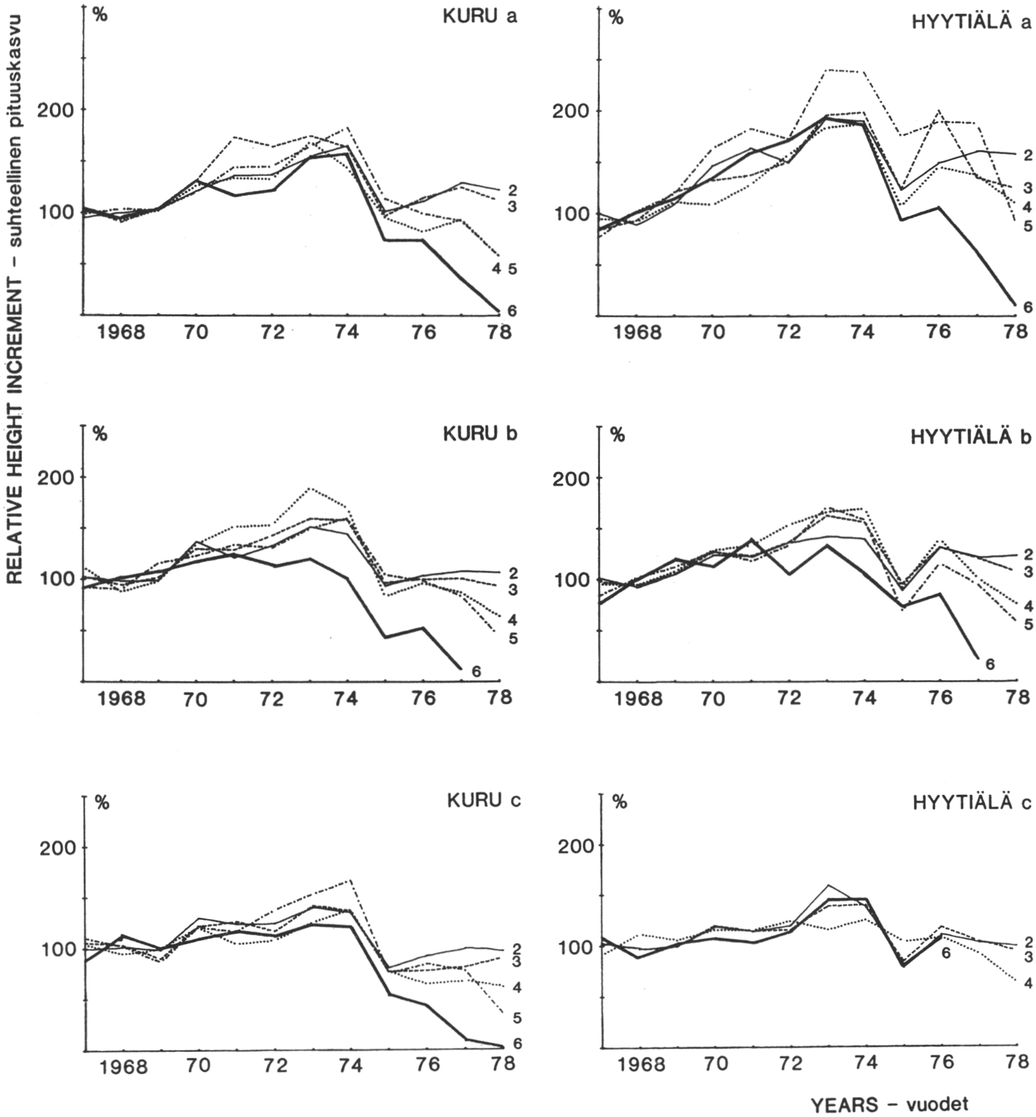

Figure 7. Relative height increment of trees in different size classes in Kuru and Hyytiälä, a) small trees, b) medium sized trees, and c) tall trees. Reference value: the growth during 1967—1969.

Kuva 7. Puiden suhteellinen pituuskasvu rinnankorkeusläpimitan perusteella muodostetuissa kokoluokissa Kurussa ja Hyytiälässä; a) pienet, b) keskikokoiset ja c) isot puut. Vertailuarvo; vuosien 1967—1969 pituuskasvu.

of the onset of the epidemic also varied in different locations. Stand treatments, such as thinning and fertilization could also affect the growth in DI-classes and cause some interaction with and between other growth factors. There was a general descending trend in height according to DI-classes, but during this 5-year period the most remarkable loss was restricted to DI-class 6. In Hyytiälä trees were affected less than in other areas, possible because that stand was fertilized three times. Growth in 1978 was

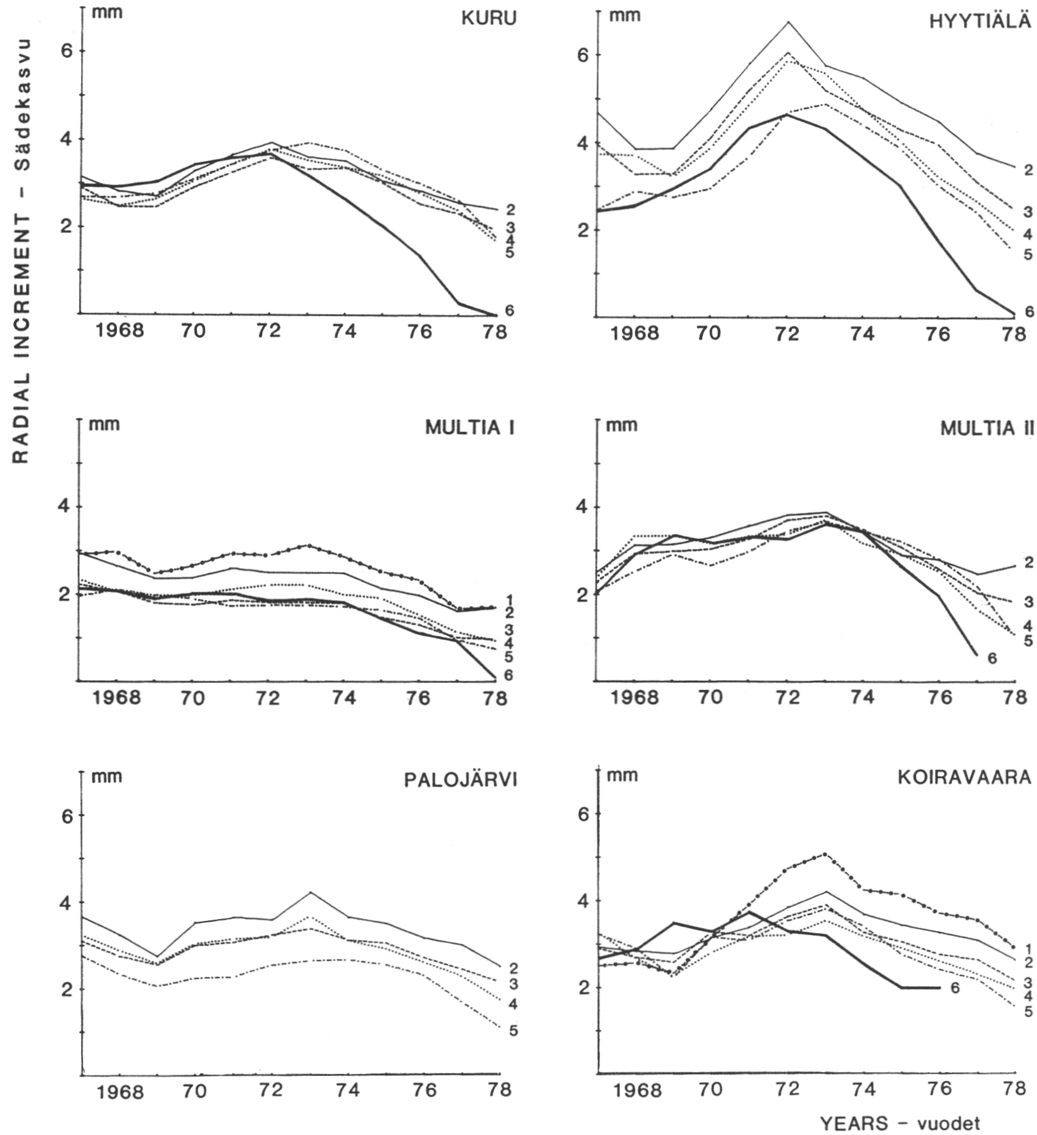

Figure 8. Actual radial increment of pines according to disease incidence classes.
Kuva 8. Mäntyjen sädekasvu tutkimusmetsiköissä kuntoluokittain.

very strictly correlated with DI in Hyytiälä as well.

For the period of 1974—1978, the highest total losses in height growth, 25,5 %, occurred in Multia II, but generally, the average losses were bearable, in Hyytiälä negligible 0,9 % (Table 7). Because of the rapid development of the epidemics, the growth retarded substantially in 1978, the losses exceeding 30 % in all four western stands. In the east, in Palojärvi and Koiravaara, the rate of development was slower and the total losses in height growth there were 11,8 and 13,6 % respectively.

Table 7. The average annual loss of growth increment during 1974—1978 and the increment loss in 1978.
Taulukko 7. Keskimääräinen vuotuinen kasvunmenetys vuosina 1974—1978 sekä kasvunmenetys vuonna 1978.

Stand	Increment loss in the sample trees, % of expected value			
	ir[a]		ih[b]	
	1974—78	1978	1974—78	1978
Kuru	12.3	27.0	14.9	30.4
Hyytiälä	8.5	25.7	0.9	31.1
Multia I	13.3	33.1	15.9	33.4
Multia II	14.0	54.0	25.5	57.6
Palojärvi	3.7	7.4	6.3	11.8
Koiravaara	6.1	9.6	5.6	13.6

a) ir = increment in radius — *sädekasvu*
b) ih = increment in height — *pituuskasvu*

332. Radial increment

Radial growth increased generally from 1969 until 1972 or 1973, when it began to decrease. In Kuru, Hyytiälä and Multia II, the decrease in radial growth occurred one year earlier than the decrease in height growth. In Multia I, Palojärvi and Koiravaara the decrease in both growth rates began at the same time (Fig. 8). Site fertility significantly affected growth in all stands, but again it has to be remembered that fertility was closely associated with topographic differences in these areas. In Multia I, the trees in DI-classes 3—6, and in Hyytiälä DI-classes 5—6, were already growing at a significantly slower rate than other trees in 1967—1969. That might also be connected with site fertility variation. Radial growth correlated well with DI-classification, although the difference between Classes 4 and 5 was not as clear as the differences between other Classes (Table 8). Most trees in the DI-class 6 in 1979 were already dead in 1978.

Table 8. Radial increment by DI-classes as percentages of expected value in 1978.
Taulukko 8. Sädekasvu tautisuusluokittain prosentteina odotusarvosta vuonna 1978.

Stand *Metsikkö*	DI-class — *Tautisuusluokka* 1	2	3	4	5	6
Kuru	—	100.0	89.5	78.4	77.7	11.9
Hyytiälä		100.0	84.4	67.2	67.0	5.8
Multia I		100.0	74.6	69.1	57.7	8.4
Multia II		100.0	73.5	39.3	44.7	0.0
Palojärvi		100.0	99.1	77.0	59.1	—
Koiravaara		100.0	85.0	77.6	60.1	0.0

The relative growth of diseased trees (when compared to the growth of the healthy trees of DI-class 1 or 2) had already begun to decrease in 1970, most clearly so for trees in DI-class 6 in Multia I, Kuru, and Koiravaara. The disease stress and the competition among the trees apparently became still more intense after 1972—1974 (Fig. 2 and 9). A strong differentiation in radial growth followed in all DI-classes, with the inevitable succumbing of the trees in DI 6 in 3—6 years.

As the curves for height growth (Fig. 7), also those for radial growth (Fig. 10) showed that the effect of the disease since 1972—1974 was relatively stronger in small trees than in large ones among which only DI 6 was significantly differentiated from all other classes. It also appears that the later killed (DI 6) large trees increased their growth more effectively after 1968 than the trees in the other DI-classes.

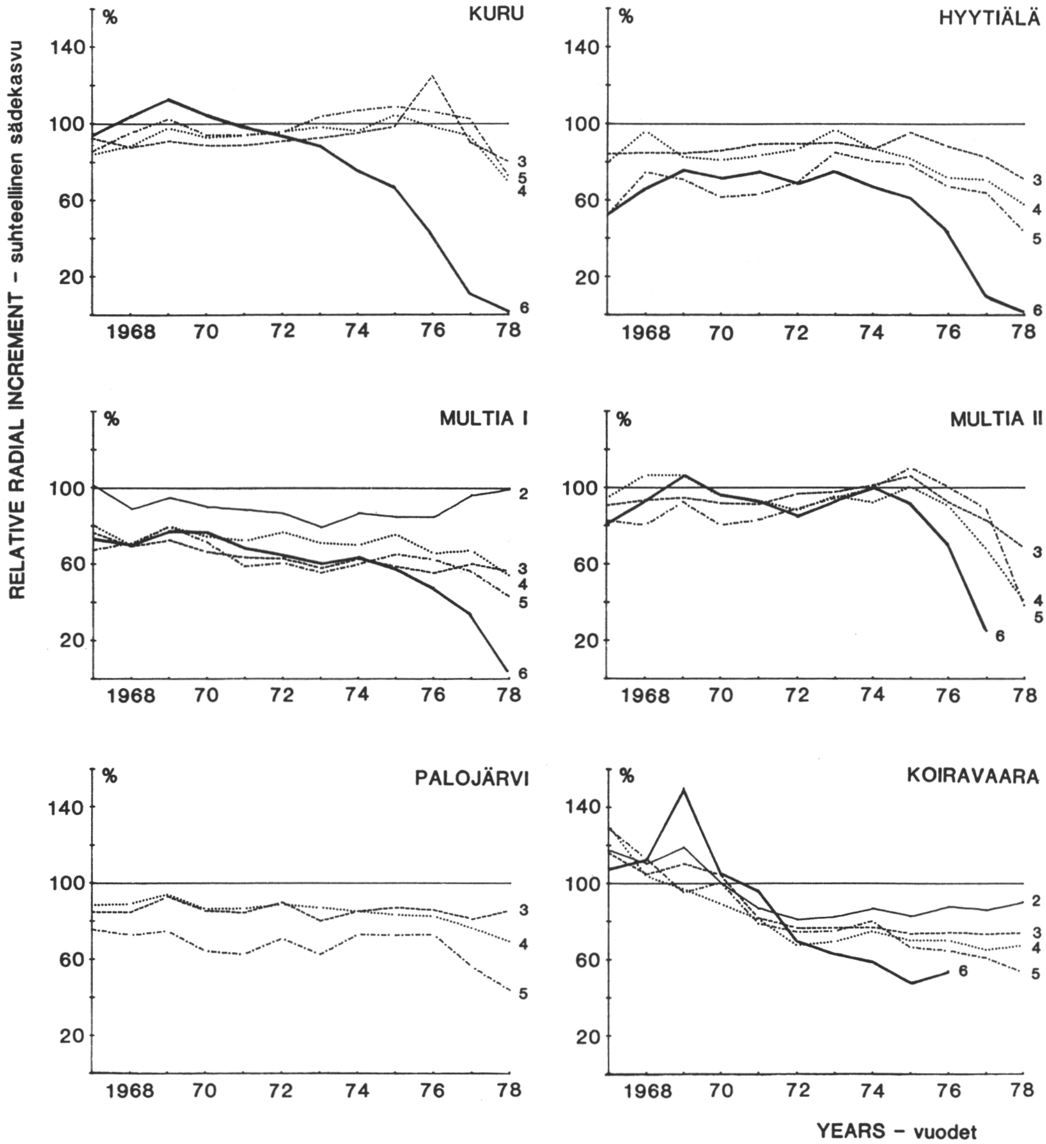

Figure 9. Relative radial increment of pines according to disease incidence classes.
Kuva 9. Mäntyjen suhteellinen sädekasvu tutkimusmetsiköissä tautisuusluokittain.

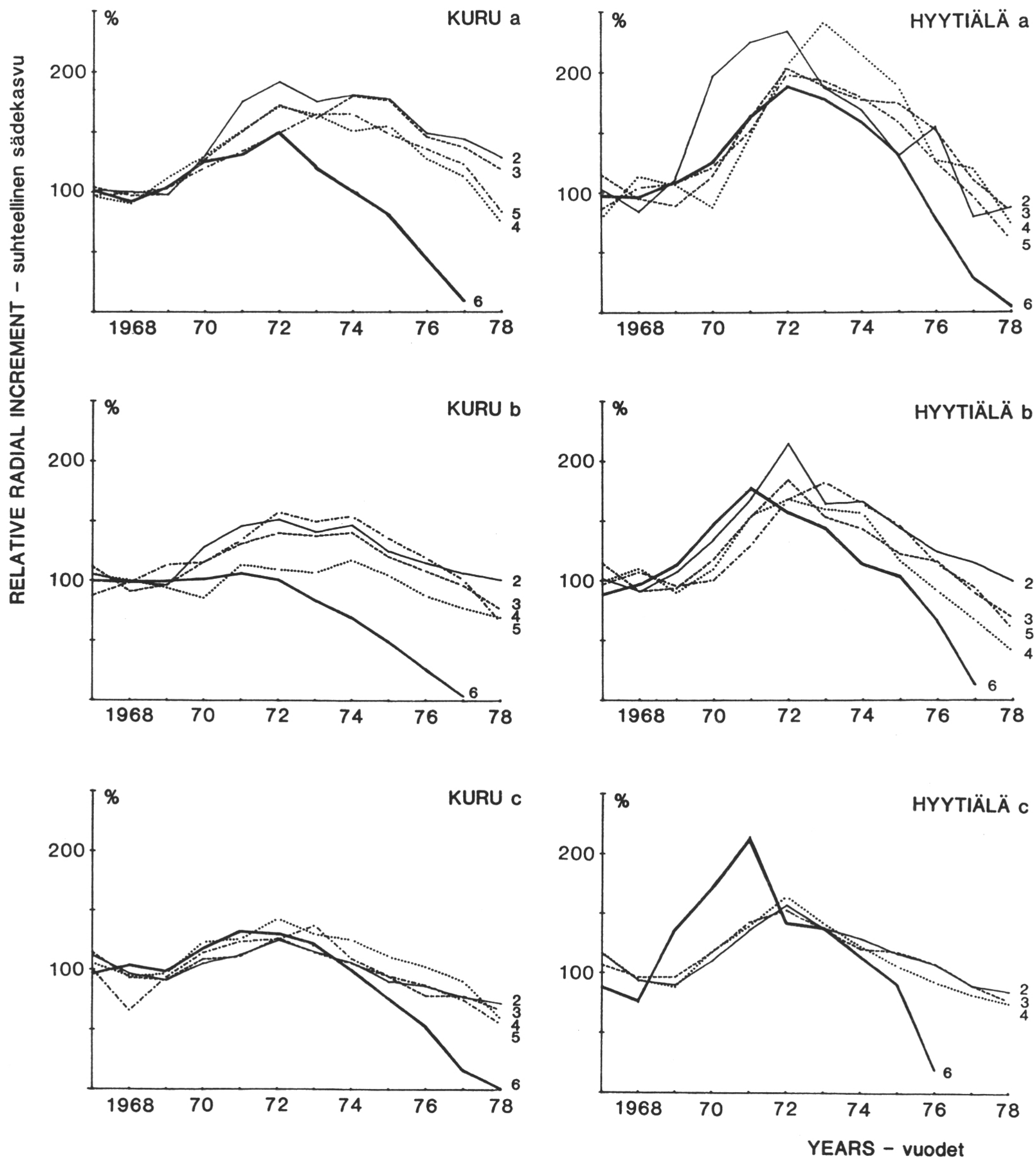

Figure 10. Relative radial increment of trees in different size classes in Kuru and Hyytiälä, a) small trees, b) medium sized trees, and c) tall trees. Reference value: the growth during 1967—1969.

Kuva 10. Puiden suhteellinen sädekasvu rinnankorkeusläpimitan perusteella muodostetuissa kokoluokissa Kurussa ja Hyytiälässä; a) pienet, b) keskikokoiset ja c) isot puut. Vertailuarvo: vuosien 1967—1969 pituuskasvu.

4. DISCUSSION

41. Onset of epidemics and growth response

In dating the onset of a Gremmeniella epidemic, there are some alternatives among the signs and symptoms of the disease which can be used. Apparently the time when cankers are established on the stem is closely related with the onset. The infection may occur about six months before the damage to the cambial tissue becomes apparent in the spring. If infection occurs in small branches, it may require one year or more for mycelium to reach the cortical tissue of the stem. It is very difficult to later determine whether the first damage to the cambium was caused by a microbe or, e.g. by frost, and whether it occurred in the spring or the previous autumn. The canker age in this study, determined by a stereomicroscope, was defined as the age of the oldest annual growth ring connected with the canker.

In affected stands it appeared that some cankers were established almost every year, which may be due to a generally high susceptibility to cambial injuries, due e.g. to frost. Such a canker may or may not become infected (Roll-Hansen 1964, Pomerleau 1971). When infected by *G. abietina,* a canker may still recover and the fungus remain latent, if predisposition in the trees has not been strong enough for disease development (Kurkela 1981). In this study, for practical purposes, the onset of the Gremmeniella epidemic was defined as the time when continuously extending cankers, fatal for the trees, were established. Thus, only the three largest cankers were examined in each sample tree. This way the greater part of the youngest cankers was rejected, although they would also be fatal if they occurred in large numbers on the same tree.

Increased canker formation was found to be associated with a decrease in growth which occurred either at once or up to 1—4 years later. The trees which later died were also those which first showed negative deviation in the growth rate from the other trees. At the stand level, decrease in growth can also be almost immediate, or show a lag between infection and the growth responses of several years, depending on the intensity of the infection. The onset of epidemics can evidently be determined most accurately by examining stem cankers. In the Scots pine stands studied, the observed growth response curves resembled those in Corsican pine described by Butin and Hackelberg (1978) in Germany where, however, the more temperate climate means that the time required for the appearance of any response will probably be shorter than in Finland.

Changes of leading shoots are mostly the result of infections or frost damage. In this material, remarkable changes were observed for the first time in 1975, when there were drastically more frost days than in the previous years during the summer months. Continuous dying of young shoots in the following years discoloured the stands a conspicuous brown, and led to the detection of this disease situation both in the studied stands as well as in several other places (Kurkela 1981).

Thus, following the history of the epidemic, there was a lag of c. five years between the onset and the detection of the diseased pine stands. This suggests that the condition of pine forests should be observed more carefully. Specifically, damp topographic depressions are places where adverse environmental factors can easily predispose pines to disease, and thus make them more susceptible to *G. abietina* (see Uotila 1984). This situation is also known to occur in Canada (Dorworth 1973, 1978).

42. Management of diseased stands

Substantial growth losses were observed in each stand. The pines, except in DI-classes 5 and 6, were expected to recover despite the damage, if the disease stress disappeared. Generally, pine seems to have a great recovery potential (see Butin and Hackelberg 1978). Taking growth losses as temporary, the density of a stand is a decisive factor when considering the value of the stand for further production. According to Vuokila (1981), in Southern Finland, about 1500 stems per hectare gives a maximal volume growth after the first commercial thinning of overdense pine stands. A somewhat more intensive thinning (to 1300—1200 stems/ha) gives a better immediate profit and adds to the benefits derived from increased dimensional development of the growing stock.

Except in Koiravaara, the disease had caused partial understocking (number of stems < 1200/ha) in each stand up until 1979. When the number of stems/ha is 1000 or 600, the average loss in volume increment in a healthy stand will be 11 and 26 %, respectively, during the years immediately after thinning (Vuokila 1981). The number of stems in the depressions in Kuru and Multia I was decreased below 600—700/ha, which in the present thinning directives (District Board of Forestry . . . 1976) is the lower limit for acceptable stocking. Parts of the study areas with a density of less than 700 stems/ha and trees belonging to DI-classes 1—4, were recommended for clear cutting and reforestation. In this type of diseased forests, the lower limit for acceptable stocking should be even higher because of the uncertain recovery, the threat of succeeding damage by bark beetles (*Tomicus* spp.), and the poor quality of the remaining trees. In Hyytiälä the disease caused some openings which remained until 1979, but which would not justify reforestation, since the whole stand covered only 0,7 ha. In each stand, it was recommended to cut trees belonging to DI-classes 5 and 6, and to remove them from the stand to avoid further losses by bark beetles and to decrease inoculum potential.

The reforestation of such clear-cut stands may be problematic. If pine is used, only local or proved seed origin should be accepted in order to avoid predisposition by climate in the future. Other tree species can also be considered. Spruce is often excluded because of its very poor frost hardiness in topographic depressions. Birch can be used, if site fertility allows it and the area is not so remote that it is a favorable elk habit. One possible species for most threatened sites in Finland is Siberian larch, which is known to be flexible in its fertility requirements as well as being frost hardy. However, Siberian larch is not totally resistant to *G. abietina,* either.

In practical forestry, reforestation methods should be carefully considered before the final harvesting in areas where Gremmeniella problems can be expected. Especially in topographic depressions in spruce forests, it may be more profitable to leave adequate shelter to ensure natural spruce regeneration, rather than to make repeated plantings of pine after clear-cutting.

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SELOSTE

Versosyöpätauti ja ympäristö männyn kuntoon ja kasvuun vaikuttavina tekijöinä

Johdanto

Nuorissa männiköissä erityisesti Etelä-Suomessa on todettu 1970-luvun puolivälistä lähtien pahoja versosyöpätuhoja. Taudin aiheuttamat tuhot ovat lisääntyneet viime vuosina jälleen myös Pohjois-Suomessa. Etelä-Suomessa epidemia näyttää nyt jonkin verran laantuneen. Monin paikoin männyn taimikoita tai riukuasteen männiköitä ehti tuhoutua kasvatuskelvottomiksi ja riittävän tiheänäkin säilyneissä männiköissä tauti on aiheuttanut huomattavia kasvunmenetyksiä latvuston supistumisen takia.

Tässä tutkimuksessa seurattiin epidemian kehitystä ajoittamalla erilaisten puissa todettujen vioitusten syntyä sekä puiden pituus- ja sädekasvureaktioita. Metsätyypin ja topografian suhdetta taudin runsauteen selvitettiin myös.

Aineisto ja menetelmät

Tutkimusalueiksi valittiin versosyövän vaivaamia riukuasteen männiköitä Kurussa, Juupajoella, Multialla, Nurmeksessa ja Valtimossa (kuva 1). Osalla metsiköistä oli tyypillistä suuret maaston korkeuserot ja kylmän ja kostean ilman kokoontumiselle otolliset notkelmat. Kaikissa tapauksissa kosteutta lisäämässä oli alueen läpi tai välittömässä läheisyydessä virtaava joki, puro tai ojitettu suo (liitteet 1—3). Metsätyyppi oli joko MT tai VT. Osin koealueet olivat kivisiä. Metsiköistä 5 oli perustettu kylväen ja yksi (Juupajoki, Hyytiälä) oli istutettu (taulukot 1 ja 2).

Puusto inventoitiin linjoittaisella ympyräkoealamenetelmällä paitsi Hyytiälässä, missä puut tarkastettiin riveittäin. Puista mitattiin rinnankorkeusläpimitta (d) ja arvioitiin tautisuus (DI, 1—6) (taulukot 3 ja 4). Joka kymmenes koealan puu tai joka seitsemäs Hyytiälässä otettiin koepuuksi, joka kaadettiin ja mitattiin pituuskasvu sekä sädekasvu kantoleikkauksesta 11 vuoden ajalta, 1967—1978. Koepuista tutkittiin lisäksi latvanvaihdot ja kolme suurinta rungossa olevaa koroa.

Tulokset ja tulosten tarkastelu

Kasvuympäristö ja puiden kunto

Puuston kunto oli heikoin maaston alimmissa osissa, missä olot versosyöpätartunnalle ovat otollisimmat korkeamman kosteuden ja mahdollisesti puita heikentävien suurten lämpötilan vaihteluiden takia (kuva 4). Kasvupaikan viljavuus (metsätyyppi) vaikutti tilastollisesti merkitsevästi puiden kuntoon ja kasvuun. Usein kuitenkin sekä puiden kunto että metsätyyppi vaihtelivat maaston korkeussuhteiden mukaan, joten metsätyypin vaikutuksen erottaminen korkeussuhteiden erittäin selvästä vaikutuksesta ei yleensä ollut mahdollista.

Korojen muodostuminen koepuihin kiihtyi selvästi vuonna 1972 ja saavutti yleisesti huippunsa 1974 tai 1976 (kuva 2). Myöhemmin koroja saattoi syntyä vielä runsaammin, mutta toistaiseksi pienialaisina niitä ei tässä yhteydessä tutkittu. Latvanvaihtoja koepuissa tapahtui runsaasti vuonna 1975 ja sen jälkeen (kuva 3). Latvanvaihdoilla ja edellisen vuoden korojen muodostuksella on ilmeinen syy-yhteys. Taudin voimistumiseen vuosien 1974 ja 1975 jälkeen lienee ratkaisevasti vaikuttanut erittäin sateinen syyskesä 1974 ja poikkeuksellisen hallainen kesä 1975.

Puiden pituus- ja sädekasvu

Sairaiden puiden keskimääräinen vuotuinen pituuskasvu oli terveiden tai kuntoluokan 2 puiden kasvua heikompi Kurussa, Hyytiälässä ja Multia II:ssa. Koiravaarassa sairaat puut kasvoivat aluksi terveitä voimakkaammin (kuvat 5—7). Sädekasvu oli terveiden puiden kasvua heikompi koko mittausjakson aikana Hyytiälässä, Multia I:ssä ja Palojärvellä. Koiravaarassa sairaiden puiden sädekasvukin oli terveiden kasvua voimakkaampi mittausjakson alussa. Kurussa, Multia II:ssa ja Koiravaarassa vuonna 1969 sädekasvu oli voimakkainta kuntoluokan 6 puissa (kuvat 8—10).

Vuosina 1967—1969, jolloin versosyöpää ei männiköissä ollut, tai taudin vaikutus oli vähäinen, ainoastaan kahdessa metsikössä (Multia I ja Hyytiälä) todettiin tautisuusluokkien välisiä tilastollisesti merkitseviä eroja sekä pituus- että sädekasvussa. Osa kasvueroista luokkien välillä näytti kuitenkin johtuvan siitä, että suuri osa taudin pahimmin vaivaamista puista kasvoi näissä kohteissa karuissa painanteissa. Sekä pituus- että sädekasvu heikkeni tutkimusalueiden männyissä yleisesti 1970-luvun loppupuoliskolla. Kyseessä oli ilmeisesti osaksi metsiköiden nuoruusvuosien voimakkaamman kasvun jälkeen tapahtuva normaali hidastuminen. Epäedulliset muutokset kasvukausien säissä olivat myös omiaan vähentämään kasvua.

Vuosien 1971—1976 aikana männyt kuntoluokassa 6, kuolleet puut vuoden 1979 luokituksessa, erottuivat muista puista kasvun heikentyessä muita voimakkaammin. Pituuskasvun osalta erottuminen tapahtui ensiksi Multia II:ssa ja viimeksi Palojärvellä. Muidenkin kuntoluokkien välillä esiintyi vuonna 1976 jo tilastollisesti melkein merkitseviä tai merkitseviä eroja. Vuoden 1978 kasvussa (taulukko 6) oli kaikissa kohteissa kuntoluokkien (1) 2—5 välillä erittäin merkitseviä eroja ($P < 0{,}01$). Sädekasvun heikentyminen tapahtui lähes samalla tavoin. Tärkeimpiä eroja pituuskasvuun nähden oli, että puut reagoivat luokassa 6 hieman myöhemmin. Sädekasvun yleinen aleneminen alkoi jo vuonna 1973, mutta eri tautisuusluokkien (luokkaa 6 lukuunottamatta) välille kehittyi versosyöpään yhdistettävissä olevia selviä eroja vasta 1977. Suhteellinen sädekasvu eri kuntoluokissa vuonna 1978 on esitetty taulukossa 8.

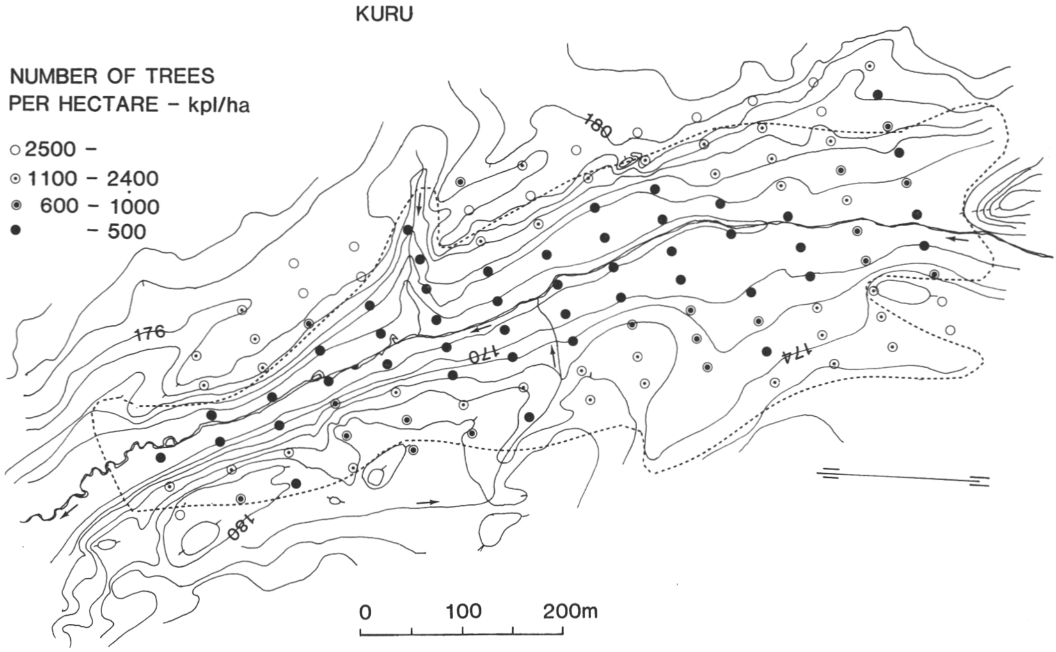
Pienet puut reagoivat tautiin suhteellisesti voimakkaammin kuin isot puut. Ilmeisesti alistetussa tilassa tai karummalla paikalla kasvavat puut menettivät kasvukykynsä nopeammin kuin taudin saastuttamat valtapuut keskimäärin (kuvat 7 ja 10). Kokonaiskasvutappiot tämänlaatuisissa sairaissa metsiköissä riippuvat tuhoalueen rajauksesta. Suhteellinen kasvutappio on sitä pienempi mitä enemmän terveitä puita aineistoon sisältyy, joten tällaiset laskelmat ovat tuskin yleistämiskelpoisia. Nyt tutkitun puuston kasvunmenetykset vuosien 1974—78 kasvusta sekä vuoden 1978 kasvusta on esitetty taulukossa 7.

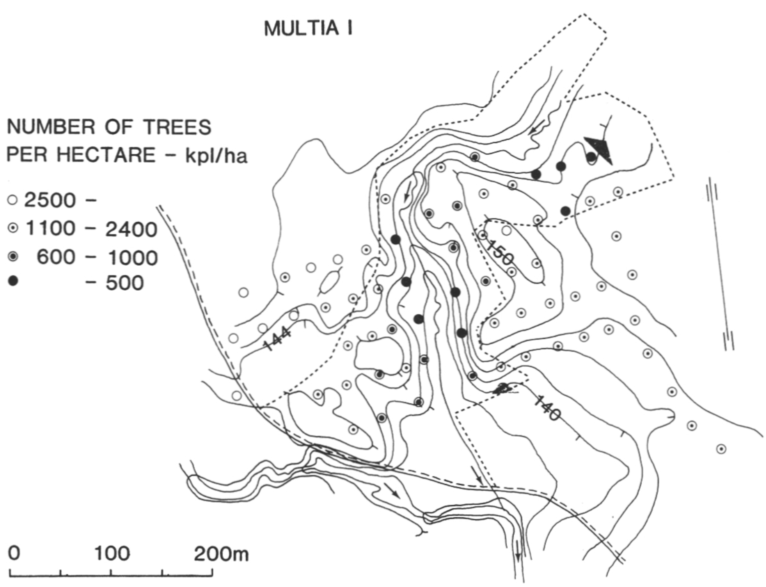
Näkökohtia versosyöpämänniköiden käsittelystä

Versosyöpämänniköille tehtiin inventoinnin perusteella käsittelysuositukset. Puiden kuntoluokissa 1—4 arveltiin toipuvan taudista. Kun näiden puiden runkoluku hehtaaria kohden ylitti 600 (—700), kpl katsottiin metsikön edelleen kasvattaminen vielä taloudellisesti mahdolliseksi. 600 runkoa/ha on keskusmetsälautakuntien suosituksen mukainen kasvatuskelpoisuuden alaraja riukuasteen männikölle ensiharvennuksen jälkeen. Sairaissa männiköissä hyväksyttävän runkoluvun alaraja saisi olla kuitenkin yleisiä ohjeita korkeampi, koska yleensä ei voida varmuudella ennustaa, milloin epidemia päättyy ja toisaalta taudin runteleman puuston toipuminen voi kestää yllättävän kauan. Hyväksyttävä alaraja voisi olla esim. 700—800 runkoa/ha, jolloin korkeampi runkoluku korvaisi taudin aiheuttaman kasvunvähennyksen.

Tutkituissa metsiköissä epidemia ei päättynyt vuonna 1979 Kurussa, Hyytiälässä eikä Multialla. Avohakkuut ja harvennukset tehtiin näissä metsiköissä annettujen suositusten mukaisesti jo syksyllä 1979 tai seuraavana talvena. Epidemian jatkuessa näissä kohteissa avohakkuualueita jouduttiin myöhemmin tuntuvasti laajentamaan. Sairaan puuston hakkuulla pyritään yleisesti myös parantamaan metsän hygieniaa ja vähentämään epidemian edelleen leviämisen tai uusiutumisen mahdollisuutta. Havaintojen mukaan tällaisiin saniteettihakkuisiin olisi kuitenkin ryhdyttävä jo ennen kuin merkittävää tuhoa metsikkötasolla esiintyy. Näin metsän hygieniaa voidaan parantaa poistamalla yksittäisiä sairaita puita. Näiden poiskuljettaminen ei ole välttämätöntä, sillä jo puiden maahan kaataminen vähentää versosyöpäsienen toimeentulomahdollisuuksia oksissa. Syksyn ja talven aikana kuolleiden puiden kuori saattaa olla vielä tuoretta ytimennävertäjien (*Tomicus* spp.) parveillessa keväällä. Aisaamalla tai kuljettamalla pois paksummat rungon osat vähennetään ytimennävertäjien lisääntymismahdollisuuksia sekä niiden aiheuttamia seuraustuhoja versosyövän heikentämässä puustossa.

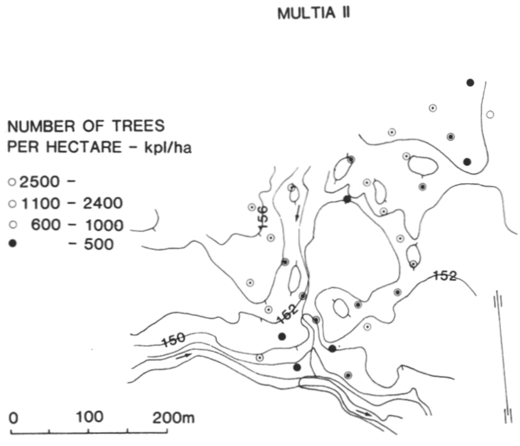
AALTO-KALLONEN, T. & KURKELA, T. 1985. Gremmeniella disease and site factors affecting the condition and growth of Scots pine. Seloste: Versosyöpätauti ja ympäristö männyn kuntoon ja kasvuun vaikuttavina tekijöinä. Commun. Inst. For. Fenn. 126: 1—28.

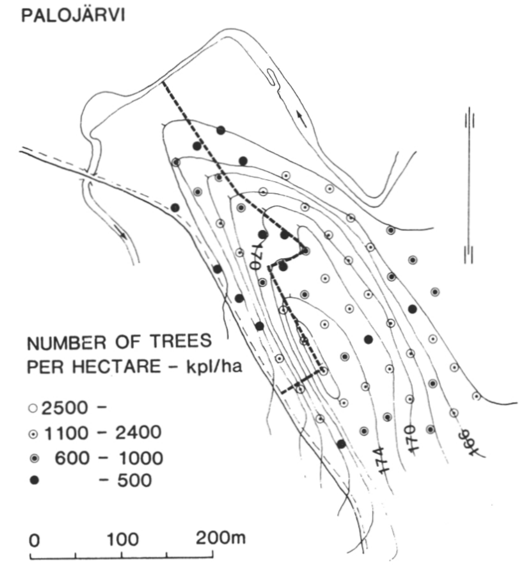




Appendix 1. Experimental areas 1. Kuru, Itä-Aure and 3. Multia I. Survey plots and contour lines, meters above sea level.

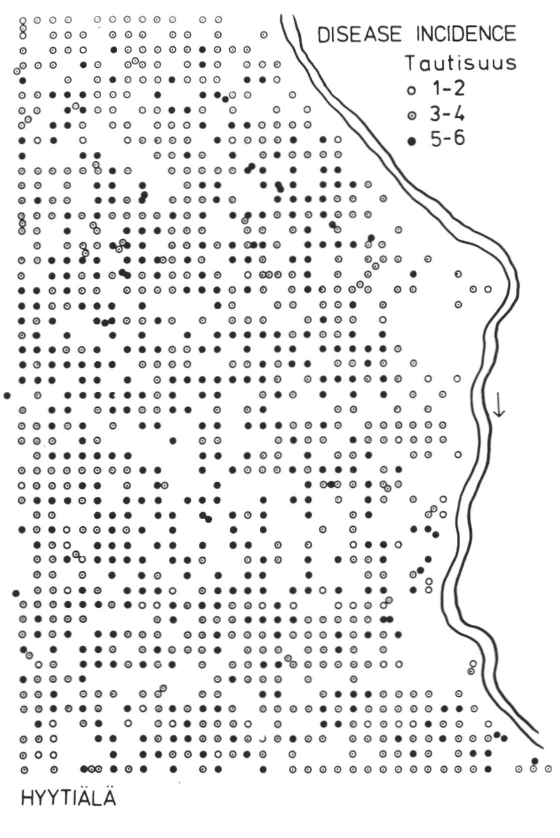
Liite 1. Kohdealueet 1. Kuru, Itä-Aure ja 3. Multia I. Inventoinnin koealat ja korkeuskäyrät, m merenpinnasta.





Appendix 2. Experimental areas 4. Multia II and 5. Nurmes, Palojärvi. Survey plots and contour lines, meters above sea level.

Liite 2. Kohdealueet 4. Multia II ja 5. Nurmes, Palojärvi. Inventoinnin koealat ja korkeuskäyrät, m merenpinnasta.



Appendix 3. Experimental area 2. Juupajoki, Hyytiälä. Location and DI-class of trees.

Liite 3. Kohdealue 2. Juupajoki, Hytiälä. Merkit kartalla osoittavat puiden sijainnin ja tautisuusluokan.

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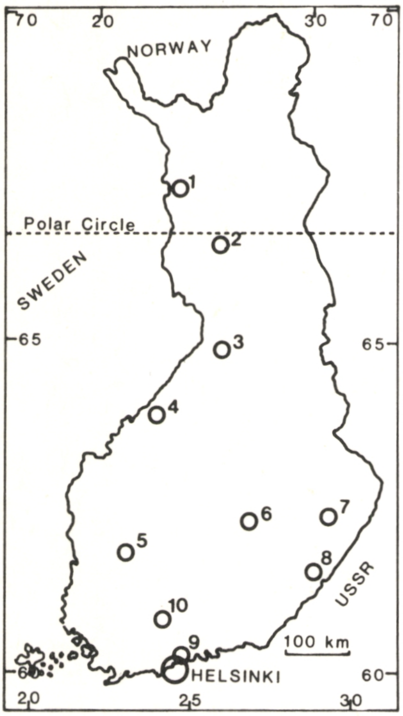

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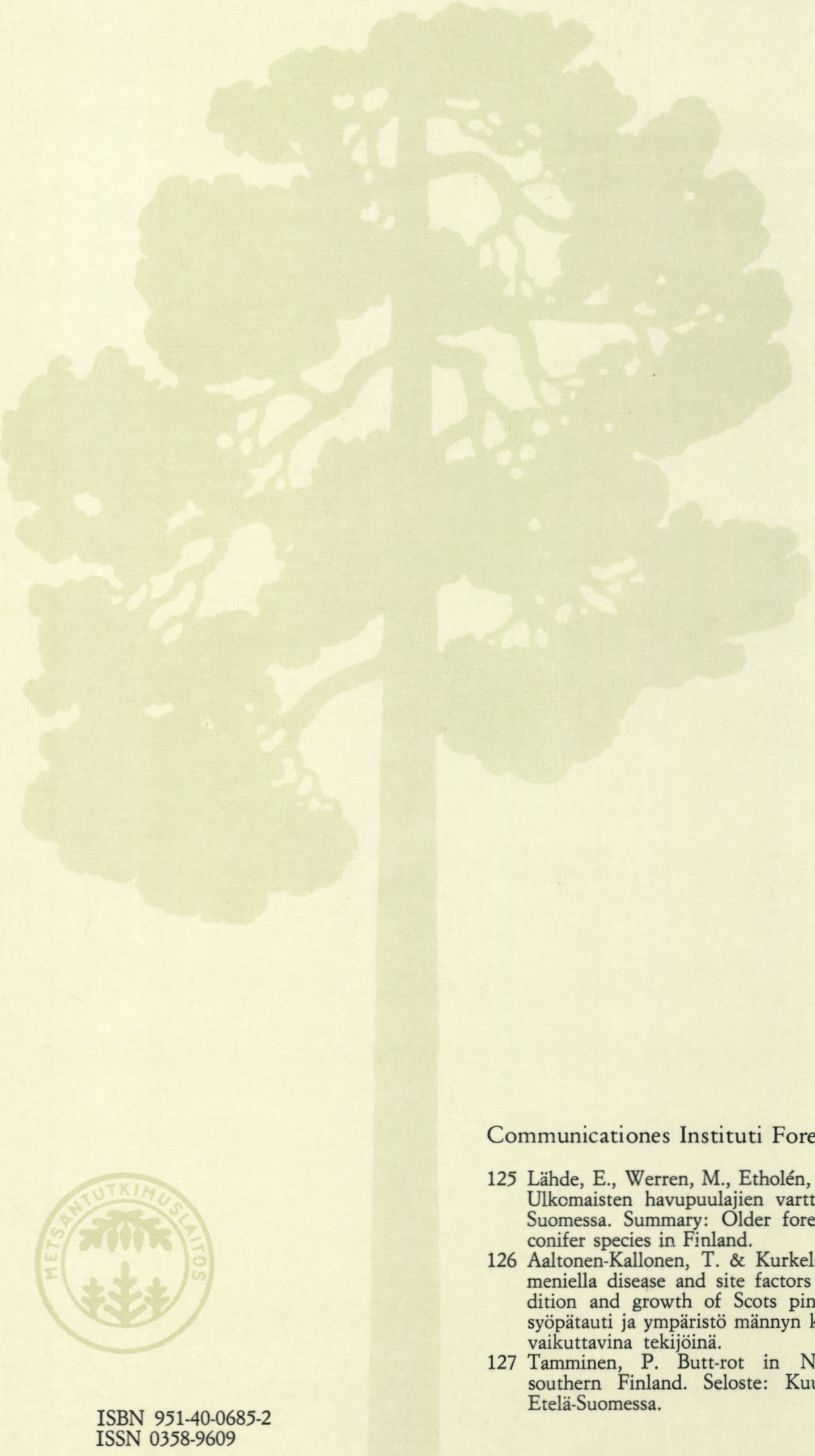
FACTS ABOUT FINLAND

Total land area: 304 642 km^2 of which 60—70 per cent is forest land.

Mean temperature, °C:	Helsinki	Joensuu	Rovaniemi
January	-6,8	-10,2	-11,0
July	17,1	17,1	15,3
annual	4,4	2,9	0,8
Thermal winter (mean temp. < 0°C):	20.11.—4.4.	5.11.—10.4.	18.10.—21.4.

Most common tree species: Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens



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