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ANTTI UOTILA

INFECTION OF PRUNING WOUNDS IN SCOTS PINE BY PHACIDIUM CONIFERARUM AND SELECTION OF PRUNING SEASON

MÄNNYN PYSTYKARSINTAVIOITUSTEN SYYSHAAVAKKATARTUNTA JA KARSINTA-AJAN VALINTA

THE SOCIETY OF FORESTRY IN FINLAND
THE FINNISH FOREST RESEARCH INSTITUTE

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ACTA FORESTALIA FENNICA 215

INFECTION OF PRUNING WOUNDS IN SCOTS PINE BY *PHACIDIUM CONIFERARUM* AND SELECTION OF PRUNING SEASON

Männyn pystykarsintavioitusten syyshaavakkatartunta ja karsinta-ajan valinta

Antti Uotila

To be presented, with the permission of the Faculty of Agriculture and Forestry of the University of Helsinki, for public criticism in Auditorium XII of the University main Building, Fabianinkatu 33, on 1 February 1991, at 12 o'clock noon.

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The Scots pine pruning experiments were established in different geographical regions of Finland. The pines were pruned at 16 different times during the year. Half of the trees were inoculated with conidia of *P. coniferarum*. Annual cankers were produced in the inoculated trees pruned during October – December. The safe pruning season ended in autumn when the five-day mean temperature decreased below +7 °C. The unsafe pruning season terminated when the temperature remained permanently < 0 °C. Dry-pruned branches were infected only if the phloem had been wounded. The mycelia of the fungus were pathogenic in the phloem in the inoculations made from October to March. The fungus occurred commonly in slash and in pines wounded during the autumn. The fungus has a one-year life cycle.

Männyn karsintakokeita perustettiin Suomen eri maantieteellisiin osiin. Mäntyjä karsittiin 16 eri ajankohtana vuoden aikana. Puolet karsintahaavoista ympättiin syyshaavakan kuromaitiöillä. Yksivuotisia koroja muodostui loka – joulukuussa karsittuihin ja ympättyihin puihin. Turvallinen karsintakausi päättyi syksyllä, kun viiden vuorokauden keskilämpötila laski alle +7 °C:n. Altis karsinta-aika päättyi, kun lämpötila oli jatkuvasti < 0 °C:n. Kuolleina karsitut oksat saivat tartunnan vain, jos nilaa oli vioitettu. Sienen rihmasto oli patogeeninen nilassa loka – maaliskuun ympäyksissä. Syyshaavakka esiintyi yleisesti hakkuutähteissä ja syksyllä vioitetuissa männyissä. Sienen elinkierto on yksivuotinen.

Keywords: *Phacidium coniferarum, Pinus sylvestris,* pruning, pruning season, canker.
ODC 443.3 + 245 + 172.8 *Phacidium coniferarum*

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Contents

Preface

The project on pruning damage of Scots pine was initiated by the suggestion of the National Board of Forestry. The project was carried out during 1985 – 1988 at the Finnish Forest Research Institute. The financial support provided by the Ministry of Agriculture and Forestry made the study possible.

Co-operation was done with the National Board of Forestry, the Central Forestry Board Tapio, and the Forestry Board of Helsinki. I would like to express my thanks to Carl-Gustav Zilliacus, M.For. and Hannu Kukkonen, M.For.

I am very grateful for the help provided by my assistants during the project: Forest technician Kirsi Joukas-Niemi, Forest technician Mikko Vuohelainen, Forest engineer Reijo Kuosmanen, Forest engineer Juha Suominen, Forest technician Taina Hirvonen and Forestry student Asko Lehtijärvi. The diligence of Kirsi Joukas-Niemi was especially important in the laborious stage of experiment establishment. I am also thankful to the whole personnel of the Department of Forest Protection for their advice.

I am also grateful for the useful comments on my manuscript and other support I received from Professor Eeva Tapio, Professor Timo Kurkela, Dr Lalli Laine and Mr John Derome (linguistic correction). Establishing and measuring the experiments meant a lot of travelling across the country for father, for which I wish to apologize to my wife Terhi and my daughters Tiina and Taina.

1. Introduction

11. Pruning of Scots pine

Pruning of Scots pine (*Pinus sylvestris* L.) has been done in order to improve timber quality. Pruning has been a practical silvicultural method or at least an object for forest research throughout the distribution area of Scots pine (Mayer-Wegelin 1936, Krigul 1961, Heiskanen and Taipale 1963, Ericson 1985, Sairanen 1985).

In Finland, 2000 – 13 000 hectares of Scots pine stands have been pruned each year during 1983 – 1988 (Metsätilastollinen Vuosikirja 1984–1988, Tapion vuosikertomus 1988). According to the Forest 2000 program, the aim is to reach an annual pruning level of 20 000 hectares (Metsä 2000 -ohjelma...).

In pruning the lower branches are removed from 350 – 600 trees/ha. In dry pruning only the dead branches are removed, but in green pruning the lowest living branches are also removed. The branches are sawn off close to the stem without wounding the trunk phloem in order to shorten the healing-over time. Despite careful pruning work, pruning injuries can still appear. The phloem of the basal swelling can be injured or the pruning equipment can cause internodal wounds in the phloem. In this study the term mechanical wound is used to describe all such man-made injuries around the normal pruning wound. The canker is described as the unwounded area of the phloem around the pruning scar, which is killed by pathogenic fungi.

The pruning height varies from 3.1 m to 5.5 m depending on the height of the stand. Only dead branches and weakened, living branches are removed. The mean breast height diameter in acceptable pruning stands is 7 – 15 cm. The branches of trees suitable for pruning should not be thicker than 25 mm (Pystykarsintaopas 1987).

Finnish pruning studies carried out before 1984 indicated that pruning does not cause decay that would decrease the timber quality of Scots pine (Heiskanen and Taipale 1963).

Before 1984 it was recommended (Vuokila 1976, Tuimala 1983) that Scots pine could be pruned throughout the year, but these recommendations were not based on inoculation experiments. Pruning directions only warned about pruning during spring, when the living bark is easily detached (Pystykarsintaohjeet 1982). Since 1985 it has been recommended that pruning should be done during the period 1. 1. – 30. 9. in southern Finland and 1. 12. – 15. 9. in northern Finland. During sap flow in the spring, however particular care in pruning work is recommended so as to prevent bark stripping (Pystykarsintaopas 1987).

Some reports in the literature have given pruning recommendations for conifer species other than Scots pine based on inoculation tests and observations on pruned trees. Hahn (1957b) recommended that white pine should be pruned during the growing season. Gremmen (1973) recommended pruning *Larix kaempferi* (Lamb.) Carrière during May to July in the Netherlands. Zycha (1952) recommended pruning *Pseudotsuga menziesii* (Mirbel) Franco and *Larix kaempferi* in the summer. Generally speaking, woody plants are best pruned during the growing season when the response of the new phellogen is rapid (Hudler 1984).

12. *Phacidium coniferarum*

The lack of knowledge about the biology of pruning was well illustrated when pruning was carried out in late autumn 1983. In summer 1984 bark beetles were found to have killed trees pruned the previous autumn along the southern coast of Finland. Bark necrosis around pruning wounds was also found (Räisänen et al. 1986). Bark necrosis around pruning wounds with the association of *Phacidium coniferarum* (Hahn) DiCosmo et al. (syn. *Potebniamyces coniferarum*, *Phacidiella coniferarum*, conidial stage: *Apostrasseria* sp., *Phacidiopycnis pseudotsugae*, *Pho-*

mopsis pseudotsugae, *Discula pinicola*, *Ligniella pinicola*) has been earlier documented in Sweden (Ericson and Beyer-Ericson 1984, Karlman 1984). The first symptom of the disease is abundant resin flow from the area surrounding cankered pruning wounds. This symptom is not always clear and it is difficult to distinguish from the resin flow of healthy pruning wounds. After 3 years diameter growth large cankers are visible as a depression. In some cases the bark becomes loosed from the cankers. The damage was attributed to *Phacidium coniferarum*. DiCosmo et al. (1983 and 1984) revised the systematics of this ascomycetous fungus. The bibliography of *P. coniferarum* is also published (Uotila and Laine 1989).

P. coniferarum is known as a wound pathogen of conifers (Wilson 1920, Hahn 1957b, Gremmen 1973). It also infects frost-damaged tissues (Roll-Hansen and Roll-Hansen 1971), vole-damaged Scots pine seedlings (Lagerberg 1934) and larches browsed by reindeer (Loftsson 1976). It grows in the host tissues during the dormant period. Gross and Weidensaul (1967) reported that *P. coniferarum* causes cankers in harvesting wounds of *Tsuga canadensis* (L.) Carrière. *P. coniferarum* also causes blueing of pine timber and obtains nutrients from the protoplasts of the parenchyma cells in pine sapwood (Lagerberg et al. 1927). The fungus can grow at low temperatures, even below 0 °C (Tarocinsky 1963). The fungus can grow in the host tissues during the growing season only, if the condition of the host is weakened e.g. by drought (Hartmann 1976).

P. coniferarum has been found on pruned *Larix kaempferi* (Gremmen 1973), *Pseudotsuga menziesii* (Sachsse 1983), *Pinus sylvestris* (Beyer-Ericson and Ericson 1985, Räisänen et al. 1986) and *Pinus contorta* Dougl. ex Loudon (Stefansson 1957, Karlman 1985). In all these reports *P. coniferarum* has caused damage in pruning done during the dormant period. The fungus occurs on at least 27 species of conifers (DiCosmo et al. 1984), and is distributed over wide areas troughout Europe and North America, and New Zealand (CMI Map 320, 1985).

According to CMI map no 320 (1985), Finland lies outside the distribution range of *P. coniferarum*. However, the HFR herbarium (The Finnish Forest Research Institute) has some specimens of this fungus from Scots pine, Douglas fir and larches. Kujala (1950) mentioned the fungus as a killer of douglas fir shoots.

Other possible pathogens, in addition to *P. coniferarum*, that can occur in pruned pines are *Ascocalyx abietina* (Lagerb.) Schläpfer-Bernhard, *Crumenulopsis sororia* (Karsten) J. W. Groves, *Cronartium flaccidum* (Alb. & Schwein.) Winter, *Stereum sanguinolentum* (Alb. & Schwein.:Fr.) Fr. and *Phellinus pini* (Brot.:Fr.) Murr.

13. Defence reactions of pruning wounds

The stub of a green-pruned branch is an open infection route for pathogens and a tree must protect itself in order to prevent the decay process from spreading in the xylem and canker formation in the phloem.

In the healing process a resin tap is formed over the pruning wound (Pietilä 1989). The resin tap consists of bark and resin.

In addition to the cut surface of the branch, pruning causes wounds on the bark ridge surrounding the base of the branch, or even to the trunk phloem or xylem (Heiskanen and Taipale 1963). The healing of a pruning wound normally takes at least five years, and so a tree needs more rapid methods to prevent infection.

Resin flow is the first defence reaction of a pine to wounding. During the growing season resin flow covers at least part of the wound surface within a few minutes. Wounds or cankers formed during the dormant season are isolated by resin at the beginning of the growing season. The chemical composition of the resin changes after wounding or fungal infection (Shrimpton and Whitney 1968, Russell and Berryman 1976, Cook and Hain 1987, Gref and Ericsson 1985).

In green pruning the periderm is broken and a tree must cover the injured periderm with a new periderm in order to protect the wound from desiccation and wound pathogens.

Mullick (1977) has studied non-suberized impervious tissues (NIT) and necrophylactic periderm (NP) formation in conifers. NIT formation can be induced by wounds, insect saliva or the toxins produced by pathogens. NIT is found on at least 10 coniferous species and on many hardwoods and shrubs (Biggs et al. 1984). It is necessary for the formation of necrophylactic periderm, and isolates wounded tissues from living tissues (Mullick 1977, Biggs 1985). The time required to produce NIT after wounding depends on environmental factors (Puritch and Mullick 1975, Romakkaniemi and Poteri 1987). When wounds occur in the dormant season, NIT is formed during the following growing season (Mullick and Jensen 1976).

A reaction zone is formed in the xylem after green pruning in order to protect the sound sapwood from desiccation and fungal infections (Aufsess 1975). It is formed as a result of chemical changes in the dying parenchyma cells (Coutts 1976, 1977). Decay is often compartmentalized and does not spread through the reaction zones. The new growth rings formed after wounding are healthy (Shigo 1984, Shortle 1979).

Traumatic resin canals can also appear after wounding (Nylinder 1951, Tippett and Shigo 1981, Sachsse 1983). If the pine or spruce sapwood is wounded during the growing season traumatic resin canals appear immediately. If the sapwood is wounded during the dormant period the traumatic resin canals appear in the beginning of the next growing season in the springwood of the new growth ring (Nylinder 1951).

The chemical composition and moisture content of the reaction zone resembles that of heartwood (Reid et al. 1967). On pines reaction zone wood and heartwood contain pinosylvin and pinosylvin monomethylether, which are produced in the slowly dying parenchyma cells after wounding (Jörgensen 1961, Shain 1967).

When the lower branches die naturally, a tree must produce a reaction zone between the living and dead tissues in order to protect the xylem against desiccation and fungal penetration. In the phloem the barrier is formed between the trunk phloem and branch phloem. In the wood the reaction zone is formed around and in the knot. The resin content of knotwood is even higher than that in heartwood, although the moisture content is low. The resin content of trunk knotwood on Scots pine is higher than that in knotwood outside the trunk (Boutelje 1966). This enhances the dropping of dead branches. Pinosylvin is also produced in the base of dead branches of pines during the first year after a branch has died (Jörgensen 1961). The chemical composition of wounded wood inhibits the growth of decay fungi (Rennerfelt 1945, Shain 1967, Cobb et al. 1968, Shrimpton and Whitney 1968, Hintikka 1970, Väisälä 1974, Flodin and Fries 1978).

14. The aim of the study

The aim of this study was to investigate how Scots pine can be pruned without causing fungal or insect damage that decreases the sawtimber value. The research problems were the selection of pruning season, geographical distribution of damage, the biology and distribution of *P. coniferarum*, the importance of pruning intensity as a predisposing factor for fungus and insect damage, and the effect of weather on *P. coniferarum* infection.

2. Material and methods

21. Pruning damage surveys

Fifty pine stands pruned during autumn were investigated by the author to find possible infections by *Phacidium coniferarum*. The stands were located in different parts of Finland and were pruned during 1981 – 1984. In addition, C-G. Zilliacus from the Regional Forestry Board of Helsinki investigated 42 stands pruned in autumn 1983 along the southern coast. In winter 1985 the Central Forestry Board Tapio investigated 113 stands pruned during January to May.

The presence of cankers was investigated by peeling off the inner bark surrounding a pruning wound. In addition, the surveyers noted possible insect damage in pruned trees. The damage in pruning stands was classified visually as severe and slight or healthy. The damage was classified as severe if there were frequent cankers > 10 cm long on the pruned trees. Small cankers or a few large cankers were permitted in slightly damaged stands. Pruning time, stand area and tree size were obtained from pruning records.

One damaged stand at Säkylä (61°00', 22°30') (Fig. 1) was investigated in detail in order to obtain preliminary material for planning the sampling in pruning experiments. Four compartments were pruned in September and October 1984. The outer bark surrounding the pruning scar was peeled off from the first, the third and the fifth pruned whorl (up to down) on the southern side of 12 trees in each compartment. Canker length and width were measured. Mechanical wounds reaching the xylem were included as cankers.

Eight diseased trees were felled four growing seasons after pruning in order to study the healing time of cankers. Radial growth and healing after pruning were measured from 181 canker cross sections.

22. Fungal isolation and culturing

Mycelium of *Phacidium coniferarum* was isolated from the phloem or xylem of diseased pruned trees. Attempts were made to isolate the fungus from different depths in the wood below the canker. Monospore isolations were made from spreading cultures of conidia.

The growth of nine *P. coniferarum* isolates was examined at temperatures of 0, 5, 10, 15, 20, and +25 °C in the dark. Colony diameter was measured after 1, 2 and 3 weeks. This was done on 5 – 6 inoculations per isolate and temperature. The isolates used in the initial tests were 1 (Sweden, Värmland, code D46, isolated by L. Beyer-Ericson), 2, 3 (isolated by T. Kaleva) and 4 (Table 1). Mycelial growth on oat agar and on 1 % malt agar was compared at +15 °C. Oat agar medium was prepared from 30 g of cooked and strained oatmeal, 20 g agar and 1 litre H_2O. 10 drops of filtered lactic acid were added to the medium after autoclaving. The same test arrangement was used in the second test with the isolates 6, 7, 9, 10, 11 (Table 1).

Table 1. *Phacidium coniferarum* isolates used in the laboratory and field experiments.
Taulukko 1. Laboratorio- ja kenttäkokeissa käytetyt syyshaavakka-isolaatit.

Isolate *Isolaatti*	Collected *Kerätty*	Coordinates *Koordinaatit*
1. Avradsberg (Sweden)	11. 9. 1982	60°25', 13°44'
2. Tenhola	9. 8. 1984	60°05', 23°15'
3. Janakkala	5.10. 1984	60°55', 24°45'
4. Jämsänkoski	30. 1. 1985	62°00', 25°00'
5. Ruokolahti	20. 3. 1985	61°20', 28°55'
6. Kullaa	7. 5. 1985	61°30', 22°15'
7. Mynämäki	7. 5. 1985	60°45', 22°00'
8. Lestijärvi	17. 6. 1985	63°35', 24°45'
9. Punkaharju	20. 6. 1985	61°50', 29°25'
10. Noormarkku	15. 7. 1985	61°35', 22°00'
11. Säkylä	15. 7. 1985	61°00', 22°30'
12. Espoo	3. 9. 1987	60°15', 24°35'

23. The production and germination of conidia

Conidia of *P. coniferarum* were produced on barleycorn medium (15 g barley, 50 ml H_2O, autoclaving) in Erlenmeyer flasks. The cultures were grown in light at +15 °C.

A diluted conidia suspension from two isolates (6 and 9 in Table 1) was spread at room temperature on 1% malt agar in order to study germination at 0, 5, 10, 15, 20 and +25 °C. Four Petri dishes of both isolates were used at each temperature. The germination was recorded after 1, 2 and 3 days' incubation. A spore was considered to have germinated when it had elongated or its germ tube had become visible. Swollen spores were not counted as germinated ones.

The effect of suspending the spores in water on the speed of germination was studied by keeping conidia in distilled water for 0 – 48 hours at +15 °C before spreading on the agar. Germination was recorded after one day's incubation at +15 °C.

24. Inoculation into pine discs

Discs of Scots pine wood for the blue-staining test were sawn in winter and stored in a freezer prior to inoculation. The discs were barked to leave the inner layer of phloem intact, and then cut into sectors. Half of these disc sectors were surface sterilized by immersion in alcohol. After burning off the alcohol, the disc sectors were transferred to autoclaved Petri dishes (120 mm in diameter) containing dry or wet filter paper. 24 disc sectors were inoculated with the *P. coniferarum* spore mass. The isolates were 9 and 11 (Table 1). One disc sector was left as an uninoculated control. The inoculum was applied at a point on the phloem or as a radial line on the xylem. The disc sectors were checked after 24 days storage at +10 and +20 °C, and the fungus reisolated at a distance of 1 – 3 cm from the inoculation point.

25. Mycelial inoculation in living pines

Canker formation by *Phacidium coniferarum* in pine bark was investigated at Tuusula (60°20', 25°00')(Fig. 1). This Scots pine stand was planted 30 years ago and had been thinned once before inoculation.

The *P. coniferarum* isolates used in the tests were 1, 2, 3 and 4 (Table 1.). In the same test the trees were also inoculated with two isolates of *Ascocalyx abietina* (Lagerb.) Schläpfer-Bernhard (Uotila 1990). Each isolate was inoculated in ten trees once a month from April 1985 to March 1986. Four inoculations (two isolates of *Phacidium coniferarum*, one isolate of *Ascocalyx abietina* and one control) were made on the southern face of the test trees in random order. The inoculations were made in the middle of the internodes up to a height of 1 – 3 meters. A total of 240 trees were inoculated.

Holes were bored through the phloem to the surface of the xylem with a cork borer (4 mm). A piece of mycelium was then inserted into the hole using tweezers, and a piece of bark replaced in the hole. All equipment was sterilized with alcohol between inoculations. Only a hole was bored in the controls. Records were made of the weather conditions during inoculation. Resin flow from the inoculation points was checked one month after inoculation.

Lesion length and width (canker) were measured to an accuracy of 1 mm in June 1986. Canker size was first measured at the outer layer of the phloem, and then at the surface of the xylem.

Blocks of wood were sawn for reisolating the fungi. Samples were taken from one inoculated tree representing each inoculation time. 116 isolations were made from 22 *P. coniferarum* inoculation samples, and 57 isolations from 13 control inoculation samples. The isolations were made from the inner bark and xylem, primarily at the edges of the cankers.

Canker area was estimated using the formula for a diamond shape:

$$\text{Area} = 2 \times \text{width} \times \text{length}/3$$

Theoretical canker length was estimated on the basis of the diurnal mean temperatures running from the inoculation date to the end of April, and the growth rate of the fungus on oat agar at comparable temperatures. Theoretical canker length was compared to real canker size in the inoculation and pruning experiments.

Table 2. Description of the experiment stands.
Taulukko 2. Koemetsiköiden kuvaus.

Location *Sijainti*	Regeneration method *Uudistus-menetelmä*	Age, a *Ikä, v*	Site, type *Metsätyyppi*	Mean d1,3, cm *Keskilpm, cm*	Mean height, m *Keskipituus, m*	Maximum pruning height, m *Karsintakorkeus, m*	Mean branch thickness, mm *Keskioksanpaksuus, mm*
1. Tenhola 1	Planting *Istutus*	23	VT*	13.2	9.3	4.5 – 5.0	21.1
2. Tenhola 2	Planting *Istutus*	16	VT	9.5	5.7	2.0	14.4
3. Padasjoki 1	Planting *Istutus*	25	VT	13.4	10.1	4.5	18.3
4. Padasjoki 2	Planting *Istutus*	15	MT	8.3	5.6	2.0	11.8
5. Vilppula 1	Sowing *Kylvö*	30	MT	14.4	11.3	4.5	15.9
6. Vilppula 2	Planting *Istutus*	23	VT	11.2	7.8	3.0	16.5
7. Rovaniemi 1	Natural *Luontainen*	37	EVT	11.7	8.9	4.0	13.6
8. Rovaniemi 2	Natural *Luontainen*	50	ECT	10.5	7.0	2.0	11.1
9. Tuusula	Planting *Istutus*	20	CT	8.9	5.9	2.5	14.2

*VT = Vaccinium type
MT = Myrtillus type
EVT = Empetrum Vaccinium type
ECT = Empetrum Calluna type
CT = Calluna type

26. Pruning experiments

261. Pruning stands

Eight stands were pruned in four research areas located in different parts of Finland (Fig. 1) during May 1985 – April 1986. The locations of the experiments were selected so as to represent different climatic conditions. One 8 to 11 meter-high and one 6 to 8 meter-high Scots pine stand were pruned in each research area.

Breast height diameter, tree height and the living crown length were measured. A general description of the experimental stands is given in Table 2. The distribution of breast height diameter, height and branch thickness in the experimental stands is described in Appendices 1, 2 and 3.

The experimental stands were rather healthy before pruning. The lower branches had been killed by *A. abietina* in six of the southern stands, but only in the Vilppula 2 stand had the fungus caused damage to the upper crown during the epidemic of 1982. In the Padasjoki 2 stand, *Blastesthia turionella* (L.) Obr. had caused leader changes in 52 % of the experiment trees during the three-year period before pruning. *Phacidium coniferarum* was not found in any of the experimental stands before pruning.

262. Testing the effect of season on the development of damage

Test prunings were carried out 16 times during the year in order to determine the safe pruning times for Scots pine. This was done once a month in all 8 experimental stands. However, from the beginning of September to the end of December pruning was carried out at two-week intervals. A total of 1280 trees were pruned in this experiment.

The branches were sawn off as close to the stem as possible without producing wounds on the basal swelling (Fig. 6, see page 17). Lower dead branches were cut off using a pruning chisel. The work was done with the same degree of care as in practical pruning.

The maximum pruning height depended on the height of the stand, 0 – 5 whorls being green-pruned. Both trees with slender and thick branches were pruned. Normally about half of the trees in the stand were pruned. In Padasjoki 2 stand all the trees were pruned.

The level of the lowest living branch was marked by cutting off the lowest living branch to leave a long stub bearing some green needles. The trees were numbered using aluminium tape.

The conidium suspension for the inoculations was prepared in the forest just before spraying. 30 ml of H_2O were added to an Erlenmeyer flask containing slimy lumps of conidia and then shaken and diluted with water give a final volume of 0.5 litre. The isolates used in the inoculations were 1, 2, 3, 5, 7, 8 (Table 1).

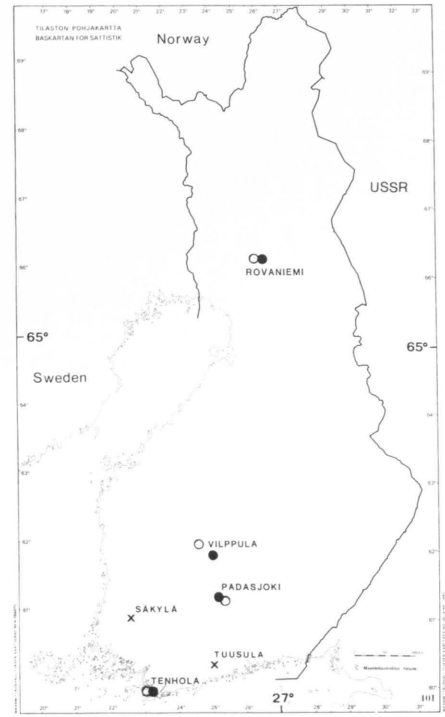

Figure 1. Location of the experimental stands.
○ = pruning height 4 – 5 m,
● = pruning height 2 – 3 m,
× = other experimental stand.
Kuva 1. Tutkimusmetsiköiden sijainti.
○ = *karsintakorkeus 4 — 5 m,*
● = *karsintakorkeus 2 — 3 m,*
× = *muu koemetsikkö.*

The conidium suspension of *P. coniferarum* was applied using a houseplant atomizer immediately after pruning on every other pruned tree. The trees were sprayed a month after pruning if the air temperature was below – 12 °C, as in the case of January prunings at Padasjoki and Vilppula. About 1 ml of suspension was sprayed on each pruning scar, i. e. enough to make the pruning scar wet. At Rovaniemi the trees were sprayed immediately after pruning only in May, June, August and April. The prunings done in September and October were sprayed in October, and the prunings from November to March were sprayed in April. The spore concentration in the conidium suspensions was at least 170 000 conidia/ml. No pieces of mycelium were found during the counting procedure. Germination after one day's incubation at +15 °C was at least 35 % when tested.

The experiments were surveyed during June – September in 1986. The lesion length and width, and the thickness of the branch were measured to an accuracy of 1 mm. The canker (bark necrosis) was measured from the border of the xylem and phloem. In addition, the size of mechanical pruning wounds extending into the xylem was measured.

One pruning scar in the first, third and fifth whorls was investigated on both the southern and northern face of the trees. This sampling technique was adopted on the basis of the canker size variance in the Säkylä pruning stand. The aim was to achieve a 95 % probability of a 30 % difference in the canker area mean at each pruning time (Cochran 1966). 60 pruning scars were measured each pruning time. A total of 7680 pruning scars were investigated in eight experiments.

Observations were made on possible insect damage and on the development of pycnidia. Samples were taken from the cankers for reisolating *P. coniferarum*. Meteorological data obtained from the Finnish Meteorological Institute were used (Kuukausikatsaus...1985 – 1989, Suomen Meteorologinen Vuosikirja 1916 – 1988).

Two-way analysis of variance was used to find statistically significant differences among pruning times, between dry and green pruning, and between inoculations and the controls. The calculations were done with the whole data combined, and separately for each experiment. Tukey's test was used

to determine possible significant differences among pruning times. The results of the statistical analyses are expressed as probabilities according to Warren (1986). The regression between branch thickness and canker area was studied in the autumn prunings. BMDP programs were used in all the statistical analyses of this study (BMDP ...).

Canker area (A) was estimated on the basis of canker length (L), width (W) and branch diameter (D):

$$A = a \times (0.785 \times W \times L - 0.785 \times D^2)$$

The shape of 12 cankers representing different size classes was measured in order to estimate exact canker area for determining a constant (a = 0.525). The model was defined such that if the width and length of the canker was the same as the thickness of the branch, the canker size was zero.

263. Testing the effect of spore concentration and delayed inoculation

The importance of spore concentration and the time of inoculation was investigated at Tuusula. 80 test trees were pruned on November 2nd, 1987, in the 20 -year-old Scots pine stand growing on the Calluna site type. The spore concentrations used were 3.0×10^1 - 3.0×10^6 conidia/ml (isolate 12 in Table 1).

The two highest concentrations were counted in a Bürker chamber. In the case of the smaller suspensions, the concentrations were calculated on the basis of the dilution.

The significance of delayed inoculation time was studied by spraying five trees with the conidial suspension (concentration = 3.0×10^6) immediately and 1, 2, 4, 7, 14, 28, 72 days after pruning. The control trees were not inoculated. Temperatures ranged from -1.0 °C to +8.8 °C during the five-day period after pruning. It did not rain during the following week. During the second week after pruning there were considerable falls of sleet. The cankers were measured in June.

264. Green pruning intensity

Pruning intensity experiments were established in 6 to 8 m-high Scots pine stands: Tenhola, Padasjoki, Vilppula and Rovaniemi. Pruning intensity formed a continuous series ranging from no green pruning to whole-crown, green pruning at intervals of one whorl (Tenhola, Padasjoki and Vilppula) or a distance of 0.5 m (Rovaniemi). 8 – 10 trees were pruned in all stands on 16 occasions as in the pruning time experiments. A total of 558 trees were pruned.

Insect damage was investigated in summers 1986 and 1987. At the same time observations were made of the vitality of the trees and possible fungal infections. The effect on growth is to be measured in a future study.

3. Results

31. The occurrence of pruning damage

No significant damage, in spite of mechanical wounds, was found in prunings done during February to August. Pruning damage occurred in stands pruned during September – January over the period 1981 – 1984. All cases of severe damage appeared in stands pruned in October – December. The cases of severe damage were concentrated along the southern coast or in southwestern Finland.

Along the southern coast (area of the Regional Forestry Board of Helsinki) there was severe damage in 38 % and slight damage in 50 % of the stands pruned during October – December 1983. Often cankers were formed only on upper, green-pruned whorls. In central Finland some stands pruned during September – November were slightly damaged. Dry-pruned stands were healthy in central Finland even though they had been pruned during autumn. Some of the stands pruned in January along the southern coast were also slightly damaged.

Insect damage was found in individual trees. These trees were either infected by *P. coniferarum* or had been green-pruned very intensively.

In Säkylä there were only a few cankers on trees pruned in September (maximum length 11 cm), but the number and size of the cankers increased (maximum length 27.5 cm) in October pruning (Table 3). In the compartment pruned at the end of October, 14 % of the pruned trees were killed as a result of secondary attack by insects. One-way analysis of variance showed statistically significant differences in canker size between pruning times. The cankers had grown more in a downwards direction (mean 3.6 cm) than upwards (mean 2.0 cm).

The healing time of the cankers (the necrotic area around the pruning wound) depended on the canker width and the diameter growth of the tree. When canker width was below 5 mm, all the cankers had healed within two years. 26 % of the 5 to 10 mm-broad cankers had healed within one year, and 64 % of the same canker size class had healed within two years. 21 % of the 11 to 15 mm-broad cankers had healed within 4 years. When the canker width was over 15 mm, only a few cankers had healed within four growing seasons after pruning. Cankers were formed during the first dormant season after pruning (Fig. 2). Canker expansion was not detected during three subsequent dormant seasons.

Table 3. Canker length and width in four compartments pruned in autumn 1984 at Säkylä.*

Taulukko 3. Korojen pituus ja leveys neljällä metsikkökuviolla, jotka karsittiin syksyllä 1984 Säkylässä.

Pruning date *Karsinta-ajankohta*	Length, cm *Pituus, cm*	S.E.M. cm *Keski-virhe, cm*	Range, cm *Vaihtelu-väli, cm*	Width, cm *Leveys, cm*	S.E.M, cm *Keski-virhe, cm*	Range, cm *Vaihtelu-väli, cm*
11. – 22. 9.	1.5	0.4	0 – 11.0	0.03	0.02	0 – 0.5
24. 9. – 13. 10	3.3	0.8	0 – 21.5	0.3	0.13	0 – 3.0
15. – 24. 10	6.9	0.9	0 – 19.5	0.5	0.15	0 – 3.5
25. – 26. 10	10.5	1.3	0 – 27.5	0.6	0.28	0 – 8.0

* The diameter of branch is not included in canker length or width.
Oksan läpimitta ei sisälly koron pituuteen tai leveyteen.

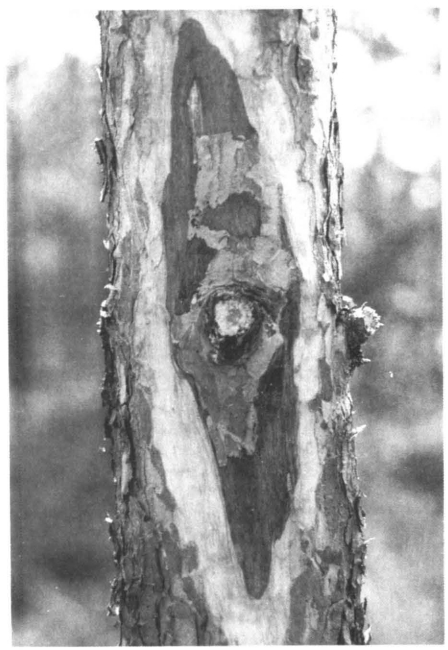

Figure 2. A canker caused by *P. coniferarum* in a pine pruned on November 2nd in 1987. Photographed in June 1988.
Kuva 2. Syyshaavakan aiheuttama koro 2. 11. 1987 karsitussa männyssä. Valokuvattu kesäkuussa 1988.

32. The distribution and life cycle of *Phacidium coniferarum*

P. coniferarum was isolated from pruned trees in 12 stands. The mycelia of the fungus were isolated from the edges of the canker phloem or from the middle of the canker phloem. Isolations made from green phloem

at a distance of 2 mm from brown, dead phloem failed. In addition, specimens containing conidial stage were collected from 22 stands (Fig. 3).

Salla (67°10', 29°15') is the northernmost location in Finland where *P. coniferarum* were found. Cone harvesting scars in the area were infected by the fungus in autumn 1988 causing the dieback of some pine shoots.

The fungus has a one-year life cycle (Fig. 4). Infection usually occurs in autumn or during periods of thaw in the winter. The pycnidia begin to develop during the following summer, and the first pycnidia ripen in the beginning of September. Most of the pycnidia release conidia during autumn, but some conidia remain in the pycnidia over winter. The pycnidia develop under the periderm and, when they are ripe, the periderm ruptures and the pycnidia appear. The 0.5 to 1.0 mm-wide pycnidia are formed in groups (Fig. 5b). Some new pycnidia may appear the following year on the bark. Germinating conidia were found in the pycnidia of pruning cankers even four years after pruning. Pycnidia are also formed on the wood. During wet weather in autumn the light grey, slimy conidial mass is extruded from the pycnidium. Dry spore tendrils were visible during dry periods in autumn. The size of the conidia was 4.5 – 6.5 µm x 2 – 4 µm (Fig. 7b). In February most of pycnidia were empty.

The perfect state of the fungus was found only at Tuusula (8. 2. 1988) and at Orivesi (4. 9. 1990). At Tuusula the apothecia were growing on branches fallen to the ground. These branches had been pruned in October 1986. At Orivesi the apothecia appeared on a branch that had fallen to the ground as a result of snowfall during January 1990. The specimens are stored in the HFR herbarium (The Finnish Forest Research Institute). By the beginning of September the apothecia had developed, but only a few apothecia and asci contained ascospores. By February most of the ascospores were released, but the apothecia also contained a few asci with ascospores and some of the asci had not yet produced ascospores. The apothecia had grown through the periderm (Fig. 5a). The width of the apothecia was 0.9 – 1.3 mm, and the size of the ascospores 15 – 22 µm x 3.5 – 5 µm (Fig. 7a). The asci were 63 – 125 µm x 11 µm (on average 100 x 11 µm).

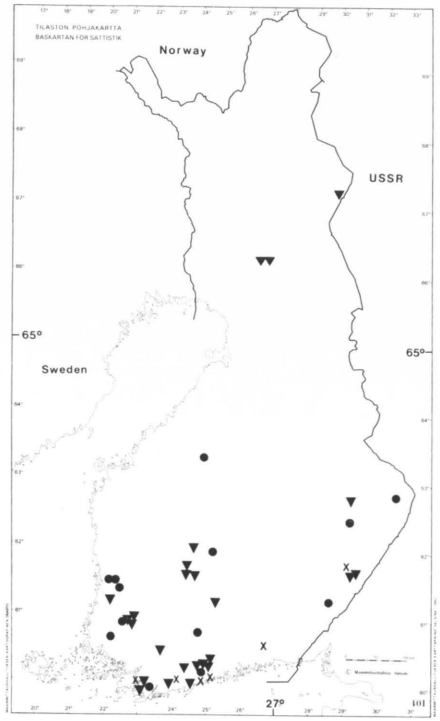

Figure 3. The distribution of *P. coniferarum* in Finland according to observations, anamorph specimens and mycelial isolations.
▼ = specimen with anamorph, × = herbarium specimen collected before 1984, ● = mycelial isolation from a pruned tree.
Kuva 3. Syyshaavakan levinneisyys havaintojen, näytteiden ja rihmastoeristysten perusteella.
▼ = näyte, jossa kuromapulloja, × = ennen vuotta 1984 kerätyt kokoelmanäytteet, ● = rihmastoeristys karsitusta puusta.

There was some pink or lilac colour in the hymenium (Fig. 5c).

Apothecia formation was preceded by weather conditions favourable for fungal growth: summer 1987 was cool and rainy, and the winter 1990 was mild. No apothecia were found in autumns 1985 and 1986 following dry and warm summers and cold winters. The apothecia appeared next to the pycnidia.

The fungus can infect wounds of Scots pine made during the dormant period. The fungus was found in pruning wounds on

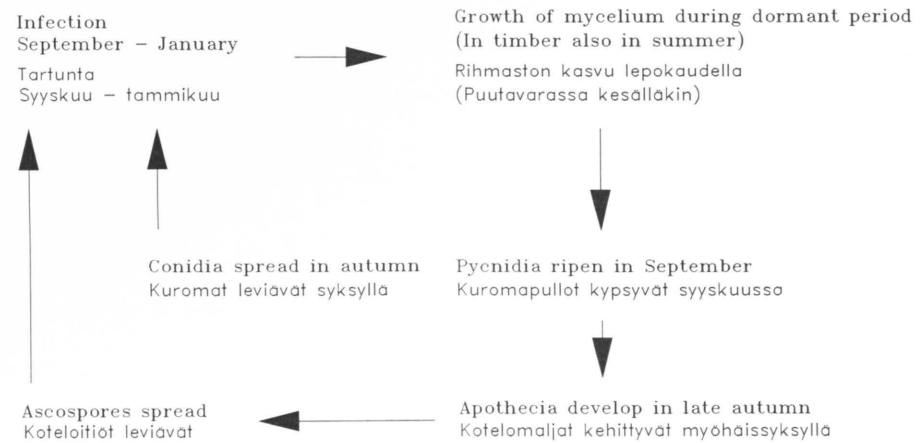

Figure 4. The life cycle of *P. coniferarum*.
Kuva 4. Syyshaavakan elinkierto.

Scots pine, pruned branches lying on the ground, slash, round timber, saplings damaged by moose, branches broken by snow and seedlings felled by brush saw.

On *Pinus contorta* the fungus was found on saplings damaged by moose browsing. In this case some pycnidia were also found on the needles. The fungus also occurred on the shoots of *Pseudotsuga menziesii*.

33. Fungal growth, production and germination of conidia and blueing of pine wood

P. coniferarum is a fast-growing fungus. Colony diameter growth at +15 °C was 4.7 mm/day on malt agar and 5.2 mm/day on oat agar. The fungus grew 0.5 mm/day at 0 °C, but the growth was already 1.7 mm/day at +5 °C. The fungus grew fastest at +20 °C, colony diameter growth being over 7 mm/day (Fig. 8). There were no statistical differences between the growth of different isolates. The young colony of the fungus was white, but later turned light grey and then grey-brown after the colony had reached the edges of the Petri dish. After one month *P. coniferarum* began to produce a light grey, slimy mass of conidia. The production of conidia was abundant on barley corn medium in Erlenmeyer flasks.

The conidia germinated at a temperature of 0 °C even. Within three days incubation time at 0 °C, 20 – 45 % of the conidia had germinated. However, 100 % of the conidia had germinated within the same time at +5 °C. At the optimum temperature (+20 °C) 100 % of the conidia had germinated within one day.

The conidia did not germinate in a water suspension, but the rate of germination improved when they were kept in a water suspension before preparing the spreading cultures. 59 % of the conidia germinated when the suspension was spread on the agar 0 – 2 hours after dilution. When the conidia were kept for one day in a water suspension at +15 °C the germination rate improved to 71 %, and after two days to 83 %. Germination was counted 24 hours after spreading the spores on the agar.

In the inoculation test, *P. coniferarum* caused grey-blue staining. The discs kept at 10 °C were stained only near the inoculation point, but the discs kept at 20 °C were often stained throughout. The discs kept on wet filter paper were more strongly stained than those on dry filter paper. According to the

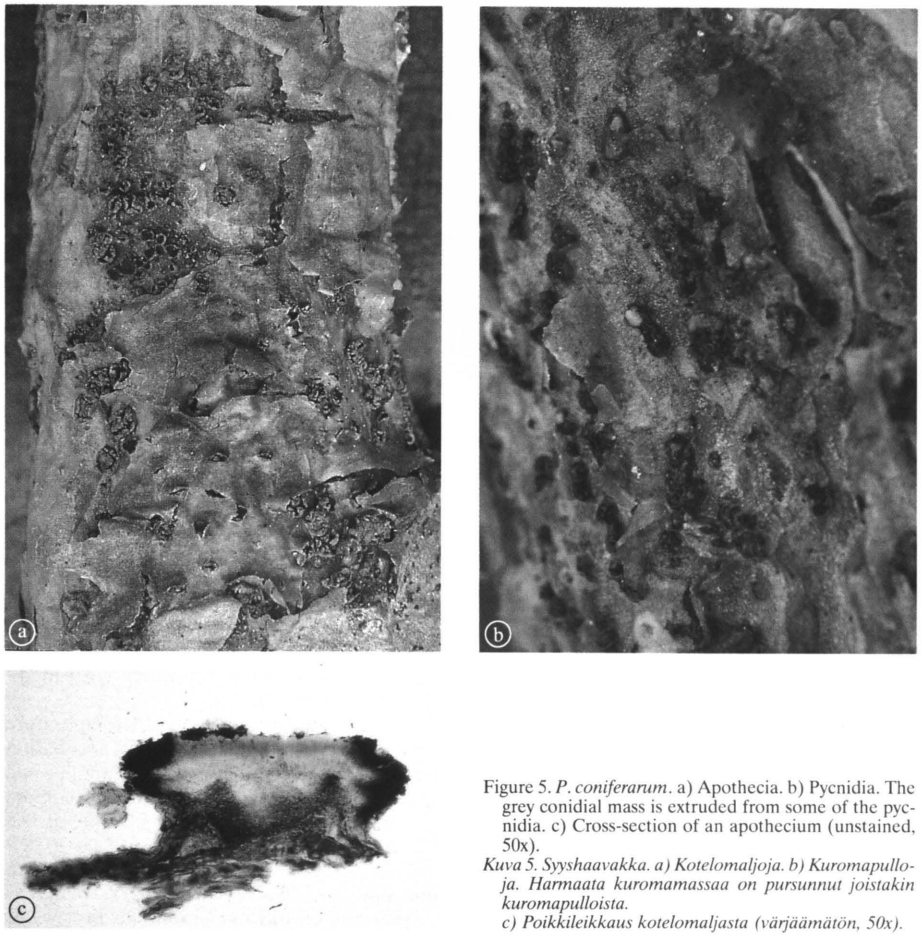

Figure 5. *P. coniferarum*. a) Apothecia. b) Pycnidia. The grey conidial mass is extruded from some of the pycnidia. c) Cross-section of an apothecium (unstained, 50x).
Kuva 5. Syyshaavakka. a) Kotelomaljoja. b) Kuromapulloja. Harmaata kuromamassaa on pursunnut joistakin kuromapulloista.
c) Poikkileikkaus kotelomaljasta (värjäämätön, 50x).

fungal isolations, the mycelium of the fungus had grown further from the inoculation point than the visible staining. Pycnidia began to develop on the discs after 3 week's growth. The fungus was reisolated regularly from the discs. The mycelia grew e.g. through fenestriform pits in the xylem (Fig. 9).

Grey-blue staining was also observed in the wood under large pruning cankers or branches colonized by the fungus. Under large cankers staining even reached the pith of the pruned trunk, from where the mycelium was also isolated.

34. Canker formation by *Phacidium coniferarum* in the phloem of Scots pine

Large cankers (> 10 cm long) were formed in inoculations made from October to March (Fig. 10). The cankers formed from winter inoculations were smaller than those from late autumn inoculations. The largest cankers were 20 – 30 cm long and 2 – 3 cm broad on the surface of the xylem.

P. coniferarum grew faster in the outer layer of the phloem than in the inner layer. The canker area on the surface of the xylem was 27 – 37 % of the canker area on the surface of the phloem. The value for the controls was only 17 %. The canker area on the surface of the xylem is the area that has to heal over.

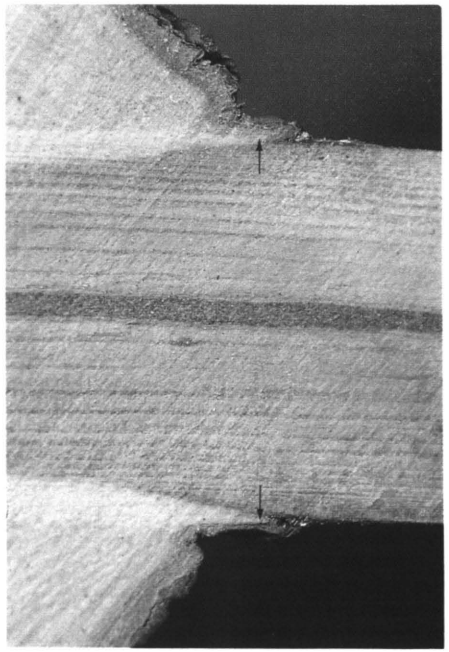

Figure 6. Longitudinal section of the branch base. The basal swelling is marked with the arrow.
Kuva 6. Oksan tyven pitkittäisleikkaus. Kynnäs merkitty nuolella.

There were no differences between the growth of the *P. coniferarum* isolates in the phloem. The growth of *P. coniferarum* was greatest in inoculations made in October and November. When *P. coniferarum* was inoculated during the growing season, the canker length varied from 0 – 10 cm on the surface of xylem, but the canker frequency was low. In the April inoculations some necrotic lesions longer than 10 cm were produced on the surface of the phloem. The cankers formed from June inoculations were larger than those from the May and July inoculations ($p < 0.0001$ and $p = 0.01$). March inoculations resulted in larger cankers than the February or April inoculations ($p = 0.0008$ and $p < 0.0001$) (Fig. 10).

According to the t-test, inoculation times gave the same result for the surface of the xylem and phloem with one exception (pair December – January). Statistically significant differences were not found on the surface of the xylem, although there were statistically significant differences on the surface of the phloem. This was most probably caused by differences in inoculation depth.

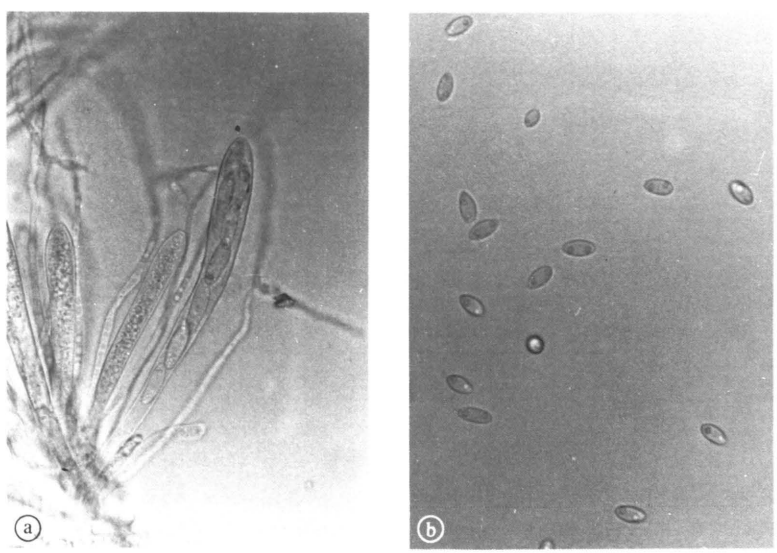

Figure 7. a) Ascospores (unstained, 480x). b) Conidia (unstained, 750x).
Kuva 7. a) Koteloitiöitä (värjäämätön, 480x). b) Kuromia (värjäämätön, 750x).

In December the trees were inoculated with mycelia when the temperature was -15 °C. The inoculations had probably not reached the xylem owing to the hard, frozen bark.

One month after inoculation resin flow was observed in 75 % of the inoculations done during April to September. Resin flow ceased in October. At that time resin had flown from only 25 % of the inoculations. No resin flow was detected one month after inoculation in the case of inoculations made during November to February. Resin flow was detected from all March inoculations in June, but at that time resin flow was also observed from the winter inoculations.

35. Canker formation in the pruning experiments

Both the inoculated and control trees that were pruned during January to August remained healthy in all the experimental stands (Fig. 11).

Cankers were formed in 10 % of the pruning wounds in inoculated trees pruned at the

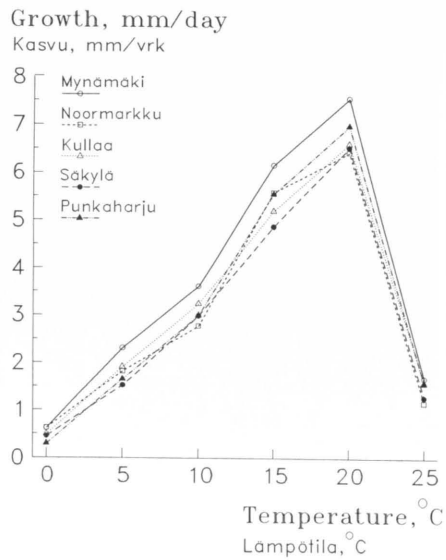

Figure 8. Mycelial growth (colony diameter) of five isolates of *P. coniferarum* on oat agar at six different temperatures.

Kuva 8. Viiden syyshaavakkakannan rihmaston kasvu (pesäkkeen halkaisija) kaura-agarilla kuudessa eri lämpötilassa.

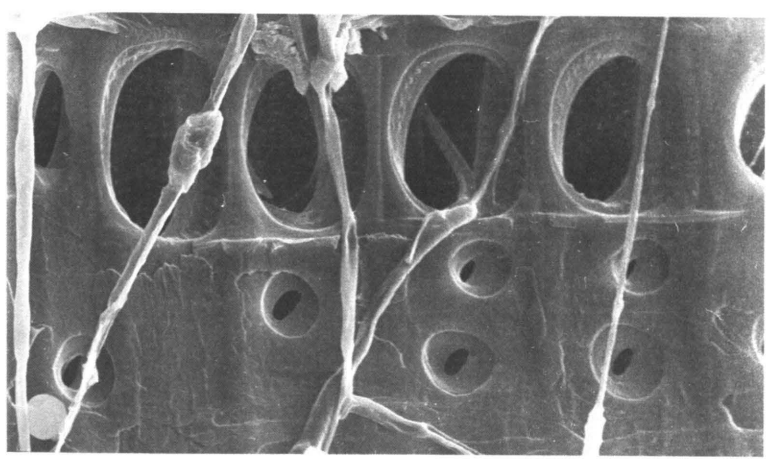

Figure 9. The hypha of *P. coniferarum* has grown through a fenestriform pit in blue-stained pine wood. (SEM, x1500).

Kuva 9. Syyshaavakan sienirihma on kasvanut ikkunahuokosen läpi sinistyneessä mäntypuussa. (SEM, x1500).

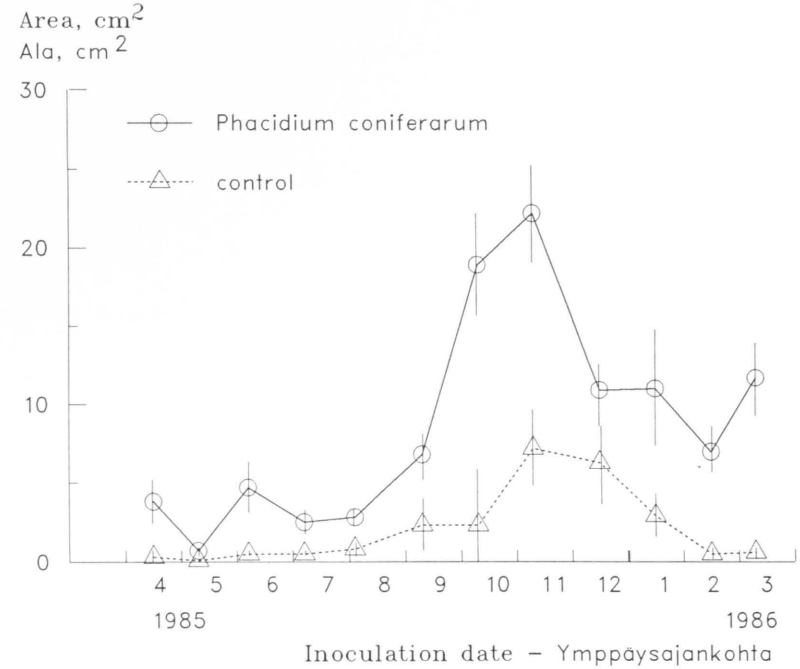

Figure 10. Mean canker area of four *P. coniferarum* isolates and the control in the mycelium inoculation experiment at Tuusula. 95 % confidence intervals are marked with lines. Measured in June 1986.

Kuva 10. Neljän syyshaavakkakannan ja kontrolliymppäysten aiheuttamien korojen keskikoko rihmastoymppäyskokeessa Tuusulassa. 95 % luottamusvälit merkitty viivoin. Mitattu kesäkuussa 1986.

beginning of September in the Padasjoki 1 stand when the trees were pruned and inoculated in the middle of September, a few large cankers were also formed in the Tenhola 1 and Vilppula 2 stands. In these cases the cankers were mainly formed in the surroundings of serious mechanical wounds or in intensively green-pruned trees. In the Vilppula 2 stand cankers were mainly formed on the pruning scars of lower, dead branches pruned with a pruning chisel. When the trees were pruned in the beginning of October, the canker frequencies were still low, but the cankers were 10 – 39 cm long.

The period during which the pines were susceptible to damage by *P. coniferarum* shortened on moving from the south to the north (Fig. 11). The most susceptible pruning season begun in the middle of October in all pruning stands. At Tenhola the susceptible pruning season continued up until the middle of December. At Padasjoki and at Vilppula it continued up until the beginning of November. At Rovaniemi cankers were formed only, when the trees were pruned in the middle of October. Analogously the length of largest canker was 39 cm at Tenhola, 32 cm at Padasjoki, 24 cm at Vilppula and 16 cm at Rovaniemi.

The mean canker area at Tenhola 1, varied from 12 cm^2 to 18 cm^2 in the case of inoculated autumn prunings, and <5 cm^2 for non-inoculated autumn prunings (Fig. 11). The mean canker area in autumn prunings made at Padasjoki was <13 cm^2 in inoculated trees and <4 cm^2 in non-inoculated trees (Fig. 11). The mean canker areas at Vilppula were <6 cm^2 in inoculated trees and <0.6 cm^2 in control trees (Fig. 11). At

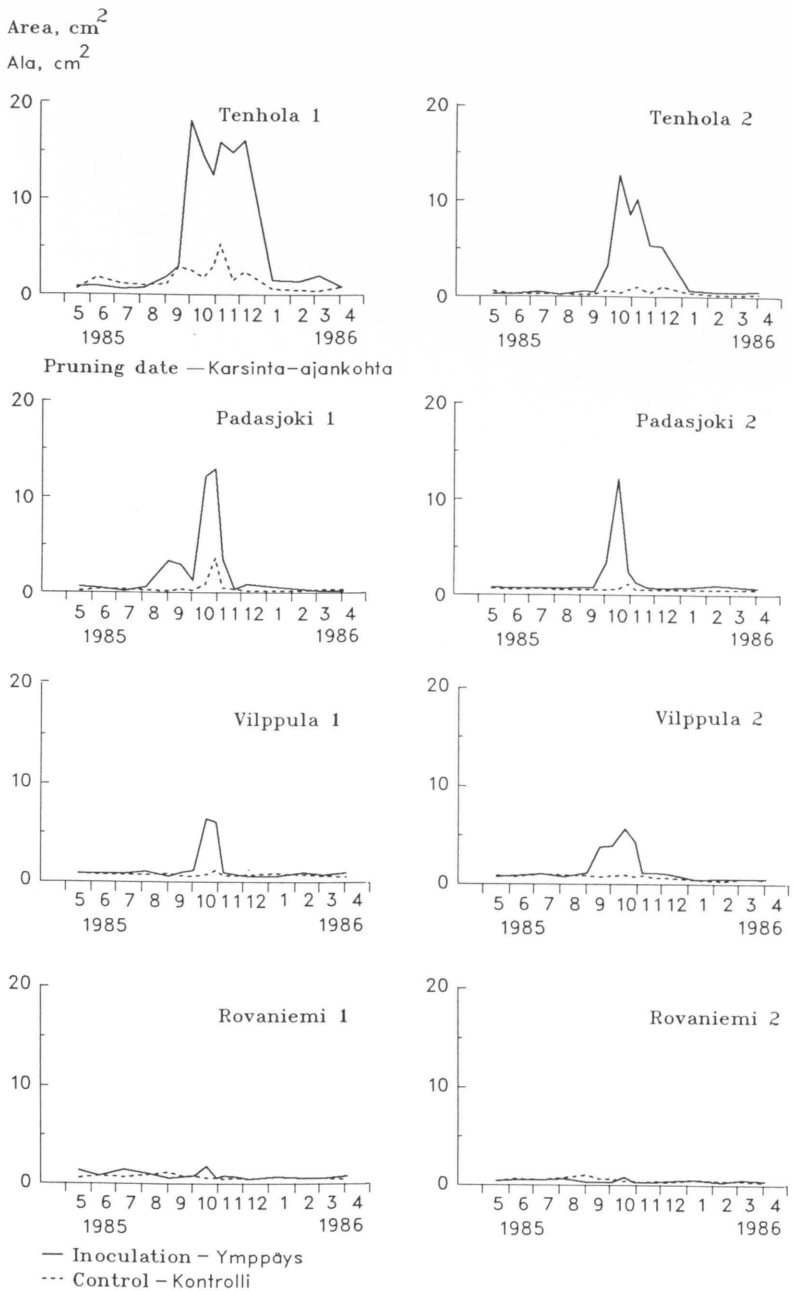

Figure 11. Effect of pruning date on canker area in the experimental stands.
Kuva 11. Karsinta-ajankohdan vaikutus koron kokoon tutkimusmetsiköissä.

Table 4. Proportion (%) of cankers more than 4 cm^2 in size in dry and green-pruned branch stubs. Branches inoculated with *P. coniferarum* from October to December are included.
Taulukko 4. Yli 4 cm^2 korojen osuus (%) kuolleina ja elävinä karsituissa oksissa. Syyshaavakalla ympätyt karsintahaavat loka – joulukuun karsinnoista.

Stand *Metsikkö*	Green-pruned *Elävinä karsitut*	Dry-pruned *Kuolleina karsitut*
Tenhola 1	80.0	28.3
Tenhola 2	55.6	10.7
Padasjoki 1	42.5	15.0
Padasjoki 2	29.3	12.3
Vilppula 1	26.7	6.0
Vilppula 2	22.7	19.9
Rovaniemi 1	1.6	0.0
Rovaniemi 2	0.9	0.0

Rovaniemi the mean canker area was < 1.6 cm^2 in inoculated trees and < 0.7 cm^2 in control trees (Fig. 11). 11 cankers longer than 5 cm were recorded in the two pruning stands at Rovaniemi. The largest canker in the pruning wounds was 11 cm long, but there was one 16 cm-long canker surrounding an internodal wound.

Only a few cankers were formed in the non-inoculated trees. According to two-way analysis of variance, the canker area of the controls and inoculations differed statistically significantly in all three southern locations ($p < 0.0001$). It differed significantly ($p = 0.0138$) in the Rovaniemi 1 stand, but not in the Rovaniemi 2 stand ($p = 0.0636$).

The proportion of cankers (> 4 cm^2) was clearly higher on the green-pruned pruning scars made during October to December than on the dry-pruned ones (Table 4). This comparison therefore included some safe pruning times at Padasjoki, Vilppula and Rovaniemi.

Cankers were produced in the inoculated green-pruned trees if the pruning was done during the period when pine is susceptible. In the case of dry pruning, cankers were only produced when the phloem surrounding the pruning scar was wounded. For instance, all of the 20 inoculated green pruning wounds produced cankers on the trees in Tenhola 1 pruned in the beginning of November, whereas only one out of 10 inoculated dry pruning wounds developed a canker.

Annual height growth ceased in those trees with several cankers > 20 cm long. Developing pycnidia were observed already at the end of June in large cankers of *P. coniferarum*.

Some new infections had appeared in peeling wounds one year after peeling off the bark at Vilppula and at Rovaniemi. These cankers were usually on inoculated trees, but in some cases cankers were found in control trees. The fungus had most probably been transferred from inoculated trees to non-inoculated ones via the knife. The pruning scars were peeled off in August 1986 at Rovaniemi, and in September at Vilppula.

In addition to the normal pruning scars mechanical wounds were also caused by sawing the branch at the wrong angle to the stem, by leaving too short a stub, by sawing a stem and by using a pruning chisel to remove thick branches. However, the most common cause of mechanical wounds was bark stripping from under the branch when the branch fell down.

Mechanical wounds reaching the xylem were found on 7.8 % of the pruning scars. In 1.2 % of cases the mechanical wounds were larger than 4 cm^2. 26 % of the surroundings of branch stub were mechanically wounded in the Vilppula 2 stand, when a pruning chisel was used.

The proportion of mechanical wounds (all stands included) varied from 2.9 % to 6.3 % during November to April, but from 7.9 % to 15 % during May to October.

351. Branch thickness and canker area

The branch thickness affected canker area in three experimental stands in the case of green pruning, and in two experimental stands in the case of dry pruning (Table 5). Canker area increased in these stands along with an increase in branch thickness. However, the effect was relatively slight because the branch thickness explained only 12 – 31 % of the total variation in canker area according to the linear regression model (BMDP 6D).

When the 8 stands were combined the polynomial regression model (BMDP 5R) of branch thickness explained 17 % of the canker area variation in the inoculated autumn green prunings. The value for dry prunings was only 5 %.

Large cankers were even found in the pruning wounds of thin branches. In the case

Table 5. Coefficients of determination for the relationship between branch thickness and canker area. Inoculated trees pruned in October – December.
Taulukko 5. Oksan paksuuden selitysaste koron pinta-alan vaihtelusta tutkimusmetsiköissä loka – joulukuun karsinnoissa.

Stand *Metsikkö*	Coefficient of determination (R^2) *Selitysaste*	
	Green pruning *Elävinä karsitut oksat*	Dry pruning *Kuolleina karsitut oksat*
Tenhola 1	0.20	–
Tenhola 2	0.12	0.26
Padasjoki 1	0.31	0.18
Padasjoki 2	–	–
Vilppula 1	–	–
Vilppula 2	–	–
Rovaniemi 1	–	–
Rovaniemi 2	–	–

– = effect of branch thickness not statistically significant ($p > 0.05$)).
– = *oksan paksuuden vaikutus ei ollut tilastollisesti merkitsevä* ($p > 0.05$)).

of green pruning there was one 40 cm^2 canker, although the branch thickness was only 7 mm. In contrast, cankers associated with the wounds of thick branches (>30 mm) were not always large.

36. The effect of spore concentration and delayed inoculation

At high spore concentrations, cankers were formed regularly in pruning wounds at Tuusula. The mean canker area increased when the inoculum density increased (Fig. 12). When the inoculation concentration was 3 000 or less, the frequency of large cankers (>20 cm^2) was 0 – 6,7 % of the pruning scars. 11,7 % of the controls had large cankers. When the spore concentration was 30 000 conidia/ml or more, large cankers were formed on at least 53,3 % of the pruning scars.

The age of the pruning wound at the time of inoculation affected the mean size and frequency of the cankers. When inoculation was done less than one week after pruning, the mean canker sizes varied from 23 to 39 cm^2 (Fig. 13). The mean canker area was 12 cm^2 when the pruning scars were inoculated two weeks after pruning. When pruning wounds were inoculated one or two months after pruning during winter, the mean canker size was only 1 – 3 cm^2. Large cankers were not found on these trees.

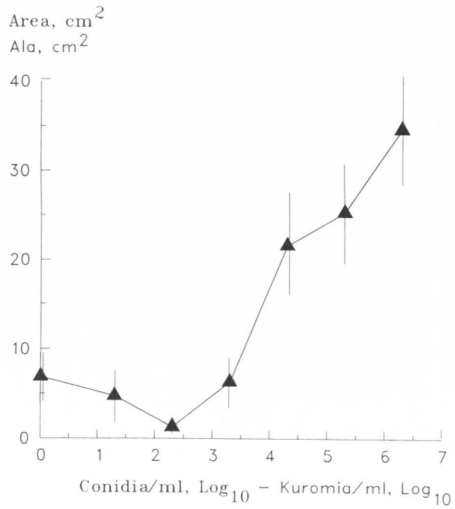

Figure 12. Effect of spore density of the inoculum on canker area in stand 2 at Tuusula. 95 % confidence intervals for the mean are marked with lines. Pruned 2. 11. 1987. Measured in June 1988.
Kuva 12. Ymppäysseoksen itiötiheyden vaikutus koron pinta-alaan Tuusulassa. Keskiarvojen 95 % luottamusvälit on merkitty viivoin. Karsittu 2. 11. 1987. Mitattu kesäkuussa 1988.

37. The effect of weather conditions on infection and growth of *Phacidium coniferarum*

It was safe to prune during the growing season, irrespective of the weather conditions. Cankers were commonly formed in autumn prunings when the mean temperature for the five-day period after pruning was < +7 °C. The mean five-day temperature was > +8 °C in cases where the canker frequencies were still low in prunings made in September or in the beginning of October. The weather on the pruning day did not affect the incidence of infections. Pruning wounds became infected even when they were pruned and inoculated at low temperatures. The diurnal mean temperature was -8.7 °C at the Piikkiö weather station when the test trees were pruned nearby at Tenhola in December. However, cankers were produced as a result the mild periods that occurred after pruning. The first period (3 days) started three days after pruning with a maximum

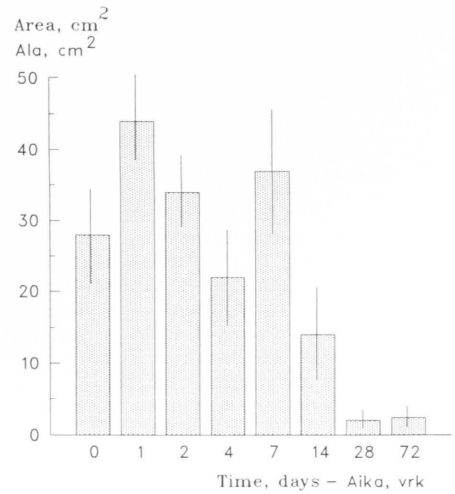

Figure 13. The effect of the time elapsed between pruning and *P. coniferarum* inoculation on mean canker area at Tuusula. 95 % confidence intervals for the mean are marked with a line. Pruned 2. 11. 1987. Measured in June 1988.
Kuva 13. Karsinnan ja syyshaavakkaymppäyksen välisen ajan vaikutus korojen kokoon Tuusulassa. Keskiarvojen 95 % luottamusvälit on merkitty viivoin. Karsittu 2. 11. 1987. Mitattu kesäkuussa 1988.

temperature of +5.0 °C. The second period (6 days) began two weeks after pruning with a maximum temperature of +5.6 °C. During these two thaw periods the 30 cm-thick snow cover melted completely.

In the other locations cankers did not appear in prunings carried out in December. At Padasjoki (Pälkäne weather station) the diurnal maximum temperature was +1.5 °C during the first thaw period, and +4.5 °C during the second. In addition, the second thaw period was one day shorter than that at Tenhola.

Although the temperature in March and April remained for long periods > 0 °C, no infections appeared in the trees pruned during this time. In 1988 six pines were pruned at Tuusula in the beginning of February. The temperature varied from -1.1 °C to +2.5 °C at Helsinki-Vantaa airport during the week after pruning. The relative humidity correspondingly varied between 83 to 98 %. The rest of the winter was cold. However, only small cankers (0 – 8 cm^2, mean = 1.7 cm^2) formed in inoculated branches. The non-inoculated trees remained healthy.

No cankers (> 1 cm^2) appeared in pines pruned and inoculated on 28th February in 1989. During the week after pruning the temperature measured at Helsinki-Vantaa Airport varied from +0.0 °C to +3.4 °C (Ilmatieteen laitos, Ilmastopalvelu). The mean temperature for March was +1.5 °C.

On 27th March resin flow had started in the pruning wounds of three test trees (total 6 of six test trees). The maximum air temperature between pruning date and first checking was +8.7 °C and the minimum was -3.9 °C. Maximum of diurnal mean temperature was +5.5 °C. On 9th April the resin had partly or totally covered pruning scars of all test trees. The temperature maximum between 27th March and 9th April was +8.1 °C and the minimum -9.1 °C.

In the mycelium inoculations carried out from the beginning of October up until March, the fungus growth reacted to temperature in the same way as on the agar cultures. The growth curve estimated on the basis of the growth on the agar and the air temperature resembled the measured growth curve in inoculated trees (Fig. 14). The can-

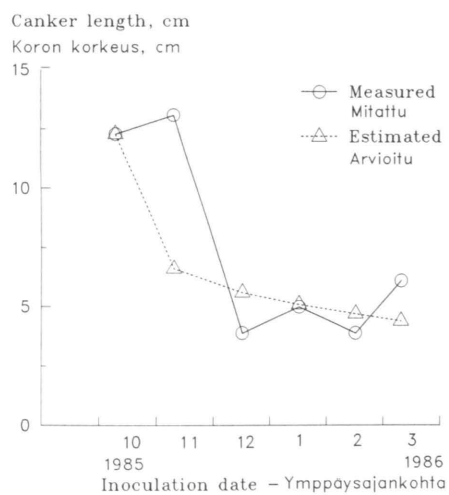

Figure 14. Canker length (*P. coniferarum*) in the mycelium inoculation experiment and canker length estimated on the basis of air temperature and growth rate on oat agar.
Kuva 14. Syyshaavakan aiheuttaman koron pituus ymppäyskokeessa ja arvioitu pituus syyshaavakan laboratoriokokeissa todetun kasvun ja ilman lämpötilan perusteella.

ker size decreased along with a reduction in the time the temperature remained > 0 °C. In the mycelium inoculation experiment the five-day mean temperature was +9.5 °C after the first successful inoculation time in the beginning of October. Cankers formed in inoculations made in October were smaller than expected on the basis of the results of the November inoculations. This was probably caused by defence reactions, which were partially functioning in the beginning of October.

38. Damage caused by insects and other fungi

In four of the stands in pruning intensity experiment 2.7 % of the test trees had been killed by insects one year after pruning. These trees had been green-pruned intensively to give a living crown length of 0.3 to 1.4 m. The pruned pines were susceptible to insect attack after too intensive pruning of the living crown or if there was severe infection by *P. coniferarum* in the pruning wounds. *Tomicus piniperda* L. and *T. minor* Hart. were the most common pests killing weakened, pruned pines. In some cases mother galleries of these species without any signs of larval development were found in living pines suffering from *P. coniferarum*.

Insects were even able to kill a dry-pruned tree after serious infection by *P. coniferarum*. In the pruning time experiment 0.7 % of the pines, and in the spore concentration experiment at Tuusula 23.7 % of the pines with normal pruning intensity were killed by insects. These trees had several 10 to 30 cmlong cankers caused by *P. coniferarum*.

In the pruning intensity experiment three intensively summer-pruned pines (< 0.7 m living crown) were killed by *Rhagium inquisitor* L. Larvae of this species were found in the base of dead trunks. *Trypodendron lineatum* Ol. attacked dead trees and had also transferred blue-stain fungi causing darker staining than *P. coniferarum*.

Four autumn-pruned test trees in the pruning intensity experiment at Tenhola had become naturally infected by *P. coniferarum* before attack by bark beetles. In these trees the length of the living crown was 0.5 – 2.1 m. Trees with a longer living crown were healthy in the pruning intensity experiment. Large cankers appeared in one tree pruned in the beginning of October in the Tenhola 1 stand. In this tree only 1.8 m living crown was left after pruning, while in the other inoculated trees in this pruning time the length of the living crown after pruning was at least 4 m. The latter trees had only a few cankers.

Stereum sanguinolentum was common in dead, pruned trees. This fungus produced basidiocarps on the trunk even before the crown was completely dead. Another decay fungus growing in damaged pruned trees is *Trichaptum fuscoviolaceum* (Ehrenb.:Fr.) Ryv. It was found on the dead side of a still living trunk.

4. Discussion

41. The biology of *Phacidium coniferarum*

The observations made in this study have expanded the known distribution area of *P. coniferarum* to northern Finland, which is in good agreement with earlier observations made by Karlman (1985) in northern Sweden. Thus the fungus is able to complete at least its asexual life cycle in the climatic conditions prevailing in Lapland.

Pycnidia usually develope in cankers caused by *P. coniferarum*, but ascocarp development is rare. The asexual stage of the fungus is rather common, but does not seem to be very abundant.

The conidial mass is slimy and surface active. It seems to be compact after drying. It is assumed that the conidia are spread in water droplets (DiCosmo et al. 1984). If the conidia are dispersed in water they cannot spread very effectively over long distances and hence wounds located far away from the nearest pycnidia are safe from infection even in the autumn.

Ascocarps are formed after long periods of mild and damp weather. According to Hahn (1957a), ascocarps can form on the same stroma together with the pycnidia. Gremmen (1959) found ascocarps on branches that had fallen to the ground, as was also the case in this study. Holz and Butin (1972) found apothecia on Douglas fir in December, the infection having occurred during the previous winter. These observations support the claim, that *P. coniferarum* has a one-year life cycle. It would appear that apothecia develop later in autumn than pycnidia. The pairing system of the fungus has not been investigated.

The growth rates of *P. coniferarum* on agar recorded in this study were similar to the results of Tarocinsky (1963). Dormant season temperatures can be sufficient for the mycelium to grow and the conidia to germinate. Mycelial growth is fastest at temperatures of +10 – 20 °C on agar, but in the host tissues growth is eliminated by defence reactions that function at these temperatures during the growing season. The mycelium can grow in the phloem throughout the dormant season, if the temperature is favourable for growth.

The grey-blue colour of the staining caused by *P. coniferarum* resembled the colour in a picture published by Lagerberg et al. (1927), although they used the word grey-green to describe the colour of staining. It appears to be the common blue-stain fungus that grows in pine timber near bark wounds. If logs felled in autumn are sawn in late April or May they can be stained by *P. coniferarum*. Blue-staining of this sort is restricted to the vicinity of cross cuts and trimming wounds. *P. coniferarum* does not decompose wood, although it does exhibit cellulolytic activity on culture media (Nilsson 1973).

P. coniferarum is a strong pathogen in the dormant season wounds of Scots pine. This was verified in the mycelial inoculation and pruning season experiments. These results agree with earlier conclusions from pathogenicity tests on other coniferous species (Koning 1943, Van Vloten 1952, Hahn 1957b, Gremmen 1961, Smerlis 1973, Magnani 1980). *P. coniferarum* began to produce cankers in inoculations made later in autumn than *A. abietina* (Uotila 1990). The growth of both fungi was strongly dependent on the defence reactions of pine. No variation was found among the *P. coniferarum* isolates as regards pathogenicity, morphology or physiology. On the contrary of two *Ascocalyx abietina* isolates inoculated in the same trees (Uotila 1990).

According to temperature *P. coniferarum* should cause larger cankers when inoculated in the beginning of October than in November. However, the mean canker size in October inoculations was smaller than that in November, although the difference was not statistically significant. It appears that the pines could partially inhibit fungal growth in October when the five-day mean temperature after inoculation was over +9.5 °C. *P. coniferarum* grew slightly more in the June inoculations than in the May ($p < 0.001$) or July ($p = 0.01$) inoculations. This could be due to a weakening of the defence reactions during shoot elongation. Monoterpene concentrations in shortleaf pines are two to four times higher in July than in June (Cook and Hain 1987).

The technique used for mycelial inoculation proved to be a good practical method for studying pathogenicity. It is not necessary to protect the inoculation points against desiccation or to sterilize them if a piece of bark is replaced in the inoculation hole.

42. Pruning experiments

Determining the infection risk of autumn prunings presupposes that a large number of different stands be studied during a 4 to 5-year period with varying weather conditions. The time when the pruning scars of dead or living branches were susceptible under conditions where the inoculum is added or excluded was studied in this work. Connecting climatic data with one-year experimental data may permit general conclusions to be made about the safe pruning season.

Cankers of *P. coniferarum* were found in practical pruning stands in different years. Such damage in autumn prunings is not a coincidence. The fact that the controls in the pruning experiments remained healthy is probably due to the too low inoculum density. The experimental stands were not

thinned before pruning, whereas the naturally infected autumn pruning stands had often been thinned before pruning (Räisänen et al. 1986). *P. coniferarum* produces pycnidia in slash, which could explain the high infection rates in thinned stands, when they were pruned in autumn. However, pycnidia can also be found in the crown of living trees, for instance, in branches broken by snow.

The results of the spore concentration experiment show that the inoculum density may be important. The low infection frequencies were associated with low spore concentrations (3 – 3 000/ml). One interesting question is why 3 000 spores sprayed on a pruning wound did not cause cankers, whereas 30 000 spores did. The attachment of conidia to pruning wounds was not assessed, and so the exact number of spores in a single pruning scar was not known.

In Sweden 1.2 conidia/cm^2 per day have been recorded in October, but no conidia were obtained from May to August (Beyer-Ericson and Ericson 1985). The spore density in natural infections can be low. Water-dispersed conidia are always spread during conditions favourable for germination. However, large cankers are formed in inoculated wounds irrespective of the amount of precipitation after pruning. In late autumn the relative humidity is normally high enough for spore germination without any rainfall. One possible transfer route for the fungus is pruning saws. For instance, *Ophiostoma ulmi* (Buism.) Nannf. can spread via pruning saws (Opgenoth et al. 1983).

Canker size clearly decreased when the pruning wounds were inoculated two weeks after pruning. The difference was too large to be explained on the basis of the shorter period for fungal growth. The temperature after the last three inoculations was high enough for germination (> 0 °C). The failure of inoculations carried out two weeks after pruning may have been caused by chemical changes in the wounded wood tissues and phloem tissues, or by the antagonistic effect of other microbes.

Resin flow protects wounds and also isolates the infected tissues from healthy tissues. Resin flow in late autumn and winter is not intensive enough to inhibit pathogens in wound infections. According to Lyr (1967), resin flow and pinosylvin production on Scots pine begins in Germany when the mean 10-day temperature reaches +6 – 10 °C in the spring and it ceases in the autumn when this temperature drops below +6 – 10 °C. In this study pruning scars were covered by resin at mean temperatures lower than + 6 – 10 °C in the spring, although the maximum air temperatures were +6 – 10 °C at the time when resin flow started.

Pinosylvin production could be one factor inhibiting growth of the fungus. According to Jörgensen (1961), pinosylvin production is induced by aeration and desiccation on red pine, and it is produced at the end of growing season and four to nine weeks after wounding during the dormant season. These results do not agree with the results of Lyr (1967). Jörgensen (1961) did not find pinosylvin in wounds made in June – July because desiccation, which induces pinosylvin production, is inhibited by resin flow at that time, eventhough the temperature optimum for pinosylvin production in the laboratory was +25 °C.

The time between pruning and inoculation could have affected the results of the Rovaniemi experiments, which were not inoculated immediately after pruning, for example in September.

Necrophylactic periderm formation takes a rather long time (Biggs 1985) if we compare it to the growth rates of fungi at growing season temperatures. The periderm is a passive, long-lasting anatomical defence structure. Resin flow and chemical changes in wounded tissues inhibit the rapid colonization of host tissues.

The defence provided by anatomical structures such as necrophylactic periderm and nonsuberious impervious tissue, together with resin flow and chemical changes, is very effective against *P. coniferarum* because the cankers did not expand during dormant periods following the first growing season after pruning. According to the isolations, the mycelium of the fungus is often still alive in the cankers one and a half years after pruning. Roll-Hansen and Roll-Hansen (1971) have described perennial, expanding cankers in *Larix sibirica* Ledeb. in Iceland. The structure of anatomical or chemical defence zones was not investigated in this study, but for example Mullick and Jensen (1973) have found anatomical defence structures in non-expanding cankers of *Phacidium balsamicola* (Smerlis) DiCosmo et al. However, these structures were not found in expanding cankers.

P. coniferarum was found to could to grow through the unwounded disturbance zone of the branch base (Böhlmann 1970, Shigo 1985) in this study. Thus damage in autumn green pruning cannot be controlled by a careful pruning work or by leaving a stub.

The drying of autumn pruning wounds is supposed to affect susceptibility to bark beetles (Räisänen et al. 1986). This could also be important for susceptibility to *P. coniferarum*, because this fungus is rather tolerant to drying (Zimmermann and Butin 1973). However, drying alone could not have caused the cankers because the controls in the autumn prunings were healthy.

During short thaw periods in the winter the snow cover can prevent or decrease the spread of the fungus because part of the pycnidia and apothecia are isolated under the snow. The number of thaw days (mean temperature >0 °C) from November to March was less in 1985 – 1986, than the long-term mean (1916 – 1987). For example, the mean in Jyväskylä is 31 thaw days, but in 1985–1986 it was 25 thaw days from the beginning of November to the end of March. The between-year variation is wide and in Jyväskylä, for instance, there have been more ten thaw days in January in four out of the last 70 years, although the mean for January is 3 thaw days.

Tomicus spp. can attack intensively pruned trees. Only one to three whorls of the living crown were left on these trees. If the bark beetle population is high, trees with more living branches can also be killed. Similar observations have been made in practical pruning stands (Räisänen et al. 1986). *Tomicus* spp. larvae did not eat phloem infected by *P. coniferarum*. This fact can be used in determining the primary parasite of dead, pruned trees.

Stereum sanguinolentum can infect dormant season wounds, but these infections are rare in vigorously growing trees. However, the decay of pruned branches was not investigated as carefully as bark necrosis in this study. Heiskanen and Taipale (1963) studied logs sawn from pruned pines without finding any serious decay. In pine wood *Stereum sanguinolentum* is often found together with *P. coniferarum* (Lagerberg et al. 1927).

43. Avoiding pruning damage

Pruning damage can be simply avoided by not pruning during the period extending from the beginning of the dormant season to the beginning of permanent winter, when the temperature is almost continuously < 0 °C. Dry pruning can also be safely employed during the autumn if the phloem is not mechanically wounded. The phloem on the base of the branch should be dead before dry pruning. Otherwise the reaction zone in the base of the branch is not ready (Jörgensen 1961).

Phacidium coniferarum can grow in the phloem throughout the whole dormant period, but pruning is still safe during the winter if the temperature remains mostly < 0 °C. This was demonstrated by the healthiness of the inoculated winter pruning wounds. The temperature in March and April was suitable for fungal growth and spore germination, but the pruning wounds did not become infected. This may have been due to the action of defence reactions. The capasity to these reactions is not the same in March and in November.

It appeared that pine started to become susceptible when the mean temperature for the five-day period after pruning decreased below +7 °C. This is rather close to the cessation point of resin flow in autumn (Lyr 1967). Single, large cankers can be formed even at higher temperatures if a tree is green-pruned intensively. Defence reactions decrease the energy reserves of trees. For example, the dry weight percentage of soluble sugars in the phloem of shortleaf pines dropped from 15 % to 5 % within two days after wounding (Cook and Hain 1987). Bark wounds on Norway spruce consume the starch reserves, and the defence reactions are dependent on the energy transported from the crown (Christiansen and Ericsson 1986). This could explain why very intensively pruned trees were susceptible to infection earlier in autumn than trees with a normal pruning intensity.

44. Recommendation for determining the safe pruning season

Different recommendations should be given for each climatic area. Long mild periods

can occur even after winter proper has begun, and they are impossible to predict. Thus the beginning and end of the safe pruning time should be determined using probabilities based on climatic statistics.

The start of the unsafe pruning time in relation to the risk of *P. coniferarum* is defined as the time when the mean five-day temperature is below +7 °C. On the average, the temperature falls below +7 °C during the period 3. 10. – 7. 10 in Helsinki and Pori. In Jyväskylä the period is 23. 9. – 27. 9. and in Kajaani 18. 9. – 22. 9. (Ilmatieteen laitos, Ilmastopalvelu). Yearly variation is taken into account such that the risk of it being colder than +7 °C for long-term temperature should not exceed 20 % (Harjama and Laitinen 1966 a and b). The end of the unsafe pruning time is defined here such that the probability of then being more than 10 thaw days a month is < 20 %.

Finland can be divided into three pruning time zones (Fig. 15). The first consists of the southern coast and southwestern Finland comprising the forestry boards of Helsinki, Uusimaa-Häme, Lounais-Suomi and the coastal part of Satakunta. The second is central Finland, and the third is northern Finland (consisting of the forestry boards of Pohjois-Pohjanmaa, Kainuu, Lappi and Koillis-Suomi). The coastal part of Pohjois-Pohjanmaa is included in the central zone. The northeastern part of Pohjois-Karjala belongs to the northern zone. In the southern zone pruning is recommended during 1. 2. – 15. 9., in the central zone during 1. 1. – 15. 9., and the northern zone during 15. 11. – 1. 9. According to the pruning guide (Pystykarsintaopas 1987), it is possible to prune in southern Finland at the end of September and in January. However, this is not a very big discrepancy, because in this study strict safety margins were used. The country is also divided into three zones instead of the two in the pruning guide. This makes it possible to take climatic variation into account.

The pruning guide (Pystykarsintaopas 1987) warns about pruning during May – June. It is true that the bark easily comes loose at that time, but on the other hand the wounds heal rapidly. It is therefore as safe a pruning time as later in summer. Bark stripping can be prevented by using a saw that has a blade for hitting the branch from below. Pruning wounds heal over best when the stub is sawn as short as possible without

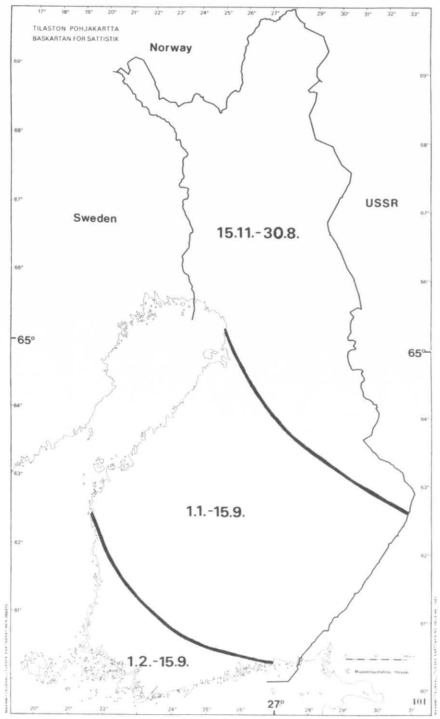

Figure 15. Recommendation for determining the safe pruning season.
Kuva 15. Suositus turvallisen karsinta-ajan määrittämiseksi.

wounding the phloem swelling. The resin tap is longer on thick than thin branches, which is one reason to avoid pruning trees with thick branches (Pietilä 1989).

The results of this study could also be used when formulating pruning directions for larches. *P. coniferarum* is pathogenic to larches (Gremmen 1973, Roll-Hansen and Roll-Hansen 1971), and the susceptible pruning time will probably be almost the same as for Scots pine.

Chemical changes in the sapwood or phloem wound in relation to time and pathogens could provide the basic information needed in understanding the defence mechanisms of trees. The structure of the reaction zone in sapwood at different pruning times could also be an interesting topic for further studies.

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Seloste

Männyn pystykarsintavioitusten syyshaavakkatartunta ja karsinta-ajan valinta

Johdanto

Männyn pystykarsinnan biologisten perusteiden tuntemuksen puute paljastui kesällä 1984, jolloin eteläranikolla havaittiin kuolleita syksyllä karsittuja mäntyjä. Ruotsalaiset tutkijat olivat myös havainneet koroja syksyllä karsituissa männyissä. Tuhojen oletettiin olevan syyshaavakkasienen (*Phacidium coniferarum*) aiheuttamia.

Syyshaavakka tunnetaan havupuiden haavapatogeenina tai pakkasvaurioihin liittyvien korojen aiheuttajana. Karsituissa puissa sitä on tavattu japaninlehtikuusella, douglaskuusella, männyllä ja kontortamännyllä.

Aiempien kotimaisten tutkimusten mukaan mäntyä voitiin pystykarsia turvallisesti ympäri vuoden. Näihin tutkimuksiin perustuvissa vuotta 1984 edeltäneissä pystykarsintaohjeissa varoitettiin vain kevään nilaaikana karsimisesta.

Elävänä karsitun oksan arpi on avoin tartuntareitti tuhosienille.

Puun on suojattava arpi, jotta laho ei leviäisi pintapuuhun eikä nilaan syntyisi koroja. Pystykarsintatyössä nila saattaa vioittua oksa-arven ympäriltä tai oksakiehkuroiden välistä.

Männyn kuorta kasvukaudella vioitettaessa pihkan erittyminen suojaa haavan kuivumiselta ja sienitartunnoilta. Myöhemmin vioituksen ympärille muodostuu korkkiutumaton ja vettä läpäisemätön solukko. Haavakorkki kehittyy korkkiutumattoman ja vettä läpäisemättömän solukon alle korkkijällen muodostamana. Jos mäntyä vioitetaan lepokauden aikana pihkaa ei merkittävästi erity ennen kevättä, ja vioitusta suojaavat rakenteetkin muodostuvat vasta seuraavana kasvukautena.

Vioituksen ulottuessa pintapuuhun havupuut suojaavat haavan reaktiovyöhykkeellä. Reaktiovyöhyke muodostuu pihkan erityksestä sekä pintapuun tylppysolujen kuolemisen aiheuttamien kemiallisten muutosten seurauksena. Reaktiovyöhyke muistuttaa kemialliselta koostumukseltaan ja kosteudeltaan sydänpuuta sisältäen männyillä mm. pinosylviinia ja sen monometyylieetteriä.

Tämän tutkimuksen tarkoituksena oli selvittää, miten mäntyä voidaan pystykarsia aiheuttamatta sahatavaran arvoa alentavia sieni- tai hyönteistuhoja. Tutkimusongelmia olivat vaurioiden esiintyminen eri osissa maata, syyshaavakan biologia ja levinneisyys, karsintavoimakkuus hyönteis- ja sienituhoille altistavana tekijänä sekä sään vaikutus syyshaavakkatuhoihin. Lopullisena tavoitteena oli näiden tutkimusten antamien tulosten perusteella valita sellainen karsinta-aika, jolloin merkittäviä vaurioita ei synny.

Aineisto ja menetelmät

Pääosin tutkimus perustui karsintakokeiden tuloksiin, mutta koetulosten lisäksi tutkimusaineistoon sisältyi käytännön karsintametsiköiden tarkastustuloksia. Laboratoriossa tutkittiin lähinnä syyshaavakan biologiaa ja tuotettiin itiöitä sieniymppäyksiä varten.

Syyshaavakka eristettiin rihmastona korojen kuolleesta nilasta tai korojen alta sinistyneestä puusta. Myös yksi-itiöeristyksiä tehtiin kuromaitiölevitteestä. Syyshaavakan rihmaston kasvua sekä kuromaitiöiden itävyyttä tutkittiin eri lämpötiloissa kaura- ja mallasagarilla. Syyshaavakan sinistämiskykyä tutkittiin ymppäämällä syyshaavakan kuromia tuoreeseen mäntypuuhun.

Rihmastoymppäyskokeessa tutkittiin neljän syyshaavakkakannan kasvua männyn nilassa. Kukin sienikanta ympättiin 10 puuhun kerran kuussa huhtikuusta 1985 maaliskuuhun 1986. Kesäkuussa 1986 ymppäysreiän ympärille muodostuneen koron korkeus ja leveys mitattiin.

Toukokuun 1985 ja huhtikuun 1986 välisenä aikana perustettiin karsintakokeet Tenholaan, Padasjoelle, Vilppulaan ja Rovaniemen mlk:aan. Kullakin paikkakunnalla karsittiin puita yhdestä 6 – 8 metrin ja yhdestä 8 – 11 metrin pituisesta männiköstä.

Turvallisen karsinta-ajankohdan määrittämiseksi karsittiin koemetsiköissä kerran kuussa tai syys – joulukuussa kaksi kertaa kuussa 10 koepuuta, joten karsintakertoja oli yhteensä 16. Karsintahaavat ruiskutettiin syyshaavakan kuromaitiöillä joka toisesta koepuusta. Koepuista tutkittiin kesällä 1986 yhteensä 7680 karsintahaavaa. Karsintahaavoista mitattiin koron korkeus ja leveys, mekaaninen vioitus ja oksan paksuus.

Ymppäysseoksen itiötiheyden sekä karsinnan ja ymppäyksen välisen ajan vaikutusta tutkittiin Tuusulan Ruotsinkylään syksyllä 1987 perustetuilla kokeilla. Korot mitattiin seuraavana kesänä.

Tenholaan, Padasjoelle, Vilppulaan ja Rovaniemen mlk:aan perustettiin karsintavoimakkuuskoe, jotta saataisiin selville elävien oksien karsinnan vaikutus kasvuun sekä hyönteis- ja sienituhoille altistumiseen. Koemetsiköistä karsittiin 8 – 10 puuta 16 eri ajankohtana. Elävää latvusta poistettiin 0 – 4,5 m siten, että sitä voitiin pitää jatkuvana muuttujana. Muilla paikkakunnilla koepuista poistettiin 0 – 7 elävää oksakiehkuraa. Kesällä 1986 ja 1987 koepuista tutkittiin hyönteis- ja sienituhojen esiintyminen.

Tulokset

Käytännön karsintametsiköissä sienivaurioita löydettiin vain syys – tammikuussa karsituista puista. Vakavat sienivauriot sijaitsivat eteläarannikolla ja Lounais-Suomessa. Helsingin metsälautakunnan arvion mukaan alueella vakavia sienivaurioita oli 35 %:ssa loka – joulukuussa karsituista metsiköistä. Toisaalta Keski-Suomessa syksylläkin karsitut puut olivat usein terveitä.

Säkylässä syyskuussa karsituissa puissa oli vain pieniä koroja (< 11 cm), kun lokakuun lopun karsinnassa oli suuria koroja (< 27,5 cm) (taulukko 2). Lokakuun lopulla karsitulla kuviolla 14 % puista kuoli. Kaikissa näissä oli ytimennävertäjien iskeytymiä.

Syyshaavakan elinkierto on yksivuotinen (Kuva 4). Sienen kuromaitiöt tartuttavat karsintahaavoja syys – tammikuussa. Syyshaavakan rihmasto kasvaa nilassa tartuntahetkestä seuraavan kasvukauden alkuun. Kuromapullot (suvuton aste) kehittyvät kesän aikana koroihin kypsyen syyskuussa. Kotelomaljoja (suvullinen aste) saattaa muodostua myöhäissyksyllä, jos säät ovat pitkään leutoja ja kosteita.

Syyshaavakan rihmastoa eristettiin useista karsintamänniköistä ja syyshaavakan kuromapullonäytteitä kerättiin 25 metsiköstä (kuva 3). Syyshaavakka on Eteläs-Suomessa syksyllä vioitetuissa männyissä yleinen sieni. Pohjoisin syyshaavakkanäyte kerättiin Sallasta.

Kaura-agarilla syyshaavakan pesäkkeen halkaisija kasvoi 7 mm/vrk +20 °C:n lämpötilassa (kuva 8). Sieni kasvoi hyvin vielä +5 °C:n lämpötilassa. Eri syyshaavakkakantojen välillä ei ollut merkittäviä eroja kasvunopeudessa. Nuori syyshaavakan rihmasto on vaalea, vaalean harmaa muuttuen harmaan ruskeaksi, kun pesäke on saavuttanut petrimaljan laidan. Kuukauden kuluessa rihmasto tuottaa vaalean harmaata limaista kuromamassaa.

Syyshaavakka aiheutti siniharmaata sinistymistä. Sienen rihmasto levisi puussa mm. ikkunahuokosten kautta (kuva 9). Suuren koron alla syyshaavakan rihmasto saattoi kasvaa pintapuussa puun ytimeen asti.

Rihmastoymppäyskokeessa syyshaavakka aiheutti koroja loka – maaliskuun ymppäyksissä (kuva 10). Laajimmat korot olivat rihmastoymppäyskokeessa (ymppäysvioitus 4 mm) 20 – 30 cm korkeita ja 2 – 3 cm leveitä jällestä mitattuna.

Tammi – elokuussa karsitut puut säilyivät terveinä kaikissa koemetsiköissä. Syyskuussa ja lokakuun alussa karsittuihin puihin syntyi koroja osaan koemetsiköistä, mutta pääosa karsintahaavoista säilyi terveinä (kuva 11).

Alttein karsinta-aika alkoi kaikilla paikkakunnilla lokakuun puolivälissä. Tenholassa koroja muodostui vielä runsaasti joulukuun puolivälissä karsittuihin puihin. Padasjoella ja Vilppulassa alttein aika päättyi jo marraskuun alussa. Rovaniemen maalaiskunnassa koroja muodostui vain lokakuun puolivälissä karsittaessa. Korojen koko pieneni siirryttäessä etelästä pohjoiseen (kuva 11).

Syyshaavakalla ruiskuttamattomiin puihin koroja ei muodostunut merkittävästi edes syyskarsinnoissa. Kuolleiden oksien karsintahaavat säilyivät terveinä, jos karsittaessa ei vioitettu nilaa oksan tynkien ympäriltä.

Altteimpana karsinta-aikana jokaiseen elävänä karsittuun ja ympättyyn oksaan muodostui koro osassa koemetsiköitä. Kaikki syyskarsinta-ajankohdat mukaan lukienkin elävien oksien karsintahaavoihin kehittyi selvästi enemmän koroja kuin kuolleiden oksien karsintahaavoihin (taulukko 4). Oksan paksuus vaikutti vain lievästi koroja suurentavasti. Suuria koroja kehittyi myös pienten oksien karsintahaavoihin.

Itiötiheyskokeessa koroja muodostui vasta, kun ymppäysseoksen itiötiheys oli vähintään 30 000 kuromaa/ml (kuva 12). Karsintahaavojen piti saada syyshaavakkatartunta kahden viikon kuluessa karsinnasta korojen muodostumiseksi (kuva 13).

Kasvukauden aikana oli turvallista karsia säästä riippumatta. Sen sijaan lepokaudella lokakuulta huhtikuulle karsinnan jälkeinen lämpötila vaikutti tartunnan onnistumiseen tai sienen kasvuun nilassa. Syksyllä karsittaessa koroja muodostui, kun karsintaa seuraavan viiden vuorokauden keskilämpötila laski < +7 °C:n. Tenholassa muodostui joulukuussa karsittuihin puihin koroja -8 °C:n lämpötilassa karsittaessa ja ympättäessä, kun kolmen viikon kuluessa karsinnasta tuli kaksi suojajaksoa, jolloin lämpötilat nousivat > +5 °C:een. Padasjoella suojajaksot olivat lyhyempiä kuin Tenholassa maksimilämpötilojen jäädessä < +5 °C:n.

Padasjoelle koroja ei muodostunut joulukuussa karsittuihin puihin.

Helmikuussa 1988 karsittuihin ja ympättyihin puihin kehittyi vain pieniä koroja kontrollien ollessa terveitä. Karsinnan jälkeisellä viikolla lämpötila oli -1,1 °C:n ja +2,5 °C:n välillä. 1989 helmikuun lopussa karsittuihin ja ympättyihin puihin kehittyi < 1,1 cm^2 koroja, vaikka lämpötila oli > 0 °C melkein koko karsinnan jälkeisen maaliskuun ajan.

Hyönteiset tappoivat joko syyshaavakan tai voimakkaan karsinnan heikentämiä puita. Karsintavoimakkuuskokeessa hyönteisten tappamien puiden elävän latvuksen pituus oli karsinnan jälkeen 0,3 – 1,4 m. Vakavan syyshaavakkatartunnan jälkeen hyönteiset tappoivat puita, joista oli karsittu vain kuolleita oksia ja kuolevia alaoksia.

Tulosten tarkastelu

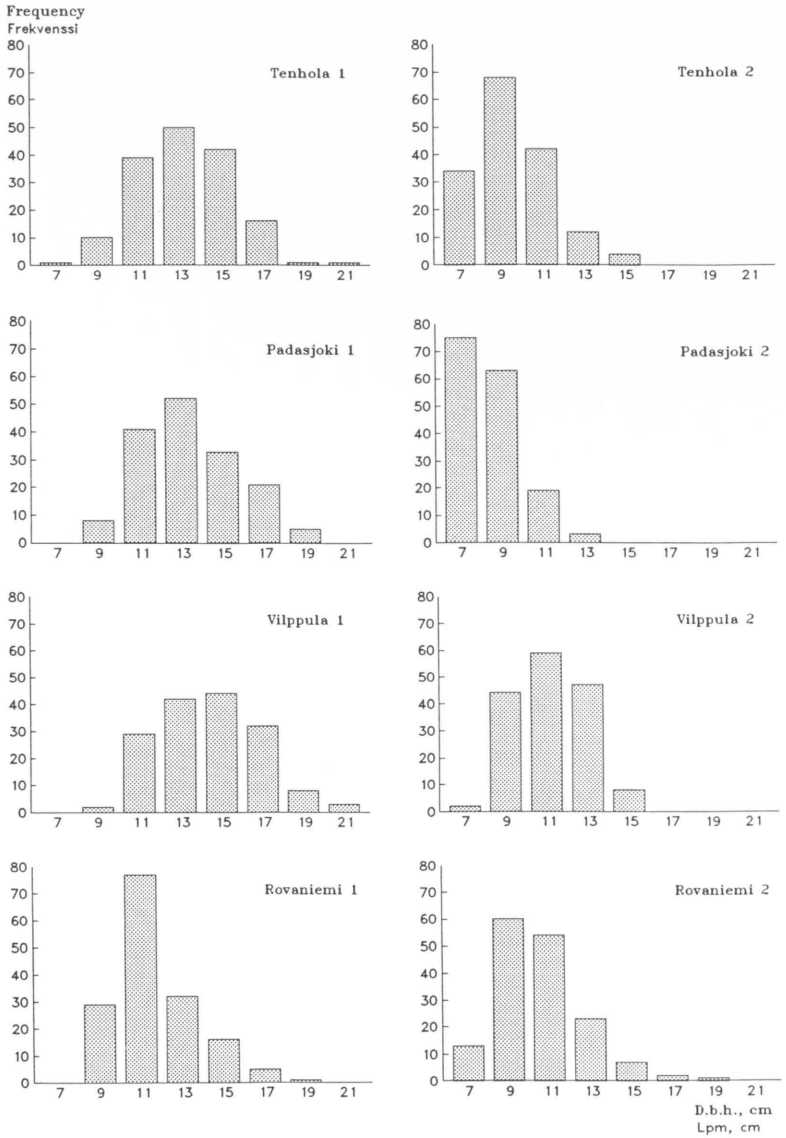
Rihmastoymppäyskokeessa syyshaavakka kasvoi lokakuun ymppäyksissä vähemmän kuin marraskuun ymppäyksissä, mikä johtui männyn osittaisesta puolustuskyvystä lokakuussa, kun viiden vuorokauden keskilämpötila oli +9,5 °C ymppäyksen jälkeen.

Syyshaavakka voi aiheuttaa sinistymistä myöhäissyksyllä kaadettuun puutavaraan kuorivioitusten läheisyyteen ja tukin päihin, jos tukit sahataan vasta keväällä.

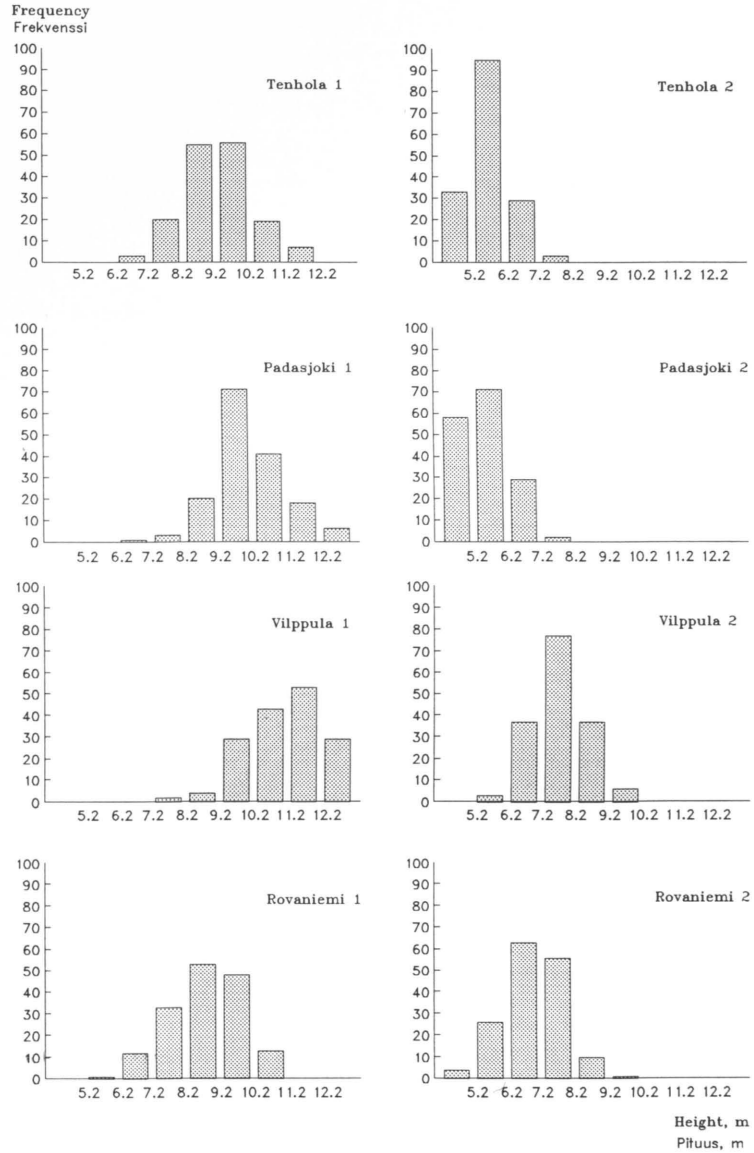
Syyshaavakan kuromat leviävät vesipisaroiden mukana, mikä merkitsee sitä, että sieni ei leviä tehokkaasti pitkiä matkoja. Sienen itiöiden puute ilmeisesti selittää tutkimusaineiston kontrollipuiden säilymisen terveinä. Sairastuneet käytännön karsintametsiköt oli usein harvennettu ennen pystykarsintaa, jolloin hakkuutähteistä leviävät syyshaavakan kuromaitiöt saattoivat tartuttaa syksyllä karsitut puut.

Syyshaavakan korot männyissä eivät laajentuneet toisen karsinnan jälkeisen lepokauden aikana, vaikka sienen rihmastoa eristettiin koroista vielä tällöinkin. Siten haavakorkin muodostuminen yhdessä pihkanjuoksun ja kemiallisten muutosten kanssa estivät tehokkaasti korojen laajenemisen.

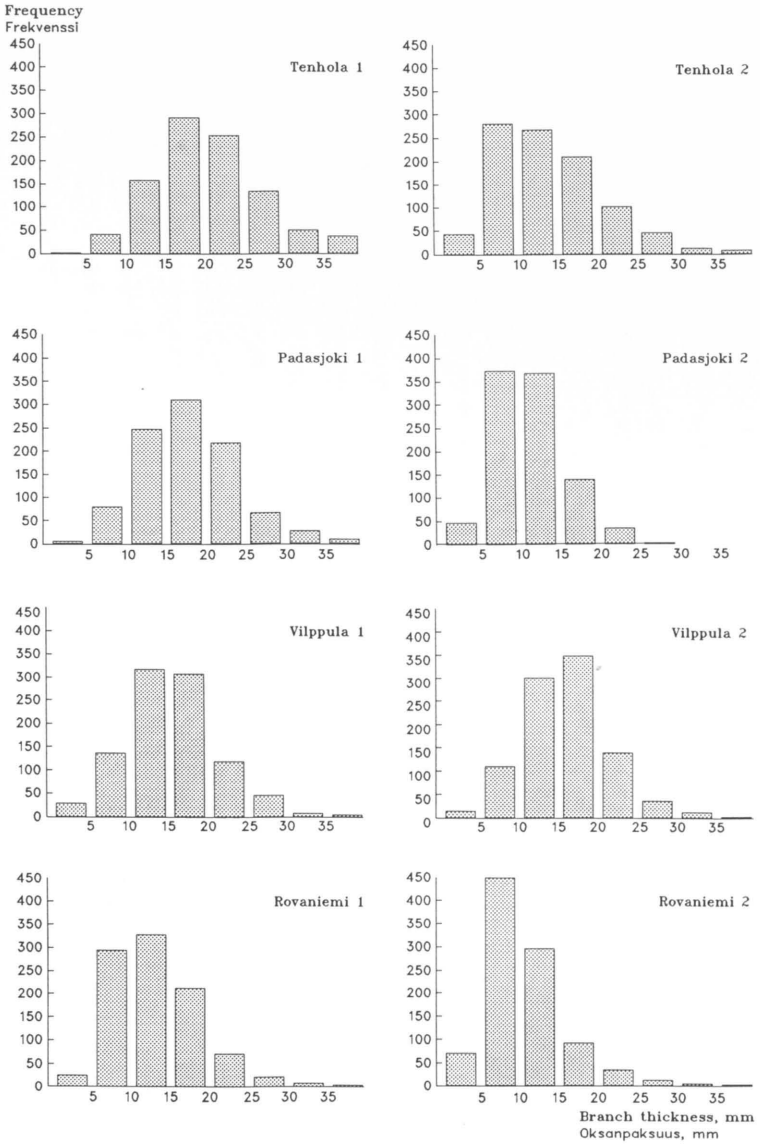
Suojapäivien lukumäärä koevuotena oli jonkin verran keskimääräistä vähäisempi. Siten kokeissa todettu altis karsintakausi voi lauhana talvena jatkua myöhemmälle kuin talvella 1985 – 1986. Tämä on otettu huomioon karsinta-aikavyöhykesuositusta laadittaessa (kuva 15). Eteläisellä vyöhykkeellä karsintaa tulisi tehdä 1. 2. – 15. 9. Keskisellä vyöhykkeellä suositeltava karsintakausi olisi 1. 1. – 15. 9 ja pohjoisella vyöhykkeellä 15. 11. – 1. 9. Nila-aikana touko – kesäkuussa ei tarvitse välttää karsimista. Turvallisen karsinta-ajankohdan alussa todennäköisyys olla yli 10 suojapäivää kuukaudessa on alle 20 %. Turvallinen karsinta-aika päättyy, kun viiden vuorokauden keskilämpötila laskee alle +7 °C. Suositellun karsinta-ajan päättyessä viiden vuorokauden keskilämpötila on pienempi kuin +7 °C alle 20 % todennäköisyydellä.



Appendix 1. Distribution of breast height diameter of the pruned trees.
Liite 1. Karsittujen puiden läpimittajakauma.



Appendix 2. Height distribution of the pruned trees.
Liite 2. Karsittujen puiden pituusjakauma.



Appendix 3. Distribution of the branch thickness of pruned branches.
Liite 3. Karsittujen oksien paksuusjakauma.

Instructions to authors — Ohjeita kirjoittajille

Submission of manuscripts

Manuscripts should be sent to the editors of the Society of Forestry as three full, completely finished copies, including copies of all figures and tables. Original material should not be sent at this stage.

The editor-in-chief will forward the manuscript to referees for examination. The author must take into account any revision suggested by the referees or the editorial board. Revision should be made within a year from the return of the manuscript. If the author finds the suggested changes unacceptable, he can inform the editor-in-chief of his differing opinion, so that the matter may be reconsidered if necessary.

Decision whether to publish the manuscript will be made by the editorial board within three months after the editors have received the revised manuscript.

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The author is responsible for the scientific content and linguistic standard of the manuscript. The author may not have the manuscript published elsewhere without the permission of the publishers of Acta Forestalia Fennica. The series accepts only manuscripts that have not earlier been published.

The author should forward the final manuscript and original figures to the editors within two months from acceptance. The text is best submitted on a floppy disc, together with a printout. The covering letter must clearly state that the manuscript is the final version, ready for printing.

Form and style

For matters of form and style, authors are referred to the full instructions available from the editors.

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