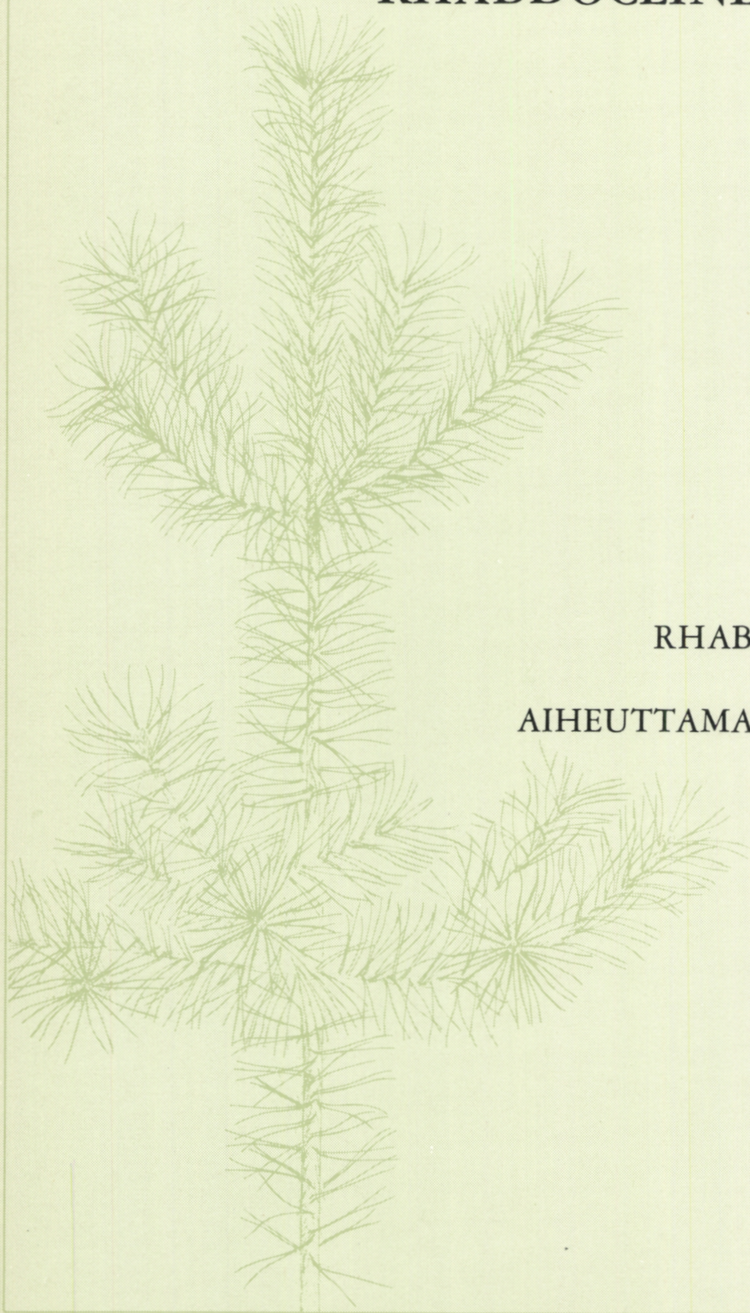
COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE 102

GROWTH REDUCTION IN DOUGLAS FIR CAUSED BY RHABDOCLINE NEEDLE CAST



TIMO KURKELA

SELOSTE

RHABDOCLINE-KARISTEEN AIHEUTTAMA KASVUNVÄHENNYS DOUGLASKUUSELLA

HELSINKI 1981

COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE

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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 mill. 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 effect of needle cast on the height and radial increments was studied in a Douglas fir stand. The material was divided into different disease incidence classes and into three tree classes: dominant, codominant, and suppressed trees.

Both height and radial increment decreased as the severity of the infection increased. The disease had a parallel effect on the height growth of both dominant and suppressed trees. The slightly infected codominant trees were able to increase their height growth in comparison to both their previous average growth and the growth in other tree classes. The same kind of interaction was not detected in radial growth between tree classes and disease incidence.

Following the deepest depression in the rate of radial increment, nearly 10 years were necessary for the recovery of the seriously infected dominant trees. Seriously infected codominant and suppressed trees were not able to recover, and continued at the depressed rate of radial increment.

Rhabdocline karisteen vaikutusta douglaskuusen pituus- ja sädekasvuun tutkittiin eräässä Metsäntutkimuslaitoksen koeviljelmässä. Ympyräkoealoilta kerätty aineisto jaettiin kolmeen tautisuusluokkaan ja kolmeen puuluokkaan (valtapuut, lisävaltapuut ja vallitut puut).

Mitä ankarampi karistesaastunta oli, sitä heikompi oli puiden kasvu. Taudin vaikutus oli selvä sekä pituus- että sädekasvussa. Valtapuiden ja vallittujen puiden ryhmissä taudin vaikutus pituuskasvuun oli samansuuntainen. Lievästi saastuneet lisävaltapuut kykenivät lisäämään (osaksi absoluuttisesti aikaisempaan kasvuun verrattuna ja erityisesti suhteellisesti toisiin puuluokkiin verrattuna) pituuskasvuaan. Vastaavaa yhdysvaikutusta karisteen ankaruuden ja puuluokkien välillä ei todettu sädekasvussa.

Ankarasti saastuneet valtapuut toipuivat epidemian aiheuttamasta sädekasvun vähentymisestä n. 10 vuoden kuluessa. Pahoin saastuneet lisävaltapuut ja alispuut eivät kyenneet lainkaan toipumaan, vaan jatkoivat kasvuaan karisteen alentamalla tasolla.

ODC 443.3:172.8 *Rhabdocline*: 174.7 *Pseudotsuga*
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CONTENTS

1. INTRODUCTION

Our knowledge of economic losses caused by forest diseases is deficient. Especially, losses caused by leaf damage have not been much studied in Finland. Tiihonen (1970) examined critically the effect of needle losses caused by pine sawfly on the growth of pines. There are also some observations as to the relation between foliage damage and the growth of young birch (Lilja 1973, Annila 1979).

Needle casts of conifers affects the assimilation potential of trees, which can cause further losses in growth. However, the effect of a slight needle disease is often masked by the variation caused by the climatic factors. The effect can be observed and measured most easily if the disease is severe or if epidemics repeat in several succeeding years (e.g. Rohde 1932, Mitchell et al. 1976, Martinsson 1979).

Rhabdocline needle cast caused great deterioration in stands of Douglas fir *Pseudotsuga menziesii* (Mirb.) Franco) in Central Europe about 50 years ago (e.g. Rohde 1932) and later, also in some experimental stands in Finland (Heikinheimo 1956). Both the host and the pathogen (*Rhabdocline pseudotsugae* Syd.) were introduced to Europe from North America. *P. menziesii* has been divided into 3 variations of which var. *glauca* (Mayr.) Schneid. has been most susceptible, var. *caesia* (Schwer.) Aschers. et Graebn. less susceptible, and var. *viridis* (Schwer.) Aschers. et Graebn. most resistant (Meyer 1954, Schober and Meyer 1955, Stephan 1980). The last mentioned variety can not be grown in Finland because of its poor frost hardiness (Sarvas 1964).

Rhabdocline needle cast was observed in Finland for the first time in 1952 (Heikinheimo 1956, Sarvas 1964). Based on the specimens in the HFR collections from some stands of Douglas fir, the earliest epidemic needle casts can be dated as follows:

Urjala, Nuutajärvi	(677–29)[1)]	1950
Bromarv, Solböle	(666–28)	1951
Tuusula, Ruotsinkylä	(669–38)	1954
Elimäki, Mustila	(673–46)	1954

1) The uniform grid system (Grid 27°E).

In addition, the disease has also occurred in Anjalankoski, Sippola (673–49), Tammela, Alanko (674–33) and Punkaharju (685–62). Parker and Reid (1969) divided *R. pseudotsugae* into several subspecies of which only *R. pseudotsugae* subsp. *pseudotsugae* Parker & Reid occurs in Europe, according to Moriondo (1972).

In the beginning of the 1960s, there were successive *Rhabdocline* epidemics in the experimental stands of Douglas fir in Ruotsinkylä during several growing seasons. This paper presents calculations of the growth reduction of Douglas fir due to Rhabdocline needle cast. Postepidemic radial growth was also studied.

I would like to thank Mr. Pekka Tamminen and Mr. Hannu Kukkonen for their excellent computer work.

2. MATERIAL AND METHODS

The material for this study was collected from the Douglas fir (*P. menziesii* var. *glauca*) stand in Tuusula, Ruotsinkylä (669–38). The stand was established by planting 5-year-old transplants in 1932. The provenance originated from Canada, Alberta, Crows Nest Pass 49°39' N, 114°41'W (Stand 46 in Heikinheimo 1956).

The stand was seriously infected by *R. pseudotsugae* in 1965. The fact that the disease incidence varied greatly between individual trees provided a good opportunity to study the relationship between the incidence of needle cast and the growth of the trees within a stand. Five circular plots of 300 m^2 each were sampled by means of strip survey in the autumn of 1965. The average height and diameter of the sample trees were 8,0 m and 11,9 cm, respectively. The height of dominant trees was 9–14 m. The height and radial increment were measured in each tree in the plots. The height increment was measured by means of a leveling rod, one end of which was set at the level of the tip of the last leader shoot. The length of the last shoot was then read using binoculars. An assistant climbed the tree and read the height increment figures for the last five years. Increment cores, taken in the autumn of 1965 and 1980, were measured with a special microscopic equipment (Facit-Addo).

The disease incidence (K) of individual trees was determined by counting both fallen and remaining needles in a branch sample taken from the middle part of the crown in 1965. The needles of 5 successive shoots were counted, beginning with the one-year-old shoot. Infection was not apparent in the current year needles. On the oldest needles of the trees, a fungus was found which resembled *Phaeocryptopus gaeumannii* (Rohde) Petrak; however, mature sporocarps were not found. This fungus seemed to be unrelated to the needle fall, because most of the 6-year-old needles were still attached in some of the trees while younger needles had fallen in large numbers. It was concluded that Rhabdocline needle fall epidemics had been important in the stand since 1960. Later, no systematic survey on the disease incidence was made and no serious epidemic occurred after 1965. However, the pathogen has survived in the stand until the present. Nine healthy (disease incidence, K < 10 %) trees bearing cones were detected in the stand. Those trees were used as reference material when radial increment was studied in material obtained in 1965.

Table 1. Correlation of needle cast with height, height increment, and radial increment.
Taulukko 1. Karisteen korrelaatio puiden pituuden sekä pituus- ja sädekasvun kanssa.

Variables, *Muuttajat*		Correlation, *Korrelaatio*	
Needle cast, *kariste*		K_5	K_1
K_5,	during 1960–1964, *vuosina 1960–1964*	1,000	
K_1,	in 1964, *vuonna 1964*	+ ,832	1,000
Height, *pituus*			
H_{38},	height in 1965, *pituus vuonna 1965*	– ,096	– ,133
H_{33},	height in 1961, *pituus vuonna 1961*	+ ,025	– ,021
Height increment, *pituuskasvu*			
ih_5,	during 1961–1965, *vuosina 1961–1965*	– ,613	– ,569
ih_1,	in 1965, *vuonna 1965*	– ,573	– ,500
ih_5/H_{33},	relative height increment during 1961–1965 *suhteellinen pituuskasvu vuosina 1961–1965*	– ,603	– ,571
Radial increment, *sädekasvu*			
id_1,	in 1965, *vuonna 1965*	– ,455	– ,334
id_2,	in 1964, *vuonna 1964*	– ,466	– ,305
id_3,	in 1963, *vuonna 1963*	– ,326	– ,151
id_4,	in 1962, *vuonna 1962*	– ,190	– ,041
id_5,	in 1961, *vuonna 1961*	– ,289	– ,171
id_{11+12},	in 1954 and 1955, *vuosina 1954 ja 1955*	– ,009	+ ,034

3. RESULTS

31. Needle cast incidence

In 1965, the average needle cast incidence for the years 1960–1964, K_5, in the trees in the sample plots was 73 %, varying from 25 to 99 %. The average disease incidence (K_1) for the year 1964 only was 75 %. The nine reference trees, which were also the tallest in the stand, were all outside the sample plots. In these trees K_5 was less than 10 %.

The trees of the plots were divided into three disease incidence classes:

Disease incidence class, %	0–60	60,1–80	80,1–100
Average incidence, K_5 within the classes	48,4	70,6	90,3
Number of trees	40	57	68

The average incidence remained almost unchanged when the trees were further divided into three height classes, tall, medium, and small trees, which correspond in the main to the biological classification: dominant, codominant, and suppressed trees. Since the greatest variation of disease incidence even in the subclasses was not more than ± 2 % from the nearest ten, the rounded figures 50, 70 and 90 % are used to describe the disease incidence classes when other results are presented below.

32. Effect of needle cast on the height increment

In the material as a whole, the growth in height and the needle cast incidence had a clear negative correlation (Table 1). The correlation was greater for the growth of the last 5 years (1961–1965, ih_5) than for the current year (ih_1). The variable describing needle cast incidence for the last 5 years, 1960–1964 (K_5), had a higher correlation than that for the previous year 1964 (K_1), in height. The transformations (lnK, K^2, $\sqrt{K}$, 1/K) did not substantially affect the correlation. The correlation coefficient between K_5 and ih_5 was −0,613 in the total material.

Needle cast incidence did not correlate with the height (H_{33}) or the average height growth of the trees during the time previous to the last 5-year period (Fig. 1). Despite the great variation in variables, K_5 and ih_5 had a significant negative correlation on the level of at least $P<5$ % in the groups of dominant and codominant trees, with r varying from −0,5 to −0,9 (excluding Sample Plot 5 where only 20 trees were measured). Among the suppressed trees, the correlation of K_5 and ih_5 was significant in only 2 plots.

In a two-way analysis of variance, tree height (H_{33}) and disease incidence (K_5) affected significantly the height increment (ih_1, ih_5, and ih_5/H_{33}) at the level of $P<0,1$ % (Fig. 2). The growth reducing effect of needle cast was most pronounced in codominant trees, among which the growth of slightly infected trees (K_5 50 %) was about 30 cm per year, whereas the trees with severe infection grew only about 9 cm per year. The absolute growth reduction was least in the group of suppressed trees, in which the difference between slightly and severely infected trees was only 5 cm. On the other hand, the suppressed trees seemed more likely to die under the stress of the disease.

Interaction between the height groups of the trees and needle cast was statistically significant ($P<1$ %). This is shown graphically in Figure 2. In a more detailed analysis, it was found that the codominant trees with a slight infection had been able to increase their growth more often than the trees on other groups, when compared to the height growth previous to 1961 (Fig. 1).

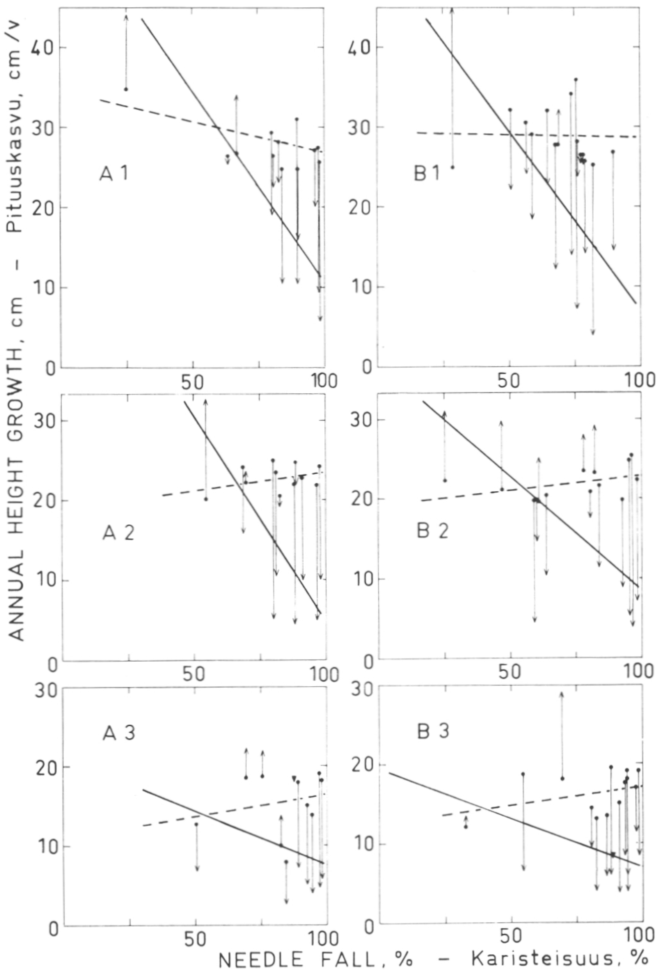

Figure 1. The effect of needle cast (Ks) on the height growth in two sample plots, A and B. Dominant (1), codominant (2), and suppressed (3) trees. Black dot indicates the earlier average height growth (ih) of a tree; arrowhead indicates the annual height growth (ihs) during the last 5 years (1961—1965). Broken line shows the correlation of the variables Ks and ih, and solid line the correlation of the variables Ks and ihs.

Kuva 1. Karisteisuuden (Ks) vaikutus pituuskasvuun kahdella koealalla, A ja B. Valtapuut (1), lisävaltapuut (2) ja vallitut puut (3). Piste osoittaa puun aiemman keskimääräisen kasvun (ih), nuolen kärki vuotuisen kasvun (ihs) viimeisen 5 vuoden aikana, 1961—1965. Katkoviiva osoittaa muuttujien Ks ja ih ja yhtenäinen viiva muuttujien Ks ja ihs keskinäisen riippuvuuden.

33. Effect of needle cast on the radial increment

The radial growth decreased due to the needle cast but not relatively as much as the height growth. The correlation coefficients between Ks and the radial growth of the last 2 years, 1965 and 1964 (id1 and id2) were —0,455 and —0,466 respectively. Generally, the correlation decreased the earlier the period at which the growth was compared with the needle cast (Table 1). No correlation was detected between the disease and growth for the 5-year period before 1961. Neither was any interaction found between the height

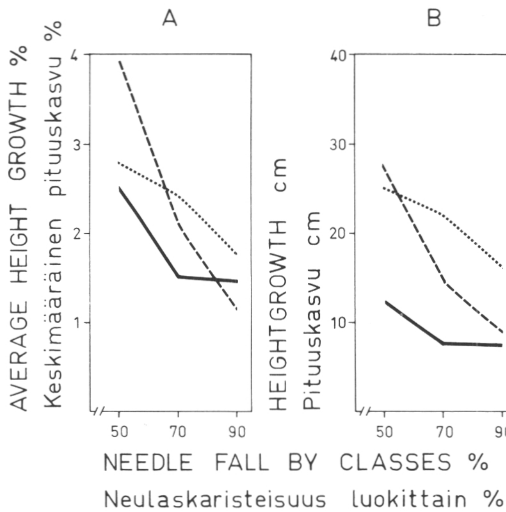

Figure 2. The effect of needle cast on the heigth growth in the different tree classes. A) The relative height growth during the last 5 years, 1961–1965. B) The height growth during 1961–1965. C) The height growth in 1965. Dotted line = dominant, broken line = codominant, and solid line = suppressed trees.

Kuva 2. Karisteen vaikutus pituuskasvuun eri puuluokissa. A) Suhteellinen pituuskasvu viimeisen 5 vuoden aikana. 1961–1965. B) Pituuskasvu (cm) vuosina 1961–1965. C) Pituuskasvu vuonna 1965. Pisteviiva = valtapuut, katkoviiva = lisävaltapuut ja yhtenäinen viiva = vallitut puut.

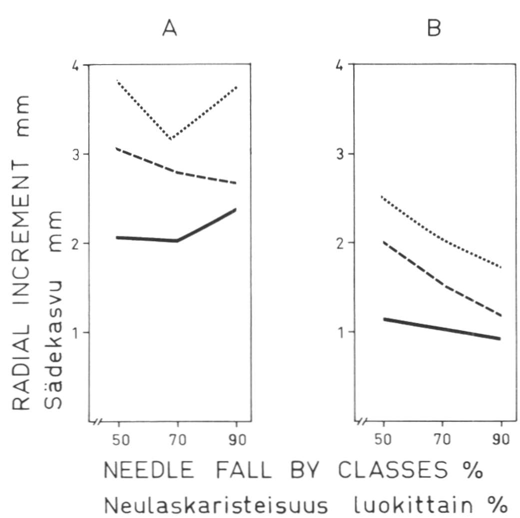

Figure 3. The effect of needle cast on the radial inrement. The radial increment. A) during the 5-year period of 1956–1960, B) during 1961–1965, C) in 1965. See Figure 2 for the legend of the lines.

Kuva 3. Karisteen vaikutus sädekasvuun. Sädekasvu A) 5-vuotiskautena 1956–1960, B) 5-vuotiskautena 1961–1965, C) vuonna 1965. Viivojen selitys, ks. Kuva 2 and the diameter of the trees and the radial growth.

Needle cast decreased radial growth significantly (P<0,1 %) in the total material (Fig. 3). An analysis of variance was computed using as a dependent variable the radial growth for two year periods going back from the year 1965. These variables in different disease incidence groups were significantly (P<1 %) different for the first time in 1958 – 1959, indicating that the needle cast had occurred to a considerable extent even before 1959, although the foliage of the year 1959 was not damaged by the disease. According to Sarvas (1964), needle cast was detected for the first time in Ruotsinkylä in 1958, but had occurred to some extent as early as 1954. That could also be concluded from the branch samples taken by Prof. Viljo Kujala in 1958 (HFR collections).

During the 10-year period, 1956 – 1965, the trees in the infected stand had a generally descending trend in their radial growth (Fig. 4A) which, however, was least among the 9 healthy trees (K_5<10 %). It was supposed that the growth reduction in the healthy trees was due to detrimental climatic factors or normal trend caused by the age (s. Mikola 1950). In the beginning of the decade, the growth of the trees on the sample plots was about 65 % of that of the healthy trees, and at the end of that period less than 50 % (Fig 4B). The effect of environmental factors other than the disease decreases with increasing disease incidence (Table 2). That may be explained by reduced competition between trees, because the remaining needles on the less affected trees were more effective in photosynthesis.

The growth reduction due to the disease could also be calculated in another way. Supposing that the factors independent of the disease equally affect each tree and that this effect on the growth of the healthy trees was −21,8 % (Table 2), one could construe the growth reduction due to the disease as the total reduction (in percentages) minus 21,8 %. In this way, however, many possible interactions between needle cast, the growth, and other environmental factors are excluded. Thus, the first presented method of calculation of growth reduction may be more correct.

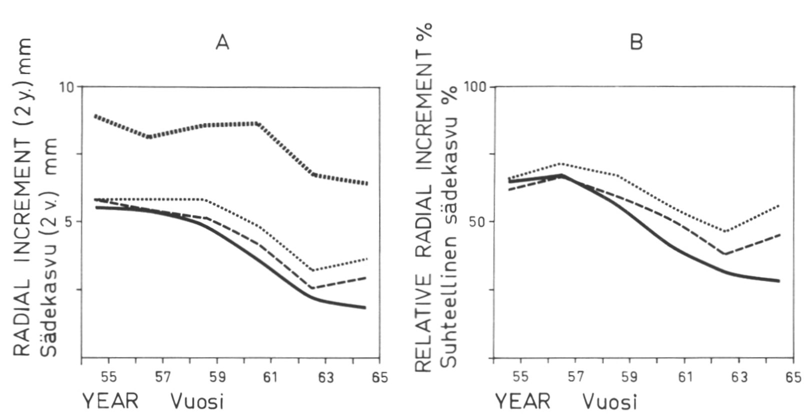

Figure 4. Radial increment of trees over a 10-year period (1956–1965). A) Growth is shown as the sum of the growth of two succeeding years. B) Relative growth of infected trees when growth of healthy trees = 100. Explanation of symbols: heavy lengthwise borken line = healthy trees; dotted line = slightly infected; broken line = averagely infected; solid line = badly infected.

Kuva 4. Puiden sädekasvu 10-vuotiskautena 1956–1965. A) Kasvu esitettynä kahden peräkkäisen vuoden summana. B) Karisteisten puiden suhteellinen kasvu, kun terveiden puiden kasvu = 100. Merkkien selitys: leveä katkoviiva = terveet puut; pisteviiva = lievästi, katkoviiva = keskimääräisesti ja yhtenäinen viiva = ankarasti saastuneet puut.

Table 2. Decrease in radial growth over a 10-year period, 1956–1965.
Taulukko 2. Sädekasvun aleneminen 10-vuotiskautena 1956–1965.

Disease incidence class *Karisteisuus*	No. of trees *Puuluku*	Change in radial increment, % *Sädekasvun muutos, %* Total change *Muutos yht.*	Effect of disease *Karisteen aiheuttama*	Other factors *Muut syyt*
Healthy trees *Terveet puut*	9	21,8	–	21,8
50 % infection *50 %:nen saastunta*	40	41,6	25,6	16,0
70 % infection *70 %:nen saastunta*	57	49,7	36,4	13,3
90 % infection *90 %:nen saastunta*	68	64,4	53,6	10,8

34. Postepidemic radial growth

The most serious infection must have occurred in the summer of 1962, because the disease had the strongest effect on the radial growth in 1963. Since that time a gradual recovery has taken place, although infection in 1964 was still very high according to the rating in 1965. New increment cores were taken in October, 1980. The radial annual increment for 20 years, 1961–1980, was measured. In that material, significant differences were found in radial growth in 1961–1962 and 1979 ($P < 1$ %), but not between 1963–1965, and again in 1966–1978 and 1980 ($P < 0{,}1$ %). The results were derived using an analysis of covariance in which the disease incidence grading made in 1965 and tree classes according to the situation in 1960 were again used.

The least affected (K 50 %) dominant trees increased their radial growth rapidly in the 4 years following 1963, to almost the level which prevailed previous to the epidemic. The more severely (K 70 or 90 %) infected trees seemed to need a period of about 10 years (Fig. 5) to reach the level of the best growing trees. Between the least and the moderately infected codominant trees, there were no significant differences: their postepidemic growth was comparable to that of severely infected dominant trees. The codominant trees with K 90 % showed no return at all (Fig. 5). Among the suppressed trees, only those with K 50 % showed a remarkable recovery, while the moderately infected trees had only a very slight return. The growth reduction on the seriously infected trees was irreversible (Fig. 5).

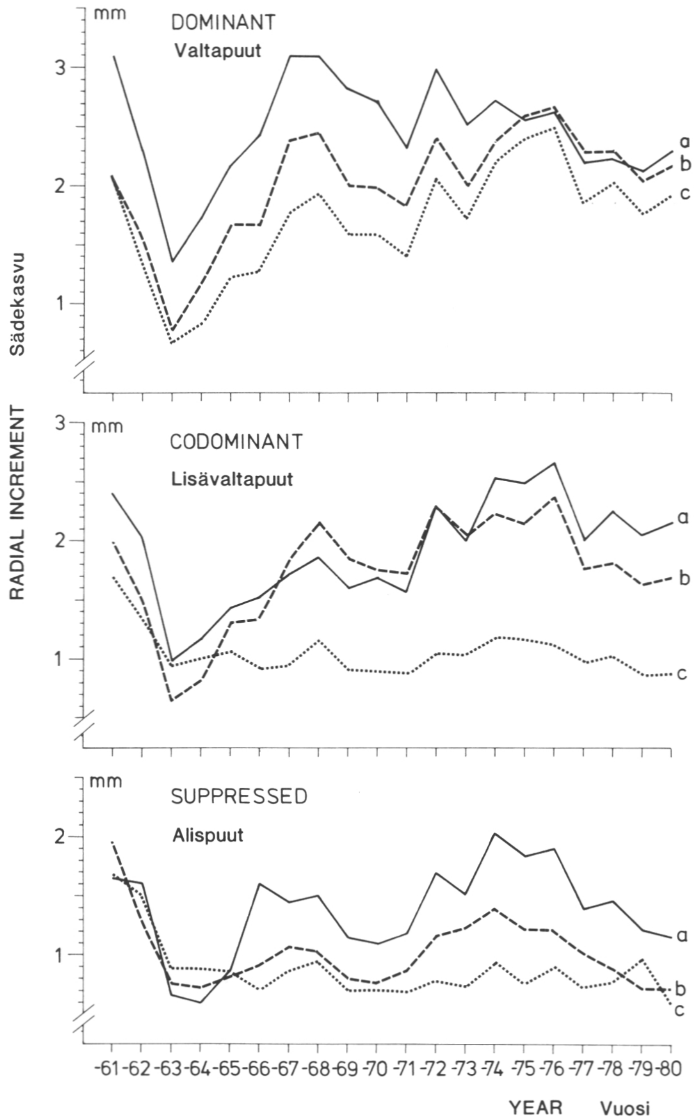

Figure 5. Annual radial incerement in the different tree classes by disease incidence class. The growth during the epidemic in 1961–1965 and postepidemic growth in 1966–1980, a) disease incidence, K 50 %, b) K 70 %, c) K 90 %.

Kuva 5. Vuotuinen sädekasvu eri puuluokissa karisteisuusluokittain. Kasvu epidemian aikana vuosina 1961–1965 ja epidemian jälkeinen kasvu vuosina 1966–1980, a) karisteisuus, K 50 %, b) K 70 %, c) K 90 %.

4. DISCUSSION

It is rather difficult to detect the effect of needle cast on the growth of trees. The difficulty arises from the fact that conifers form a current year shoot on a miniature scale in the buds of the previous growing season. Environmental factors during the bud formation seem to be more important than those during the elongation of new shoot. The tree can also compensate for the effect of a mild needle injury by more effective photosynthesis in the remaining needles. Hence, the effect of needle cast may be first noticed in the growth in the growing season following the epidemic (see Mitchell et al. 1976).

The secondary radial increment of trees occurs in the cambium by the division of cambial cells; this function continues much longer than the time needed for the elongation of new shoots during the growing season (e.g. Leikola 1969). Thus needle cast is able to affect the radial growth already during the year following infection. For that reason, in pines the reduction in radial growth has been detected in some cases more easily than that in height growth (Christensen and Gibson 1964, Mitchell et al. 1976). Van Sickle (1974) also observed a linear decrease in the radial increment of balsam fir (*Abies balsamea* (L.) Mill.), caused by a relatively slight needle rust epidemic. Artificial defoliation of the youngest needles reduces growth much more effectively than the removal of older needles (Linzon 1958, O'Neil 1962). In a young, growing conifer, the newest needles form the major and most active part of the foliage.

Rhabdocline needle cast destroys one-year-old needles in early summer at a stage when they are most important for photosynthesis. The cumulative effect of several successive epidemics was observed in this study. When 70 % of the foliage had fallen, a reduction of about 50 % in height growth was observed. However, the growth had not been completely unaffected by the disease before the most severe epidemics in 1960–1964 (s. p. 10). Thus the effect of the disease on the height growth could have been greater than that shown by the calculations. Many of the slightly infected codominant trees were able to increase their height growth despite the disease. Obviously, those trees could use the space released by decreasing competition most effectively. In the groups of suppressed and dominant trees, the relative decrease in height growth was similar. However, suppressed trees reached more frequently the absolute minimum in growth, after which they died. Suppressed trees are affected most seriously by needle damage and become easily susceptible to other pathogenic fungi, e.g. *Armillariella mellea* (Vahl. ex Fr.) Karst. (O'Neil 1963, Shaw and Toes 1977).

The pathogen *R. pseudotsugae* has survived in the stand but has caused no serious epidemics since the 1960's. However, the trees infected seriously in 1965 have probably suffered continuously from a slight needle cast infection. In addition, the descent of seriously infected trees in the "sociological" ranking due to the disease may be an additional explanation for the continuous growth differences between the disease incidence classes during the most recent years. All these differences do not lead to growth losses at the stand level. The needle cast epidemic had much the same effect as a thinning on the least infected trees. Weakened competition in the stand obviously promoted the growth recovery of the least infected trees, while other trees became more suppressed. The stand is now closing, and the competition for space is becoming a more effective factor, which can be seen in the general downward trend of radial increment (Fig. 5). The cold climatic period from 1975 to 1979 as well as ageing of the trees, may also have played some role in the latest depression of the radial increment. Why new epidemics have not appeared after 1965, is not known. Perhaps climatic factors suitable for the development of the pathogen have not coincided, or the pathogen has lost some of its virulence and reached an equilibrium with the host. It is obvious that, during the time the epidemic was most severe, a heavy reduction in radial growth occurred with little or no differences among the disease incedence classes. However in the post-epidemic growth these differences were highly significant.

A great variation between individual trees in disease incidence was observed, the major part of which can be genetically determined. Consequently, there is a possibility of resistance breeding by simple selection (s. Schober 1963, Stephan 1973). Although Douglas fir grows well in Finland, if planted on sheltered fertile sites (Sarvas 1964, Arboretum Mustila 1960), Heikinheimo (1956) considers it unsuitable for Finnish conditions because of *Rhabdocline* needle cast and poor frost hardiness. However, selecting proper provenances, it appears also possible to increase frost hardiness (Rehfeldt 1979).

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SELOSTE

Douglaskuusi (*Pseudotsuga menziesii* (Mirb.) Franco) on nopeakasvuinen ja puuainekseltaan hyvälaatuinen. Se sopii kasvatettavaksi viljavilla metsämailla. Suomessa kasvatusta haittaavat puun heikko kylmänkestävyys ja neulaskariste, douglaskuusenkariste. Ehkä juuri tämän taudin takia douglaskuusen kasvatus on meillä rajoittunut muutamiin 30-luvulla tai aiemmin perustettuihin koeviljelmiin.

Douglaskuusi ja karisteenaiheuttaja, *Rhabdocline pseudotsugae* Syd. -sieni ovat kotoisin Pohjois-Amerikasta. Sienen aiheuttamaa tautia on esiintynyt Suomessa muutamissa douglaskuusen koeviljelmissä vuodesta 1950 lähtien. Erittäin paha kariste-epidemia sattui Metsäntutkimuslaitoksen Ruotsinkylän kokeilualueessa 1960-luvun alussa. Vaikka sientä on todettu myöhemminkin douglaskuusikoissa, ei merkittävää epidemiaa ole enää esiintynyt. Tässä julkaisussa tutkittiin 1960-luvun alun kariste-epidemian vaikutusta puiden pituus- ja sädekasvuun sekä sädekasvun elpymistä epidemian jälkeen eräässä douglaskuusen koemetsikössä Tuusulan Ruotsinkylässä.

Metsikön puusto, peräisin Brittiläisestä Columbiasta, oli vuonna 1965, jolloin ensimmäiset mittaukset tehtiin, 38 vuoden ikäistä. Linjoittaisella ympyräkoeala-arvioinnilla metsiköstä valittiin 5 koealaa, joilta mitattiin yhteensä 163 koepuuta. Puista mitattiin pituus, läpimitta ($D_{1,3}$), pituuskasvu sekä sädekasvu. 15 vuotta myöhemmin mitattiin sädekasvu uudestaan.

Keskimääräinen karisteisuus oli n. 70 % vuonna 1965. Tällöin pituuskasvu oli alentunut n. 50 % ja sädekasvu n. 36 %. Karisteen ankaruus ja puiden asema metsikössä olivat vuorovaikutussuhteessa kasvuun. Vähiten saastuneet lisävaltapuut pystyivät käyttämään hyväkseen vähentyneen puiden välisen kilpailun lisäämällä pituuskasvuaan epidemian aikana useammin kuin muiden puuluokkien puut.

Sädekasvun elpyminen oli nopeinta yleensä valtapuilla, joista vähiten saastuneiden elpyminen kesti n. 4 vuotta ja ankarimmin saastuneiden n. 10 vuotta. Ankarasti saastuneiden lisävaltapuiden ja alispuiden sädekasvussa ei tapahtunut lainkaan elpymistä 15 vuoden aikana epidemian jälkeen. Jossakin määrin tauti on saattanut vaivata pahiten alttiita puita vuosittain, vaikka varsinaista epidemiaa ei ole todettu myöhemmin.

Karisteisuus vaihteli suuresti puuyksilöittäin. Yksinkertaisen valinnan avulla saattaisi olla mahdollista aikaansaada douglaskuusilajike, jolla olisi käytännön metsätalouteen riittävä karisteenkestävyys.

Kurkela, T. 1981. Growth reduction in Douglas fir caused by Rhabdocline needle cast. Rhabdocline -karisteen aiheuttama kasvunvähennys douglaskuusella. Commun. Inst. For. Fenn. 102: 1–16.

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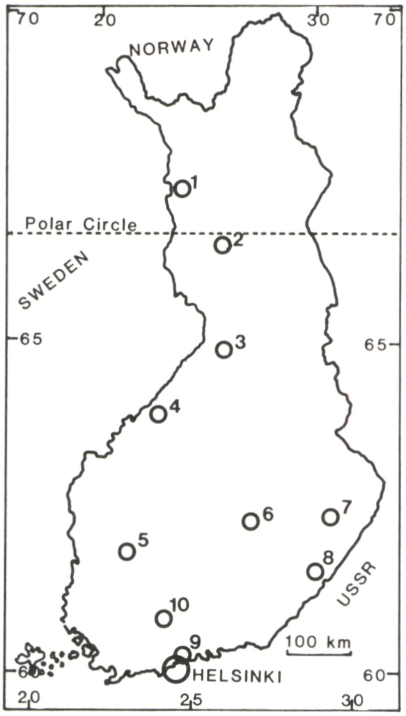

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FACTS ABOUT FINLAND

Total land area: 304 642 km² 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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