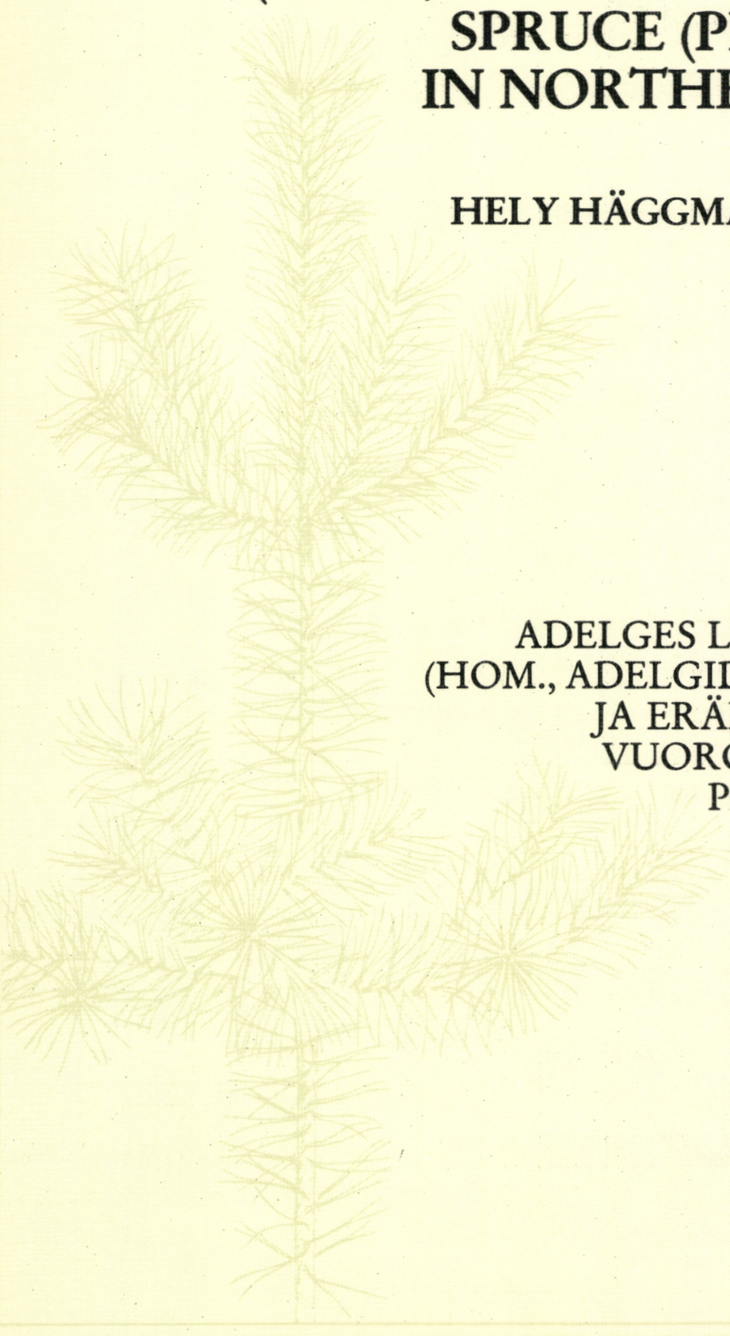
COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE 135

INTERACTION BETWEEN THE APHID ADELGES LAPPONICUS CHOL. (HOM., ADELGIDAE) AND SOME SPRUCE (PICEA) SPECIES IN NORTHERN FINLAND

HELY HÄGGMAN & MATTI ROUSI



SELOSTE

ADELGES LAPPONICUS CHOL. (HOM., ADELGIDAE) HAVUKIRVAN JA ERÄIDEN KUUSILAJIEN VUOROVAIKUTUSSUHDE POHJOIS-SUOMESSA

HELSINKI 1986

COMMUNICATIONES INSTITUTI
FORESTALIS FENNIAE

THE FINNISH FOREST RESEARCH INSTITUTE
(METSÄNTUTKIMUSLAITOS)

Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

Director:
Professor Aarne Nyyssönen

telex: 125181 hyfor sf
attn: metla/

phone: 90-661 401

Distribution and exchange of publications:

The Finnish Forest Research Institute
Library
Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

Publications of the Finnish Forest Research Institute:

- Communicationes Instituti Forestalis Fenniae (Commun. Inst. For. Fenn.)
- Folia Forestalia (Folia For.)
- Metsäntutkimuslaitoksen tiedonantoja

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

COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE

135

HELY HÄGGMAN & MATTI ROUSI

INTERACTION BETWEEN THE APHID ADELGES LAPPONICUS CHOL. (HOM., ADELGIDAE) AND SOME SPRUCE (PICEA) SPECIES IN NORTHERN FINLAND

Approved on 6.6.1986

SELOSTE

ADELGES LAPPONICUS CHOL. (HOM., ADELGIDAE) HAVUKIRVAN JA ERÄIDEN KUUSILAJIEN VUOROVAIKUTUSSUHDE POHJOIS-SUOMESSA

HELSINKI 1986

HÄGGMAN, H. & ROUSI, M. 1986. Interaction between the aphid *Adelges lapponicus* Chol. (Hom., Adelgidae) and some spruce *(Picea)* species in Northern Finland. Seloste: *Adelges lapponicus* Chol. (Hom., Adelgidae) havukirvan ja eräiden kuusilajien vuorovaikutussuhde Pohjois-Suomessa. Commun. Inst. For. Fenn. 135. 12 p.

This is the first time that an *Adelges lapponicus* Chol. (Hom., Adelgidae), a gall-forming aphid, has been reported in Finland. The aphid attacked three different spruce species *Picea abies* (Norway spruce), *P. glauca* (white spruce) and *P. mariana* (black spruce) grown in field experiments in the northern part of Finland.

The differences in susceptibility of the species to aphid attack were pronounced. The aphids strongly favoured Norway spruce and also white spruce seemed to be preferred to black spruce. The height of Norway spruce correlated positively to the number of galls in the provenance trials and in the half-sib families. Also the survival of Norway spruce from different origins was positively correlated with the number of galls. The aphids strongly favoured families and progenies which showed good survival and growth. This may mean that well adapted trees contained positive factors for aphids.

The colour and the size of the galls varied among the spruce species. Anatomical paraffin preparates indicated a very pronounced starch accumulation in the mesophyll cells of the gall tissue in all the spruce species. The enzymatic sugar analyses revealed that in white spruce and black spruce the aphids utilized fructose, which probably acts as a feeding stimulant. The total phenol content of the reference samples for Norway spruce seemed to be smaller than in the other spruce species but the differences were not statistically significant for the small material.

Tässä tutkimuksessa esitetään ensimmäiset varmennetut tiedot *Adelges lapponicus* Chol. (Hom., Adelgidae) äkämiä muodostavan havukirvan esiintymisestä Suomessa. Havukirvan todettiin esiintyvän kuusella *(Picea abies)*, valkokuusella *(Picea glauca)* ja mustakuusella *(Picea mariana)*. Aineisto kerättiin puulajikokeista Kolarin Tappikummussa.

Kuusilajien välillä oli huomattavia eroja äkämien määrässä. Eniten äkämiä oli kuusessa ja vähiten mustakuusessa. Äkämien määrä oli sekä alkuperä- että risteytyskokeissa sitä suurempi mitä pitempiä puut *(Picea abies)* olivat. Samaten äkämiä esiintyi sitä runsaammin mitä enemmän kuusialkuperästä oli elossa. Kirvoja esiintyi erityisesti sellaisissa kuusialkuperissä ja risteytyserissä, joiden sekä elävyys että kasvu olivat hyviä. Hyvin sopeutuneet puut sisältänevätkin kirvoille positiivisia tekijöitä.

Äkämien väri ja koko vaihtelevat eri kuusilajien välillä. Anatomiset parafiinipreparaatit osoittivat huomattavaa tärkkelyksen keräytymistä äkämäsolukon mesofyllisoluihin kaikilla tutkituilla kuusilajeilla. Entsymaattisista sokerianalyyseistä voitiin päätellä, että kirvat käyttävät hyväkseen fruktoosia, joka todennäköisesti toimii kirvojen syönnin stimulaattorina. Kokonaisfenolipitoisuus näytti kuusessa olevan pienempi kuin valko- tai mustakuusessa, mutta aineiston pienuuden vuoksi ero ei ollut tilastollisesti merkitsevä.

ODC 145.7 × 14.28/.39 *Adelges lapponicus* + 174.7 *Picea* + (480.99)
ISBN 951-40-0743-3
ISSN 0358-9609

Helsinki 1986. Valtion painatuskeskus

CONTENTS

PREFACE

The study was carried out at Kolari Research Station, the Finnish Forest Research Institute. The authors planned and carried out the present study together. The manuscript was written by H. Häggman and completed together.

We wish to thank Mr Osmo Heikinheimo at the Department of Agricultural and Forest Zoology, University of Helsinki, for recognizing the aphid *Adelges lapponicus*. He also led us to literary sources about *Adelges lapponicus* and refined the manuscript.

Special thanks are due to the personnel of Kolari Research Station: to Mr Kauko Raatiniemi and Mr Reijo Rauniomaa for the field work, to Mr Juha Numminen for statistical analyses and to the excellent laboratory assistants Ms Anneli Kurkkio, Ms Irma Lantto and Ms Marita Ylläsjärvi. Ms Sirkka Himanka typed the manuscript. We would also like to thank Juhani Häggman, Phil. Lic., for the photographs.

The manuscript has been read by Professor Erkki Annila, Professor Max. Hagman, Dr Kari Heliövaara, Dr Kari Löyttyniemi and Dr Pekka Niemelä, whose suggestions have been taken into consideration. Mr John Langille checked the English.

We would like to thank all those mentioned above for their invaluable assistance during the course of the present work.

Authors

1. INTRODUCTION

Adelges lapponicus Chol. (Hom., Adelgidae), which has now for the first time been reported in Finland, has been known earlier in the Soviet Union (Cholodkovsky 1889, Gabrid 1983). Spruce galls formed by different *Adelges* species have been studied earlier in Sweden (Wahlgren 1935, 1938, 1940, 1957, 1960, Ossiannilsson 1959, 1969, Julin 1959) and in Finland (Julin 1959, Löyttyniemi 1971) but more accurate species identification has not been carried out in North Finland. Galls formed by *Adelges lapponicus* have been found from different spruce species (Gabrid 1983). The aphid hibernates as an immature fundatrix at the buds. In the spring they become active, change their skin three times and oviposit. Gallicolae hatching from these eggs feed on the growing new needles. Feeding by the fundatrices stimulates the gall formation. Parthenogenetic reproduction continues as the galls develop. Galls open mainly in June—July (Cholodkovsky 1889, Gabrid 1983).

Over the years a lot of work has been done to clarify the interactions of plants and insect herbivores. In particular the role of secondary compounds as protective agents and other plant defence mechanisms have been studied extensively (Beck 1965, Feeny 1976, Rhoades & Cates 1976, Swain 1977). The studies of aphid/plant interactions have shown that intraspecific competition for the resources of the host plant can be severe and the quality and/or quantity of the phloem sap can be the limiting factor for the growth and development of aphids (e.g. Whittam 1978). Adelgids seem to feed largely on parenchyma tissue although phloem elements may be tapped in young growing shoots (Auclair 1963). The variation in secondary compounds (e.g. Feeny 1976), physical texture, the demography of plant parts (Hartnett & Bazzaz 1984) and nutritional factors (Beck 1965) may be informative in expanding some patterns of herbivory caused by aphids.

The present work was constructed in order to study the interaction between *Adelges lapponicus* and three spruce species *Picea abies* (L.) Karst., *Picea glauca* (Moench) Voss and *Picea mariana* (Mill.) B.S.P. In addition to the measurements in the field also sugar and phenol analyses and anatomical preparates have been made from the shoots of the spruce attacked by the aphid.

2. MATERIAL AND METHODS

Recognition of the aphid *Adelges lapponicus* Chol. was based on the microscopical preparates made by Osmo Heikinheimo and on the gall development schedule given in the literature (Cholodkovsky 1889, Gabrid 1983).

The material was collected from three different experimental stands 444, 457 and 475 grown in Tappikumpu (67°15′N, 23°45′E) in Northern Finland. These experiments were laid down in years 1973, 1972 and 1971 with 2, 3 and 4 year old seedlings, respectively on a former *Hylocomium-Myrtillus* site type (see Kalela 1961) that was burned in 1970. There were 19 half-sib families of *P. abies* (L.) Karst. (Norway spruce) from Northern Finland in experiment 457, 38 *P. abies* provenances (from northern Sweden to Poland) in experiment 475 and seven *P. mariana* (Mill.) B.S.P. (black spruce) and three *P. glauca* (Moench) Voss (white spruce) provenances in experiment 444. In every experiment the trees were planted at 2 × 2 m distance in 4—5 replicates containing 49 (experiments 457 and 444) and 20 (experiment 475) trees.

For the regression analyses the height of the test trees and the viability percentage (survival) of different tree origins and half-sib families were determined during October 1983. The twig samples were collected simultaneously from the third whorl of branches in the randomly chosen test trees. These twigs with three annual shoots were taken from the main compass bearings, one twig per test tree. The number of the twigs per different tree origin or half-sib families was 20 on the average. The total amount of test twigs collected was 844 from the Norway spruce, 100 from black spruce and 43 from white spruce. The number of galls were counted in the laboratory. The viability of gall tissues was analysed with the tetrazolium test (Larcher 1969) using a 0.1 % aqueous solution of 2,3,5-triphenyltetrazolium chloride, (TTC) as a viability indicator. During the summer of 1984 the development of the new galls was followed and measured once a week from the end of June to the middle of July. At the end of June when the galls were still growing (Fig. 2) gall samples were collected from Norway spruce, black spruce and white spruce for TTC-tests, (as in October 1983), and for anatomical sections. For anatomical sections the gall material was fixed in FAA (= formalin, acetic acid, ethyl alcohol, 5:5:90 v/v) and embedded in paraffin. The paraffin sections were stained with Safranin-fast green (Gerlach 1969).

At the beginning of July (July 5th) twig samples with new galls were collected so as to analyse both the amount of monosaccharides glucose and fructose and the amount of total phenols. Three twigs per tree, five trees per one replication and three replications per experiment were collected so that the total number of sample twigs per origin or half-sib family was about 45. The samples from the twigs were obtained in accordance with Fig. 1. The reference samples were taken from healthy current shoots in the close vicinity of the gall formed shoots. The gall samples (Fig. 1) were taken from the upper part of the annual shoot where a gall had developed. These kinds of samples were thought to represent the situation where the already developed galls with aphids possibly influenced the chemical structure of the sample twig. Unfortunately it was impossible to get enough of this kind of material from Norway spruce because after gall formation only a few needles grew or the annual shoot did not develop at all. The control samples consisted of annual shoots from branches which had no new or old galls (not seen in Fig. 1).

The material for biochemical analyses was brought to the laboratory in cold bags and stored in liquid nitrogen. Samples were homogenized in 40 ml of distilled water with an Omnimixer, extracted at 60°C in a shaking water bath for 3 hours, cooled to room temperature, diluted to 100 ml and filtered with vacuum. The sugars were analysed using an enzymatic

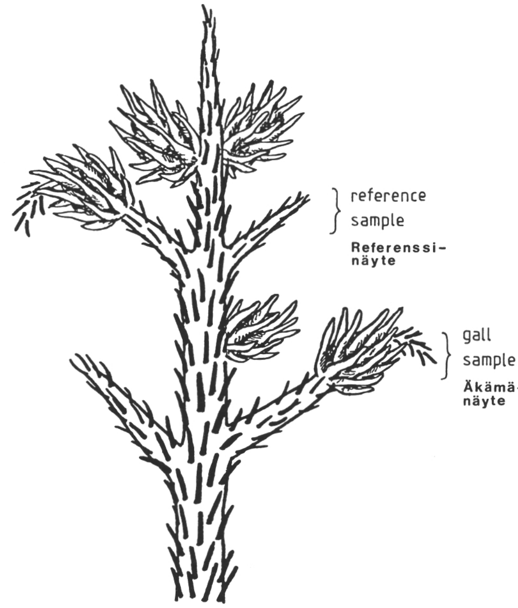


Fig. 1. Reference and gall samples for sugar and phenol analyses.

Kuva 1. Referenssi- ja äkämänäytteet sokeri- ja fenolianalyysejä varten.

method (Boehringer Mannheim GmbH Biochemica 1976/77, Beutler et al. 1978, Fuchs & Wretling 1979). To determine the amount of total phenols the material was dried at +105°C for 24 h and 2 × 0.4 g of the dried material was used for total phenol analyses using the Folin-Denis method (A.O.A.C. 1960).

The statistical analyses were performed using BMDP-programs (Biomedical programs designed at UCLA, Los Angeles, CA). The mean values ± single standard errors are presented. Regression analyses, analyses of variance and pairwise t-tests using Bonferroni probabilities were performed. The test value symbols are the following: r, the standardised regression coefficient; F, test quantity of variance analyses; t, pairwise t-test; p, tail probabilities.

3. RESULTS

The colour and size of the galls caused by *Adelges lapponicus* Chol. varied between the spruce species. At the end of June 1984 the galls in the black spruce were violet, in the white spruce mostly red with some green colour and in Norway spruce they were reddish green (contingency coeff. 0.724). At the end of June the galls were still expanding and at the beginning of July they were at their largest after which the size (Fig. 2) reduced, because the galls had ripened and the gall tissue began to dry. When comparing the tree species the size of the galls (Fig. 2) varied significantly ($F = 8.49$, $p = 0.0004$) at the beginning of July. On the average the galls of the white spruce were largest and those of black spruce smallest.

Morphologically the galls were formed either around the shoot base or more or less asymmetric. If the gall grew around the shoot base the shoot usually died. If the gall grew asymmetrically the shoot formed an angle even of 90°, but could still survive.

Detailed morphological observations were performed with TTC-tests. The TTC-test on the October 1983 samples indicated that in all cases the brown gall tissues were dead, as expected. When the gall was around the shoot base the apex of the annual shoot was in most cases dead but the lateral buds were alive indicating that these were able to

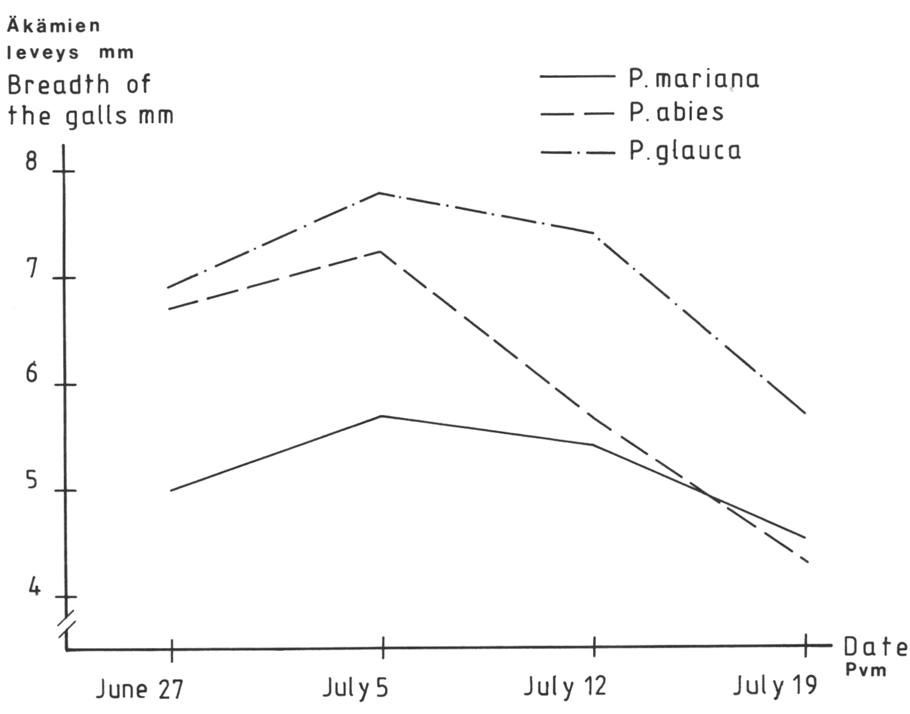


Fig. 2. The change in the breadth of the galls from the end of June to the middle of July. In Norway spruce n = 45 and in black- and white spruce n = 18.
Kuva 2. Muutos äkämien leveydessä kesäkuun lopulta heinäkuun puoliväliin kuusella n = 45 ja musta- ja valkokuusella n = 18.

continue the growth during the summer of 84. The TTC-test from the June 1984 samples revealed that the gall tissues were alive at this time and the soon to be released gallicolae could be seen in the gall chambers.

Anatomical paraffin sections from the galls collected at the end of June revealed that the gall chambers were developed between the modified needle bases. The anatomical structure of these needle bases was greatly modified, the mesophyll was hypertrophied, the endoderm was in most cases badly developed and there were a lot of starch granules in the mesophyll cells (see Fig. 3).

According to 1-way variance analyses of sugars (Table 1) the glucose ($F = 8.57$, $p = 0.0003$) and fructose content ($F = 8.43$, $p = 0.0008$) of the reference samples varied very significantly between the spruce species. In white spruce ($t = 4.62$, $df = 3.41$, $p = 0.0153$*, Bonferroni probabilities) and in black spruce ($t = 5.37$, $df = 10.16$, $p = 0.0003$***, Bonferroni probabilities) the reference samples contained more fructose than gall samples. Unfortunately it was impossible to get enough gall sample material from the Norway spruce for the sugar analyses.

The amount of total phenols in the reference samples in Norway spruce (74.1 ± 2.1 mg/g d.wt., $n = 9$) was smaller than for white spruce (87.5 ± 4.8 mg/g d.wt., $n = 3$) or black spruce (82.8 ± 5.5 mg/g d.wt., $n = 5$) but probably because of the scantiness of the samples the differences were not statistically significant ($F = 3.37$, $p = 0.0637$). In white spruce the mean phenol content of the control samples (96.64 ± 6.9 mg/g d.wt., $n = 2$) was higher and in black spruce (74.91 ± 1.4 mg/g d.wt., $n = 2$) lower than in the reference samples (see above) but neither of these differences were statistically significant. The differences of susceptibility for these three spruce species to aphid attack (Fig. 4) were pronounced ($F = 29.86$, $p < 0.0000$). It was evident that the aphids strongly favoured Norway spruce and also white spruce seemed to be preferred to black spruce.

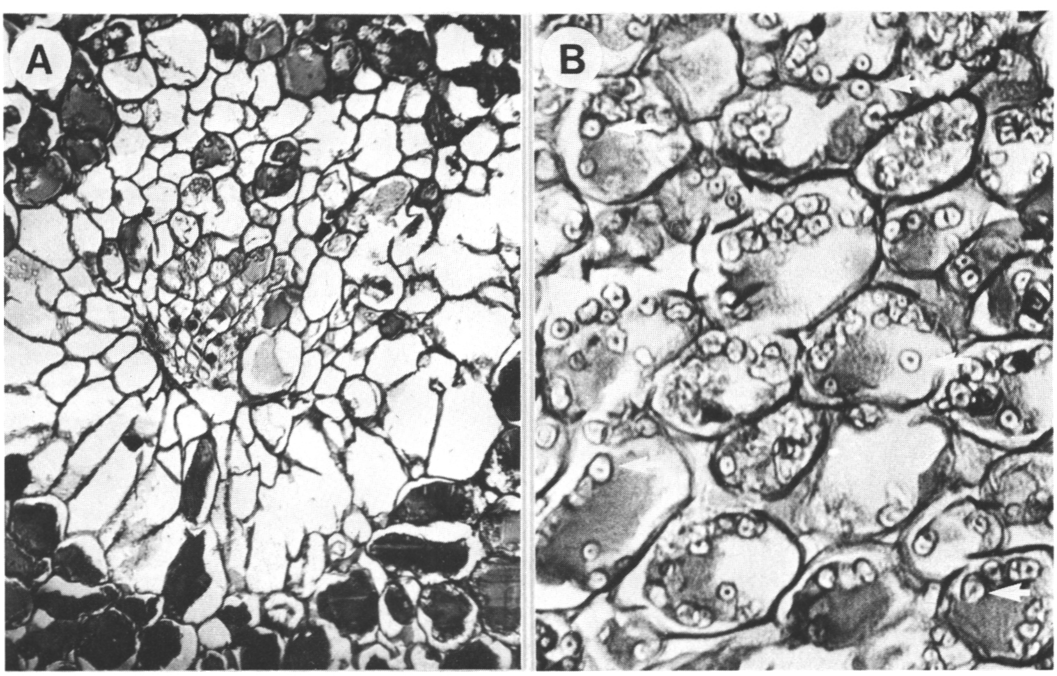


Fig. 3. The anatomical structure of the gall tissue.
a) The vascular bundle of the leaf base of Norway spruce. Endoderm is indistinct. x 375.
b) Starch granules in the mesophyll cells of gall tissue in black spruce. x 720. Arrows indicate starch granules.

Kuva 3. Äkämäsolukon anatominen rakenne.
a) Kuusen neulasen tyvellä olevaa johtosolukkoa. Endodermi on epäselvä. x 375.
b) Tärkkelysjyväsiä mustakuusen äkämäsolukon mesofyllisoluissa. x 720. Nuolet osoittavat tärkkelysjyväsiä.

Table 1. The amount of glucose, fructose and the relatioship glucose/fructose in the new shoots of *Picea abies, P. glauca* and *P. mariana* collected in the beginning of July. Each sample consisted of mixed material from 45 sample twigs per origin or half-sib family. Mean ± S.E.

Taulukko 1. Glukoosin ja fruktoosin määrä (mg/g kp) ja glukoosi/fruktoosi suhde heinäkuun alussa kerätyissä kuusen, valkokuusen ja mustakuusen uusissa versoissa. Keskiarvo ± S.E.

	P. abies			*P. glauca*			*P. mariana*	
	reference *referenssi* n = 11	control *kontrolli* n = 10	reference *referenssi* n = 4	gall *äkämä* n = 3	control *kontrolli* n = 1	reference *referenssi* n = 11	gall *äkämä* n = 2	control *kontrolli* n = 1
glu mg/g d.wt.	16.4 ± 3	12.8 ± 2	17.4 ± 2	22.2 ± 1	19.3	25.9 ± 2	23.1 ± 8.3	23.1
fru mg/g d.wt.	16.3 ± 3	12.0 ± 2	5.8 ± 1	0.7 ± 0	—	10.4 ± 1	2.8 ± 1.5	11.8
glu/fru	1	1	3	32	—	3	8	2

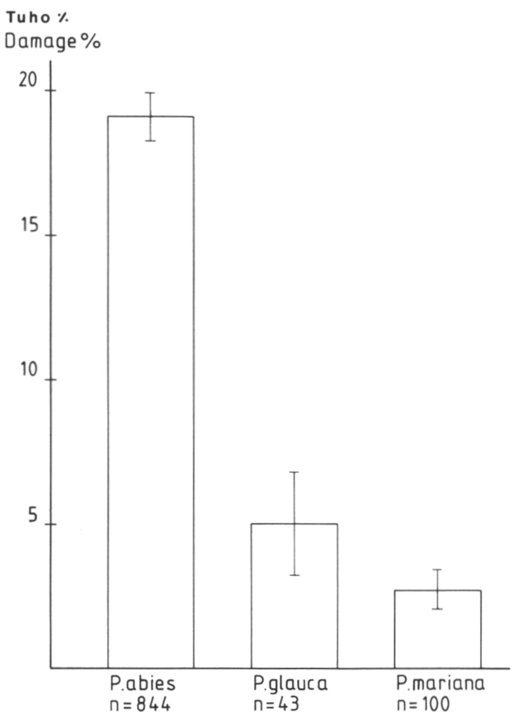


Fig. 4. The differences in susceptibility of Norway spruce, white spruce and black spruce to aphid *Adelges lapponicus* Chol. attack. Mean ± single S.E. Damage % = amount of the tops of the sample twigs damaged by the aphids.

Kuva 4. Kuusen, valkokuusen ja mustakuusen väliset erot Adelges lapponicus Chol. havukirvan aiheuttamien tuhojen määrissä. Keskiarvot ± S.E. Tuho % = näyteoksien kärkien määrä, joissa on kirvojen aiheuttamia äkämiä.

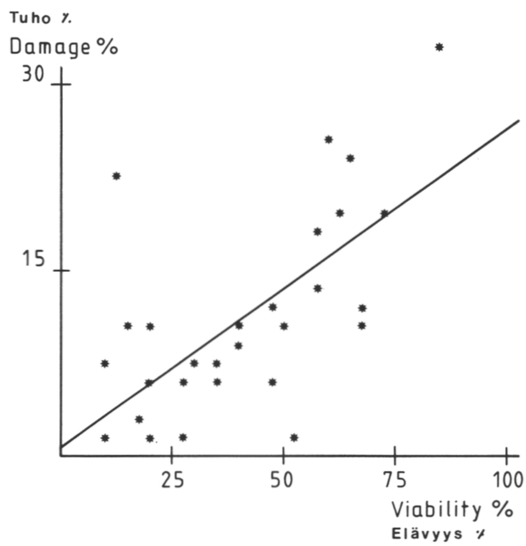


Fig. 5. Correlation ($r = 0.75$, $p < 0.0000$) between the damage % and the survival of different Norway spruce origins.

Kuva 5. Eri kuusialkuperien tuhojen määrän ja elävyyden välinen korrelaatio ($r = 0.75$, $p < 0.0000$).

The survival percentage of different Norway spruce origins correlated positively with the damage percent ($r = 0.757$, $p < 0.0000$) (Fig. 5) but in the survival of half-sib families the correlation was not statistically significant ($r = 0.23$, $p = 0.33$). The height of the Norway spruces was positively correlated to the damage percentage in provenance trials ($r = 0.528$, $p = 0.0008$) and half-sib families ($r = 0.540$, $p = 0.017$). It seemed that galls formed in the same trees year after year; the correlation between the old and new damage percent was positive in the provenance trial ($r = 0.907$, $p < 0.0000$) and in half-sib families ($r = 0.92$, $p < 0.0000$).

There were no differences in aphid attack intensity between the shoots aiming in different directions ($F = 1.4$, $t = 0.25$).

4. DISCUSSION

The distribution of spruce galls formed by *Adelges* species has been found earlier in Northern Finland as far as the northern limit of Norway spruce by Löyttyniemi (1971) which was also confirmed in our additional studies (Häggman & Rousi 1985). This suggests either rapid expansion capacity and/or growth potential of the aphid under suitable environmental conditions.

The scale insect *Physokermes hemicryptus* and aphid *Sacciphantes abietis* were slightly more abundant on branches on the south and west sides where the exposure was favourable (Schwerdtfeger 1963, Löyttyniemi 1971). In the present study we could not find any differences in the distribution of the galls caused by *Adelges lapponicus* in relation to the main directions of the compass. Maybe because of the short winter or long summer days of Lapland the direction of shoots makes no difference. This is especially true, when trees are small and spacing is sparse as was the case in our experiment.

Gall formation may be caused by the feeding of the fundatrices (Saalas 1949, Campbell & Balderston 1972, Rohfritsch 1982). Some amino acids, amides and enzymes occurring in aphid saliva have been held partly responsible for gall formation (Auclair 1963, Gabrid 1983). According to Gabrid (1983) the reason for the different colours of the galls caused by *Adelges lapponicus* on Norway spruce was the variation in light exposure. In the present study the colour as well as the size of the gall varied between the spruce species. In our material the galls in Norway spruce were a little bit bigger (mean 0.72 cm) than the galls measured (0.3—0.7 cm) by Gabrid (1983) in the Issik-Kul valley of Kirgizia in the Soviet Union. In the present study a large amount of starch granules in the mesophyll cells of the gall tissues in early July were characteristic of all galls caused by *A. lapponicus*. This observation is interesting because in general starch is high in the spring and autumn and low throughout the rest of the year (e.g. Höll 1985).

The results of enzymatic sugar analyses revealed that for black and white spruce the fructose concentration in reference samples was much higher than in the gall samples. The amount of glucose remained quite even but sucrose (data not published) was found only randomly in a few samples. On the basis of these results the most important function of fructose could be the role of a feeding stimulant (e.g. Beck 1965). Partly it may act as a component of honeydew oligossaccharides, the function of which is osmoregulatory (e.g. Auclair 1963, Fisher et al. 1984). However, this hypothesis does not answer the question about why the amount of glucose in our samples was so similar eventhough the honeydew oligosaccharides are known to include glucose, too.

It has been shown that the Adelgid *Chermes (Sacchiphantes) abietis* L., is subject to various resistance mechanisms e.g. hairs, lignins and tannins (Rohfritsch 1982) and that resistant trees of Norway spruce have shown a higher phenol content (Tjia 1973). In many tree species an increase in phenol content after an insect attack has been shown (Thielges 1968, Baltensweiler et al. 1977, Niemelä et al. 1979). On the other hand it has been shown that the tree locust *(Anacridium melanorhodon)* survives better and grows faster when certain phenols are added to the food plant (Bernays & Woodhead 1982). Interestingly, we found that in white spruce the phenol content in reference samples seemed to be lower and in black spruce higher than in the control samples but these differences were not statistically significant. Our material is limited and possible statistical differences are masked behind rather large standard errors. This may be because the A.O.A.C. method measures some substances other than plant phenolics. It is also quite possible that if secondary compounds play a role in the food selection of the *Adelges* species the study should be concentrated on more specific chemical groups than the total phenols.

Instead of avoidance of certain secondary metabolites the food selection of herbivores could be based on selecting some positive factors in food plants. Low fructose content in the gall samples of white and black spruce suggested that aphids utilize fructose. In our experiment the aphids strongly favoured families and progenies of Norway spruce which showed good survival and growth (see also Service 1984). It could be suggested that in spite of the rather high population density of aphids the trees remain in good condition and maybe there is no need for spruce to invest in defence against aphids.

The differences in susceptibility of the three spruce species to aphid attack were pronounced. The aphids strongly favoured Norway spruce if compared with white spruce and black spruce. As far as the authors know the latter spruce species have not been reported earlier to be food plants of *Adelges lapponicus*. Thus, it is quite possible that *Adelges lapponicus* has co-evolutioned to use Norway spruce; to detoxify secondary metabolites, and to use positive factors etc.

REFERENCES

A.O.A.C. 1960. Official methods of the association of official agricultural chemists, 9th edition. Washington 4, D.C.

Auclair, J. L. 1963. Aphid feeding and nutrition. Ann. Rev. Entomol. 8:439—490.

Baltensweiler, W., Benz, G., Bovey, P. & Delucchi, V. 1977. Dynamics of larch bud moth populations. Ann. Rev. Entomol. 22:79—100.

Beck, S. D. 1965. Resistance of plants to insects. Ann. Rev. Entomol. 10:207—232.

Bernays, E. A. & Woodhead, S. 1982. Plant phenols utilized as nutrients by a phytophagous insect. Science 216:201—203.

Beutler, H. O., Michal, G. & Beinstingl, G. 1978. Enzymatische Analyse von komplexen Kohlenhydratgemischen. Deutsche Lebensmittel-Rundschau 74:431—434.

Boehringer Mannheim GmbH Biochemica. 1976/77. Methods of enzymatic food analysis, 2nd section.

Campbell, R. L. & Balderston, C. P. 1972. Insecticidal control of eastern spruce gall aphid during autumn in Ohio. J. Econ. Ent. 6:1745—1746.

Cholodkovsky, N. 1889. Neue Mitteilungen zur Lebensgeschichte der Gattung Chermes. Zool. Anz. 12:387—391.

Feeny, P. 1976. Biochemical coevolution between plants and their insect herbivores. In: Gilbert, L. E. & Raven, P. H. (ed.) Coevolution of animals and plants. Univ. Texas Press. p. 3—19.

Fisher, D. B., Wright, J. P. & Mettler, T. E. 1984. Osmoregulation by the aphid *Myzus persicae:* a physiological role for honeydew oligosaccharides. J. Insect Physiol. 30:387—393.

Fuchs, G. & Wretling, S. 1979. Bestämning av fruktos, glukos och sackaros i livsmedel. Laboratorienytt. Vår Föda 31:435—439.

Gabrid, N. V. 1983. A contribution to the biology of *Adelges lapponicus* Chol. — the early pine aphid. Entomologicheskie Issledovaniya v. Kirgizii 14: 116—122.

Gerlach, D. 1969. Botanische Mikrotechnik. Georg Thieme Verlag, Stuttgart. p. 134—135.

Hartnett, D. C. & Bazzaz, F. A. 1984. Leaf demography and plant-insect interactions: goldenrods phloemfeeding aphids. Am. Nat. 124:137—142.

Häggman, H. & Rousi, M. 1985. Havukirvojen vaikutus eräissä puulajikokeissa. In: Saastamoinen, O. & Poikajärvi, H. (ed.). Metsäntutkimuspäivät Rovaniemellä 1985. Metsäntutkimuslaitoksen tiedonantoja 196:67—74.

Höll, W. 1985. Seasonal fluctuation of reserve materials in the trunkwood of spruce [*Picea abies* (L.) Karst.]. J. Plant Physiol. 117:355—362.

Julin, E. 1959. The distribution of the spruce gall aphids in Sweden. Opusc. Ent. 24:167—175.

Kalela, A. 1961. Waldvegetationszonen Finnland und ihre klimatischen Paralleltypen. Arch. Soc. Vanamo 16:65—83.

Larcher, W. 1969. Anwendung und Zuverlässigkeit der Tetrazoliummethode zur Feststellung von Schäden in pflanzlichen Geweben. Mikroskopie 25:207—218.

Löyttyniemi, K. 1971. On the occurrence of *Physokermes* Targ. species (Hom., Lecaniidae) and *Sacchiphantes abietis* L. (Hom., Adelgidae) on various local races of *Picea abies* in Finland. Ann. Ent. Fenn. 37:60—64.

Niemelä, P., Aro, E.-M. & Haukioja, E. 1979. Birch leaves as a resource for herbivores. Damage-induced increase in leaf phenols with trypsin-inhibiting effects. Rep. Kevo Subarctic Res. Stat. 15:37—40.

Ossiannilsson, F. 1959. Contributions to the knowledge of Swedish aphids II. List of species with find records and ecological notes. Kungl. Lantbr. högsk. Ann. 25:375—527.

— 1969. Catalogus insectorum sueciae. Homoptera: Aphidoidea. Opusc. Ent. 34:35—72.

Rhoades, D. F. & Cates, R. G. 1976. Toward a general theory of plant antiherbivore chemistry. In: Wallace, J. & Mansell, R. L. (ed.) Recent advances in

phytochemistry. Vol. 10: Biochemical interactions between plants and insects. p. 168—213.
Rohfritsch, O. 1982. Behaviour and biology of two species related to gall morphogenesis. Proc. 5th Int. Symp. Insect-Plant Relationship, Wageningen. p. 431—434.
Saalas, U. 1949. Suomen metsähyönteiset sekä muut metsälle vahingolliset ja hyödylliset eläimet. WSOY, Porvoo, Helsinki. p. 174—181.
Schwerdtfeger, F. 1963. Ökologie der Tiere. 1. Autökologie. Hamburg-Berlin. p. 461.
Service, P. 1984. Genotypic interactions in an aphid-host plant relationship: *Uroleucon rudbeckiae* and *Rudbeckia laciniata*. Oecol. 61:271—276.
Swain, T. 1977. Secondary compounds as protective agents. Ann. Rev. Plant Physiol. 28:479—501.
Thielges, B. A. 1968. Altered polyphenol metabolism in the foliage of *Pinus sylvestris* associated with European pine sawfly attack. Can. J. Bot. 46:724—725.
Tjia, B. 1973. Relation between phenol content and eastern spruce gall aphid resistance in Norway spruce. Hort Science 8:279—280.
Wahlgren, E. 1935. Cecidiologiska anteckningar III. Aphidina. Ent. Tidskr. 55:1—42.
— 1938. Svenska bladlöss (Aphidina). Ent. Tidskr. 58:166—187.
— 1940. Till kännedomen om Skånes bladlusfauna. Opusc. Ent. 5:25—32.
— 1957. Cecidiologiska anteckningar X. Ent. Tidskr. 78:159—177.
— 1960. Cecidiologiska anteckningar XII. Ent. Tidskr. 81:11—21.
Whittam, T. G. 1978. Habitat selection by *Pemphigus aphids* in response to resource limitation and competition. Ecology 59:1164—1176.

Total of 38 references

SELOSTE

Adelges lapponicus Chol. (Hom., Adelgidae) havukirvan ja eräiden kuusilajien vuorovaikutussuhde Pohjois-Suomessa

Pohjois-Suomessa kuusella yleisenä esiintyvä havukirvalaji *(Adelges)* määritettiin nyt lajiksi *Adelges lapponicus*. Kirvoja todettiin seuraavilla Pohjois-Suomen puulajikokeissa (67°15'N, 23°45'E) kasvavilla kuusilajeilla: kuusi *(Picea abies* (L.) Karst.), valkokuusi *(Picea glauca* (Moench) Voss) ja mustakuusi *(Picea mariana* (Mill.) B.S.P.). Tutkimuksessa tarkastellaan havukirvan ja sen eri ravintokasvilajien välisiä vuorovaikutussuhteita käyttäen apuna mm. mikroskooppisia ja biokemiallisia menetelmiä näytteiden analysoinnissa.

Tutkimustulokset osoittivat, että eri kuusilajien välillä (kuva 4) oli huomattavia eroja äkämien määrissä ($F = 29.86$, $p < 0.0000$). Olikin ilmeistä, että kirvat suosivat kotimaista kuusta pohjois-amerikkalaisiin kuusilajeihin verrattuna, joista valkokuusi oli suositumpi kuin mustakuusi. Usein hyönteisten ravintokasvien valinta perustuu haitallisten aineiden kuten fenolien välttämiseen. Kokonaisfenolipitoisuuksien määritysten perusteella näytti siltä, että kuusessa olisi vähemmän fenoleita kuin valko- tai mustakuusessa, mutta pienen aineiston vuoksi tulos ei ollut tilastollisesti merkitsevä. Toisaalta, koska sekä valko- että mustakuusi ovat *Adelges lapponicuksen* uusia ennen havaitsemattomia ravintokasvilajeja, on mahdollista, että kirva on koevoloitunut käyttämään kuusta tekemällä sen sekundääriyhdisteitä myrkyttömiksi, käyttämään hyväksi positiivisia tekijöitä jne.

Tutkittaessa kuusen eri alkuperä- ja risteytyskokeita havaittiin, että mitä pitempiä puut olivat sitä suurempi oli äkämien määrä ($r = 0.528$, $p = 0.0008$ ja $r = 0.540$, $p = 0.017$). Puiden elävyys puolestaan korreloi positiivisesti äkämien prosentuaalisen määrän kanssa (kuva 5) alkuperäkokeissa ($r = 0.757$, $p < 0.0000$), kun taas risteytyskokeissa vastaavaa korrelaatiota ei ollut ($r = 0.230$, $p = 0.33$).

Äkämien koko ja väri vaihtelivat eri kuusilajeilla. Anatomisista parafiinipreparaateista (kuva 3) havaittiin, että äkämäsolukoiden mesofyllisolut sisälsivät heinäkuun alussa runsaasti tärkkelysjyväsiä kaikilla tutkituilla kuusilajeilla. Yleensä tärkkelystä esiintyy runsaammin keväällä ja syksyllä ja vain vähän talvella tai kesällä (esim. Höll 1985).

Entsymaattisten sokerianalyysien perusteella (taulukko 1) musta- ja valkokuusinäytteissä kirvat olivat aiheuttaneet fruktoosin määrän vähenemisen. Todennäköisesti fruktoosi toimiikin kirvojen syönnin stimulaattorina.

Tiettyjen sekundääristen metaboliittien välttämisen sijasta kasvinsyöjien ruuan valinta voi perustua myös joihinkin ravintokasvien positiivisiin tekijöihin kuten sokereihin (esim. fruktoosi). Kuusikokeissa havaittiin selvästi, että kirvat valitsevat hyväkasvuisia ja korkean elävyysprosentin omaavia kuusialkuperiä ja risteytyseriä, jotka kirvojen suhteellisen suuresta määrästä huolimatta pysyivät hyväkuntoisina. Tämän perusteella voidaan olettaa, että kirvojen puille aiheuttama haitta ei ole kovin suuri.

HÄGGMAN, H. & ROUSI, M. 1986. Interaction between the aphid *Adelges lapponicus* Chol. (Hom., Adelgidae) and some spruce (*Picea*) species in Northern Finland. Seloste: *Adelges lapponicus* Chol. (Hom., Adelgidae) havukirvan ja eräiden kuusilajien vuorovaikutussuhde Pohjois-Suomessa. Commun. Inst. For. Fenn. 135. 12 p.

ODC 145.7 × 14.28/.39 *Adelges lapponicus* + 174.7 *Picea* + (480.99)
ISBN 951-40-0743-3
ISSN 0358-9609

HÄGGMAN, H. & ROUSI, M. 1986. Interaction between the aphid *Adelges lapponicus* Chol. (Hom., Adelgidae) and some spruce (*Picea*) species in northern Finland. Seloste: *Adelges lapponicus* Chol. (Hom., Adelgidae) havukirvan ja eräiden kuusilajien vuorovaikutussuhde Pohjois-Suomessa. Commun. Inst. For. Fenn. 135. 12 p.

The present work deals with the interaction between *Adelges lapponicus* Chol. (Hom., Adelgidae), a gall forming aphid, and three spruce species *Picea abies* (L.) Karst., *Picea glauca* (Moench) Voss and *Picea mariana* (Mill.) B. S. P. grown in field experiments in the northern part of Finland. In addition to the measurements in the field also sugar and phenol analyses and anatomical preparates were made from the shoots of the spruce attacked by the aphid.

Authors' addresses: *Häggman:* The Finnish Forest Research Institute, Kolari Research Station, SF-95900 Kolari, Finland. *Rousi:* The Finnish Forest Research Institute, Punkaharju Research Station, SF-58450 Punkaharju, Finland.

ODC 145.7 × 14.28/.39 *Adelges lapponicus* + 174.7 *Picea* + (480.99)
ISBN 951-40-0743-3
ISSN 0358-9609

HÄGGMAN, H. & ROUSI, M. 1986. Interaction between the aphid *Adelges lapponicus* Chol. (Hom., Adelgidae) and some spruce (*Picea*) species in northern Finland. Seloste: *Adelges lapponicus* Chol. (Hom., Adelgidae) havukirvan ja eräiden kuusilajien vuorovaikutussuhde Pohjois-Suomessa. Commun. Inst. For. Fenn. 135. 12 p.

The present work deals with the interaction between *Adelges lapponicus* Chol. (Hom., Adelgidae), a gall forming aphid, and three spruce species *Picea abies* (L.) Karst., *Picea glauca* (Moench) Voss and *Picea mariana* (Mill.) B. S. P. grown in field experiments in the northern part of Finland. In addition to the measurements in the field also sugar and phenol analyses and anatomical preparates were made from the shoots of the spruce attacked by the aphid.

Authors' addresses: *Häggman:* The Finnish Forest Research Institute, Kolari Research Station, SF-95900 Kolari, Finland. *Rousi:* The Finnish Forest Research Institute, Punkaharju Research Station, SF-58450 Punkaharju, Finland.

Tilaan kortin kääntöpuolelle merkitsemäni julkaisut (julkaisun numero mainittava).

Please send me the following publications (put number of the publication on the back of the card).

Nimi
Name ______________________

____

____

Osoite
Address ______________________

____

____

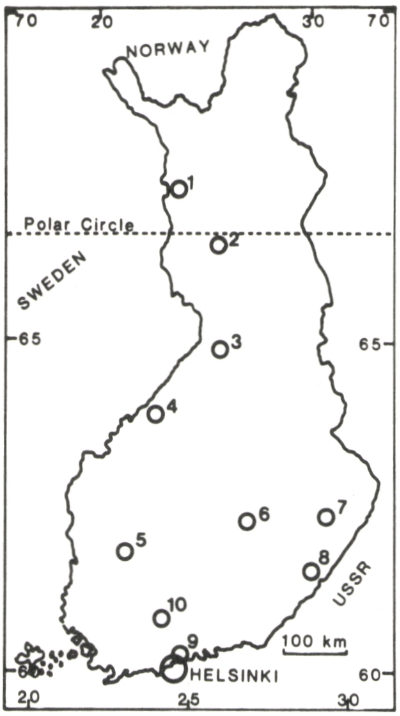
____

Metsäntutkimuslaitos
Kirjasto/*Library*
Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

Folia Forestalia

Communicationes Instituti Forestalis Fenniae

Huomautuksia
Remarks



THE FINNISH FOREST RESEARCH INSTITUTE

DEPARTMENTS (Helsinki)

Administration Office
Information Office
Experimental Forest Office
Dept. of Soil Science
Dept. of Peatland Forestry
Dept. of Silviculture
Dept. of Forest Genetics
Dept. of Forest Protection
Dept. of Forest Technology
Dept. of Forest Inventory and Yield
Dept. of Forest Economics
Dept. of Mathematics

RESEARCH STATIONS

1 Kolari
2 Rovaniemi
3 Muhos
4 Kannus
5 Parkano
6 Suonenjoki
7 Joensuu
8 Punkaharju
9 Ruotsinkylä
10 Ojajoki

FACTS ABOUT FINLAND

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

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

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

Communicationes Instituti Forestalis Fenniae

ISBN 951-40-0743-3
ISSN 0358-9609