# SILVA FENNICA

1988 · Vol. 22 N:o 2

SOCIETAS FORESTALIS FENNIAE

SUOMEN METSÄTIETEELLINEN SEURA
SOCIETY OF FORESTRY IN FINLAND

# SILVA FENNICA

**A quarterly journal of forest science**

## PUBLISHER – JULKAISIJA

The Society of Forestry in Finland
Suomen Metsätieteellinen Seura r.y.

## EDITORS – TOIMITUS

Editor-in-chief – Vastaava toimittaja Markku Kanninen
Editor – Toimittaja Tommi Salonen

Unioninkatu 40 B, SF-00170 Helsinki, Finland
tel. +358 0 658 707, telex 125 181 HYFOR SF



## AIM AND SCOPE – TAVOITTEET JA TARKOITUS

Silva Fennica publishes papers relevant to Finnish forestry and forest research. The journal aims to cover all aspects of forest research, ranging from basic to applied subjects. Besides research articles, the journal accepts research notes, scientific correspondence, and reviews.

Silva Fennicassa julkaistaan artikkeleita, joilla on merkitystä Suomen metsätalouden ja metsäntutkimuksen kannalta. Sarja kattaa metsätalouden kaikki osa-alueet ja julkaisee sekä metsätieteen perusteita käsitteleviä että sovellutuksiin tähtääviä kirjoituksia. Tutkimusraporttien lisäksi julkaistaan tiedonantoja, keskusteluartikkeleita ja katsauksia.

## SUBSCRIPTIONS – TILAUKSET

Subscriptions and orders for back issues should be addressed to Academic Bookstore, P.O. Box 128, SF-00101 Helsinki, Finland. Annual subscription price is FIM 220. Exchange inquiries can be addressed to the editorial office.

Tilaukset ja tiedustelut pyydetään osoittamaan toimitukselle. Silva Fennican tilaushinta kotimaahan on 160 mk, ulkomaille 220 mk.



# Early effects of peat ash on growth and mineral nutrition of the silver birch (Betula pendula) on a mined peatland

Ilari Lumme

*SELOSTE: TURVETUHKAN ALKUVAIKUTUKSISTA RAUDUSKOIVUN KASVUUN JA RAVINNETALOUTEEN TURVETUOTANNOSTA POISTUNEELLA SUOLLA*

Lumme, I. 1988. Early effects of peat ash on growth and mineral nutrition of the silver birch (*Betula pendula*) on a mined peatland. Seloste: Turvetuhkan alkuvaikutuksista rauduskoivun kasvuun ja ravinnetalouteen turvetuotannosta poistuneella suolla. Silva Fennica 22(2): 99–112.

Two-year-old silver birch seedlings were fertilized with three peat ash dosages 10, 50 and 150 metric t/ha and planted at three densities, 2 000, 10 000 and 25 000 seedlings/ha. The peat and mineral soil were mixed together by deep ploughing before peat ash application. The results indicate that the 10 t/ha of peat ash may be too low a dosage and 150 t/ha too high for the silver birch seedlings. The 50 t/ha ash dosage increased growth markedly, obviously due to an enhancement in soil and foliar P, Mg and Ca content, soil pH, microbial activity and mobilization of soil organic nitrogen. Both foliar and soil P were already enhanced with the 10 t/ha peat ash dosage. The K content of the peat ash was low, however, and it may be that fertilizer K should be applied later.

Koivunviljelykokeessa kaksivuotiaat rauduskoivun taimet lannoitettiin kolmella turvetuhka-annoksella, 10 t, 50 t ja 150 t/ha, ja istutettiin kolmelle istutustiheydelle, 2 000, 10 000 ja 25 000 tainta/ha. Turve ja kivennäismaa sekoitettiin keskenään ennen tuhkan levitystä. Alkukehitys osoitti, että tuhka-annos 10 t/ha oli ehkä liian alhainen ja 150 t/ha liian korkea annos rauduskoivun viljelyn kannalta. Tuhka-annos 50 t/ha lisäsi rauduskoivun kasvua merkittävästi. Tuhka kohotti maaperän ja koivun lehtien P-, Mg- sekä Ca- pitoisuutta, maan pH:ta ja mikrobiologista aktiivisuutta sekä ilmeisesti turpeen orgaanisen typen mobilisaatiota. Sekä lehtien että maaperän P-pitoisuus kohosi kuitenkin jo 10 t/ha tuhka-annoksella. Toisaalta turvetuhkan kaliumpitoisuus oli alhainen ja K-lisälannoitusta tarvittaneen pitkällä aikavälillä.

Keywords: *Betula pendula*, silver birch, fertilization, peat ash, nitrogen, mined peatlands.
ODC 176.1 *Betula pendula*+237.4+2−−114.444

Correspondence: Ilari Lumme, Research Institute of Northern Finland, University of Oulu, SF-90570 Oulu, Finland.

Accepted February 29, 1988

# 1. Introduction

The area of mined peatlands in Finland is increasing and is expected to amount between 20 000 and as much as 100 000 ha by the beginning of the next century (Ahonen and Huusko 1986). Most of these areas are situated in the northwestern coastal region. Their use for agriculture is not an attractive alternative especially in northern Finland, whereas forestry offers a most interesting way of cultivating them.

Scots pine (*Pinus sylvestris* L.), white birch (*Betula pubescens* Ehrh.) and silver birch (*Betula pendula Roth.*) can be considered the most viable alternatives for forestry on mined peatlands. The white birch grows naturally on peatlands in Finland, but according to Lehtiniemi and Sarasto (1973) and Kurkela (1973) it may be difficult to cultivate silver birch on drained peatlands. Mined peatlands can be considered as an intermediate soil type between mineral and peat soils as the peat layer is usually quite shallow. According to Kaunisto (1981) and Ferm and Kaunisto (1983) the silver birch can form naturally born stands on mined peatlands in southwestern Finland.

Large amounts of peat ash are generated in Finland (70 000–100 000 metric tonnes/a in 1984–1985) due to the use of peat for energy production (Energiataloudellinen yhdistys 1986), and this figure can be expected to increase in the future with the opening of new peat power plants. Peat ash causes an environmental problem, but also contains several valuable plant nutrients (Paarlahti 1980). As earlier experiments have shown bark and wood ash are beneficial for tree growth on drained peat soils, but peat ash may have weaker effects, as it does not contain the same amount of plant nutrients (Mikola 1975, Paarlahti 1980, Lumme et al. 1984, Silfverberg and Huikari 1985 and Kaunisto 1987). Bark and wood ash have also been shown to have a longer fertilization effect on forest growth on drained peat soils than PK fertilizers (Silfverberg and Huikari 1985), but it is not yet known whether this is also the case with peat ash.

The aim of this research work was to study effects of peat ash fertilization on survival and growth of the silver birch (*Betula pendula*) on a mined peatland. The research was performed at the Research Institute of Northern Finland, University of Oulu and was financed by the Ministry of Trade and Industry in 1984-1985 and the Finnish Academy and Kemira Oy in 1986-1987. Vapo Oy, a peat producing company, supplied the test area and a lot of technical assistance during the establishment of the experiment and the ensuing research. The foliar and soil analysis were performed at the Department of Botany, University of Oulu. The head of the Department, Professor Paavo Havas, kindly allowed the author to use its laboratories and equipment. The initiator of this research was Dr. Eino Kiukaanniemi of the Research Institute of Northern Finland. Associate Professor Eino Siuruainen at the University of Oulu has also greatly supported this work. The English manuscript was revised by Mr. Malcolm Hicks, M.A., of the Technology Centre of Oulu. Dr. Seppo Kaunisto and Mr. Klaus Silfverberg, M.Sc., of the Finnish Forest Research Institute made valuable corrections to the manuscript. The author wishes to thank all those mentioned here, especially Dr. Eino Kiukaanniemi, for their support.

# 2. Material and methods

## 21. Experimental area and layout

A field experiment was established in 1984 at Hirvineva, Liminka (64°42'N, 25°20'E, altitude 50 m above sea level), in a mire area released from peat harvesting in 1982. The thickness of the remaining peat layer varied between 5 and 30 cm. Drainage was improved in 1983 by deepening the ditches. The site was deep-ploughed and harrowed in order to mix the peat and underlying mineral soil together.



Table 1. Peat ash dosages, N and NK fertilization, planting density of *Betula pendula* and number of replicates used in the Hirvineva birch experiment.

| Birch seedlings/ha | Metric t of ash/ha (d.w.) and N+NK fertilization | | | | |
|---|---|---|---|---|---|
| | 0 | $0_{+N+NK}$ | $10t_{+N+NK}$ | $50t_{+N+NK}$ | $150t_{+N+NK}$ |
| 2 000/ha | 1 | 1 | 2 | 2 | 2 |
| 10 000/ha | 1 | 1 | 2 | 2 | 2 |
| 25 000/ha | 1 | 1 | 2 | 2 | 2 |

Table 2. Chemical and physical characteristics of the peat ash (of dry matter) from Toppila power plant, Oulu City, used in the experiment.

| Parameter | Concentration g/kg |
|---|---|
| pH | 10.5 |
| Ca | 52.0 |
| K | 2.1 |
| P | 21.8 |
| Mg | 7.3 |
| Fe | 223.6 |

In 1984 the area was divided into 24 experimental plots (750 m$^2$ each) and three dosages of peat ash from the Toppila power plant in the city of Oulu, was spread on 18 randomly chosen plots (Table 1). The soil and ash were then mixed together by harrowing the surface layer to a depth of 0-25 cm. All the peat ash plots were subsequently fertilized with a nitrogen fertilizer (oulunsalpietari 27.3 % N, 4 % Ca and 2.2 % Mg) 250 kg/ha and NK fertilizer (13.7 % N, 38.2 % K) 250 kg/ha, which implied an administration of 102 kg of N/ha and 96 kg K/ha (Table 1). No chemical fertilizer was used after 1984. Three of the six control plots were fertilized with both N fertilizer and NK fertilizer at similar dosages to the peat ash plots. The three other control plots received no treatment except for deep ploughing and harrowing (0 controls) (Table 1).

Two-year-old bare-rooted *Betula pendula* seedlings (origin Pudasjärvi 65°15'N, 27°00'E) were planted in the 0–20 cm soil layer in May 1984 at three planting densities (Table 1).

## 22. Parameters analysed

The following parameters were analyzed during 1984-1987:

A. Soil
- pH($H_2O$) (1:4)
- tot N %
- ammonium-N
- nitrate-N
- AAAc soluble phosphorus
- exchangeable potassium
- exchangeable magnesium
- –"– calcium
- AAAc soluble iron
- cellulose decomposition
- soil temperature
- organic matter content

B. Birch seedlings
- foliar N
- –"– P
- –"– K
- –"– Mg
- –"– Ca
- –"– Fe
- height and stem diameter of the birches

Only the quality of the peat ash, the soil parameters and the survival of the birch seedlings were analyzed in 1984. Peat ash samples were taken from each truck load. The results in Table 2 represent mean values from separate analyses. Soil samples (0–20 cm) were collected twice a year, at the end of June and the beginning of August. Each soil sample was a combination of ten subsamples, which were mixed together before analyses.

Foliar samples were collected from randomly selected trees (40 trees/plot) at the same time as the soil samples from each plot. Young fully grown leaves from the annual shoots were collected from several parts of each tree (Heinsdorf 1984). All chemical soil and foliar analyses were performed according to Halonen et al. (1983) and SFS (1976). The soil samples for ammonium and nitrate analyses were extracted in 1 M KCL and those for P, K, Mg, Ca and Fe analyses in 0.5 M $CH_3COOH$- 0.5 M $CH_3COOH$-$NH_4$ (abbreviated here as AAAc), pH 4.65. Total N in the foliar and soil samples was determined by the Kjeldahl method and the foliar P, K, Mg, Ca and Fe content was analyzed by dry combustion at 480°C and HCl extraction. N and P concentrations in the solutions were determined on a spectrophometer and K, Mg, Ca and Fe concentrations were analysed on an atomic absorption spectrophotometer.

Table 3. Dry mass equations for the silver birch. $Y = a X^b e$, $X = d^2h$ (d= stem base diameter mm, h= stem height cm, a and b = constants).

| Age yr. | | n | a | b | $R^2$% |
|---|---|---|---|---|---|
| 3 | Stem | 20 | 0.01981 | 0.5342 | 98 |
| | Branch | | 0.00734 | 0.5871 | 97 |
| 4 | Stem | 20 | 0.02035 | 0.6986 | 98 |
| | Branch | | 0.00589 | 0.7920 | 96 |
| 5 | Stem | 20 | 0.02254 | 0.7501 | 98 |
| | Branch | | 0.00491 | 0.8012 | 96 |

Table 4. Mean monthly temperatures (°C) at Hirvineva in 1984–1987 and long-term means 1930–1980.

| | Mean temperature °C | | | | Long term mean |
|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1987 | 1930–1980 |
| May | 11.6 | 5.6 | 8.8 | 6.9 | 7.3 |
| June | 13.0 | 13.0 | 15.5 | 12.2 | 12.8 |
| July | 14.7 | 15.2 | 15.8 | 14.2 | 16.2 |
| August | 12.5 | 14.3 | 10.9 | 10.4 | 14.0 |
| September | 7.8 | 8.5 | 5.2 | 7.1 | 8.4 |

Table 5. Effective temperature sum (>+5°C dd°C) at Hirvineva in 1984–1987 and long-term means 1930–1980.

| | Sum of effective temperature dd°C | | | | Long-term mean |
|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1987 | 1930–1980 |
| May | 228 | 51 | 123 | 75 | 95 |
| June | 241 | 241 | 315 | 216 | 240 |
| July | 295 | 316 | 336 | 284 | 340 |
| August | 220 | 287 | 183 | 160 | 270 |
| September | 83 | 110 | 44 | 65 | 105 |
| Total | 1 136 | 1 051 | 1 001 | 800 | 1 050 |

Table 6. Mean monthly precipitation at Hirvineva in 1984–1987 and long-term means 1930–1980.

| | Precipitation mm | | | | Long-term mean |
|---|---|---|---|---|---|
| | 1984 | 1985 | 1986 | 1987 | 1930–1980 |
| May | 10 | 31 | 59 | 28 | 32 |
| June | 68 | 24 | 25 | 85 | 57 |
| July | 90 | 25 | 71 | 87 | 71 |
| August | 31 | 103 | 180 | 104 | 71 |
| September | 33 | 66 | 97 | 56 | 57 |

The results of the soil and foliar analyses in Tables 8–12 and Figures 1–8 represent the means from the two sets of samples collected in June and August each year.

Cellulose decomposition activity in the soil was measured by placing ten birch cellulose strips (5x20 cm) in the soil of each plot at the beginning of June. The strips were taken out at the end of September. Soil temperature was measured by placing 10 thermometers/plot at the depth of 15 cm in five plots throughout the experiment. The readings were listed three times a week.

The size of the seedlings (height in cm and stem diameter in mm) was measured after planting in 1984, and the height and stem diameter increment of randomly chosen seedlings at the end of each growing season in 1985–1987 (25 % of the total number of seedlings/plot). The stem diameter was measured both from the base and at the height of one metre.

A dry mass equation for silver birch stems and branches was used to estimate annual biomass production according to Björklund and Ferm (1982), Nilsson (1982) and Hytönen (1985). The general equation was of the form of $Y = a \cdot X^b e$, $X = d^2H$ (d= stem base diameter mm, h= stem height cm), a and b= constants, which were solved by $\ln Y = \ln a + b \ln X + \ln e$. The square of the basal stem diameter and the tree height were used in resolving the equation (Table 3).

The results obtained from all measurements were tested statistically using the one way analysis of variance and t-test. The symbols (*) used in Tables 8–11 correspond to the following levels of statistical significance for the differences between the treatments: *= $p<0.05$, **= $p<0.01$ and ***= $<0.001$.

## 23. Weather conditions in 1984–1987

Considerable variation occurred in the weather conditions at Hirvineva in 1984–1987 (Tables 4–6). The effective temperature sum was highest in 1984, due to the warm May. Precipitation in June and July 1985 was considerably below the long-term mean. In August 1986 temperatures were unusually low and precipitation was well above the long-term mean (at Ruukki Agricultural Research Station, 10 km south of Hirvineva). The whole summer of 1987 was exceptionally cold, and precipitation was above normal in June, July and August.





# 3. Results

## 31. Effect of peat ash on soil chemical and physical characteristics

### *311. pH and exchangeable Ca*

The soil pH rose from 4.7 to 5.4 at the peat ash application of 50 metric t/ha and to 5.8 at 150 metric t/ha in 1984 ($p<0.05$), whereas 10 metric t/ha did not cause any marked change in pH (Table 8). This effect was consistent throughout the research period 1984–1987, although pH decreased slightly during 1986–1987. The original Ca content of the soil was low and 50 t and 150 t/ha of peat ash increased the exchangeable Ca content ($p<0.01$) during 1984–1987 (Table 8).

Table 7. Soil chemical and physical characteristics at the depth of 0–20 cm before fertilization.

| Parameter | Peat layer | Mineral soil |
|---|---|---|
| pH | 4.5 | 5.0 |
| Ammonium-N mg/l | 12.7 | 1.4 |
| Nitrate-N –"– | 0.3 | 0.1 |
| Tot N % | 2.3 | 0.3 |
| C:N | 20:1 | |
| AAAc soluble P mg/l | 0.6 | 2.6 |
| Exchangeable K –"– | 21.0 | 76.0 |
| –"– Mg –"– | 59.2 | 108.3 |
| –"– Ca –"– | 351.0 | 435.0 |
| –"– Fe –"– | 124.7 | 88.2 |
| CEC meq/100 g | 124 | 11 |
| Organic matter % | 85 | 11 |
| Peat quality/Soil type | Carex H7 | Sand-silt moraine |

Table 8. Soil pH and exchangeable Ca content (mg/l) in 1984–1987.

| Year/ | 1984 | | 1985 | | 1986 | | 1987 | |
|---|---|---|---|---|---|---|---|---|
| Peat ash | pH | Ca | pH | Ca | pH | Ca | pH | Ca |
| 0 t/ha | 4.7 | 394 | 4.7 | 391 | 4.5 | 382 | 4.5 | 345 |
| 10 –"– | 4.8 | 399 | 4.9 | 388 | 4.7 | 358 | 4.4 | 372 |
| 50 –"– | 5.4* | 1032** | 5.4* | 1001** | 5.2* | 999** | 5.2* | 968** |
| 150 –"– | 5.8** | 1898*** | 5.9** | 1886*** | 5.5** | 1685*** | 5.6** | 1787*** |

### *312. Nitrogen*

Total N was originally high in peat, but low in mineral soil. The ammonium concentration was similarly fairly high in the peat, but low in mineral soil. The nitrate content of both peat and mineral soil was extremely low (Table 7). Deep ploughing reduced the total N content in the soil from 2.3 to 1.7 %. In addition the nitrogen-free peat ash reduced the total N content from 1.7 % to 1.0–1.2 % at the 150 t/ha peat ash dosage and from 1.7 % to 1.2–1.4 % at 50 t/ha (Table 9).

The available nitrogen concentration of the soil (ammonium and nitrate-N) was quite high in 1984, after nitrogen fertilization, decreasing during the growing season of 1985 (Table 9). In the growing seasons of 1986 and 1987, however, the ammonium concentration was higher with 50 t/ha of peat ash than with any other treatment ($p<0.05$). The nitrate concentration in the soil was low throughout, except at the start of the experiment, when a nitrate containing fertilizer was used (Table 9).

Table 9. Soil total N (%), ammonium and nitrate concentration (mg/l) in 1984–1987 (CNK= NK fertilized control).

| Peat ash t/ha/ Year | Tot N % CNK | 10 | 50 | 150 | Ammonium-N mg/l CNK | 10 | 50 | 150 | Nitrate-N mg/l CNK | 10 | 50 | 150 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 1.7 | 1.7 | 1.3 | 1.1 | 27 | 26 | 28 | 24 | 35 | 33 | 36 | 32 |
| 1985 | 1.6 | 1.7 | 1.4 | 1.1 | 16 | 12 | 9 | 10 | 8 | 11 | 6 | 9 |
| 1986 | 1.5 | 1.5 | 1.3 | 1.2 | 13 | 13 | 20* | 16 | 0.6 | 0.6 | 0.9 | 0.4 |
| 1987 | 1.7 | 1.6 | 1.2 | 1.0 | 2.0 | 2.1 | 6.0* | 2.7 | 0.9 | 0.4 | 1.0 | 1.5 |

*313. AAAc soluble P, exchangeable K, Mg and AAAc soluble Fe*

The original level of AAAc soluble P in both peat and mineral soil was low (Table 7) (Kurki 1982). A consistently higher ($p<0.01$) soluble P concentration was obtained with the peat ash applications than with the unfertilized control plots (6–39 mg/l vs. 1.4–1.9 mg/l; Fig. 1). The 50 t and 150 t/ha ash dosages increased soil soluble P content more than did 10 t/ha ($p<0.01$) and 150 t/ha more than did 50 t/ha ($p<0.05$). AAAc soluble P concentrations showed some fluctuation during the growing season, the P level usually being higher at the beginning of the season than at the end. The overall level of soluble P nevertheless decreased from 1984 to 1987 in the plots fertilized with peat ash (Fig. 1).

The concentration of exchangeable K was originally extremely low in the peat, but somewhat higher in the mineral soil (Kurki 1982). The soil K content increased at first in all plots, with the exeption of the 0 control, due to NK fertilization and peat ash, but decreased considerably during 1986–1987 (Fig. 2). By 1987 the soil K level was higher in the peat ash fertilized plots than in the 0 and NK control plots (48–59 mg/l vs. 17–21 mg/l; $p<0.05$).

The original level of exchangeable Mg was low in both the peat and mineral soil (Table 7) (Kurki 1982). The 50 t and 150 t/ha ash dosages increased the soil Mg concentration above the control level ($p<0.01$) and to a greater extent than did the 10 t/ha dosage (Table 10).

A lower concentration of AAAc soluble Fe ($p<0.05$) was obtained with 150 t/ha of peat ash from 1985 onwards than with the other ash applications or in the controls (Table 10).

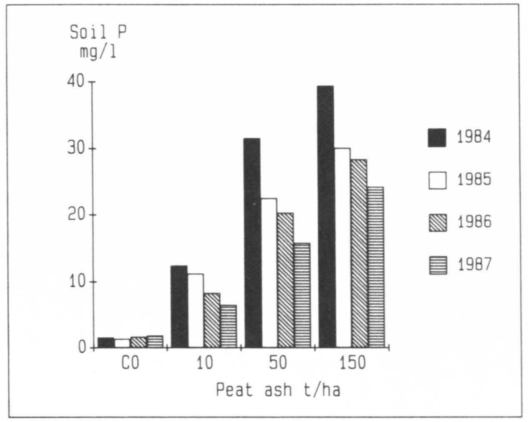


Fig. 1. Soil AAAc soluble P concentrations (mg/l) in 1984–1987. C0 = 0 control.

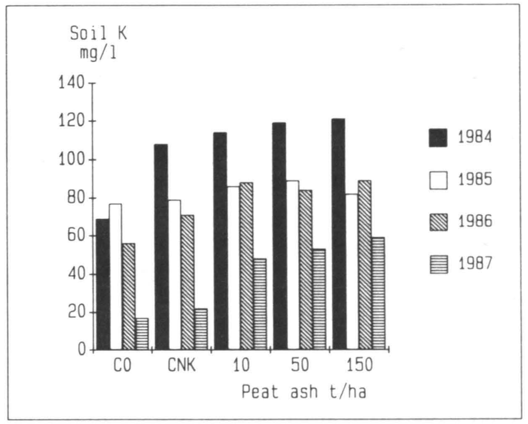


Fig. 2. Soil exchangeable K concentrations (mg/l) in 1984–1987. CNK = NK fertilized control, C0 = 0 control.

Table 10. Concentrations of exchangeable Mg and AAAc soluble Fe (mg/l) in soil in 1984–1987.

| Peat ash t/ha/ Year | Mg mg/l 0 | 10 | 50 | 150 | Fe mg/l 0 | 10 | 50 | 150 |
|---|---|---|---|---|---|---|---|---|
| 1984 | 80 | 82 | 133** | 140** | | | | |
| 1985 | 79 | 76 | 131** | 129** | 118 | 113 | 116 | 62* |
| 1986 | 76 | 64 | 117** | 118** | 105 | 105 | 103 | 55* |
| 1987 | 74 | 82 | 124** | 149** | 144 | 139 | 178 | 101* |



*314. Soil temperature*

Considerable variations in soil temperature (at 15 cm) occurred in 1984–1987 (Fig. 3), but no differences were obtained with any of the three peat ash applications. Soil temperature was fairly high in 1984, and it was also high until the end of July in 1986, after which it fell markedly. Unusually low soil temperatures were obtained throughout the growing season both in 1985 and in 1987 except for August-September 1985, when the figures remained fairly high (Fig. 3).

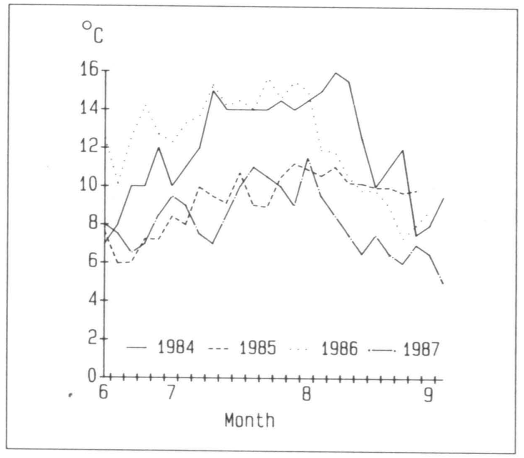


Fig. 3. Soil temperature (°C) at depth 15 cm in 1984–1987.

## 32. Cellulose decomposition activity in soil

Cellulose decomposition activity in the soil varied only marginally in 1984–1986, but was lower in 1987 probably due to the cold summer. The peat ash applications increased cellulose decomposition compared with the 0 control (Fig. 4). The 50 t and 150 t/ha peat ash dosages enhanced cellulose breakdown more than did 10 t/ha (20–28 % weight loss vs. 9.0–21 % w.l.; $p<0.05$), while the controls had a weight loss of 0.5–2 % ($p<0.001$).

## 33. Foliar nutrients

*331. Nitrogen*

The foliar N content was highest ($p<0.001$) in the N-fertilized controls in 1985 (Fig. 5.), while the differences between the ash dosages and the 0 controls were marginal. By 1986 the nitrogen content of the N-fer-

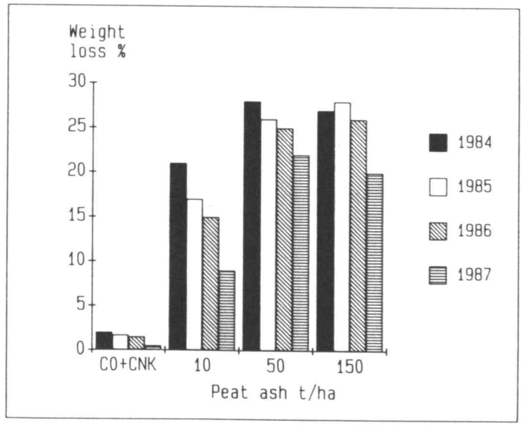


Fig. 4. Cellulose decomposition activity at depth 0-15 cm (% weight loss) in 1984–1987. CNK = NK fertilized control, C0 = 0 control.

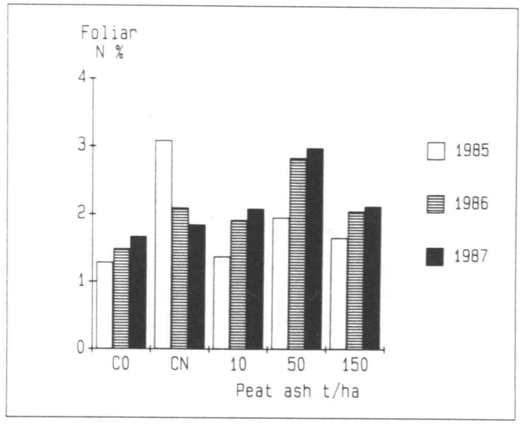


Fig. 5. Foliar N content (%) of the silver birch in 1985–1987. CN= N fertilized control, C0= 0 control.

tilized controls had fallen, but an increase was noted at 50 t/ha of peat ash ($p<0.01$). In 1986 the foliar N content was higher with the 50 t/ha ash dosage (2.84 %) than with any other (1.49-2.1 %; $p<0.01$). In 1987 the N content was also higher with 50 t/ha of peat ash ($p<0.05$) than in the controls, with 10 t and 150 t/ha (Fig. 5).

### *332. P, K, Mg, Ca and Fe*

The peat ash applications enhanced the foliar P content above the control level ($p<0.01$; Fig 6). By 1987 it was higher with 50 t/ha of ash than with 10 t and 150 t/ha (4.21 mg/g vs. 3.33–3.52 mg/g; $p<0.05$). The overall level of foliar P increased from 1985 to 1987 (Fig. 6).

The foliar K concentration varied markedly only in 1985, when the K content in the 0 controls was lower ($p<0.01$) than with the three peat ash dosages (Fig. 7). No further differences between any of the treatments were noted during the growing seasons, although the overall level of K was higher ($p<0.05$) in 1987 than in the other years (Fig. 7).

In 1985–86 the foliar Mg content increased above the control level with 50 t/ha of peat ash ($p<0.05$), while in 1987 the 10 t/ha peat ash dosage gave also a higher Mg concentration ($p<0.05$) than was found on the control plots or with the 150 t/ha (Table 11).

The 50 t and 150 t/ha peat ash dosages enhanced ($p<0.05$) the foliar Ca content beyond the control level in 1985–1987 (Table 11). The overall foliar Ca content increased from 1985 to 1987.

The 10 t/ha and 50 t/ha peat ash applications gave more foliar Fe during 1985–1986 than was found on the controls ($p<0.05$), but with 150 t/ha the Fe content remained at the control level (Table 11). No marked differences were noted between any of the dosages or controls in 1987 in the foliar Fe content.

The 50 t/ha of peat ash altered the proportions of foliar N, P, K, Mg and Ca considerably compared with the unfertilized controls (Table 12).

Table 11. Foliar Mg, Ca and Fe contents (mg/g) of the silver birch in 1985–1987.

| Year/ Peat ash | Mg mg/g 1985 | 1986 | 1987 | Ca mg/g 1985 | 1986 | 1987 | Fe mg/g 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|---|---|---|
| 0 t/ha | 2.9 | 2.2 | 3.4 | 3.6 | 4.0 | 5.7 | .101 | .098 | .121 |
| 10 –"– | 3.2 | 2.4 | 4.0* | 3.9 | 4.0 | 7.5 | .168* | .159* | .134 |
| 50 –"– | 3.5* | 3.6* | 4.1* | 5.1* | 5.6* | 8.2* | .175* | .160* | .150 |
| 150 –"– | 2.8 | 2.2 | 3.6 | 5.8* | 6.3* | 8.8** | .111 | .118 | .122 |

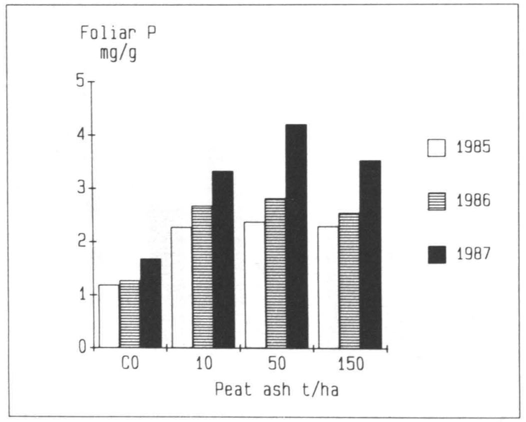


Fig. 6. Foliar P content (mg/g) of the silver birch in 1985–1987. CO = 0 control.

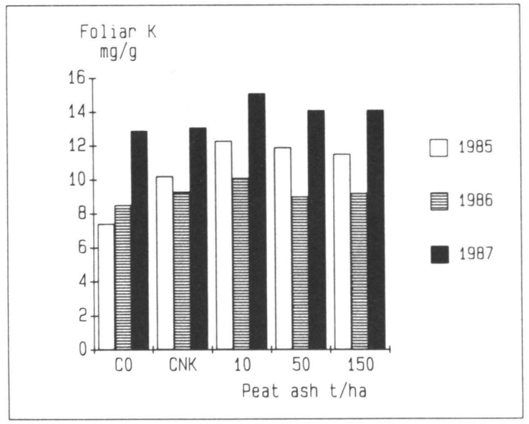


Fig. 7. Foliar K content (mg/g) of the silver birch in 1985–1987. CNK= NK fertilized control, CO= 0 control.



Table 12. Foliar nutrient proportions of the silver birch on unfertilized control plots and on peat ash fertilized (50 t/ha) plots in 1985–1987.

| | Control 1985 | 1986 | 1987 | Peat ash 50 t/ha 1985 | 1986 | 1987 | Optimum Ingestad (1962) |
|---|---|---|---|---|---|---|---|
| N | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| K | 58 | 62 | 80 | 58 | 29 | 43 | 64 |
| P | 9 | 8.5 | 10 | 12 | 9 | 13 | 8 |
| Mg | 22 | 15 | 20 | 17 | 8 | 13 | 9 |
| Ca | 28 | 27 | 34 | 25 | 18 | 25 | 11 |
| Fe | 0.8 | 0.7 | 0.7 | 0.9 | 0.5 | 0.5 | 0.7 |

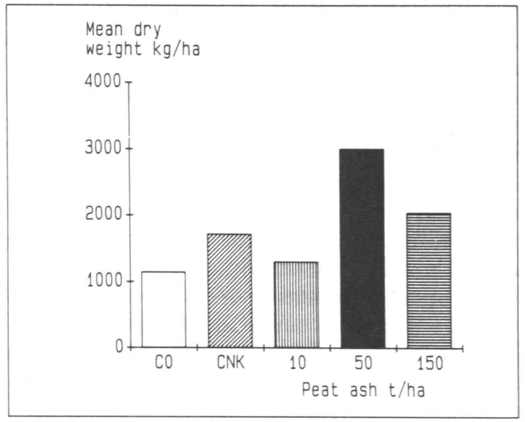


Fig. 8. Leafless above-ground biomass production (kg/ha d.w.) of the silver birch in 1984–1987. CNK= NK fertilized control, CO= 0 control.

## 34. Survival and biomass production

No marked differences in the survival of the silver birches were obtained between the peat ash dosages and controls. In August 1984 98.3 % of the 2 year old seedlings planted in May 1984 were alive, but some died during 1985–1987 (6 % at a planting density of 10 000 plants per ha and 11 % at 25 000 plants per ha and 15 % at 2 000 plants per ha).

The 50 t/ha of peat ash increased growth of the birch seedlings more ($p<0.05$) than did the other dosages (3 009 kg/ha d.w. vs. 1 146–2 045 kg/ha d.w.; Fig. 8). Growth also varied markedly with planting density, biomass production being 1 046 kg/ha/a with 2 000 seedlings/ha, 2 366 kg/ha/a with 10 000 seedlings/ha ($p<0.01$) and 5 340 kg/ha/a with 25 000 seedlings/ha ($p<0.01$).

# 4. Discussion

The growth of the 3–5 year old silver birches on the control plots (no peat ash application or only NK fertilization) was low (1–1.5 t/ha/a, dry weight) compared with that found in other birch experiments on peat soils. According to Björklund and Ferm (1982) (experiments located in the northwestern coastal area of Finland) and Ferm and Kaunisto (1983) (experiments located in the southwestern coastal area) a mixture of 10–14 year old native silver and white birches can produce as much as 4.0 to 7.7 t/ha/a d.w.. Native white birch stands in drained peat areas in northern Finland have produced 3–5 t/ha/a d.w. at the age of 5–15 years (Issakainen 1980). The silver birches in the present study were younger than those in the experiments mentioned above, however.

The 50 t/ha peat ash dosage (+NK fertilization) increased the growth of the silver birch seedlings more than the other dosages did. The results indicate that 10 t/ha of peat ash may be too low a dosage and 150 t/ha too high for the seedlings under the prevailing conditions. The effect of fertilization on birch stands has been shown in other studies to be weak and of short duration (Viro 1974, Jonsson and Möller 1975, Oikarinen and Pyykkönen 1981, Moilanen 1985 and Paarlahti and Paavilainen 1985). These studies were not carried out on mined peatlands, however, whereas Kaunisto (1987) found substantial growth enhancement of silver birches with PK fertilization and soil preparation in such areas.

The growth figures obtained with the 50 t/ha peat ash dosage were still somewhat lower than in the experiments mentioned above. Kaunisto (1987) found both negative and positive reactions to 3 t, 6 t and 12 t/ha of peat ash in silver birch seedlings growing on a mined peatland. According to Lumme et al. (1984) peat ash rates > 50 t/ha are required for growth enhancement in fast-growing willow stands (*Salix dasyclados* Wimm) in such areas, while Silfverberg and Issakainen (1987a) found yield increments with 22 t/ha of P rich peat ash in a 115-year-old spruce mire forest (*Picea abies* Karst.). According to Silfverberg and Huikari (1985), fertilization with 1–16 t/ha of wood ash can increase forest growth markedly on peat soils, if the total nitrogen content of the peat is sufficient (>1.0 %).

The foliar analysis suggests that the effect of N fertilization ceased after two growing seasons, whereas the 50 t/ha peat ash dosage may have increased the mobilization of the organic N in the mixture of peat and mineral soil. Microbiological activity, measured by the cellulose decomposition test, increased markedly with 50 t and 150 t/ha of peat ash and consequently ammonification may also have been more pronounced in soil. Karsisto (1979) found that wood ash fertilization at 10-12 t/ha enhanced cellulose decomposition activity and increased the amount of bacteria capable of ammonification in drained peat soils.

According to Kaunisto and Norlamo (1976) and Kaunisto (1975) soil rotavation or deep ploughing alone can increase the mobilization of organic N in peat by increasing soil temperature and microbiological activity. Thus N mobilization in the present case may also have been enhanced due to the deep ploughing.

According to Ingestad (1962) and Heinsdorf (1984), the optimum foliar N level in silver birch seedlings is 2.9–4.0 %, and a deficiency appears at 1.5–2.9 %. The foliar analyses thus suggest that a moderate N deficiency in the 0 control plots and with the 10 t and 150 t/ha peat ash dosages may have been obtained here throughout the period studied. With 50 t/ha of ash the foliar N content was under the optimum in 1985 and close to or in the optimum range in 1986–1987. According to Ferm and Markkola (1985) foliar N content varied between 2.5–3.5 % in a three-year-old naturally born white birch stand on a drained peat soil.

The P content of the peat ash tested was close to the level found in wood ash (Hakkila and Kalaja 1983), and thus even the lowest peat ash dosage used, 10 t/ha, improved the low phosphorus concentration of the soil and increased the foliar P level. The fertilization effect of P lasted through-out the study period. Moilanen et al. (1987) found a marked increase in foliar P content in white birch seedlings due to peat ash fertilization at 8 t and 17 t/ha in a greenhouse test and Lumme et al. (1984) and Lumme and Kiukaanniemi (1987) obtained a similar effect with 50 t and 200 t/ha of peat ash in a fast-growing willow stand (*S. dasyclados*). In the studies of Silfverberg and Issakainen (1987a, 1987b) P rich peat ash at 22 t/ha markedly increased the foliar P content in a spruce mire, but no effect was obtained on foliar P content in a pine mire forest with P poor peat ash at 500 kg–8 000 kg/ha.

According to Tamm (1956), Ingestad (1962), Miller (1983) and Heinsdorf (1984) the optimum range for foliar P content in silver birch seedlings is 1-4 mg/g and a deficiency can appear at 0.08–2.0 mg/g. A moderate P deficiency may thus have occurred in the control plots in 1985–1987, whereas a luxury level was obtained with the 50 t/ha peat ash dosage in 1987. Ferm and Markkola (1985) found that foliar P content varied between 2.0–3.5 mg/g in a three-year-old naturally born white birch stand on a drained peat soil.

The foliar K content in the NK fertilized control plots suggests that the effect of NK fertilizer probably lasted only two growing seasons. Viro (1974) obtained similar results with silver birches growing on mineral soils.

The K level of the peat ash was low compared to the results obtained by Hakkila and Kalaja (1983) and Kaunisto (1987). Peat ash fertilization increased somewhat the available K content of the soil, but no marked differences in foliar K content were obtained between the treatments, even with the highest ash dosage 150 t/ha in 1986-1987. According to Ingestad (1962) the optimum range for foliar K in birch seedlings is 15–31 mg/g, and a moderate deficiency is evident at 5–15 mg/g and a visual decifiency occurs at 5 mg/g. No K deficiency or only a moderate deficiency may thus have occurred on the peat ash plots in 1985–1986. Supplementary K from a potassium fertilizer may be required later, however. According to Ferm and Markkola (1985) foliar K content varied between 6–9 mg/g in a three-year-old naturally born white birch stand on a drained peat soil.

The foliar K content in the seedlings increased in 1987 also in the 0 control plots, however. This suggests that the mineral soil may have increased the amount of available K in the rooting zone of the trees. Kaunisto (1987) has emphasized the importance of the mineral soil for the tree nutrient balance on mined peatlands.

According to Moilanen et al. (1987) 8 t and 17 t/ha of peat ash had no effect on the foliar K content of white birch seedlings in a greenhouse test. Lumme et al. (1984) found a visible and analytically detectable foliar K deficiency in a fast-growing willow stand (*S. dasyclados*) in the second growing season with 50 t/ha of peat ash. In the studies of Silfverberg and Issakainen (1987a and 1987b) 22 t and .500–8 000 kg/ha of peat ash had no effect on foliar K content in either a spruce mire or in a pine mire forest.

The 50 t/ha peat ash dosage and also 10 t/ha in 1987 increased the foliar Mg content, while the 150 t/ha may have caused an inhibition of Mg uptake by manganese in the ash (Raitio 1983). In the study of Moilanen et al. (1987) 8 t and 17 t/ha of peat ash reduced the foliar Mg content in white birch seedlings in a greenhouse test. Silfverberg and Issakainen (1987b) found a similar reduction in foliar Mg content in a pine mire forest after application of 500 kg-8 000 kg peat ash/ha. According to Ingestad (1962) the optimum range for foliar Mg in silver birch seedlings is 1.7–5.0 mg/g, and a deficiency appears at 0.1–1.7 mg/g. The foliar analysis in the present study thus indicates that the Mg content did not restrict birch growth with any treatment.

The Ca content of the peat ash was fairly low compared with that of wood ash (Hakkila and Kalaja 1983). Therefore the overall effect on the soil pH was relatively weak even at the highest ash dosage. The 50 t/ha and 150 t/ha peat ash dosages increased both the soil and foliar Ca content. According to Ingestad (1962) a foliar Ca deficiency appears at 0.6–1.2 mg/g in birch seedlings. The foliar Ca content thus propably remained above the deficiency level in all the treatments in 1985–1987.

The figures used here to represent optimum and deficiency levels for foliar N, P, K, Mg and Ca in silver birch seedlings as given by Ingestad (1962) were nevertheless obtained using nutrient solutions in laboratory tests and may be over-estimations compared with field conditions.

According to Moilanen et al. (1987), however, 8 t and 17 t/ha of peat ash reduced the foliar Ca content of white birch seedlings in a greenhouse test. Lumme et al. (1984) found an increase in foliar Ca with >50 t/ha of peat ash in a fast-growing willow stand. Silfverberg and Issakainen (1987a, 1987b) noted that a 22 t/ha peat ash dosage enhanced the foliar Ca content in a spruce mire forest, whereas 500 kg–8 000 kg/ha reduced it in a pine mire forest.

The Fe concentration in the peat ash used was high and the 10 t and 50 t/ha ash dosages increased the foliar Fe content in 1985-1986. It is not clear whether the rather high Fe concentrations restricted the growth of the silver birches. Moilanen et al. (1987) noted a marked increase in the foliar Fe content in white birch seedlings due to peat ash fertilization at 8 t and 17 t/ha in a greenhouse test.

The present results indicate that it was possible to increase the early growth of silver birch on a nitrogen-rich mined peatland by heavy peat ash fertilization, and probably also by deep ploughing of the soil. The optimum ash dosage would probably be >10 t <100 t/ha with the type of peat ash used here. Due to the low potassium content of the peat ash K deficiency can occur in the long run, however.

# References


Ahonen, A. & Huusko, A. 1986. Pajuhakkeen tuotantoalan, kustannusten ja kilpailukyvyn kehitys pitkällä aikavälillä. English abstract. University of Oulu, Research Institute of Northern Finland, C67. 38 p.

Björklund, T. & Ferm, A. 1982. Pienikokoisen koivun ja harmaalepän biomassa ja tekniset ominaisuudet. Abstract: Biomass and technical properties of small-sized birch and grey alder. Folia For. 500. 37 p.

Energiataloudellinen yhdistys 1986. Turve- ja turveseostuhkan nykyinen hyötykäyttö ja hyötykäyttömahdollisuudet. Mimeograph. 66 p.

Ferm, A. & Kaunisto, S. 1983. Luontaisesti syntyneiden koivumetsiköiden maanpäällinen lehdetön biomassatuotos entisellä turpeennostoalueella Kihniön Aitonevalla. Abstract: Above-ground leafless biomass production of naturally generated birch stands in a peat cut-over area at Aitoneva, Kihniö. Folia For. 558. 32 p.

— & Markkola A. 1985. Hieskoivun lehtien, oksien ja silmujen ravinnepitoisuuksien kasvukautinen vaihtelu. Abstract: Nutritional variation of leaves, twigs and buds in Betula pubescens stands during the growing season. Folia For. 613. 28 p.

Hakkila, P. & Kalaja, H. 1983. Puu- ja kuorituhkan palauttamisen tekniikka. Abstract: The technique of recycling wood and bark ash. Folia For. 552. 37 p.

Halonen, O., Tulkki, H. & Derome, J. 1983. Nutrient analysis methods. Metsäntutkimuslaitoksen tiedonantoja 121. 28 p.

Heinsdorf, D. 1984. Wirkung von Mineraldüngung auf Ernährung und Wachstum von Birken (Betula pendula) auf sandigen Kippbodenformen ausgekohlter Braunkohlentagebaue. Arch. Naturschutz u. Landschaftsforsch. 24:135–152.

Hytönen, J. 1985. Teollisuuslietteellä lannoitetun vesipajun lehdetön maanpäällinen biomassatuotos. Abstract: Leafless above-ground biomass production of Salix aquatica fertilized with industrial sludge. Folia For. 614. 16 p.

Ingestad, T. 1962. Macro element nutrition of pine, spruce and birch seedlings in nutrient solutions. Meddelanden från Sveriges skogsforskningsinstitut 51:1–150.

Issakainen, J. 1980. Luontaisten vesakoiden biomassantuotoskyvystä. Metsäntutkimuslaitos, Muhoksen tutkimusaseman tiedonantoja 18:37–47.

Jonsson, S. & Möller, G. 1975. Björkens reaktion på kvävegödsling. Summary: The response of birch (Betula pendula) to nitrogen fertilization. Fören. skogsträdsförädl. o. inst. för. skogsförbättr. Yearbook:103–144.

Karsisto, M. 1979. Maanparannustoimenpiteiden vaikutuksista orgaanista ainetta hajottavien mikrobien aktiivisuuteen suometsissä, osa 2. Effect of forest improvement measures on activity of organic matter decomposing micro-organisms in forested peatlands, part 2. Suo 30:81–91.

Kaunisto, S. (ed.) 1975. Metsityskokeet Kihniön Aitonevalla. Summary: Afforestation experiments at Aitoneva, Kihniö. Metsäntutkimuslaitoksen tiedonantoja 177. 53 p.

— 1981. Rauduskoivun (Betula pendula) ja hieskoivun (Betula pubescens) luontainen uudistuminen turpeennoston jälkeisellä suonpohjan turpeella Kihniön Aitonevalla. Summary: Natural regeneration of Betula pendula and B. pubescens on a peat cut-away area. Suo 32:53–60.

— 1987. Lannoituksen ja muokkauksen vaikutus männyn ja rauduskoivun istutustaimien kasvuun suonpohjilla. Abstract: Effect of fertilization and soil preparation on the development of Scots pine and silver birch plantations on peat cut-over areas. Folia For. 681. 23 p.

— & Norlamo, M. 1976. On nitrogen mobilization in peat. 1. Effect of liming and rotavation in different incubation temperatures. Seloste: Typen mobilisaatiosta. 1. Kalkituksen ja muokkauksen vaikutus erilaisissa haudutuslämpötiloissa. Commun. Inst. For. Fenn. 88(2).27 p.

Kurkela, T. 1973. Godronia multisporan aiheuttama tauti raudus- ja hieskoivun taimissa eräissä metsänlannoituskokeissa turvemaalla. Summary: A disease caused by Godronia multispora groves on young Betula verrucosa and B. pubescens on fertilized peatland. Suo 24:9–15.

Kurki, M. 1982. Suomen peltojen viljavuudesta 3. Summary: On the fertility of Finnish tilled fields in the light of investigations of the soil fertility carried out in the years 1955-1980. Viljavuuspalvelu Oy. Helsinki. 181 p.

Lehtiniemi, T. & Sarasto, J. 1973. Kokemuksia rauduksen istutuksesta ojitetuille soille. Summary: Betula verrucosa plantations on peat. Silva Fennica 7:24–44.

Lumme, I. & Kiukaanniemi, E. 1987. Nopeakasvuisten pajujen (Salix spp.) lyhytkiertoviljelystä ja rauduskoivun (Betula pendula) viljelystä turvetuotannosta poistuneella suolla, Limingan Hirvinevalla. Abstract: Short-rotation cultivation of fast-growing willows and plantations of Betula pendula on Hirvineva, a mire formerly used for peat production, in Liminka Finland. University of Oulu, Research Institute of Northern Finland, C77. 48 p.

— Tikkanen, E., Huusko, A. & Kiukaanniemi, E. 1984. Pajujen lyhytkiertoviljelyn biologiasta ja taloudellisesta kannattavuudesta turpeentuotannosta poistuneella suolla Limingan Hirvinevalla. Abstract: On the biology and economical profitability of willow biomass production on an abandoned peat production area. University of Oulu, Research Institute of Northern Finland, C54. 79 p.

Mikola, P. 1975. Turvetuotannosta vapautuvan maan metsittäminen. Summary: Afforestation of bogs after industrial exploitation of peat. Silva Fennica 9:101–115.





Miller, H. 1983. Wood energy plantations. Diagnosis of nutrient deficiencies and the prescription of fertilizer applications in biomass production. Forest Energy Agreement. Programme group B. Biomass Growth and Production. Report no 3. 20 p.

Moilanen, M. 1985. Lannoituksen ja harvennuksen vaikutus hieskoivun kasvuun ohutturpeisilla ojitetuilla rämeillä. Abstract: Effect of fertilization and thinning on the growth of birch (Betula pubescens) on the drained mires with thin peat layer. Folia For. 629. 29 p.

— Ferm, A. & Issakainen, J. 1987. Kasvihuonekokeita erilaisten jäteaineiden vaikutuksesta hieskoivun alkukehitykseen turvealustalla. Metsäntutkimuslaitoksen tiedonantoja 281. 36 p.

Nilsson, L-O. 1982. Determination of current energy forest growth and biomass production. Projekt Energiskogsodling. Sveriges Lantbruksuniversitet, Teknisk Rapport 19. 47 p.

Oikarinen, M. & Pyykkönen, J. 1981. Harvennuksen ja lannoituksen vaikutus turvekankaan hieskoivun kehitykseen Pohjois-Pohjanmaalla. Abstract: The effect of fertilization and thinning on the growth of pubescent birch (Betula pubescens) on drained Myrtillus spruce svamp in Ostrobothnia. Folia For. 486. 15 p.

Paarlahti, K. 1980. Tuhkan tuotanto ja ominaisuudet. Metsäntutkimuslaitoksen tiedonantoja 20:13–15.

— & Paavilainen, E. 1985. Turvemaiden varttuneiden kuusikoiden ja koivikoiden lannoitus, ennakkotuloksia. Summary: The fertilization of mature spruce and birch stands on peat soils. Preliminary results. Metsäntutkimuslaitoksen tiedonantoja 206:4–18.

Raitio, H. (ed.) 1983. Metsäpuiden fysiologiaa 1. Ravinnetalouden perusteita. Helsingin yliopiston metsänhoitotieteen laitoksen tiedonantoja 39. 200 p.

Silfverberg, K. & Huikari, O. 1985. Tuhkalannoitus metsäojitetuilla turvemailla. Abstract: Wood-ash fertilization on drained peatlands. Folia For. 633. 25 p.

— & Issakainen 1987a. Turpeentuhkan vaikutuksista puuston kasvuun ja ravinnetilaan käytännön lannoitustyömailla. Summary: Growth and foliar nutrients in peat-ash fertilized stands. Suo 38:53–62.

— & Issakainen 1987b. Tuhkan määrän ja laadun vaikutus neulasten ravinnepitoisuuksiin ja painoon rämemännikössä. Nutrient contents and weight of Scots pine needles in ash-fertilized peatland stands. Metsäntutkimuslaitoksen tiedonantoja 271. 25 p.

Tamm, C. 1956. Studier över skogens näringsförhållanden 3. Försök med tillförsel av växtnäringsämnen till ett skogsbestånd på mager sandmark. Studies on forest nutrition 3. The effects of supply of plant nutrients to a forest stand on a poor site. Meddelanden från Sveriges skogsforskningsinstitut 44(3):1–53.

Viro, P. 1974. Fertilization of birch. Seloste: Koivun lannoitus. Commun. Inst. For. Fenn. 81(4). 38 p.

*Total of 36 references*


# Seloste

## *Turvetuhkan alkuvaikutuksista rauduskoivun kasvuun ja ravinnetalouteen turvetuotannosta poistuneella suolla*


Tutkimus käsittelee turvetuhkan alkuvaikutuksia rauduskoivun (*Betula pendula* Roth) kasvuun ja ravinnetalouteen turvetuotannosta poistuneella suolla, Limingan Hirvinevalla (64°42'N, 25°20'E, sijainti 50 m merenpinnan yläpuolella). Mikäli kaikki turvevoimalasuunnitelmat toteutuvat, ensi vuosituhannen alkuun mennessä Suomessa on arvioitu olevan 20 000–100 000 ha turvetuotannosta poistuneita suonpohjia. Toisaalta turpeenpoltossa muodostuu kasviravinteita sisältävää turvetuhkaa runsaasti (70 000–100 000 t/vuosi).

Viljelykoe perustettiin vuonna 1984 kaksi vuotta aiemmin turvetuotannosta poistuneelle turvealueelle. Turpeennoston jälkeen turvekerroksen paksuus oli 5–30 cm. Turve ja kivennäismaa sekoitettiin keskenään ennen tuhkan levitystä. Koeruuduille levitettiin turvetuhkaa 10 t, 50 t ja 150 t/ha ja kaksivuotiaat paljasjuuriset rauduskoivun taimet (alkuperä Pudasjärvi 65°15'N, 27°00'E) ) istutettiin kolmelle istutustiheydelle; 2 000, 10 000 ja 25 000 tainta/ha. Tuhkaruudut ja puolet kontrolliruuduista lannoitettiin lisäksi N- ja NK- lannoitteilla. Puolet kontrolliruuduista jäi 0 kontrolleiksi, joissa ainoastaan turve ja kivennäismaa sekoitettiin keskenään.

Kivennäismaan sekoittaminen turpeeseen ja turvetuhka alensivat maaperän kokonaistypen pitoisuutta. Turvetuhka lisäsi maaperän selluloosanhajotusaktiivisuutta. Vaikutus jatkui koko tutkimusjakson ajan. Lisäys oli voimakkain 50 t ja 150 t/ha tuhka-annoksilla (kuva 4). Mikrobiologisen aktiivisuuden kohoaminen ilmeisesti lisäsi turpeen orgaanisen typen mobilisaatiota mikä puolestaan kohotti koivunlehtien typpipitoisuutta 50 t/ha tuhkakäsittelyllä (kuva 5). Toisaalta myös kivennäismaan ja turpeen sekoittaminen keskenään saattoi

olla eräänä syynä typen mobilisaation lisääntymiseen.

Turvetuhka kohotti maaperän liukoisen fosforin ja koivun lehtien P pitoisuutta merkitsevästi jo 10 t/ha tuhka-annoksella. Lisäys maassa oli suurin 150 t/ha annoksella ja lehdissä 50 t/ha annoksella (kuvat 1 ja 6). Magnesiumin ja kalsiumin konsentraatiot sekä pH kohosivat maaperässä 50 t ja 150 t/ha tuhkamäärillä. Lehdissä Mg pitoisuus kasvoi 10 t ja 50 t/ha käsittelyillä ja Ca pitoisuus lisääntyi 50 t ja 150 t/ha annoksilla. Runsaasti rautaa sisältänyt turvetuhka ei lisännyt maan vaihtuvan Fe pitoisuutta merkittävästi, mutta lehdissä konsentraatio kasvoi 10 t ja 50 t/ha tuhkakäsittelyillä (taulukot 8, 10, ja 11).

Turvetuhkan kaliumpitoisuus oli kuitenkin alhainen minkä vuoksi tuhkalannoitus ei lisännyt koivun lehtien K-konsentraatiota. Selvää K-puutosta ei koivun lehdissä kuitenkaan havaittu alkuvaiheessa, mutta K lisälannoitusta voidaan tarvita pitkällä aikavälillä. Toisaalta kivennäismaan sekoittaminen turpeen kanssa on saattanut parantaa rauduskoivun kaliumin saantia (kuvat 2 ja 7).

Rauduskoivujen elinkyky muokatulla turve-kivennäismaa alustalla oli melko hyvä. Rauduskoivun kasvu (biomassantuotto kg kuiva-ainetta/ha) lisääntyi neljän ensimmäisen kasvukauden aikana merkittävästi 50 t/ha turvetuhka-annoksella. Tulosten mukaan ainakin alkuvaiheessa 10 t/ha tuhkakäsittely oli liian alhainen ja 150 t/ha oli liian korkea rauduskoivuviljelmälle näissä olosuhteissa (kuva 8).