COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE 109

METSÄNTUTKIMUSLAITOS
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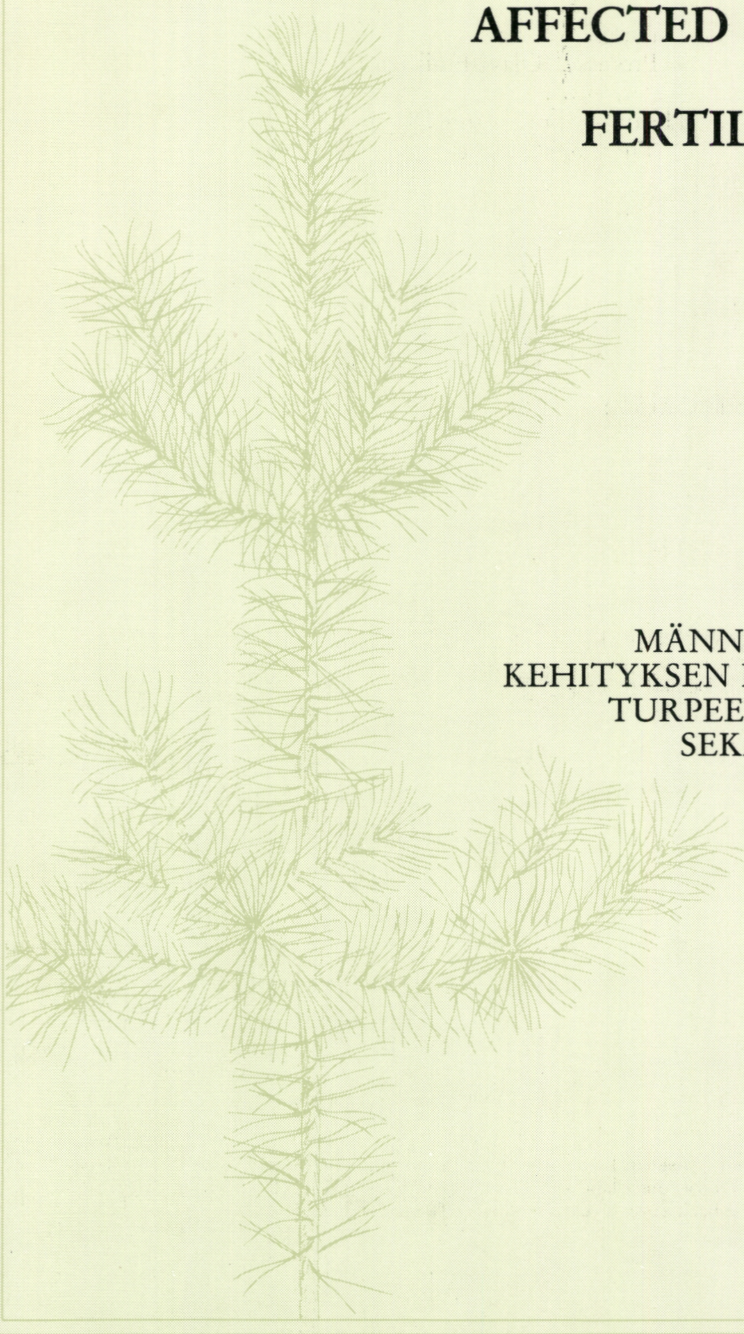
DEVELOPMENT OF PINE PLANTATIONS ON DRAINED BOGS AS AFFECTED BY SOME PEAT PROPERTIES, FERTILIZATION, SOIL PREPARATION AND LIMING



SEPPO KAUNISTO

SELOSTE

MÄNNYN ISTUTUSTAIMIEN KEHITYKSEN RIIPPUVUUS ERÄISTÄ TURPEEN OMINAISUUKSISTA SEKÄ LANNOITUKSESTA, MUOKKAUKSESTA JA KALKITUKSESTA OJITETUILLA AVOSOILLA

HELSINKI 1982

COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE

THE FINNISH FOREST RESEARCH INSTITUTE
(METSÄNTUTKIMUSLAITOS)

Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

telex: 125181 hyfor sf
attn: metla/

phone: 90-661 401

Director:
Professor Olavi Huikari

Head of Information Office:
Tuomas Heiramo

Distribution and exchange of publications:

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FINLAND

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

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KAUNISTO, S. 1982. Development of pine plantations on drained bogs as affected by some peat properties, fertilization, soil preparation and liming. Seloste: Männyn istutustaimien kehityksen riippuvuus eräistä turpeen ominaisuuksista sekä lannoituksesta, muokkauksesta ja kalkituksesta ojitetuilla avosoilla. Commun. Inst. For. Fenn. 109: 1—56.

The investigation is based on material collected from four factorial experiments. NPK as compared to PK fertilization increased the height growth of pine seedlings in three most oligotrophic experimental areas (mean total N 0.87 %—1.12 % in the 5—10 cm peat layer) and decreased growth in the most nitrogen-rich area (mean total nitrogen content 1.99 %). Height growth increased linearly as the total and NH_4 nitrogen contents and humification degree of peat increased on PK fertilized sample plots. On the NPK fertilized plots the above-mentioned factors had no effect or affected negatively. The lowest critical values indicating nitrogen fertilization need were 1.15 % for total peat nitrogen, 29 mg/l for ammonium nitrogen and 2.7 (acc. to v. Post) for humification in 5—10 cm peat layer. The limit values varied, however, from one experiment to another and in differently combined materials. Soil preparation and simultaneous mixing of fertilizers stimulated growth. Liming of unprepared surface decreased growth, but if mixed into peat height growth was increased to some extent. Liming decreased the foliar nitrogen, phosphorus, potassium, boron and manganese levels, but increased the foliar zinc levels. Nitrogen fertilization and soil preparation increased the frequency of growth disturbances.

Tutkimus perustuu neljästä faktoriaalikokeesta kerättyyn aineistoon. NPK-lannoitus lisäsi männyn taimien kasvua PK-lannoitukseen verrattuna kolmella karuimmalla koealueella (totaali-N keskimäärin 5—10 cm:n kerroksessa 0.87 %—1,12 %) ja vähensi kasvua runsastyyppisimmällä koealueella (totaalityppipitoisuus keskimäärin 1,99 %). PK-lannoituksen yhteydessä kasvu lisääntyi suoraviivaisesti turpeen totaali- ja NH_4-typen sekä maatuneisuuden lisääntyessä. NPK-lannoitetuilla koealoilla em. suureiden vaikutus kasvuun oli indifferentti tai negatiivinen. Typpilannoitustarpeen alhaisimmat raja-arvot tutkimuksessa olivat 1,16 %:a turpeen totaalitypelle, 29 mg/l ammoniumtypelle ja 2,7 maatuneisuudelle. Raja-arvot kuitenkin vaihtelivat eri kokeissa, samoin kuin eri tavoin ryhmitellyissä aineistoissa. Muokkaus, samoin kuin lannoitteiden sijoittaminen muokkauksen yhteydessä lisäsivät kasvua. Kalkitus muokkaamattomaan pintaan heikensi kasvua, mutta turpeeseen sekoitettuna lisäsi sitä jonkin verran. Kalkitus alensi neulasten typpi-, fosfori-, kalium-, boori-, kupari- ja mangaanipitoisuuksia ja kohotti neulasten sinkkipitoisuuksia.

ODC 2--114.444+237+160.2+161.4
ISBN 951-40-0597-X
ISSN 0358-9609

Helsinki 1982. Valtion painatuskeskus

PREFACE

Numerous bog afforestation experiments were established in the area of Parkano Experimental Forest by the Peatland Forestry Department and Parkano Research Station of the Finnish Forest Research Institute in the 1960s and 1970s. More than 60 reports based on these experiments have been published, dealing with fertilization, soil preparation, drainage, sowing vs. planting, etc. on peatlands. The present investigation is based on some of the latest bog afforestation experiments, established in 1973. The purpose was to find out the need for nitrogen fertilization in varying natural nitrogen conditions of peat and also to examine the possibilities of affecting the nitrogen status of peat by soil preparation and ameliorants.

My best thanks are due to the following persons for their valuable contribution. The late Mr Esko Mansikkaviita, Mr Kalle Nevanranta and Mr Tauno Suomilammi assisted in the field work. Mrs Arja Ylinen and Miss Merja Vestergård performed the laboratory analyses. Mrs Riitta Heinonen, M.A., and Mrs Airi Piira helped in calculation. The figures have been drawn by Miss Liisa Majuri and the text has been typed by Mrs Anne Ahti, B.Sc.(Econ.), Mrs Paula Häkli and Miss Pirkko Marjamäki. Mrs Leena Kaunisto, M.A., has translated the text from Finnish into English. Prof. Eero Paavilainen, Dr Juhani Päivänen, Dr Olavi Laiho, Mr Michael Starr, B. Sc., Mr Heikki Veijalainen, B.Sc., and Mr Antti Reinikainen, Lic.For., have read the manuscript giving constructive suggestions.

CONTENTS

1. INTRODUCTION

The extensive afforestation experiments of bogs, especially in the British Isles, Norway and Finland, have shown fairly consistently that the minimum growth factor of trees on drained bogs is the low phosphorus level in the substrate (e.g. Zehetmayer 1954, Meshechok 1968, Dickson 1971, Mannerkoski & Seppälä 1970, Laine & Mannerkoski 1980). Similarly, low potassium levels characterize bog peats (Valmari 1956, Puustjärvi 1965, Meshechok 1968). Growth can usually be stimulated by potassium fertilization (Meshechok 1968, Atterson & Binns 1973), although there may be enough potassium for the initial development of seedlings on deep-peat areas (Mannerkoski & Seppälä 1970, Kaunisto 1972). In Finland the potassium deficiency has led to high mortality in pine plantations and to dieback and death of even tall trees on afforested bogs.

It seems that without phosphorus fertilization and without potassium application at least at some developmental stage of the stand, the growing of mature stands poses great problems on bogs. In recent years the investigations have shown that micronutrient deficiencies also limit the development of stands on drained bogs (e.g. Huikari 1974, Braekke 1979, Veijalainen 1975 and 1981).

The duration of phosphorus and potassium fertilization influence depends on the nitrogen status of peat. On nitrogen-rich bogs the effect of phosphorus fertilization may last for even 15—20 years (Paavilainen & Simpanen 1975, Paavilainen 1979 a), whereas the effect of phosphorus and phosphorus-potassium fertilization on relatively nitrogen-poor bogs may be confined only to 5—8 years (Karsisto 1974, Paavilainen 1977). On the most nitrogen-poor substrates there is no growth response at all to phosphorus and potassium application (Kaunisto 1971) and even the effect of NPK fertilization may last only for 5—6 years (Kaunisto 1977).

As the PK fertilization affects only for a short time on oligotrophic bogs, it may be assumed that these nutrients would become stored and that the growth of stands could be maintained by merely refertilizing with nitrogen. The report by Paavilainen (1977 a) supports this assumption. On the other hand, Kaunisto (1977) and Kaunisto & Paavilainen (1977) have pointed out that mere nitrogen refertilization may at first impair the growth of seedlings, although the growth may again be stimulated in a few years. Furthermore, Kaunisto & Paavilainen (1977) state that nitrogen refertilization may lead to dieback or even death of seedlings. Thus to maintain growth on oligotrophic bogs, frequent fertilizations with at least nitrogen, phosphorus and potassium are necessary.

It is evident that presently in Finnish conditions the use of bogs for wood production is economically sensible only if enough mineral nitrogen is released from peat for tree growth, because in addition to phosphorus and potassium also the costliest main nutrient, nitrogen, has to be applied and the duration of the fertilization influence is only a part of the lasting time on nitrogen-rich bogs.

The mineralization of organic nitrogen is, in the first place, influenced by the amount of organic nitrogen and the activity of protein-decomposing microbes.

In Finland the nitrogen status of peat has traditionally been determined on the basis of ground vegetation. This type of site type classification (originally introduced by Cajander 1909 and 1913) correlates fairly well with the peat nitrogen level (see Vahtera 1955 and Westman 1981). Huikari & Paavilainen (1972) and Paavilainen (1979) suggest that nitrogen fertilization is not necessary if the site is dominated by tall sedges or more demanding plant species. However, the above-mentioned investigations by Vahtera and Westman show a rather wide distribution between the total peat nitrogen content and site type. With the ageing of drainage and afforestation the ground vegetation undergoes a succession lasting possibly for the whole rotation time and in addition is affected by fertilization. Thus difficulties may arise if the estimation of nitrogen conditions is based solely on plant communities. Therefore, in addition to a plant sosiological analysis, other methods should be developed in order to describe the nitrogen status of the site and predict the future development of nitrogen conditions for tree growth.

The activity of proteolytic bacteria can be influenced by many soil treatments such as soil preparation and soil ameliorants. Usually these measures affect also the number of consumers of nitrogen released by proteolytic bacteria. For example Gardiner (1975) and Kaunisto & Norlamo (1976) showed that liming increased the overall bacterial activity but decreased strongly the amount of mineral nitrogen in peat. According to Kaunisto (1982) liming did not affect the amount of mineral nitrogen on a peat cut-away area in the second growing season after liming. Adams & Dickson (1973) found that the foliar nitrogen level of Sitka spruce *(Picea sitchensis)* decreased in the growing season after liming, but Adams et al. (1978) found that the foliar nitrogen level was restored in five years in the same experimental area. Meshechok (1968) reported that liming had decreased the initial growth of pine seedlings, but that the growth had improved ten years after liming on the plots treated simultaneously with a multinutrient fertilizer (Meshechok 1971, see also Huikari 1973). This response was probably caused by the rapid increase in the overall microbial activity which resulted in an instantaneous fixation of nitrogen by microorganisms after liming and by the later decline in microbial activity due to the decrease in the easily decomposable organic matter.

Soil preparation improves the growth of seedlings (Paavilainen 1970 b and 1977 c, Kaunisto 1971, 1972 a, 1974, 1975 Mannerkoski 1978). Growth improvement is often attributed to lesser competition of ground vegetation, improvement of soil thermal conditions and hence the stimulation of microbial activity, improvement of water conditions and increase in the air space of peat. An effective soil preparation of peat has also been shown to increase the mineralization of nitrogen in peat (Kaunisto 1982).

The present investigation deals with the possibilities of growing pine on different kinds of bogs and examines the role of fertilization, site preparation and liming at afforestation. Furthermore, the effect of certain peat properties (total nitrogen, NH_4—N, pH, degree of humification and thickness of peat layer) on the development of seedlings is studied. The critical values of the measured peat properties indicating the need for nitrogen fertilization are sought and the dependence between foliar nutrients and development of trees investigated.

2. MATERIAL AND METHODS

21. Experimental areas

The investigation is based on four factorial experiments established in the Parkano experimental area of the Finnish Forest Research Institute in 1973. Two experiments (1 and 4) are in Karvia (62°10′N, 22°75′E) a. 2 km apart from each other and two experiments (2 and 3) in Parkano (62°02′N, 22°43′E) also a. 2 km apart from each other and a. 33 km from the first-mentioned experiments. Exps. 1 and 4 are a. 175 m above sea level and Exps. 2 and 3 a. 147 m.

The experimental areas were of varied peatland types ranging from *Sphagnum* small-sedge to tall-sedge flark bogs (Table 1). Exp. 3 was the least fertile (ombrotrophic) on the average, while Exp. 4 was the most fertile (meso-oligotrophic). The peatland types of the other experiments varied considerably. The peat depth varied in experimental areas 1, 2 and 4, but was always less than 2.3 m. Exp. 3 represented deep-peat bogs.

The degree of humification of surface peat in Exp. 1 ranged from 1 to 5 according to v. Post scale (Table 2). It increased steadily when going down from peat surface. The range in Exp. 2 was similar but there were two clearly distinguishable layers of peat: a slightly decomposed surface layer, whose depth varied from some centimetres to 25—30 cm. Under this layer there was a well-decomposed layer (5—6 according to v. Post). The peat in Exp. 3 was weakly decomposed (1—2 according to v. Post), while in Exp. 4 well-decomposed (5—6) throughout. Peat nitrogen content varied within a large scale. The lowest nitrogen content was in Exp. 3 and the highest in Exp. 4.

Two control plots of each experimental area were analyzed for soluble phosphorus (extractant NH_4OAc, pH 4.8), exchangeable potassium and manganese, hot-water soluble boron and hydrochloric acid-soluble (2N) copper, iron and zinc as well as total boron determined from ash (for procedure see Halonen & Tulkki 1981). Comparing the values with those of arable soils (Kurki 1972), each experimental area had little potassium and phosphorus, very little copper and zinc, moderately manganese, except in Exp. 4 which had a shortage of manganese but plenty of iron (Table 3). Apart from iron, the smallest amounts of all the analyzed elements were found in Exp. 4.

Table 1. Peatland site type and peat depth of the experimental areas.
Taulukko 1. Koealueiden suotyypit ja turvesyvyys.

Experiment *Koe*	Code *Koodi*	Peatland site types[1)] *Suotyypit[1)]*	Drainage year *Ojitusvuosi*	Peat depth, m / Turpeen syvyys, m Range *Vaihtelu*	$\bar{x}$
Ylimysneva 109 B	1	RLkN, LkN, VSN	1970	0,6—2,3	1,6
Kartiskakorpi	2	RLkN, LkN, VSN	1967	0,3—3,4	2,0
Valkoinen keidas	3	LkN	1968	4+	4+
Ylimysneva 109 A	4	RiSSN	1970	0,2—1,9	0,6

1) RLkN = a fuscum-rich small-sedge bog — *Rahkainen lyhytkortinen neva*
LkN = a small-sedge bog — *Lyhytkortinen neva*
VSN = a tall-sedge bog — *Suursaraneva*
RiSSN = a flarky tall-sedge bog — *Rimpinen suursaraneva*

Table 2. Peat characteristics of the experimental areas at different depths.
Taulukko 2. Koealueiden turpeen ominaisuuksia eri syvyyksillä.

Experiment *Koe*	Decomposition (v. Post) *Maatuneisuus (v. Post)* 5—10 cm Range *Vaihtelu*	$\bar{x}$	15—20 cm Range *Vaihtelu*	$\bar{x}$	Nitrogen content of peat, % from dry matter *Turpeen typpipitoisuus, % kuiva-aineesta* 5—10 cm Range *Vaihtelu*	$\bar{x}$	15—20 cm Range *Vaihtelu*	$\bar{x}$	30—35 cm Range *Vaihtelu*	$\bar{x}$
1	1—4	2,2	2—5	2,8	0,43—1,75	1,05	0,59—1,85	1,35	0,82—2,00	1,32
2	1—5	2,2	1—6	3,2	0,57—1,85	1,12	0,82—2,22	1,63	0,94—2,26	1,81
3	1—2	1,4	1—2	1,7	0,68—1,35	0,87	0,78—1,37	1,04	0,96—1,84	1,22
4	5—6	5,2	5—6	5,5	1,08—3,05	1,99	1,59—2,96	2,11	—	—[1)]

1) No determinations from the 30—35 cm layer.
1) Ei määrityksiä 30-35 cm:n kerroksesta.

Table 3. Amounts of exchangeable potassium and manganese, ammonium acetate soluble phosphorus, water soluble and total boron and hydrochloric acid soluble copper, iron and zinc on the unfertilized plots in the 5–10 cm peat layer.
Taulukko 3. Vaihtuvan kaliumin ja mangaanin, ammoniumasetaattiliukoisen fosforin, vesiliukoisen ja kokonaisboorin sekä suolahappoliukoisen kuparin, raudan ja sinkin määrät koealueiden lannoittamattomilla koealoilla 5–10 cm:n turvekerroksessa.

Exp. *Koe*	Element — *Alkuaine*							
	K, mg/l	Mn, mg/l	P, mg/l	B, ppm[1]	B, ppm[2]	Cu, ppm	Fe, ppm	Zn, ppm
1	59	7,9	4,2	0,1	2,2	0,72	316	2,70
2	30	9,5	6,0	0,7	8,4	0,55	380	3,27
3	34	5,7	4,5	0,8	6,1	0,67	255	3,88
4	24	4,1	3,5	0,2	1,9	0,60	440	2,97

1) Water soluble — *vesiliukoinen*
2) Total boron — *totaali-boori*

22. Treatments

The treatments scheme is shown in Table 4. The table also shows the number of plots in each treatment combination. There were two liming treatments: control and dolomite 1000 kg/ha as broadcast; three soil preparation treatments: control, strip rotavation and profiling complete rotavation. Liming, fertilization and soil preparation were carried out in 1973. The rotavator used was the preparation-fertilization-seeding machine, LAMU IV, which rotavates an a. 20-25-cm-deep and a. 180-cm-wide strip. The machine also ploughs a furrow in the centre and an a. 10-20-cm-high ridge on both sides of the furrow (see Kaunisto 1975). In strip rotavation the strips are made so that the centre-to-centre distance of strips is a. 5 m. In the profiling complete rotavation the strips are side by side forming ridges and furrows alternatively. Two fertilization modes were included: top dressing and mixing of fertilizers into the rotavated peat layer. The results focus on the following combinations of soil preparation and fertilization: unprepared + top dressing, strip rotavation + top dressing and strip rotavation + mixing of fertilizers into the rotavated peat layer. All these treatments were used in both unlimed and limed sample plots.

Three fertilization treatments were used: control, PK and NPK fertilization. In the PK fertilization treatment 400 kg/ha of PK fertilizer for peatlands (0—24—15 = 42 kg/ ha of P as rock phosphate and 50 kg/ha of K as KCl) was applied. In the NPK fertilization treatment the plots received in addition to PK fertilizer 400 kg/ha of oulu saltpetre containing 52 kg NH_4-N and 52 kg NO_3-N. Only in one combination of soil preparation and fertilization (Table 4) were fertilizers spread mechanically stripwise and rotavated into the peat, otherwise they were spread over the whole area of plots.

The experimental areas were drained with 30 m ditch spacings in 1967—1970. The strips were divided into 20 m × 15 m plots and separated from each other by 2-m-wide untreated zones across the strip. No untreated zones were left between the plots along the strip. The following table shows the number of plots and replications in different experiments:

Experiment	Plots	Replications
1	82	2—4
2	96	4
3	55	2—3
4	48	2
Total	281	

The plots were afforested with pine (*Pinus sylvestris*) in the spring of 1973. Four rows of transplants were planted (1M + 1A)[1], a total of 32 transplants/plot) across the plots. The rest of the plot area was sown mechanically as row seeding. Only the transplants were measured for this investigation. The origin of pine transplants was Saarijärvi (62° 45'N, 25° 30'E.)

Because of growth disturbances all the plots were fertilized with fertilizer borate (10 kg/ha = 1.4 kg of B) in the spring of 1978.

23. Collection of material, analytical and statistical methods

Each plot was sampled for soil and needles in the autumn of 1978. Soil samples comprised five subsamples, systematically taken. Soil samples of Exp. 1—3 were taken from the following depths: 5—10, 15—20 and 30—35 cm below the peat surface. In Exp. 4 it was impossible to include the 30—35 cm layer in the sampling, as the depth of peat was only 20 cm in some plots.

The initial calculation revealed that the peat characteristics obtained from the 30—35 cm layer did not much affect growth. Thus in calculations the results only from 5—10 and 15—20 cm peat layers will be reviewed.

Peat samples were analyzed for total nitrogen with the Kjeldahl method, NH_4 nitrogen from 0.5 M KCl extract by distilling in an alkaline MgO solution.

1) 1M + 1A = 1 year in plastic greenhouse + 1 year unsheltered

Table 4. Treatment scheme and the number of plots per treatment. Figures express the number of summed plots of all the four experiments in each treatment.
Taulukko 4. Käsittelykaavio ja koealojen lukumäärä kussakin käsittelyssä. Luvut ilmoittavat kaikkien neljän kokeen yhteisen koealojen lukumäärän kussakin käsittelyssä.

Liming *Kalkitus*	Soil preparation *Muokkaus*	Method of fertilization *Lannoitustapa*	Fertilization — *Lannoitus* 0	PK	NPK
Control *Kontrolli*	1 = Control — *Kontrolli*	Surface broadcast — *Pintaan, hajalevitys*	13	13	13
	2 = Strip rotavation — *Kaistajyrsintä*	Surface broadcast — *Pintaan, hajalevitys*	12	14	11
	3 = Strip rotavation — *Kaistajyrsintä*	Mixing, broadcast — *Sijoitus, hajalevitys*	12	11	11
	4 = Complete rotavation *Täysjyrsintä*	Mixing, broadcast — *Sijoitus, hajalevitys*	9	13	10
	5 = Strip rotavation — *Kaistajyrsintä*	Mixing, strip fertilization — *Sijoitus, kaistalevitys*	13	12	12
Liming *Kalkitus*	1 = Control *Kontrolli*	Surface *Pinta*	10	13	11
	2 = Strip rotavation *Kaistajyrsintä*	Surface *Pinta*	9	11	11
1000 kg/ha	3 = Strip rotavation *Kaistajyrsintä*	Mixing *Sijoitus*	13	13	11
		Total — *Yhteensä*	91	100	90

PK = PK for peatland forests (0-24-15) 400 kg/ha containing 42 kg phosphorus as rock phosphate and 50 kg potassium as potassium chloride
NPK = PK + oulu saltpetre 400 kg/ha containing 52 kg NH_4 and 52 kg NO_3 nitrogen
PK = SUO-PK (0-24-15) 400 kg/ha sisältäen 42 kg fosforia raakafosfaattina ja 50 kg kaliumia kaliumkloridina
NPK = PK + Oulunsalpietaria 400 kg/ha sisältäen 52 kg NH_4- ja 52 kg NO_3- typpeä

The pH of peat was determined in distilled water (peat/water V/V = 1/5). All the analyses were carried out with oven dry peat. The humification degree of peat was determined in field according to v. Post (1922).

Needles were collected from the top branch whorls of 10 trees in each plot in November 1978 and combined into one sample. The investigation on needle nutrients focused mainly on the variation in nitrogen levels, which were determined in all the plots (281 plots in all). The phosphorus, potassium, zinc, copper, manganese, calcium and boron levels of needles were determined in one replication of each experiment (a total of 48 fertilized and 24 unfertilized sample plots). The statistical analyses have been calculated only from samples collected on fertilized sample plots, although the figures show results of needle analyses also from unfertilized plots.

All planting spots in each plot were checked and the height of live transplants in 1978 and height growth in 1974—1978 were recorded. Simultaneously, the "normality" of transplants was determined. In this context entirely normal refers to a transplant having a prominent leader with a distinctly dominating terminal bud.

Analyses of regression, variance and covariance were used for the statistical handling of the data. As the material was collected from factorial experiments with a number of chemical and physical analyses, the final results are based mainly on the analyses of covariance and variance. The programme used for the analyses of variance and covariance was Pine TR, which allows the inclusion of only first order interactions (see Paavilainen & Simpanen 1975). Only the effects of single regression parameters on tree characteristics were investigated at the time using either their linear or quadratic forms.

Preliminary calculations indicated that, at least in some cases, the measured properties of peat affected the growth of transplants in different ways in each experiment and differently on PK and NPK fertilized plots. Therefore in addition to calculations including the entire material, the material often had to be divided into rather small groups.

Peat depth was included in the analyses as a regression variable only in Exps. 1, 2 and 4, as it varied rather widely in these cases (Table 1). Decomposition was determined in all the experimental areas, but was included in the calculations only in Exps. 1 and 2, where the variation was greatest. The other measured peat properties were used as independent variables in all the experiments.

3. RESULTS

31. Peat properties

311. Total nitrogen and pH

The amount of total peat nitrogen on the plots did not depend on fertilization, liming or soil preparation indicating that different treatments had been evenly distributed to the various parts representing different nitrogen contents.

There was a positive correlation between the total nitrogen content of peat and the degree of humification in Exps. 1 and 2 (Table 5, see also Vahtera 1955, Westman 1981). In Exps. 3 and 4 the correlation was not calculated because of the very small variation in the degree of humification. A clearly negative correlation was found between the nitrogen content of peat and the thickness of peat layer in all the experiments except No. 4 (Table 6).

Although only small amounts of lime (1000 kg/ha) were applied, the pH of the 5—10 cm layer rose somewhat (Table 7). Fertilization did not influence the pH of peat.

Table 5. Dependence of the total nitrogen content of peat on the peat decomposition degree in the 5—10 and 15—20 cm layer.
Taulukko 5. Turpeen totaalityppipitoisuuden riippuvuus turpeen maatuneisuudesta 5-10 ja 15-20 cm:n syvyydessä.

Experiment *Koe*	Indep. var. *Selittävä muuttuja*		Tot. N 5—10 cm Equation *Yhtälö*	F	Coeff. of determ., % *Selit., %*	Tot. N. 15—20 cm Equation *Yhtälö*	F	Coeff. of determ., % *Selit., %*
1	Humif.-Maatun.	5—10cm	y = 0,304x+0,343	37,71***	48,6	y = 0,132x+1,012	5,11*	11,6
	”	15—20cm	y = 0,298x+0,167	14,87***	46,8	y = 0,154x+0,856	3,54	25,4
2	Humif.-Maatun.	5—10cm	y = 0,208x+0,616	19,72***	30,1	y = 0,375x+0,776	35,90***	43,8
	”	15—20cm	y = 0,103x+0,744	12,37***	21,1	y = 0,266x+0,753	77,16***	62,7

Table 6. Dependence of the total nitrogen content on the thickness of the peat layer in Exp. 1, 2 and 4 in different peat layers.
Taulukko 6. Kokonaistyppipitoisuuden riippuvuus turvekerroksen paksuudesta kokeissa 1, 2 ja 4 eri syvyyksillä.

Experiment *Koe*	Peat layer *Turvekerros* cm	Equation — *Yhtälö*	F	Coeff. of determ., % *Selitys, %*
1	5—10	y = —0,0052x + 1,85	10,26**	20,4
	15—20	y = —0,0042x + 1,98	7,99**	16,7
	30—35	y = —0,0018x + 1,63	1,18	2,8
2	5—10	y = —0,0008x + 1,23	2,44	5,0
	15—20	y = —0,0040x + 2,33	42,62***	48,2
	30—35	y = —0,0018x + 2,18	7,41**	13,8
4	5—10	y = —0,0031x + 2,18	0,64	2,9
	15—20	y = —0,00004x+2,10	0,64	0,6

Table 7. Effect of liming on peat pH in different peat layers.
Taulukko 7. Kalkituksen vaikutus turpeen pH:hon eri syvyyksillä.

Experiment *Koe*	Liming *Kalkitus, kg/ha*	Peat layer — *Turvekerros, cm* 5—10	15—20	30—35
1	0	3,9	3,8	3,9
	1000	4,1	3,8	3,9
	F	5,23*	0,06	0,62
2	0	3,8	3,8	3,9
	1000	4,0	3,8	3,9
	F	16,31***	0,97	0,25
3	0	3,6	3,5	3,6
	1000	3,6	3,5	3,6
	F	0,88	0,05	0,73
4	0	4,3	4,2	—
	1000	4,3	4,1	—
	F	0,43	0,38	

312. NH_4 nitrogen of peat

The amount of peat NH_4 nitrogen was usually lower on the PK and NPK fertilized than unfertilized plots, although the separate analysis of each experiment showed that the effect was statistically significant only in three cases (Tables 8 and 9). In the combined analysis of all the experiments the difference was statistically highly significant in both the examined peat layers. Due to phosphorus and potassium shortage, the ground vegetation developed slowly on the unfertilized plots, while on the fertilized plots cotton grass *(Eriphorum vaginatum)* particularly, but also dwarf shrubs and sedges grew richly. According to Päivänen (1970) four years after fertilization the above-ground parts of *Eriphorum vaginatum* contained on the average 49 kg of nitrogen on the NPK fertilized plots and only 11 kg of nitrogen on the unfertilized ones. A similar development possibly caused the lower amounts of NH_4 nitrogen in peat on the fertilized than unfertilized plots also in this investigation. The effect of fertilizer nitrogen on the amount of NH_4 nitrogen varied and was never statistically significant (Table 8). Peat samples were collected 5 years after fertilization, at a time when the fertilizer nitrogen had possibly already become fixed by microbes and vegetation (see e.g. Ødelien & Jerven 1968 and 1971, Päivänen 1970, Nömmik & Popovic 1971, Paavilainen 1974 and 1980, Kaunisto 1971).

The effect of liming on the amount of NH_4 nitrogen varied in the different experiments and fertilization treatments. On the unfertilized plots liming usually increased the amount of NH_4-N, except in Exp. 3 which had the lowest total nitrogen content (Tables 8 and 9). On the NPK fertilized plots the effect of liming remained vague in Exps. 1, 3 and 4, but the amount of NH_4 nitrogen clearly increased in Exp. 2. Liming decreased the amount of NH_4-N on the PK fertilized plots with only one exception. The interaction between liming and fertilization in the analyses of variance for single experiments was, however, statistically significant only in the 5—10 cm layer of Exp. 2 and 15—20 cm layer of Exp. 1. In the combined analysis of all the experiments with both fertilized and unfertilized plots the interaction between liming and fertilization was not significant, but in the analysis

Table 8. Effect of liming and fertilization on the amount of NH_4 nitrogen (mg/l) in different experiments in different peat layers.
Taulukko 8. Kalkituksen ja lannoituksen vaikutus turpeen NH_4-typen (mg/l) määrään eri kokeissa turvekerroksittain.

Expe-riment *Koe*	Fertili-zation *Lannoitus*	Peat layer — *Turvekerros* 5—10 cm, Liming — *Kalkitus* 0	1000 kg	x̄	15—20 cm 0	1000 kg	x̄
1	O	23	35	29	30	42	36
	PK	21	17	19	26	18	22
	NPK	22	20	21	25	24	25
	x̄	22	24	23	27	28	28
2	O	24	21	23	35	38	37
	PK	28	22	25	28	31	30
	NPK	16	31	24	26	34	30
	x̄	23	25	24	30	34	32
3	O	22	18	20	30	19	25
	PK	15	15	15	28	18	23
	NPK	16	18	17	22	16	19
	x̄	18	17	17	27	18	22
4	O	75	91	83	131	148	140
	PK	52	36	44	64	39	52
	NPK	39	33	36	58	60	59
	x̄	55	53	54	84	82	84
1—4	O	36	41	39	57	62	60
	PK	29	23	26	37	27	32
	NPK	23	26	25	33	34	34
	x̄	30	30	30	42	41	42

of only the fertilized plots the interaction between liming and nutrient combination in the surface layer of peat approached statistical significance (Table 9) indicating that liming influenced the amount of NH_4 nitrogen somewhat differently in PK than NPK fertilized peat. The effect of liming on the peat of the PK fertilized plots in this investigation was similar to previous investigations (see e.g. Nömmik 1968, Gardiner 1975, Kaunisto & Norlamo 1975).

Soil preparation had no effect on the amount of NH_4 nitrogen in peat (Table 9).

Out of all peat properties the total peat nitrogen and degree of humification explained best the variation of NH_4 nitrogen in peat (App. 1, Figs. 1 and 2, Table 10, see also Vlassak 1970). The relationship between pH and NH_4-N content was vague in Exps. 1, 2 and 3, but in Exp. 4 peat NH_4 N increased statistically significantly as pH increased (App. 1).

Table 9. Dependence of NH_4 nitrogen content in peat on fertilization, soil preparation and liming in different peat layers of the experiments. F values and significances. Also unfertilized plots included.

Taulukko 9. Turpeen NH_4-typen määrän riippuvuus lannoituksesta, muokkauksesta ja kalkituksesta eri kokeissa turvekerroksittain. F-arvot ja merkitsevyydet. Sisältää myös lannoittamattomat koealat.

Peat layer *Turve-syvyys*, cm	Variable *Muuttuja*	Experiment — *Koe* 1	2	3	4	1—4
5—10	1 = Liming — *Kalkitus*	0,31	0,31	0.12	0,16	1,01
	2 = Soil prep. — *Muokkaus*	2,86	0,38	1,11	0,05	0,09
	3 = Fertilization — *Lannoitus*	2,52	0,18	1,41	10,18**	9,72***
	1 × 2 Inter.-Yhdysv.	0,36	0,29	0,75	1,50	0,77
	1 × 3 ”	1,69	3,53*	0,18	0,05	1,45
	2 × 3 ”	0,51	1,03	0,48	0,69	1,37 1)
15—20	1	0,15	0,99	9,16**	1,64	0,96
	2	0,82	0,18	0,11	0,87	1,30
	3	7,75**	0,99	1,13	14,31***	16,03***
	1 × 2	0,06	0,15	0,27	0,33	0,31
	1 × 3	3,43*	0,19	0,30	0,25	1,02
	2 × 3	0,60	1,65	0,95	0,24	2,15 1)

1) F5% = 2.37. In the analysis with the fertilized plots only 1 × 3 was 3.93* in the 5—10 cm layer and 2.41 (then F5% = 3.92) in the 15—20 cm layer.

1) F5% = 2.37, pelkät lannoitetut koealat sisältävässä analyysissä 1 × 3 oli 5-10 cm:n kerroksessa 3.93 ja 15-20 cm:n kerroksessa 2.41 (tällöin F5% = 3.92).*

Table 10. Dependence of NH_4 nitrogen on the total nitrogen content of peat. All experiments.

Taulukko 10. Turpeen NH_4-typen riippuvuus turpeen totaalityppipitoisuudesta. Kaikki kokeet.

Depend. variable *Selitettävä muuttuja*	Independent variable *Selittävä muuttuja*	Equation — *Yhtälö*	F	Coeff. of determ.1) % *Selitysaste 1) %*
NH_4 5—10	N 5—10	y = 31,80x + 8,90	69,29***	65,4
	N 15—20	y = 17,60x + 4,13	23,52*	57,5
NH_4 15—20	N 5—10	y = 40,49x — 5,49	80,43***	77,9
	N 15—20	y = 35,07x — 8,74	83,01***	78,1

1) Includes also the coefficient of determination of class variables.

1) Sisältää myös luokkamuuttujien selitysasteen.

32. Needle nutrients

321. *Effect of fertilization, liming and soil preparation*

Almost without exception the foliar nitrogen content was lower in the fertilized than unfertilized seedlings (Fig. 3, see also Penttilä 1980 and Raitio 1981). Nitrogen application in addition to phosphorus-potassium fertilization had no statistically significant effect on the foliar nitrogen levels six growing seasons after fertilization (Fig. 3, App. 2). Apart from the fertilized plots of Exp. 3, the average foliar nitrogen contents were higher than the deficiency limits reported by e.g. Paarlahti et al. (1971) and Raitio (1978) (1.30 % and 1.31 % respectively) on drained peatlands.

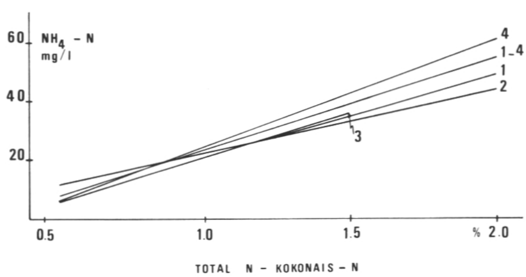

Fig. 1. Amount of peat NH_4 nitrogen as depending on the total nitrogen content in the 5-10-cm-deep peat layer in different experiments. Equations in the Appendix 1.

Kuva 1. Turpeen NH_4-typen määrän riippuvuus kokonaistyppipitoisuudesta 5-10 cm:n turvekerroksessa eri kokeissa. Yhtälöt liitetaulukossa 1.

Liming lowered the foliar nitrogen levels especially in Exp. 4, but the negative effect of liming was statistically significant also in the combined analysis of all the experiments (Fig. 3, App. 2). As stated in Chapter 312, liming usually lowered the NH_4 nitrogen content of peat on fertilized plots. The amount of NH_4 nitrogen in peat had a positive correlation with the foliar nitrogen content. The presently observed decrease in the foliar nitrogen level on limed plots possibly results from the decrease of available nitrogen in peat. The effect of soil preparation on the foliar nitrogen level was varying (Fig. 3, App. 2).

The levels of the other analyzed foliar nutrients (P, K, Zn, Mn, Cu, B and Ca) are reviewed in Figs. 4 and 5 and the results of the variance analyses in App. 3. PK and NPK fertilization increased the phosphorus and potassium contents of needles in all the experiments (Fig. 4). Yet, the foliar phosphorus levels on the fertilized plots were lower than those reported by Veijalainen (1980). The measured values were generally lower than the limit values for phosphorus deficiency reported by Paarlahti et al. (1971) and Raitio (1978) (1.40 ‰ and 1.45 ‰ respectively). Similarly, the foliar potassium levels were lower than reported by Veijalainen (1980), but higher on the average than the limit values for potassium deficiency (4.0 ‰) reported by Paarlahti et al. (1971). The only exception was the NPK fertilized plots in Exp. 4, where the foliar potassium level

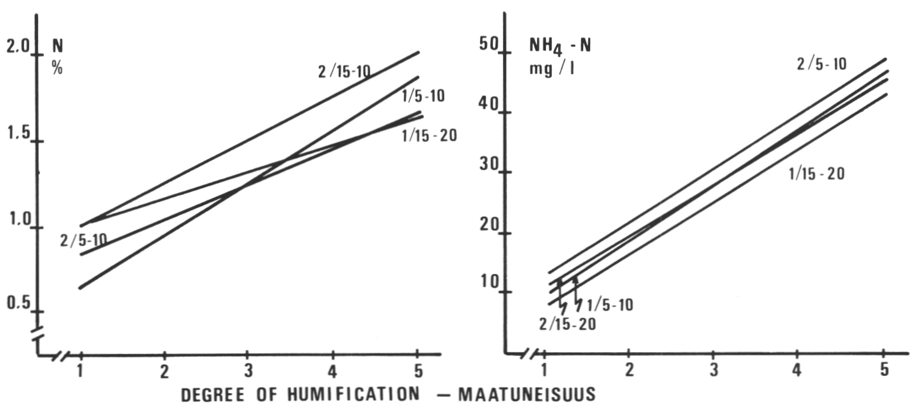

Fig. 2. Total nitrogen and NH_4 nitrogen in peat as depending on the humification degree of peat (according to v. Post). Figures = Experiment/Peat layer. Equations in Tables 5 and 10 respectively.

Kuva 2. Turpeen totaali- ja NH_4-typen riippuvuus turpeen maatumisasteesta (V. Postin mukaan). Numerot = Koe/Turvekerros. Yhtälöt taulukoissa 5 ja 10 vastaavasti.

was only 3.4 ‰, approaching the lower value of deficiency limit variation 3.0—4.4 ‰ introduced by Wittich (1957) (see also Puustjärvi 1962 c). In no case did the foliar potassium levels reach the deficiency limit (4.5 ‰) reported by Raitio (1978).

The contents of Ca, B, Cu, Mn and Zn were usually lower in the needles of fertilized seedlings than completely unfertilized ones (see also Paarlahti et al. 1971 and Veijalainen 1980). The foliar calcium levels were high compared for example to the material collected by Veijalainen (1980). The foliar zinc levels were clearly lower on the average than in the material of Veijalainen (1980) and Paarlahti et al. (1971), but greater than the slight deficiency limit (57 ppm) reported by Raitio (1978). An exception was Exp. 4 in which the foliar zinc levels of the PK fertilized seedlings were distinctly below the deficiency limit reported by Raitio.

In comparison to the above-mentioned investigations the foliar manganese levels in the experimental areas were moderate, except in Exp. 4, especially on the NPK fertilized plots. However, even in this experiment there was manganese considerably more than for example the deficiency limit of 10—20 ppm introduced by Kolari (1979) in his study based on a litarature survey or 7 ppm by Ingestad (1972).

Fairly high levels of copper were found if compared to the results by Veijalainen (1980). The foliar copper levels also surpassed the optimum lower limit (4.9 ppm) reported by Raitio (1978) in all the experiments except No. 4. Due to boron fertilization in the previous spring the foliar boron levels were high, particularly in Exp. 1, exceeding the toxic limit value for *Pinus resinosa* and *Pinus strobus* (47 and 61 ppm respectively) as reported by Stone and Bairl

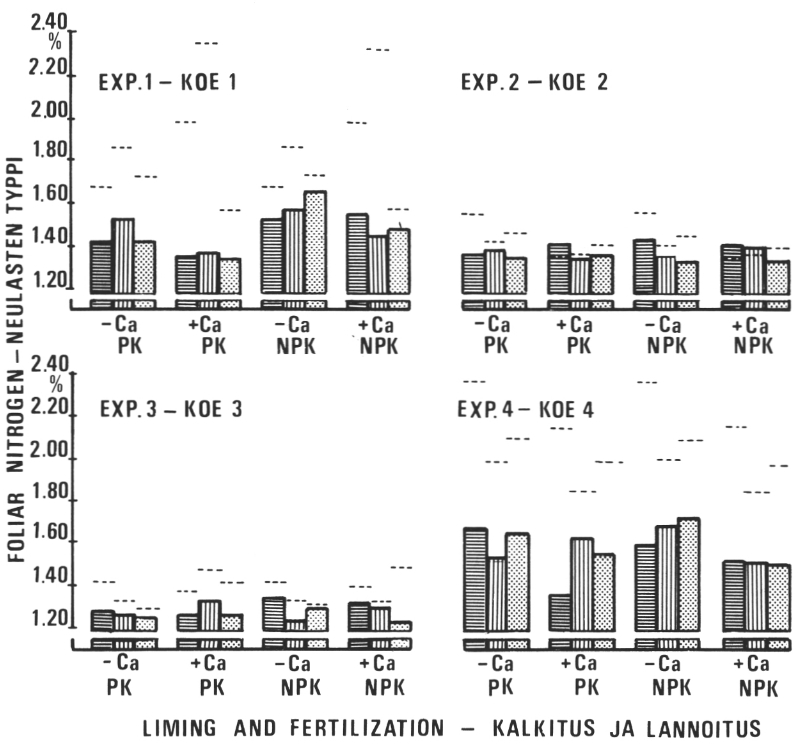

Fig. 3. Foliar nitrogen levels in different treatments. Dashed lines refer to the nitrogen levels on unfertilized plots. Horizontal lines = unprepared + broadcast topdressing vertical lines = stripwise rotavation + broadcast topdressing, stippled = stripwise rotavation + fertilizers broadcast and mixed into peat.

Kuva 3. Neulasten typpipitoisuus eri käsittelyjen yhteydessä. Katkoviivat kuvaavat typpipitoisuuksia kokonaan lannoittamattomissa koejäsenissä. Vaakaviivoitus = muokkaamaton + pintalannoitus, pystyviivoitus = jyrsitty + pintalannoitus, pilkutettu = jyrsitty + lannoitteet sekoitettu turpeeseen.

(1956). The foliar boron levels were higher on all the plots than the optimum level for *Pinus sylvestris* on peat soil, 20—25 ppm, reported by Braekke (1979) or the average boron levels of 22—38 ppm for 4-year-old Scots pine seedlings reported by Steinbeck (1966).

In addition to nitrogen, liming decreased also the potassium, manganese, boron and to some extent the phosphorus levels of needles (Fig. 5, App. 3). Zinc usually increased slightly after liming. Except molybdenum, the solubility of micronutrients in soil decreases with increasing pH (see e.g. Black 1968, Amberger 1979). In this respect the results dealing with manganese and boron agree with the previous investigations. It is, however, difficult to explain the increase of zinc after liming. It is known that abundant phosphorus hampers the uptake of zinc by plants (Amberger 1979). As liming in the investigation lowered the foliar phosphorus levels, the plants may have indirectly increased their uptake of zinc. However, the phosphorus contents in this investigation have not even at their highest been very high.

The foliar nitrogen levels in Exp. 4 were higher, while the other nutrient levels were lower than in the other experiments. Thus the ratios between nitrogen and other nutrients were higher in Exp. 4 than in the other experiments (App. 4) being in each case statistically highly significant (App. 3). Particularly large was the difference in the N/Mn ratio. The N/P ratio in Exps. 1 and 3 was at an optimum level, but in Exp. 4 somewhat too high (see Wehrmann 1959, Puustjärvi 1962, Paarlahti et al. 1971, Kaunisto & Paavilainen 1978 and Raitio 1978). The N/K ratio was usually higher than the optimum values introduced by Paarlahti et al. (1971) and Puustjärvi (1966) (3.0 and 2.6 — 2.8 respectively). The ratio was remarkably high in Exp. 4.

The above comparison leads to a conclusion that there was too much nitrogen in relation to phosphorus and potassium in Exp. 4. Furthermore, Exp. 4 had more

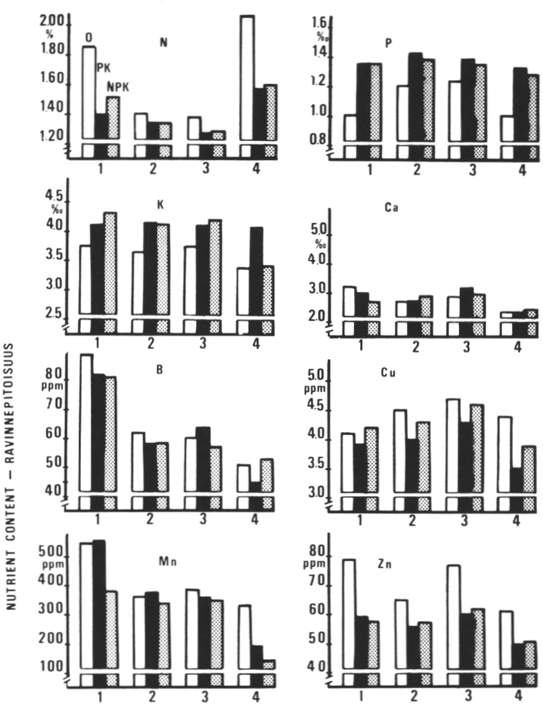

Fig. 4. Effect of fertilization on some nutrient levels of needles in different experiments.

Kuva 4. Lannoituksen vaikutus eräiden ravinteiden pitoisuuksiin neulasissa eri kokeissa.

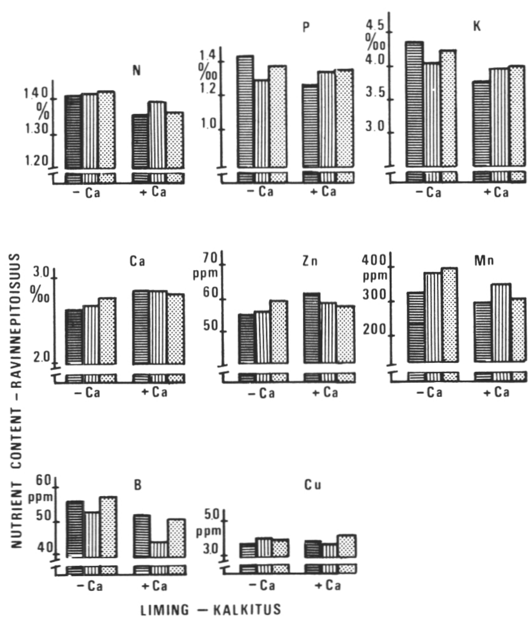

Fig. 5. Effect of liming, soil preparation and nutrient application on some nutrient levels of needles. Symbols as in Fig. 3.

Kuva 5. Kalkituksen, muokkauksen ja ravinteiden sijoituksen vaikutus eräiden ravinteiden pitoisuuksiin neulasissa. Symbolit kuten kuvassa 3.

phosphorus and boron in relation to boron and manganese than the other experiments.

Nitrogen application in addition to phosphorus and potassium fertilization increased the ratio between nitrogen and the other nutrients. Similarly, ratios Ca/Mn and B/Mn increased. The P/Cu, K/Cu, K/Zn, Ca/Cu, Mn/Cu and Mn/Zn ratios decreased (Fig. 6, App. 3).

Liming increased ratios N/K, N/B, N/Mn, P/Mn, K/Mn, Ca/B, Ca/Mn and decreased ratios K/Ca, K/Cu, K/Zn, B/Zn, B/Cu, Mn/Cu and Mn/Zn, indicating that the foliar manganese and boron levels were decreased proportionally more than the other nutrients by liming (Fig. 7, App. 3). Soil preparation decreased the values of ratios N/Mn, P/Mn, K/Mn, Ca/Mn, B/Mn, Cu/Mn and Zn/Mn (Table 11).

322. Dependence of foliar nitrogen on peat characteristics

As the relationship between peat characteristics and foliar nitrogen on the PK fertilized plots differed from that of the NPK fertilized ones, the calculations were made separately for these two nutrient combinations (App. 5). Both linear and quadratic models were examined, but only

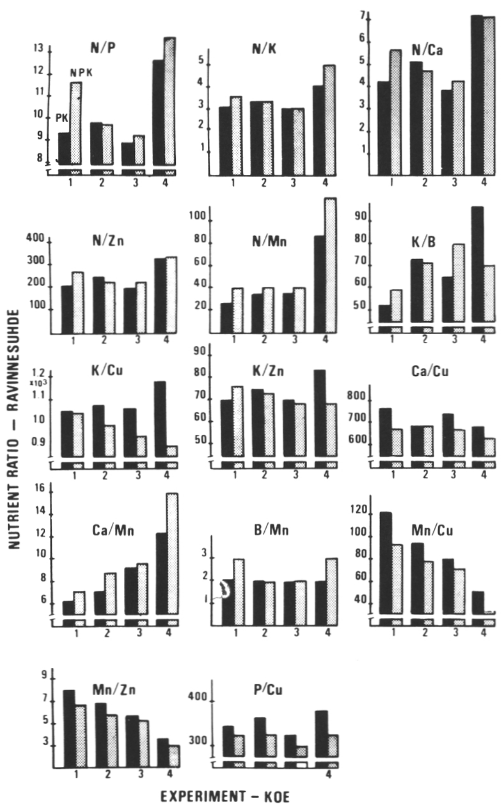

Fig. 6. Some nutrient ratios of needles as affected by fertilization in the different experiments.

Kuva 6. Lannoituksen vaikutus eräisiin ravinnesuhteisiin neulasissa eri kokeissa.

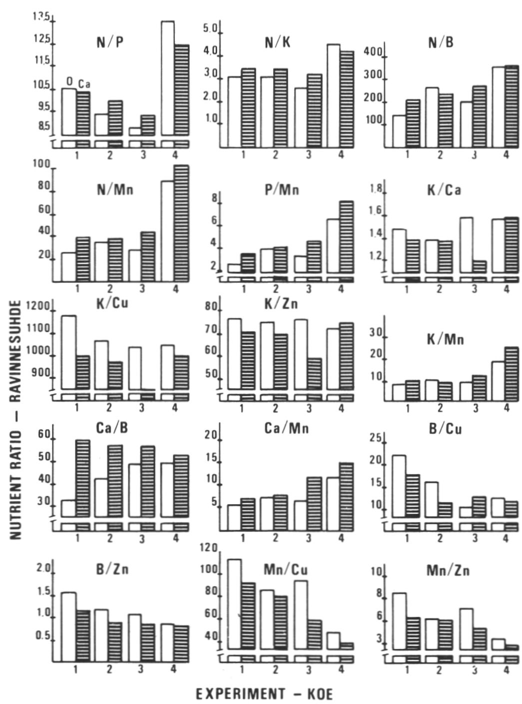

Fig. 7. Some nutrient ratios of needles as affected by liming.

Kuva 7. Kalkituksen vaikutus eräisiin ravinnesuhteisiin neulasissa eri kokeissa.

Table 11. Effect of soil preparation on the ratio between manganese and the other nutrients.
Taulukko 11. Muokkauksen vaikutus muiden ravinteiden ja mangaanin väliseen suhteeseen.

Soil preparation and fertilizer placement *Muokkaus ja lannoitteen sijoitus*	Nutrient Ratio — *Ravinnesuhde* N/Mn,	P/Mn,	K/Mn,	Ca/Mn,	B/Mn,	Cu/Mn,	Zn/Mn,
No ratavation, topdresing — *Muokkaamaton pinta-lannoitus*	58	5,3	15,6	10,6	0,24	0,016	0,22
Rotavation, topdress. — *Jyrsintä, pintal.*	47	4,2	12,6	8,4	0,17	0,014	0,18
Rotavation, placement — *Jyrsintä, sijoitusl.*	50	4,6	13,8	9,5	0,21	0,014	0,19

the linear ones proved statistically significant.

The foliar nitrogen content on the PK fertilized plots of Exps. 1 and 4 increased as the total peat nitrogen and NH_4 nitrogen increased (App. 5, see Puustjärvi 1962 a). A slight positive correlation existed between the foliar nitrogen level and the degree of humification (5—10 cm) Exp. 1 and between foliar nitrogen and peat pH (15—20 cm) in Exp. 4. The correlations were smaller and more varied on the NPK fertilized plots of Exps. 1 and 4 as well as on both PK and NPK fertilized plots in Exps. 2 and 3.

The dependence between foliar nitrogen and peat properties was very similar in the analyses of the entire material (App. 5). The foliar nitrogen levels on the PK fertilized plots were affected most by the total nitrogen content of peat in the 5—10 cm layer. Not a single regression variable on the NPK fertilized plots was significant in the analysis including all the experiments.

33. Height growth of seedlings

331. Relationship between peat properties and growth

The correlation between peat characteristics and the height growth of seedlings was examined by calculating the regression equations with regression and covariance analyses. Each measured peat characteristic was separately used as an independent variable explaining growth. Both the linear and quadratic models were calculated separately for each variable. As the material was collected from factorial experiments, the final equations were calculated by the analysis of covariance. Thus the following paragraphs are mainly based on the latter analyses, although in case of the total peat nitrogen and NH_4 nitrogen also some equations calculated with regression analysis are included.

3311. Total nitrogen in peat

A scatter diagram of seedling height against total peat nitrogen in the 5—10-cm-deep peat layer separately for the PK and NPK fertilized plots is presented in Fig. 8. The peat nitrogen contents in Exp. 3 form a cluster at the low end of the nitrogen scale and in Exp. 4 at the high end of the scale in both materials. The nitrogen contents in Exps. 1 and 2 are scattered between, although in some cases, especially in Exp. 1,

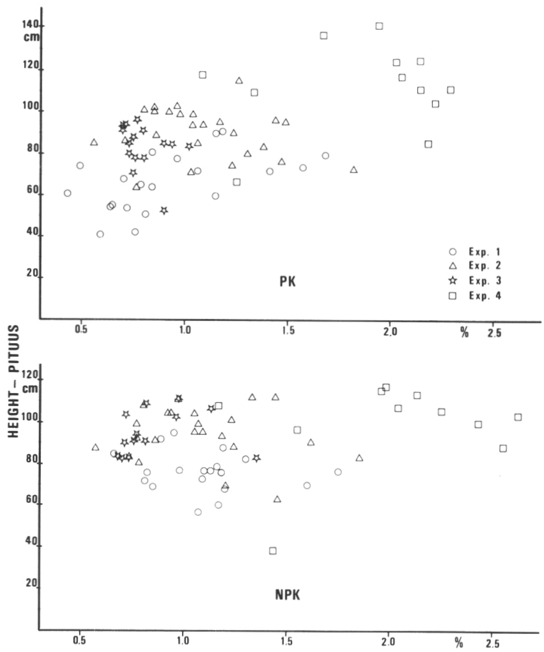

Fig. 8. Scatter diagram illustrating the dependence of seedling height on total peat nitrogen in different experiments. Original, uncorrected values.
Kuva 8. Taimien pituuden riippuvuutta turpeen totaalityppipitoisuudesta eri kokeissa kuvaava pisteparvi. Alkuperäiset, laskennallisesti korjaamattomat arvot.

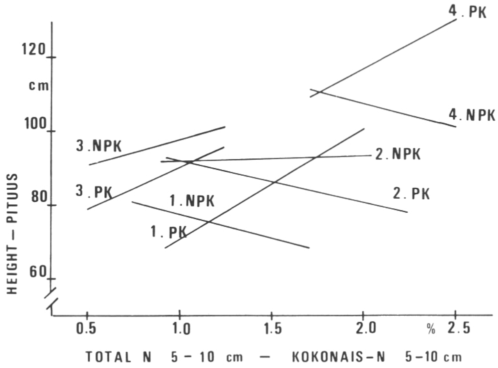

Fig. 9. Dependence of seedling height on total peat nitrogen in the 5—10-cm-deep peat layer separately on the PK and NPK fertilized plots of Experiments 1, 2, 3 and 4. Equations in App. 6.

Kuva 9. Taimien pituuden riippuvuus turpeen totaalityppipitoisuudesta 5-10 cm:n turvekerroksessa eri kokeiden (1, 2, 3, 4) PK- ja NPK-lannoitetuissa koejäsenissä. Yhtälöt liitetaulukossa 6.

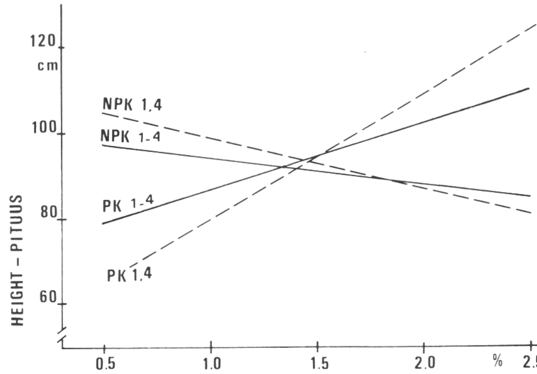

Fig. 10. Seedling height as affected by total peat nitrogen content of 5—10 cm peat layer in differently arranged materials. 1,4 = Combined analysis of Exps. 1 and 4. 1—4 = Combined analysis of all experiments. Equation in App. 7.

Kuva 10. Turpeen kokonaistyppipitoisuuden 5-10 cm:n syvyydessä vaikutus taimien pituuteen eri tavoin ryhmitellyissä aineistoissa. 1,4 = kokeiden 1 ja 4 yhteisanalyysi. 1-4 = kaikkien kokeiden yhteisanalyysi. Yhtälöt liitetaulukossa 7.

the values dropped below those of Exp. 3. It seems that in the entire PK fertilized material seedling height is positively correlated with the total nitrogen content of peat. The relationship on the NPK fertilized plots is vaguer.

App. 6 presents the regression equations calculated with the analysis of covariance between the total nitrogen content of peat and leader growth and height of seedlings for each experiment separately for the PK and NPK fertilized plots, and Fig. 9 the corresponding regression lines for the total height of seedlings. In no case was the quadratic model statistically significant. On the PK fertilized plots of Exps. 1 and 4, the growth of seedlings increased explicitly with an increase in the total nitrogen content of peat. The regression line between the peat nitrogen content and growth on the NPK fertilized plots was usually declining, although the regression was statistically significant only in Exp. 4.

The effect of peat nitrogen content was less clear in Exps. 2 and 3. The regression lines for Exp. 2 gradually declined even on the PK fertilized plots, although only one case was statistically significant. The regression lines of Exp. 3 were slightly rising both with PK and NPK fertilization in the first few years after planting, but then slightly declining in 1977—78. Coefficients of regression lines in Exp. 3 deviated from 0 with a statistical significance only in the equations obtained from the 1975 growth on the PK fertilized plots.

In all cases growth was explained by the nitrogen content better in the 5—10 cm than 15—20 cm peat layer (App. 6). Coefficients of determination of the models including class variables were fairly high in Exps. 1 and 3 and very high in Exp. 4.

As the regression lines between the seedling height and nitrogen content in Exps. 1 and 4 were approximately parallel and the experiments were situated only a. 2 km apart from each other, the materials of these two experiments were combined and new regression equations calculated for different nutrient combinations. The experiment was included as a class variable. The obtained equations are presented in App. 7, which also presents regression equations calculated from the entire material for different nutrient combinations. The lines describing the relationship between seedling height and peat nitrogen content in App. 7 are shown in Fig. 10. The height of seedlings increased with increasing peat nitrogen contents on the PK fertilized plots both for the entire material and the combination of Exps. 1 and 4. F values for the regression coefficients were statistically significant. The lines were, however, declining in case of the NPK fertilized plots. The F value was statistically significant in the combined analysis of Exps. 1 and 4. A similar trend was observed after calculating the material with the regression analysis only (App. 8). In App. 8 the coefficients of determination were, in some cases, fairly high.

The results imply that nitrogen deficiency brought on by low nitrogen levels of peat could be compensated by nitrogen fertilization up to a certain peat total nitrogen content, above which nitrogen application became unnecessary or even harmful. To find the limit values, the intersections of lines of PK and NPK fertilized plots showing the dependence of seedling growth on the total peat N content were calculated for differently arranged materials. The intersection values were calculated for lines derived from both regression and covariance analyses. The intersections of the regression lines of PK and NPK fertilized plots concerning the total height and 1978 height growth in differently arranged materials are presented in Table 12. Table 12 includes only the cases where regression coefficients deviated statistically significantly from 0 either on PK or NPK fertilized plots or both. It shows that

Table 12. Critical peat total nitrogen contents in 5—10 cm peat layer calculated by the regression (Reg.) and covariance (Cov.) analyses for differently grouped materials indicating the peat total nitrogen content under which nitrogen fertilization was unnecessary. Includes only the cases where coefficients deviated statistically significantly from 0 in the material of one or both nutrient combinations.

Taulukko 12. Kovarianssi- (Cov.) ja regressioanalyysillä (Reg.) lasketut turpeen kokonaistyppipitoisuuden raja-arvot, joiden alapuolella typpilannoitus oli tarpeeton eri tavoin ryhmitellyissä aineistoissa. Sisältää vain tapaukset, joissa suorien kulmakertoimet ovat poikenneet tilastollisesti merkitsevästi 0:sta jommankumman tai molempien ravinneyhdistelmien aineistossa.

Experiment *Koe*	Intersection, % total nitrogen *Leikkauspiste, % totaalityppeä*			
	Height *Pituus v. 1978*		Growth *Kasvu v. 1978*	
	Reg.	Cov.	Reg.	Cov.
1	1,23	1,15	1,21	1,15
4	—	1,74	—	1,68
1 + 4	1,21	1,45	1,28	1,41
1 + 2 + 3 + 4	1,22	1,36	1,24	1,30

the values of intersections calculated for the height and 1978 height growth do not, to any noticeable degree, differ from each other. Yet, in the analysis of covariance fairly wide differences were found when comparing the values between different part-materials and the entire material. The intersections of lines in Exp. 4 gave the highest peat total nitrogen content values (1.74% and 1.68% for height and 1978 height growth respectively). The material of Exp. 4 was, however, limited having high nitrogen contents, and the material should therefore be regarded with certain reserve. The corresponding intersection values in Exp. 1 were considerably lower (1.15% and 1.15%). The material was twice as large (23 PK and 19 NPK plots) as in Exp. 4 and the observations on total peat nitrogen content were more evenly distributed. The results can therefore be regarded as more reliable than those in Exp. 4.

The intersection values in the combined analysis of Exps. 1 and 4 were halfway through those calculated separately for each experiment and in the combined analyses of all experiments somewhat closer to the values from Exp. 1 than Exp. 4 (1.36% and 1.30% for height and height increment in 1978 respectively).

The intersection values obtained by the regression analysis only were very close to each other and somewhat lower in the combined material than those calculated by the analysis of covariance. Evidently the actual limit value of total nitrogen content in regard to the need for nitrogen fertilization varies between 1.15—1.45 % in this material. Exps. 2 and 3 were also combined and similar analyses of covariance calculated as above. No connection was found between the nitrogen content of peat and growth.

Appendixes 6 and 7 as well as Figs. 9 and 10 show that the lines for the PK and NPK fertilized plots were not parallel. If analyzing the PK and NPK fertilized plots together, the regression between growth and total nitrogen content of peat in Exp. 4 was curvilinear (a downward parabola, App. 9). In the other single experiments the linear model was better that the quadratic one. The regression between growth and nitrogen content in the combined analysis of Exps. 1 and 4 and all experiments together took the shape of a downward parabola

(App. 9). The peak of the parabola in relation to the nitrogen content of peat in differently combined materials varied widely (App. 9), the highest being associated with Exp. 4 and lowest with the entire material (1.97 % — 2.10 % and 1.43 % — 1.65 % of peat total nitrogen in 5—10 cm peat layer in statistically significant cases respectively).

3312. NH_4 nitrogen in peat

Fig. 11 illustrates the height of seedlings plotted against NH_4 nitrogen content measured from the 5—10 cm peat layer separately for PK and NPK fertilized plots. The figure indicates that in Exp. 3 the NH_4 nitrogen contents occupy a rather limited area at the lower end of NH_4 scale, which is similar to the previously described total nitrogen contents. In the other experiments NH_4 nitrogen contents were more distributed, although in Exp. 4 most observations were at the high end of NH_4 scale. For the entire material the seedling height on the PK fertilized plots shows a tendency towards a positive correlation with the NH_4 nitrogen content of peat. The relationship on the NPK fertilized plots is vague. The situation resembles closely that of total nitrogen. The lines calculated by the regression analysis indicate that seedling height increased on the PK fertilized plots with a statistical significance as the NH_4 nitrogen content of peat increased, as can be seen from the following figures:

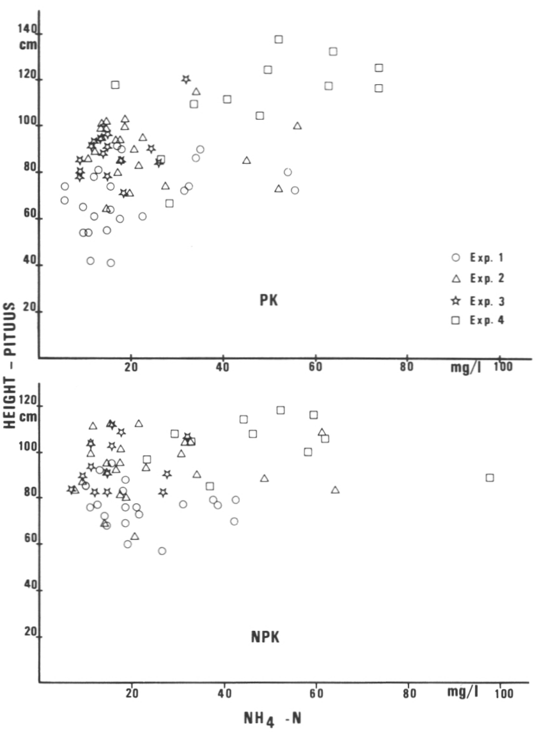

Fig. 11. Scatter diagram illustrating the dependence of seedling height on peat NH_4 nitrogen content of 5—10 cm peat layer in different experiments original uncorrected values.

Kuva 11. Taimien pituuden riippuvuutta turpeen NH_4-typpipitoisuudesta 5-10 cm:n syvyydessä eri kokeissa kuvaava pisteparvi. Alkuperäiset, laskennallisesti korjaamattomat arvot.

Fertilization	Equation	F	R^2
PK	$y = 0.495x + 75.47$	22.25***	35.3
NPK	$y = 0.192x + 85.74$	4.20*	22.3

where y = seedling height (cm)
x = amount of NH_4 nitrogen in 5—10 cm peat layer

The coefficients of regression lines on the NPK fertilized plots were considerably smaller than on the PK fertilized ones.

App. 10 presents the regression equations calculated with the analysis of covariance between the peat NH_4 nitrogen content and seedling height growth in 1974—78 and total height for different experiments separately for the PK and NPK fertilized plots and Fig. 12 the corresponding re-

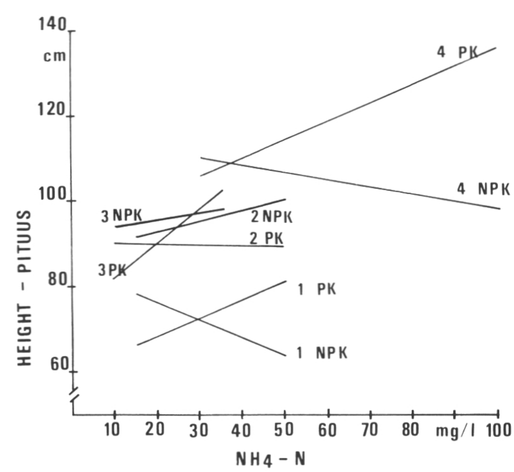

Fig. 12. Dependence of seedling height on the amount of ammomium nitrogen in the 5—10-cm-deep peat layer separately on the PK and NPK fertilized plots in Experiments 1, 2, 3 and 4. Equations in App. 10.

Kuva 12. Taimien pituuden riippuvuus ammoniumtypen määrästä 5-10 cm:n turvekerroksesta erikseen PK- ja NPK-lannoitetuissa koejäsenissä eri kokeissa (not. 1, 2, 3, 4). Yhtälöt liitataulukossa 10.

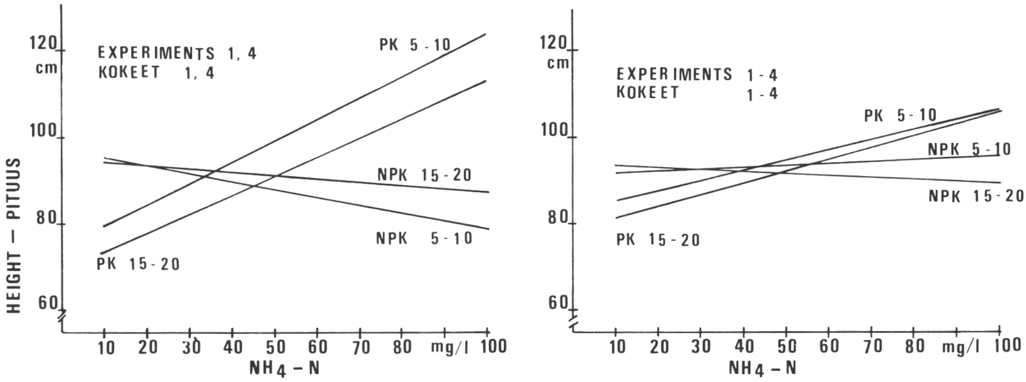

Fig. 13. Dependence of seedling height on peat NH_4 nitrogen content in different peat layers (figures) in differently arranged materials. Equations in App. 11.

Kuva 13. Taimien pituuden riippuvuus turpeen NH_4-typpipitoisuudesta eri turvekerroksissa (numerot) eri tavoin ryhmitellyissä aineistoissa. Yhtälöt liitetaulukossa 11.

gression lines for total height. In no case was the quadratic model statistically significant. The relationship between the amount of NH_4 nitrogen in peat and seedling growth was quite similar to that between growth and total nitrogen content. Growth improved with the increase of NH_4 nitrogen on the PK fertilized plots of Exps. 1, 3 and 4. On the NPK fertilized plots growth declined in Exps. 1 and 4 but improved in Exp. 3 as the amount of NH_4 nitrogen increased in peat. The effect of NH_4 nitrogen on the NPK fertilized plots was less frequently statistically significant than on the PK fertilized plots. NH_4 nitrogen had no statistically significant effect on growth in Exp. 2 with either nutrient combination.

The combined analysis of Exps. 1 and 4 revealed a solid positive correlation between NH_4 nitrogen of peat and seedling growth on the PK fertilized plots (App. 11 and Fig. 13). A negative but not statistically significant correlation prevailed on the NPK fertilized plots.

The analysis of the entire material revealed a positive correlation between growth and the amount of NH_4 nitrogen on the PK fertilized plots, although not as strong as in the combined analysis of Exps. 1 and 4 (App. 11, Fig. 13). There was no correlation on the NPK fertilized plots.

When growth was explained by NH_4 nitrogen along with the class variables, the coefficients of determination were fairly high, although somewhat lower than in case of total nitrogen. Ammonium nitrogen content in the 15—20 cm peat layer explained the growth variation slightly better than that in the 5—10 cm peat layer. This was contrary to the results with the total nitrogen contents. Table 13 shows that the intersection values of regression lines for PK and NPK fertilized plots describing the dependence of seedling growth on the amount of ammonium nitrogen in peat varied between 29 mg/l — 60 mg/l. No clear difference was observed between the various peat layers.

Table 13. Critical peat NH_4 nitrogen contents in 5—10 cm peat layer calculated by the covariance analyses for differently grouped materials indicating the peat NH_4 nitrogen content under which nitrogen fertilization was unnecessary. Includes only the cases where coefficients deviated statistically significantly from 0 in the material of one or both nutrient combinations.

Taulukko 13. Kovarianssianalyysillä lasketut turpeen NH_4-typen raja-arvot, joiden alapuolilla typpilannoitus oli tarpeeton eri tavoin ryhmitellyissä aineistoissa. Sisältää vain tapaukset, joissa suorien kulmakertoimet ovat poikenneet tilastollisesti merkitsevästi 0:sta jommankumman tai molempien ravinneyhdistelmien aineistossa.

Experiment *Koe*	Intersection, mg/l NH_4—N — *Leikkauspiste, mg/l NH_4-N*			
	Height — *Pituus 1978*		Growth — *Kasvu 1978*	
	Peat layer-Turvekerros, cm		Peat layer—*Turvekerros, cm*	
	5—10	*15—20*	5—10	15—20
1	—	29,0	—	29,8
3	29,3	—	—	10,3
4	34,0	—	—	59,7
1 + 4	33,4	50,1	33,9	50,1
1+2+3+4	52,6	—	48,0	44,7

3313. Peat pH

The effect of peat pH on the growth of seedlings proved quite negligible. By calculating equations for each experiment and nutrient combination, a gradually rising regression line was obtained to describe the relationships between the growth of the NPK fertilized seedlings in Exp. 1 and pH measured from the 5—10 cm layer as well as that of the PK fertilized seedlings in Exp. 4 and pH of the 15—20 cm layer (App. 12). The growth of seedlings improved as the pH in the 15—20 cm peat layer rose according to the combined analysis of all experiments (App. 13). Even in this case pH did not explain the variation in seedling growth as well as the total and NH_4 nitrogen content in peat.

3314. Degree of peat humification

Only Exps. 1 and 2 deal with the effect of peat humification on seedling growth, as variation in humification of Exps. 3 and 4 was too small between the sample plots for the calculation of regression equations. The correlation between humification and seedling growth in Exp. 1 was positive on the PK and negative on the NPK fertilized plots (App. 14, Fig. 14). The humification of the 15—20-cm-deep peat layer explained growth almost as well as the total nitrogen content of the 5—10-cm-deep layer. Height growth declined with increased humification in Exp. 2 in case of both nutrient combinations, although seldom with a statistical significance. This situation also resembles the one for the total nitrogen contents.

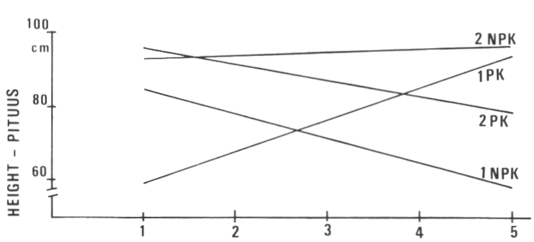

Fig 14. Dependence of seedling height on the humification degree of peat (according to V. Post) separately on the PK and NPK fertilized plots of Experiments 1 and 2.

Kuva 14. Taimien pituuden riippuvuus turpeen maatuneisuudesta (V. Postin mukaan) kokeiden 1 ja 2 PK- ja NPK-lannoitetuilla koealoilla.

Intersection values of regression lines calculated for the PK and NPK fertilized plots of Exp. 1 describing the dependence of seedling growth on the degree of humification (according to v. Post) varied between 2.6 — 2.8 in the 5—10 cm peat layer and between 2.7 — 3.5 in the 15—20 cm peat layer, in cases where at least the coefficient of one out of the two compared regression lines differed statistically significantly from zero. The figures in Exp. 2 were 2.0 — 2.5 and 4.8 — 5.2 respectively.

3315. Peat depth

As stated in Chapter 21 (see Table 1), the thickness of peat layer was over 4 m in Exp. 3 but varied widely in Exps. 1, 2 and 4. Consequently, the regression equations between seedling growth and peat depth could be calculated only from the three last-mentioned experiments. Regression equations calculated with the analysis of covariance are presented in App. 15. Also in this case all the equations were linear. Apart from the NPK fertilized plots of Exp. 1, the seedling growth usually declined as the peat layer thickened. The positive correlation between height growth on the NPK fertilized plots of Exp. 1 may be attributed to the relationship between peat depth and nitrogen level and growth and nitrogen level. In this particular experiment the nitrogen level of peat decreased with thicker peat while the growth of seedlings on the NPK fertilized plots increased to some degree with a decreasing nitrogen level (see Chapters 31 and 331). No correlation between peat depth and nitrogen level was found in Exp. 4 so that other factors (e.g. a decrease in mineral nutrients) have caused the growth decline as the peat layer thickened.

332. Effect of fertilization, soil preparation and liming

In studying the effect of fertilization on seedling growth the statistical analyses focused chiefly on the differences between PK and NPK fertilization. However, Fig. 15 also includes the average height of seedlings on unfertilized sample plots. It shows that growth was substantially increased by

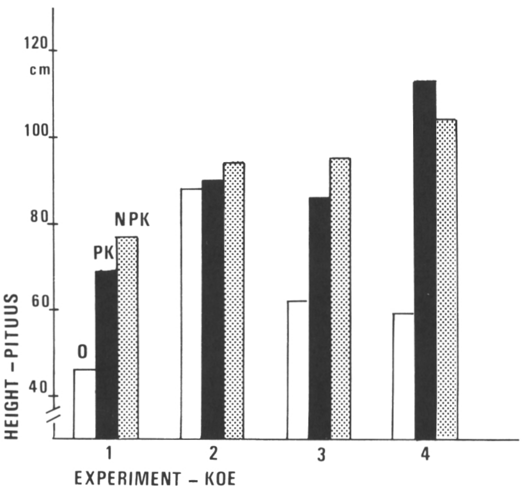

Fig. 15. Effect of fertilization on seedling height in different experiments.
Kuva 15. Lannoituksen vaikutus taimien pituuteen eri kokeissa.

fertilization in Exps. 1, 3 and 4 but less in Exp. 2. The effect was statistically highly significant in Exps. 1, 3 and 4 (F = 75.48***, 45.86*** and 115.44*** respectively) and significant at 5 % level (F = 4.85*) in Exp. 2.

Furthermore, Fig. 15 shows that seedlings had grown better on the NPK than PK fertilized sample plots in Exps. 1, 2 and 3, whereas the situation was reverse in Exp. 4. The interaction between fertilization and the experiment was statistically significant according to the analysis of variance (App. 16). According to the analyses, separately calculated for each experiment, the positive effect of nitrogen fertilization in Exp. 3 and its negative effect in Exp. 4 were statistically significant (App. 17) at 5 % level.

The effect of liming and soil preparation on seedling growth was very complex and often difficult to explain by the variables used. To obtain information on the effect of soil preparation and liming, analyses of covariance were calculated for each nutrient combination and experiment so that soil preparation and liming remained the only class variables. App. 18 presents the corresponding F values and significances of seedling height and height growth (see also Fig. 16).

Soil preparation stimulated the height growth of seedlings under all circumstances (see also Zehermayer 1954, Meshechok 1968, Paavilainen 1970, Kaunisto 1972, 1974,

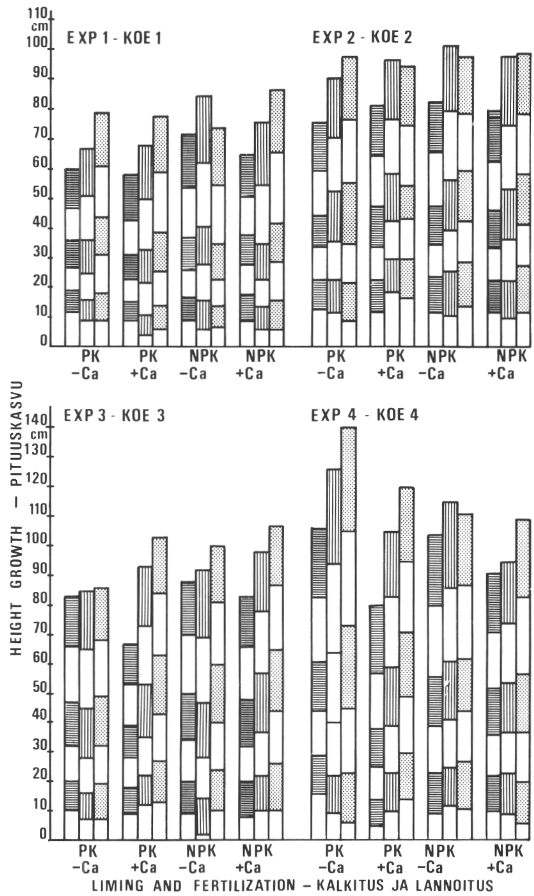

Fig. 16. Height growth and height of pine seedlings as affected by fertilization, soil preparation and liming. Horizontal lines = no preparation, topdressing, longitudinal lines = rotavation, topdressing, stippled = rotavation with fertilizers mixed into peat
Kuva 16. Lannoituksen, muokkauksen ja kalkituksen vaikutus männyn taimien pituuskasvuun ja pituuteen. Vaakaviivoitus = muokkaamaton + pintalannoitus, pystyviivoitus = jyrsitty + pintalannoitus, pilkutettu = jyrsitty ja lannoitteet + sekoitettu turpeeseen.

1975). Mixing of fertilizers into peat in comparison to top dressing produced better growth with a few exceptions (App. 18). The result agrees with the previous investigations dealing with younger seedlings (Kaunisto 1972, 1974, 1975).

Lime applied to unprepared surface diminished the growth of seedlings in Exps. 1, 3 and 4 (Fig. 16, Apps. 17 and 18) but stimulated growth in Exps. 1 and 3 if combined with soil preparation and especially if mixed into the peat. Liming had always a negative influence in Exp. 4, but the least so when lime was mixed into peat.

Viewing the individual experiments, the interaction between liming and soil preparation was statistically significant only in Exps. 3 and 4 (App. 17). The analysis involving the whole material shows that the interaction between soil preparation and liming was statistically significant (F = 3.09*). Liming decreased height growth distinctly on unrotavated plots and slightly on rotavated topdressed plots but increased growth somewhat on rotavated plots with lime mixed into peat as shown by the following figures:

	seedling height, cm	
	No lime	Limed
No soil preparation, top dressing	65.9	57.3
Soil preparation, top dressing	76.9	73.7
Soil preparation, mixing	77.3	79.9

The figures have been obtained by the analysis of covariance by using total nitrogen of peat and its square as covariates.

In addition to the above-mentioned combinations of soil preparation and fertilization, the effect of complete soil preparation + broadcast fertilization and stripwise soil preparation + stripwise fertilization (see Chapter 22, Table 4) on seedling growth was studied. The complete soil preparation did not increase growth in comparison with stripwise soil preparation (Fig. 17).

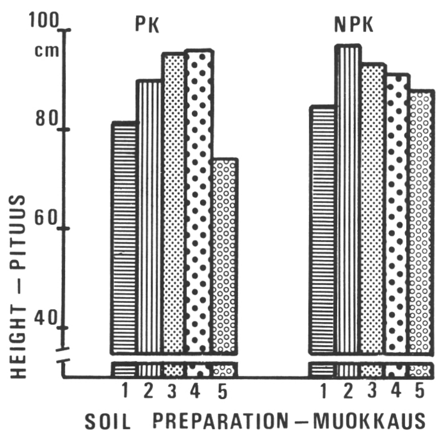

Fig. 17. Effect of soil preparation and fertilization on seedling height. Values of PK fertilized test members corrected to regression in relation to the total nitrogen content of peat in the 5—10-cm deep layer. Symbols from 1 to 3 as in Fig. 16. Bigger dots = Complete rotavation + fertilizers broadcast and mixed into peat, Circles = Stripwise rotavation + stripwise fertilization (see also Table 4).

Kuva 17. Muokkauksen ja lannoituksen vaikutus taimien pituuteen. PK-lannoitettujen koejäsenten arvot on kovarianssikorjattu turpeen totaalityppipitoisuuden suhteen 5-10 cm:n kerroksessa. Symbolit 1-3, kuten kuvassa 16. Iso pilkutus = täydellinen jyrsintä + lannoitteet sekoitettu turpeeseen, Ympyrät = kaistajyrsintä + kaistalannoitus (ks. myös taulukko 4).

333. Relationship between needle nutrients and growth

The unfertilized sample plots were omitted from calculations when studying the relationship between foliar nutrients and seedling growth.

The relatioship between the foliar nutrient level and growth was examined first within experiments and fertilizer nutrient combinations testing both the linear and quadratic models. In no case were the quadratic models statistically significant. The F values for coefficients in Exps. 2 and 3 were not statistically significant (App. 19). The growth of seedlings on the PK and NPK fertilized plots of Exp. 1 increased with higher foliar nitrogen levels, while the relationship on the NPK fertilized plots of Exp. 4 was negative and positive only on the PK fertilized sample plots (App. 19). The result mainly agreed with the correlation between peat nitrogen content and growth.

The calculations of all experiments revealed a strong positive correlation between growth and foliar nitrogen level on the PK fertilized plots but no correlation on the NPK fertilized ones (App. 19).

The intersection values of regression lines calculated for different nutrient combinations between seedling growth and foliar nitrogen level varied to some degree in statistically significant cases as indicated by the following figures:

	Intersection, % N in Exps.			
	1	4	1 and 4	1—4
Height -78	—	1.52	1.47	1.48
Growth -78	1.67	1.50	1.43	1.44

The values based on Exp. 4 do not essentially differ from the values of the other experiments.

Both the linear and quadratic models were calculated for the combined material of PK and NPK fertilized plots, separately for each experiment and the whole material. The coefficient of determination in the quadratic equations was always higher than in the linear ones, and therefore only the former models are presented and only when the coefficient of regression term deviated statistically significantly from zero. App. 20 and Fig. 18 show that growth increased with increasing foliar nitrogen levels to maximum values varying between 1.48 % and 1.60 % and then turned to decline.

According to Paarlahti et al. (1971) tree growth on a pine swamp was best at a foliar nitrogen level between 1,50 %—1.59 %. Raitio (1978) reported that the optimum foliar nitrogen level in pine seedlings was 1.40 %—1.63 %. Thus the present results agree reasonably well with the previous investigations. Miller (1981) presented somewhat higher values for *Pinus nigra* in plantations on mineral soil and stated that the location of parabolic culmination point is affected by the height of seedlings.

The relationship between the other analyzed foliar nutrient contents (P, K, Ca, Cu, B, Zn, Mn) and seedling growth was examined on the basis of one replication out of each experimental area. First the equations were calculated separately for the PK and NPK plots and then for the combined material (Apps. 21 and 22). None of the investigated nutrients or nutrient ratios on the PK fertilized sample plots significantly explained the growth of seedlings. Therefore

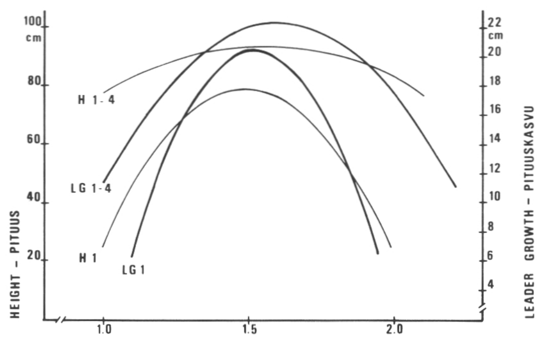

Fig. 18. Dependence of the leader growth (LG) and total height (in 1978, H) of seedlings on foliar nitrogen level in Exp. 1. and in the combined analysis of all the experiments. Equations in App. 19.

Kuva 18. Taimien pituuskasvun (LG) ja koko pituuden (H) v. 1978 riippuvuus neulasten typpipitoisuudesta eri kokeessa 1 ja kaikkien kokeiden yhteisanalyysissä. Yhtälöt liitetaulukossa 19.

the equations are not presented. The growth on the NPK fertilized plots was positively correlated with foliar phosphorus and negatively with N/P and N/K ratios indicating that there was too little phosphorus and potassium in relation to nitrogen (App. 21). Similarly, P/B and K/Zn had a positive correlation with the growth of trees.

Surprisingly the ratios between all the other investigated nutrients and manganese had a positive correlation with the 1978 growth on the NPK fertilized plots. A similar situation was found in the combined analysis of the PK and NPK fertilized plots. The latter analysis also revealed a negative correlation, which was statistically significant, between manganese and the 1978 growth indicating an excess of manganese. However, apart from the PK fertilized plots in Exp. 1, the manganese levels remained within their normal ranges as introduced by Veijalainen (1977) and Raitio (1978).

34. Mortality of seedlings

Mortality varied from one experiment to another being at its lowest in Exp. 3 and highest in Exp. 2 (Fig. 19). The difference between the experiments was statistically highly significant ($F = 8.96^{***}$). In comparison to the unfertilized plots, fertilization significantly increased mortality in Exps. 2 and 3 ($F = 6.15^{**}$ and $F = 4.12^{*}$ respectively). In Exp. 4 fertilization decreased mortality by half. The difference was statistically highly significant ($F = 9.15^{***}$). In Exp. 1 only NPK fertilization increased mortality.

NPK fertilization in comparison to PK fertilization increased mortality in each experiment (see also Seppälä 1968 and 1971, Paavilainen 1970 a and b, Kaunisto 1971), although without a statistical significance. The mortality in the combined analysis of all the experiments was higher on the NPK than PK fertilized sample plots with F value approaching significance ($F = 3.58$, $F_{5\,\%} = 3.84$).

The mortality in the analyses calculated separately for each experiment and nutrient combination significantly correlated with peat characteristics only in Exp. 4, in which seedling mortality declined with increasing total and NH_4 nitrogen contents of peat on

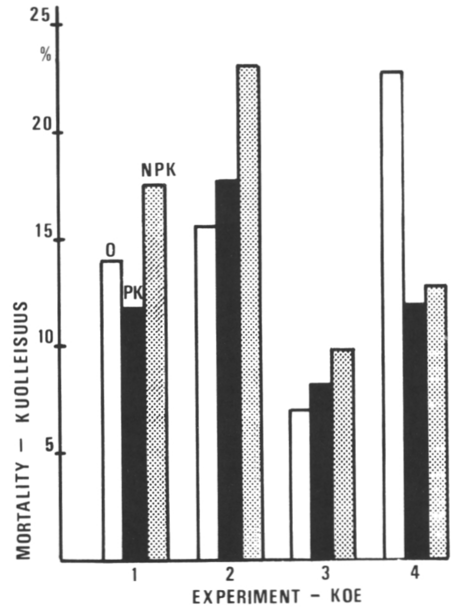

Fig. 19. Effect of fertilization on seedling mortality in different experiments.
Kuva 19. Lannoituksen vaikutus taimien kuolleisuuteen eri kokeissa.

Table 14. Effect of fertilization on the percentage of normal seedlings in the experiments.
Taulukko 14. Lannoituksen vaikutus normaalien taimien osuuteen (%) eri kokeissa.

Experiment *Koe*	Fertilization — *Lannoitus* 0	PK	NPK	x̄	F
1	21,2	36,6	24,9	27,6	3,37*
2	36,3	34,4	24,4	31,7	6,07**
3	74,7	63,0	55,7	64,5	6,02**
4	39,9	36,9	42,1	39,6	0,79
x̄	43,0	42,7	36,8	40,9	

Table 15. Proportion of normal seedlings as affected by site preparation and fertilization.
Taulukko 15. Muokkauksen ja lannoituksen vaikutus normaalien taimien osuuteen.

Rotavation and fertilizer placement *Muokkaus ja lannoitteen sijoitus*	Fertilization — *Lannoitus* PK	NPK	PK + NPK
No rotavation, topdressing *Muokkaamaton, pintalann.*	45,0	43,6	44,8
Rotavation, topdressing *Jyrsintä, pintalann.*	41,0	30,6	34,3
Rotavation, mixing *Muokkaus, sijoituslann.*	36,4	26,8	32,6
F	1,61	7,73**	7,44***

the PK fertilized sample plots (App. 23). Peat nitrogen had no statistical significance on the NPK fertilized plots. The same tendency was visible in the combined analysis of Exps. 1 and 4 the whole material (App. 23).

The result indicates that natural peat nitrogen and fertilizer nitrogen influence mortality in different ways. The natural peat nitrogen contents of this material did not affect mortality rate, while even the normal rates (used in practice) of fertilizer nitrogen proved harmful.

35. Number of normal seedlings

As stated in Chapter 2, normal in this context refers to a seedling that has one dominating leader with a clearly distinguishable dominating bud. The greatest number of normal seedlings were in Exp. 3 and the smallest number in Exp. 1 (Table 14).

Fertilization affected differently the number of normal seedlings in the various experiments (Table 14). Compared to unfertilized treatments, PK fertilization increased the number of normal seedlings in Exp. 1 but decreased it in Exps. 2, 3 and 4, NPK fertilization decreased the proportion of normal seedlings in Exps. 1, 2 and 3 in comparison to PK fertilization but increased it in Exp. 4.

The effect of liming and soil preparation on the number of normal seedlings was significant in the separate analyses of experiments. However, the analysis of the whole material showed that liming increased the number of normal seedlings from 34.3 to 40.4 % in the entire material. The difference was statistically significant (F = 5.65*). Soil preparation decreased the number of normal seedlings (Table 15). The difference on the PK fertilized plots was not, however, statistically significant.

The analyses calculated for the fertilized plots and each experiment separately revealed no correlation between peat properties and the proportion of normal

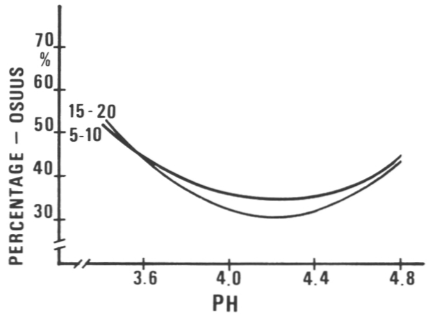

Fig. 20. Proportion of normal looking seedlings as depending on peat pH in the entire material. Equations in text (Ch. 35).

Kuva 20. Normaalien taimien osuuden riippuvuus turpeen pH:sta 5–10 ja 15–20 cm:n turvekerroksessa koko aineistosta. Yhtälöt tekstissä, luku 35.

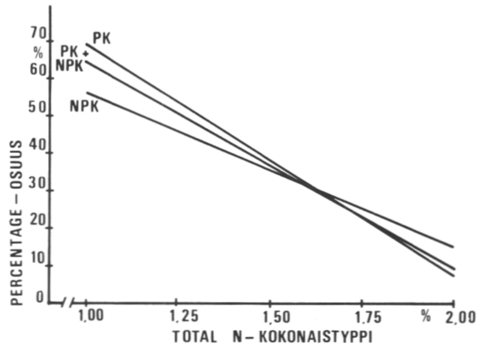

Fig. 21. The number of normal seedlings as depending on foliar nitrogen level on differently fertilized plots. All Experiments. Equations in text (Ch 35).

Kuva 21. Normaalien taimien määrän riippuvuus neulasten typpipitoisuudesta eri tavoin lannoitetuilla koealoilla. Kaikki kokeet. Yhtälöt tekstissä, luku 35.

seedlings. Yet, in the combined analysis of all fertilized plots in each experiment, a parabolic dependence was found between peat pH and the percentage of normal seedlings (y), as illustrated by the following table and Fig. 20.

Equation	F_x	F_{x^2}	R^2
$y = -4.7468x + 0.5657x^2 + 11.2157$	5.60*	5.41*	43.6 %
$y = -6.0171z + 0.7154z^2 + 13.8364$	4.80*	4.16*	51.7 %

where x = pH in 5—10 layer and z in 15—20 peat layer. The proportion of normal seedlings is illustrated by an upward parabola, whose minimum was in pH 4.2. The reason for this is not known.

The foliar nitrogen level (x) correlated negatively with the proportion of normal seedlings (y), as shown by Fig. 21 and the following regression equations from the entire material:

Fertilization	Equation	F	R^2
PK fertilized	$y = -1.4109x + 3.3694$	15.24***	54.9
NPK fertilized	$y = -0.9211x + 2.6251$	5.97*	66.6
All fertilized	$y = -1.2660x + 3.1455$	24.80***	57.5

Equations have been calculated from an arcus-sin-transformed data. The coefficient of determination (R^2) includes also the contribution of class variables.

The significance of other nutrients besides nitrogen and nutrient ratios explaining the proportion of normal seedlings was investigated on the basis of data from one replication of each experiment like in case of growth. The values of all analyzed nutrients and nutrient ratios were investigated as regression factors both in linear and quadratic models separately for the PK and NPK fertilized plots as well as for all the fertilized plots together. None of the investigated regression variables was statistically significant. A slight zinc shortage in comparison to nitrogen, potassium and boron was, however, noticeable in the NPK fertilized plots.

4. DISCUSSION

41. Material and calculation

The experimental areas under study differed clearly from one another. Exp. 3 represented a nitrogen-poor, deep-peat bog and Exp. 4 a nitrogen-rich bog with peat depth varying from 20 cm to a little over a metre. Exp. 1 represented a fairly wide nitrogen variation quite evenly distributed between the former two. Although the nitrogen range in Exp. 2 was also fairly wide, it did not reflect the peat nitrogen status for trees, because there was a raw *Sphagnum* peat layer of varying depth on well-decomposed nitrogen-rich peat. In some cases it is possible that, at least on some parts of the plot, tree roots have been able to penetrate through the undecomposed *Sphagnum* layer into the underlying well-humified peat. For these reasons, when evaluating the results of the individual experiments, the results from Exp. 1 may be considered the most representative.

When combining the experiments for calculation, it was considered best to combine adjacent experiments to form pairs in order to minimize possible climatic variations. The combined materials of Exps. 1 and 4 produced fairly explicit results of the effects of the investigated variables, whereas the results from the combined material of Exps. 2 and 3 are not introduced at all, since none of the independent variables was significant. This was possibly due to the large depth variation of the poorly decomposed surface peat in Exp. 2. In the combined analyses of all the experiments, the effects of the investigated variables were quite similar to those obtained from the separate analysis of Exp. 1 and combined analysis of Exps. 1 and 4, although even in the combined analyses Exp. 2 obviously increased variation. More unambiguous results would no doubt have been obtained by combining Exps. 1, 3 and 4, but as nothing new came up after some preliminary calculations, the previously introduced grouping of the material sufficed.

42. Growth of seedlings

421. Effect of soil preparation and liming

Soil preparation and mixing of nutrients into the rotavated peat layer invariably improved growth. However, neither soil nor foliar analyses revealed any difference between the rotavated and unrotavated plots six growing seasons after afforestation. Typically, during the first years after planting seedling height growth increases year by year. It seems that the accelerated initial growth brought on by soil preparation has made the seedlings rise to a developmental stage with faster growth, which, without soil preparation, would be characteristic of older seedlings. The situation resembles the fertilization effect illustrated by Miller (1981) in the rising part of the volume growth curve of stands.

Liming severely decreased tree growth if lime was spread on unrotavated peat surface, but less if spread on rotavated peat, and could even slightly improve growth if mixed into the rotavated peat. The foliar nutrient levels indicated that liming in this investigation weakened the nitrogen, phosphorus, potassium, manganese and boron uptake of seedlings. The decrease in foliar potassium, phosphorus and nitrogen levels was clear particularly on unrotavated plots. As nitrogen shortage was obvious only in Exp. 3 but phosphorus and potassium levels were low in all the experiments, one may assume that the growth decline brought on by liming on unprepared plots was mainly caused by decreased phosphorus and potassium uptake of seedlings. In this respect the result deviates somewhat from some previous investigations which have suggested that the growth decline of seedlings on the limed plots is caused by a decrease in available mineral nitrogen (Meshechok 1968 and 1971, Gardiner 1975, Kaunisto & Norlamo 1975). In this investigation the role of boron remains unsolved as all the foliar analyses were carried out after boron application. Liming affected the foliar manganese levels similarly in both the unprepared and prepared plots.

It is more difficult to explain the exceptionally negative effect of liming in Exp. 4 on tree growth. The effect was alleviated to some extent by soil preparation. Excluding nitrogen, both foliage and peat contained less of the investigated nutrients in Exp. 4 than in the other experiments. The ratios of N/Mn, P/Mn and K/Mn were considerably higher in Exp. 4 than in the other experiments, which implies a manganese shortage brought on by liming. On the other hand, a negative correlation between seedling growth and the foliar manganese level was found in the year of inventory.

In Exp. 4 the foliar phosphorus and potassium levels were near or under the deficiency limits reported in literature (see Chapter 32). Liming further decreased the levels of these nutrients in all experiments. Althought there were no clear differences between the experiments in response to liming, it it possible that in Exp. 4 even slight changes in the nutritional balance brought on by liming produced changes in the growth because of the exceptionally poor phosphorus and potassium conditions.

422. *Effect of fertilization and nitrogen status of peat*

Generally trees require phosphorus and potassium fertilization to grow on bogs (see Chapter 1). The present investigation came to the same conclusion. The peat in the experimental areas had only low contents of phosphorus and potassium so that the seedlings even on the fertilized plots had very low foliar phosphorus and potassium levels and showed a strong positive response to PK fertilization.

Because of high costs of nitrogen fertilization, partly due to the price of nitrogen fertilizers and partly to the need for more frequent application (see Chapter 1), it is of great importance for the practical forest fertilization work to be able to define the sites where nitrogen fertilization is unnecessary. In this investigation the nitrogen conditions varied from one experimental area to another and also within the experiments to quite a large extent, thus giving an opportunity to compare the effect of nitrogen fertilization in different peat nitrogen conditions.

Nitrogen application increased tree growth on the average in experimental areas 1, 2 and 3, where the total peat nitrogen was low or average. In experimental area 4 where the average total nitrogen content of peat was considerably higher the nitrogen application in addition to phosphorus and potassium impaired growth. In Table 16 the average total nitrogen values of the present material and some other investigations are compared. The table shows that when the total peat nitrogen is 1.90 %, NPK fertilization has caused a growth decline and if it is 1.10 % or less, growth has improved. When the total peat nitrogen content is about 1.30—1.40 %, no nitrogen fertilization has been needed. It seems that the results in this investigation quite well agree with those found in literature.

In order to more thoroughly examine the role of the nitrogen status of peat as affecting tree growth, the total peat nitro-

Table 16. Effect of NPK fertilization in comparison to PK fertilization on the growth of pine involving various total peat nitrogen contents according to some investigations.

Taulukko 16. NPK-lannoituksen vaikutus männyn kasvuun PK-lannoitukseen verrattuna erilaisten turpeen totaalityppipitoisuuksien yhteydessä eräiden tutkimusten mukaan.

Investigation – Tutkimus	N %	Response — *Vaikutus*
Huikari & Paarlahti 1966	1,38	None—*Ei*
Kaunisto 1971	0,35	+
”	1,10[1]	+
”	1,90	—
Kaunisto 1972	0,63	+
Kaunisto 1979	1,31	None—*Ei*
”	1,87	None—*Ei*
This investigation[2]		
Tämä tutkimus[2]	1,05[1]	+
”	1,12[1]	+
”	0,87	+
”	1,99	—

1) Not statistically significant — *Ei tilastollisesti merkitsevä*
2) Based on the means of the experimental fields — *Koekenttien keskiarvojen perusteella*

gen as well as some other easily measurable or visually determinable chemical and physical characteristics of peat (such as NH_4 nitrogen, degree of humification and pH) were determined and included as regression variables in the analyses of covariance when calculating the dependence of tree growth on liming, soil preparation and fertilization treatments.

The regression variable that best explained growth proved to be the total peat nitrogen in the 5—10 cm layer, but also the other factors, which either by chance (peat depth) or through biological dependence (peat humification and NH_4-N) correlated with the total peat nitrogen, explained fairly well the growth variation of trees. The relationship between peat total nitrogen content and height growth, in the statistically significant cases, was always positive when phosphorus and potassium only had been applied. However, when applying nitrogen with phosphorus and potassium, total peat nitrogen did not correlate or correlated negatively with growth, as happened in Exps. 1 and 4 and in differently grouped materials.

The regression equations calculated separately for PK and NPK fertilized plots for the relationship between tree growth and different variables reflecting nitrogen status in peat made it possible to investigate the necessity of PK and NPK fertilization in different peat nitrogen conditions. The intersections of regression lines for PK and NPK fertilized plots indicate the limit values of the total peat nitrogen content, NH_4 nitrogen content and degree of humification, below which nitrogen fertilization gave a positive growth response and above which nitrogen fertilization was unnecessary or even harmful. The values varied to some extent depending on the grouping of the material. A plausible explanation is that as the experiments were located in different areas, variables other than those measured in the study have influenced the outcome. The results from Exp. 1 are expecially interesting as the total peat nitrogen content varied in a large scale and the values were more evenly distributed than in the other experiments. The critical values of total and NH_4 nitrogen of peat in the 5—10 cm layer in Exp. 1 were 1.15 % and 29 mg/l respectively. The critical value for humification degree (according to v. Post) was 2.7. When placing the critical value of humification in the equation describing the relationship between humification and total nitrogen content, the value of peat nitrogen content 1.16 % was obtained. Thus in Exp. 1 two different ways led to almost the same critical value of total nitrogen, above which nitrogen fertilization was unnecessary. The value of NH_4 nitrogen calculated in the same way was 26 mg/l which is somewhat lower than when calculated with equations between growth and NH_4 nitrogen.

It is obvious that a fairly wide range of the total nitrogen content of peat exists within which the trees can be safely fertilized with nitrogen provided that phosphorus and potassium nutrition is in balance. This is shown by the dependence of the presently obtained critical total nitrogen values on the grouping of material as well as the fairly wide distribution of intersections in Table 13. A similar tendency is seen in the regression equations calculated in the combined analysis of both nutrient combinations of Exps. 1 and 4 and of all the experiments. Both cases resulted in downward parabolas. The maximum points were in a fairly wide range of total nitrogen contents, 1.49 %—1.92 %.

Redundant nitrogen fertilization is an important financial loss. Consequently, much interest is roused by the results that indicate the lowest peat nitrogen contents where nitrogen application is not required. In this respect Exp. 1, especially, brought forth interesting information suggesting that even rather low total nitrogen contents of peat provided pine saplings with enough nitrogen without the application of fertilizer nitrogen.

As stated previously, the total nitrogen content of peat in the 5—10 cm layer explained the growth of seedlings better than any other measured soil characteristic. Although the NH_4 nitrogen of peat was measured from samples collected late in the autumn when the function of mineral nitrogen producing and consuming organisms had slowed down, it still explained with less certainty peat nitrogen status than did the total nitrogen content of peat. However, NH_4 nitrogen, especially in the 15—20 cm layer, explained growth fairly well.

Despite the limited data the degree of humification explained the growth of seedlings almost as well as the total nitrogen content. The introduction of definite limit values, however, is not well-grounded enough because only part of the material was analyzed and also the determination method (according to v. Post) is always somewhat subjective.

This investigation deals with the role of peat nitrogen conditions for growing pine. However, the nitrogen requirements of different tree species vary a great deal. On the basis of fertilization experiments on mineral soils, Viro (1974) pointed out that pine needs less nitrogen than birch, and birch less than spruce. Based on studies on nutrient cycling in pine and birch stands, Mälkönen (1974 and 1977) stated that birch consumes more than twice the amount of nitrogen per produced dry-matter unit as compared to pine. Even more nitrogen is consumed by *Salix aquatilis,* experimented with in energy wood plantations (Pohjonen 1980, see Kaunisto 1982). In the British Isles *Pinus contorta* grows satisfactorily on oligotrophic peat without any fertilization, whereas *Picea sitchensis* requires nitrogen fertilization every third or fourth year to be successful (Dickson & Savill 1974). Thus it is evident that the adequacy of peat nitrogen for biomass production must be defined separately for each tree species.

The consumption of nitrogen increases from the young tree phase up to the growth culmination. Thus the substrate must be able to produce ever increasing amounts of mineral nitrogen to that culmination. On the other hand, peat becomes humified in the course of time after drainage making it possible for the substrate to provide more nitrogen for plants.

Although it is obvious that the amount and need of mineral nitrogen released for trees depends on many factors, the present results suggest that it is possible to measure, with uncomplicated methods, some characteristics which would help to estimate the ability of the substrate to produce enough mineral nitrogen for the stand. By combining the information received from the peat chemical analyses (total N and NH_4-N) and ground vegetation or possibly only the degree of peat humification and ground vegetation, it is possible to estimate the future nitrogen productivity of the substrate. The foliar nitrogen analysis, proved reliable in many other investigations as well (see Chapter 333), reflects the nitrogen conditions at the sampling time.

This investigation illustrates the situation in a climatically restricted area involving only one tree species at the sapling stage. Thus certain caution should be exercised in applying the introduced critical values more generally. Further investigations dealing with different climatic conditions, different developmental stages and other tree species are required.

43. Mortality of seedlings

Several investigations have reported that the application of water soluble nutrients in peat increases seedling mortality (Heikurainen et al. 1966, Paavilainen 1970 a, Kaunisto 1971, Mannerkoski 1971). The results from Exps. 1, 2 and 3 agree with the previous investigations. However, both PK and NPK fertilization drastically decreased the mortality of seedlings in Exp. 4. The reason was probably the peculiar nutritional status in this area. Compared to peat nitrogen the amounts of other nutrients in peat were low. This was also seen in the foliar nutrient levels of unfertilized seedlings. Higher foliar nitrogen but lower phosphorus and potassium levels were found in Exp. 4 than in the other experiments. The phosphorus and potassium levels of unfertilized seedlings were considerably lower than the reported deficiency limits (see Chapter 321). The foliar N/P ratio on the unfertilized plots was a. 21. According to the results from a nitrogen refertilization experiment by Kaunisto & Paavilainen (1977) the mortality of seedlings increased as the N/P ratio rose above 14—16.

According to the results the natural nitrogen of peat and fertilizer nitrogen influenced in different ways the mortality of seedlings. Nitrogen application according to practical recommendations increased mortality, whereas the mortality of seedlings decreased as the amount of natural nitrogen in peat rose (both total N and NH_4-N). The results give reason to assume that fertilization increased the amount of mineral nitrogen to a harmful level only temporarily, since the soil analyses six years after fertilization revealed a negative correlation between the NH_4 nitrogen content of peat and the mortality of seedlings.

44. Number of normal seedlings

Somewhat conflicting results were produced by this investigation about growth disturbances. Several investigations have suggested that the deficiency of one or more micronutrients causes growth disturbances (e.g. Huikari 1974, Veijalainen 1977 and 1980, Raitio 1979). Veijalainen (1981) pointed out that the application of micronutrients would decrease the frequency of growth disturbances and even improve growth. As there are very small amounts of micronutrients in the surface peat layer of bogs (Sillanpää 1975), it is conceivable that the acceleration of growth by applying the main nutrients would intensify the micronutrient demand leading to higher frequencies of growth disturbances.

In this investigation fertilization decreased the foliar zinc levels drastically, but also the foliar boron, manganese and copper levels were in most cases lower on the fertilized than unfertilized plots (see also Paarlahti et al. 1971). Although PK fertilization increased growth in this investigation, it affected in different ways and rather little the frequency of growth disturbances. Nitrogen application with phosphorus and potassium increased the frequency of growth disturbances but only in the experiments where nitrogen had improved growth (Exps. 1, 2 and 3). The importance of nitrogen on the normal, undisturbed development of the stand is emphasized also by Paavilainen (1976 c) and Kaunisto & Paavilainen (1977) who point out the damaging effect of refertilization with nitrogen only, and by Paavilainen (1976) reporting higher frequency of growth disturbances after nitrogen refertilization. In addition, this investigation shows a negative relationship between the number of normal seedlings and foliar nitrogen levels. It seems that the stimulation of seedling growth with nitrogen leads to a higher proportion of abnormal seedlings.

Soil preparation and mixing of fertilizers into rotavated peat increased the number of abnormal seedlings. Soil preparation increases the soil temperature (Kaunisto 1976) simultaneously stimulating the microbial activity, decreases the competition of ground vegetation for nutrients (Kaunisto 1975) and may increase the amount of mineral nitrogen available to plants (Kaunisto 1982). As mentioned in connection with growth, soil preparation did not, however, affect the amount of NH_4 nitrogen in peat, the foliar nitrogen levels or the ratios between nitrogen and the other nutrients statistically significantly at the time of inventory (five years after afforestation). The result implies that the soil preparation no longer actively influenced the nutrient status of soil and the development of the seedlings.

5. SUMMARY

The investigation is based on tour factorial experiments representing different peat nitrogen conditions within a rather restricted geographical area.

According to the results peat NH_4 nitrogen was decreased by liming on the PK fertilized plots and by both PK and NPK fertilization. Peat NH_4 nitrogen had a strong positive correlation with peat total nitrogen and the degree of humification.

The foliar nitrogen levels were lowered by fertilization and liming and were in a positive correlation with peat total and NH_4 nitrogen and the degree of humification on the PK fertilized plots but correlated with peat characteristics only slightly or not at all on the NPK fertilized plots. Fertilization increased, while liming decreased the foliar phosphorus and potassium levels. The micronutrient levels were lowered by fertilization and, exluding zinc, also by liming.

Height growth was increased by soil preparation and fertilization and especially so if the fertilizers were mixed into the rotavated peat layer. Nitrogen application in addition to phosphorus and potassium increased height growth on nitrogen-poor sites (Exps. 1—3) but decreased it on the nitrogen-rich site (Exp. 4).

Height growth improved with increasing peat total and NH_4 nitrogen contents and the degree of humification on the PK fertilized plots, but on the NPK fertilized plots the correlation was negligible or negative. The critical values above which nitrogen fertilization was unnecessary varied somewhat depending on the grouping of the material. The lowest critical values (Exp. 1) were 1.15 % for peat total nitrogen, 29 mg/l for peat NH_4 nitrogen and 2.7 for the degree of humification.

Liming decreased growth severely if the lime was spread over the unrotavated peat surface and slightly if spread over the rotavated peat surface, but increased growth slightly if mixed into the rotavated peat.

Height growth had a strong positive correlation with the foliar nitrogen levels on the PK fertilized plots but only weak positive (Exp. 1) or no correlation (Exps. 2 and 3) or even a negative correlation (Exp. 4) on the NPK fertilized plots. The relationship was parabolic, the foliar nitrogen value for the maximum growth varying between 1.48 % and 1.60 %.

Mortality and the number of abnormal seedlings were higher on the NPK than PK fertilized plots. The number of abnormal seedlings increased with increasing foliar nitrogen levels.

LITERATURE

ADAMS, S.N., COOPER, J.E., DICKSON, D.A., DICSON, E.L. & SEABY, D.A. 1978. Some effects of lime and fertilizer on a Sitka spruce plantation. Forestry, 51(1):57—66.

— & DICKSON, D.A. 1973. Some short-term effects of lime and fertilizers on a Sitka spruce plantation. I. Field studies on the forest litter and the uptake of nutrients by the trees. Forestry, 46(1):31—38.

ARMBERGER, A. 1979. Pflanzenernährung. Stuttgart. p. 237.

ATTERSON, J. & BINNS, W.O. 1968. Peat nutrients and tree requirements in Forestry Commission plantations.

BLACK, C.A. 1968. Soil-plant relationships. New York. 792 p.

BRAEKKE, F.H. 1979. Boron deficiency in forest plantations on peatland in Norway. (Bormangel etter skogreising på torvmark in Norge). Medd. Norsk inst. skogforsk. 35:213—236.

CAJANDER, A.K. 1909. Über Waldtypen. Acta For. Fenn. 1(1):1—175.

— 1913. Studien über die Moore Finnlands. Acta For. Fenn. 2(3):1—208.

DICKSON, D.A. 1971. The Effect of Form, Rate, and Position of Phosphatic Fertilizers on Growth and Nutrient Uptake of Sitka Spruce on Deep Peat. Forestry 44(1):17—26.

— & SAVILL, P.S. 1974. Early Growth of *Picea sitchensis* (Bong.) Carr. on Deep Oligotrophic Peat in Northern Ireland. Forestry 47(1):57—88.

GARDINER, J.J. 1975. The influence of fertilizers upon microbial activity in peat. II. Calcium and nitrogen. Irish For. 32(2): 101—114.

HALONEN, O. & TULKKI, H. 1981. Ravinneanalyysien työohjeet. Metsäntutkimuslaitoksen tiedonantoja 36:1—23.

HEIKURAINEN, L. 1959. Tutkimus metsäojitusalueiden tilasta ja puustosta. Referat: Über waldbaulich entwässerte Flächen und ihre Waldbestände in Finnland. Acta For. Fenn. 69(1):1—244.

— , PÄIVÄNEN, J. & SEPPÄLÄ, K. 1966. Koetuloksia männyn kylvöstä ja istutuksesta ojitetuilla soilla. Summary: Some results of pine seeding and planting on drained peat soils. Silva Fenn. 119(2):1—21.

HUIKARI, O. 1973. Koetuloksia metsäojitettujen soiden lannoituksesta. Summary: Results of fertilization experiments on peatlands drained for forestry. Metsäntutkimuslaitoksen suontutkimusosaston tiedonantoja 1(1973):1—154.

— 1974. Hivenravinteet ja puiden kasvu. Metsä ja puu 91(11):24—25.

— , AITOLAHTI, M., METSÄNHEIMO, U. & VEIJALAINEN, P. 1967. Puuston kasvumahdollisuuksista ojitetuilla soilla Pohjois-Suomessa. Summary: On the potential tree growth on drained peat lands in northern Finland. Commun. Inst. For. Fenn. 64(5):1—51.

— & PAARLAHTI, K. 1966. Kivisuon metsänlannoituskokeet. Kenttäopas. Helsinki. 46 p.

INGESTAD, T. 1958. Studies on manganese deficiency in a forest stand. Medd. Stat. Skogsforsk. 48(4):20 p.

KARSISTO, K. 1974. On the duration of fertilization influence in peatland forests. Int. Symp. Forest Drainage. Proc. 1974 Jyväskylä, Finland. 309—321.

KAUNISTO, S. 1971. Lannoituksen, muokkauksen ja vesipinnan etäisyyden vaikutus kylvötaimien ensi kehitykseen turvealustalla. Kasvihuoneessa suoritettu tutkimus. Summary: Effect of fertilization, soil preparation, and distance of water level on the initial development of Scots pine and Norway spruce seedlings on peat. A study performed in greenhouse. Commun Inst. For. Fenn. 75(2):1—70.

— 1972a. Effect of soil preparation and fertilization on the growth of young pine plantations on peat. Proc. 4th Int. Peat Congr., Helsinki, III:501—508.

— 1972b. Lannoituksen vaikutus istutuksen onnistumiseen ja luonnontaimien määrään rahkanevalla. Tuloksia Kivisuon koekentältä. Summary: Effect of fertilization on succesful planting and the number of naturally born seedlings on a *fuscum* bog at Kivisuo experimental field. Folia For. 139:1—11.

— 1974. On direct seeding of open peatlands. Proc. Int. Symp. Forest Drainage 2nd—6th Sept. 1974. Jyväskylä—Oulu, Finland p. 139—143.

— 1975. Jyrsintämuokkaus ja lannoitus männyn ja kuusen kylvön yhteydessä turvemailla. Kasvihuonekokeita. Summary: Rotavation and fertilization in connection with direct seeding of Scots pine and Norway spruce on peat. Greenhouse experiments. Folia For. 235:1—12.

— 1976. Muokkauksen ja lannoituksen vaikutus turpeen fysikaalisiin ja biologisiin ominaisuuksiin. Parkanon tutkimusaseman tiedonantoja 3(2):1—7.

— 1977. Ojituksen tehokkuuden ja lannoituksen vaikutus männyn viljelytaimistojen kehitykseen karuilla avosoilla. Summary: Effect of drainage intensity and fertilization on the development of pine plantations on oligotrophic *Sphagnum* bogs. Folia For. 317:1—31.

— 1979. Alustavia tuloksia palaturpeen kuivatuskentän ja suonpohjan metsityksestä. Summary: Preliminary results on afforestation of sod peat daying fields and peat cut-over areas. Folia For. 404:1—14.

— 1982. Afforestation of peat cut-away areas in Finland. Proc. Int. Symp. IPS Commissions II and IV, Minsk 1982:144—153.

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

— & PAAVILAINEN, E. 1977. Response of Scots pine plants to nitrogen refertilization on oligotrophic peat. Seloste: Typpijatkolannoituksen vaikutus männyn taimien kehitykseen karulla turve-

alustalla. Commun. Inst. For. Fenn. 92(1):1—54.
KOLARI, K.K. 1979. Hivenravinteiden puute metsäpuilla ja männyn kasvuhäiriöilmiö Suomessa. Kirjalsuuskatsaus. Summary: Micronutrient deficiency in forest trees and dieback of Scots pine in Finland. Folia For. 389:1—37.
KURKI, M. 1972. Suomen peltojen viljavuudesta II. Viljavuuspalvelu Oy:ssä vuosina 1955—1970 tehtyjen viljavuustutkimusten tuloksia. Referat: Über die Fruchtbarkeit des finnischen Ackerbodens auf Grund der in den Jahren 1955—1970 durchgeführten Bodenfruchtbarkeitsuntersuchungen. Helsinki 182 s.
LAINE, J. & MANNERKOSKI, H. 1980. Lannoituksen vaikutus mäntytaimikoiden kasvuun ja hirvituhoihin karuilla ojitetuilla nevoilla. Summary: Effect of fertilization on tree growth and elk damage in young Scots pine stands planted on drained, nutrient-poor open bogs. Acta For. Fenn. 166: 1—45.
LEYTON, L. & ARMSON, K.A. 1955. Mineral composition of the foliage in relation to the growth of Scots pine. Forest Sci. 1:210—218.
MANNERKOSKI, H. 1971. Lannoituksen vaikutus kylvösten ensi kehitykseen turvealustalla. Summary: Effect of fertilization on the development of Scots pine and Norway spruce plantations established by sowing on peat. Silva Fenn. 5:105—128.
— 1978. Avosoiden metsänviljelymenetelmien vertailukoe. Summary: An experiment comparing different afforestation methods in peatlands. Suo 29(2): 25—31.
— & SEPPÄLÄ, K. 1970. Lannoituksen vaikutus istutustaimiston alkukehitykseen lyhytkortisella nevalla. Summary: On the influence of fertilization on the initial development of plantations in open low-sedge bogs. Suo 21(1):12—17.
MESHECHOK, B. 1968. Om startgjodsling ved skogkultur på myr. Medd. Norske Skogforsøksv. 87: 1—140.
— 1971. Kalkning ved skogkultur på nedbørsmyr. Medd. Norske skogforsøksv. 114:241—259.
MILLER, H.G. 1981. Forest fertilization: Some guiding concepts. Forestry 54, (2):157—167.
— & MILLER, J.O. & COOPER, J.M. 1981. Optimum foliar nitrogen concentration in pine and its change with stand age. Can. J. For. Res. 11 (3): 563—572.
MÄLKÖNEN, E. 1974. Annual primary production and nutrient cycle in some Scots pine stands. Seloste: Vuotuinen primäärituotos ja ravinteiden kiertokulku männikössä. Commun. Inst. For. Fenn. 84(5):1—87.
— 1977. Annual primary production and nutrient cycle in a birch stand. Seloste: Vuotuinen primäärituotos ja ravinteiden kiertokulku eräässä koivikossa. Commun. Inst. For. Fenn. 91(5):1—35.
NÖMMIK, H. 1968. Nitrogen mineralization and turnover in Norway spruce (*Picea abies* (L.) Karst.) raw humus as influenced by liming. Trans. 9th Int. Congr. Soil. Sci., Adelaide. 2:533—545.
— & POPOVIC, B. 1971. Recovery and vertical distribution of ^{15}N labelled fertilizer nitrogen in forest soil. Studia For. Suecica 92:1—20.
PAARLAHTI, K., REINIKAINEN, A. & VEIJALAINEN, H. 1971. Nutritional diagnosis of Scots pine stands by needle and peat analysis. Seloste: Maa- ja neulasanalyysi turvemaiden männiköiden ravitsemustilan määrityksestä. Commun. Inst. For. Fenn. 74(5):1—58.
PAAVILAINEN, E. 1970a. Astiakokeita pintalannoituksen vaikutuksesta koivun, kuusen ja männyn kylvön onnistumiseen muokkaamattomalla kasvualustalla. Summary: On the effect of top dress fertilization on succesful seeding of birch, spruce, and pine. Vessel experiments in soil with an untreated surface. Commun. Inst. For. Fenn. 72(1):1—37.
— 1970b. Koetuloksia suopeltojen metsittämisestä. Summary: Experimental results on the afforestation of swampy fields. Folia For. 77:1—24.
— 1974. Studies on the uptake of fertilizer nitrogen by Scots pine using ^{15}N labelled area. Influence of peat thickness and application time. Commun. Inst. For. Fenn. 79(2):1—47.
— 1976a. Taimistojen lannoitus niukkaravinteisilla soilla. Parkanon tutkimusaseman tiedonantoja 3(5): 1—16.
— 1976b. Typpilannoitus ohutturpeisilla piensararämeillä. Summary: Nitrogen fertilization on shallow peated *Carex globularis* pine swamps. Folia For. 272:1—16.
— 1977a. Jatkolannoitus vähäravinteisilla rämeillä. Ennakkotuloksia. Abstract: Refertilization on oligotrophic pine swamps. Preliminary results. Folia For. 327:1—32.
— 1977b. Männyn istutus suopeltojen metsityksessä. Abstract: Planting of Scots pine in afforestation of abandoned swampy fields. Folia For. 326:1—27.
— 1979a. Jatkolannoitus runsastyyppisillä rämeillä. Ennakkotuloksia. Abstract: Refertilization on nitrogen-rich pine swamps. Preliminary results. Folia For. 414:1—23.
— 1980. Effect of fertilization on plant biomass and nutrient cycle on a drained dwarf shrub pine swamp. Seloste: Lannoituksen vaikutus kasvibiomassaan ja ravinteiden kiertoon ojitetulla isovarpuisella rämeellä. Commun. Inst. For. Fenn. 98(5): 1—71.
— 1982. Metsänparannustoimenpiteiden merkitys puuntuotannossa. Kevätmetsäviikko 1982. Metsäviikon avajaisissa ja yleisessä kokouksessa 16.3.1982 pidetyt esitelmät. p. 10—16.
— & SIMPANEN, J. 1975. Tutkimuksia typpilannoituksen tarpeesta Pohjois-Suomen ojitetuilla rämeillä. Summary: Studies concerning the nitrogen fertilization requirements of drained pine swamps in North Finland. Commun. Inst. For. Fenn. 86(4): 1—70.
PENTTILÄ, T. 1980. Neulasanalyysi turvemaan männikön jatkolannoitustarpeen määrityksessä. Metsäntutkimuslaitoksen suontutkimusosaston tiedonantoja 5/1980:1—31.
POHJONEN, V. 1980. Energiapajujen viljelystä vanhoilla turvetuotantoalueilla. Summary: On the energy willow farming on the old peat industry areas. Suo 31(1):7—9.
POST, L. von, 1922. Sveriges geologiska undersöknings torvinventering och några as dess hittills vunna resultat. Sveriges Mosskulturföreningens Tidskr. 1.
PUUSTJÄRVI, V. 1962a. Turpeen typen mobilisoitumisesta ja sen käyttökelpoisuudesta suometsissä neulasanalyysin valossa. Summary: On the mobilization of nitrogen in peat and an its usefulness in peatland forests in the light of needle analysis. Suo 13(1):2—11.

— 1962b. Suometsien fosforiravitsemuksesta ja neulasten P/N-suhteesta neulasanalyysin valossa. Summary: On the phosphorus nutrition of wet peatland forests and on the P/N ratio in their needles. Suo 13(2):21—24.
— 1962c. Suometsien kaliumravitsemuksesta ja neulasten N/K-suhteesta neulasanalyysin valossa. Summary: On the potassium nutrition of wet peatland forests and on the N/K ratio of the needles in the light of needle analysis. Suo 13(3):36—40.
PÄIVÄNEN, J. 1970. Hajalannoituksen vaikutus lyhytkortisen nevan pintakasvillisuuden kenttäkerrokseen. Summary: On the influence of broadcast fertilization on the field layer of the vegetation of open low-sedge bog. Suo 21(1):18—24.
RAITIO, H. 1978. Pääravinnelannoituksen vaikutus männyn neulasten rakenteeseen ja ravinnepitoisuuksiin ojitetulla karulla avosuolla. Parkanon tutkimusaseman tiedonantoja 7(5):1—9.
— 1979. Boorin puutteesta aiheutuva männyn kasvuhäiriö metsitetyllä suopellolla. Oireiden kuvaus ja tulkinta. Abstract: Growth disturbances of Scots pine caused by boron deficiency on an afforested abandoned peatland field. Description and interpretation of symptoms. Folia For. 412:1—16.
— 1981. Pääravinnelannoituksen vaikutus männyn neulasten rakenteeseen ja ravinnepitoisuuksiin ojitetulla lyhytkorsinevalla. Summary: Effect of macronutrient fertilization on the structure and nutrient content of pine needles on a drained short sedge bog. Folia For. 456:1—9.
SEPPÄLÄ, K. 1968. Välituloksia ojitettujen soiden viljelykokeista. Summary: Results of seeding and planting experiments on peatland. Suo 19(2): 30—28.
— 1969. Kuusen ja männyn kasvun kehitys ojitetuilla turvemailla. Summary: Post-drainage growth rate of Norway spruce and Scots pine on peat. Acta For. Fenn. 93:1—88.
— 1971. Metsityslannoituksessa käytetyn lannoitemäärän ja levitystavan merkitys istutustaimien alkukehitykselle ojitetuilla avosoilla. Summary: On the quantity of fertilizer and application methods used in afforestation of open bogs. Silva Fenn. 5:61—69.
SILLANPÄÄ, M. 1975. Hivenaineet suoprofiilissa. Summary: Distribution of trace elements in peat profiles. Suo 26(5):83—86.
STEINBECK, K. 1966. Site, height and mineral nutrient content relations of Scots pine provenances. Silva Genetica 15:33—60.
VAHTERA, E. 1955. Metsänkasvatusta varten ojitettujen soitten ravinnepitoisuuksista. Referat: Über Nährstoffgehalte der für Walderziehung entwässerten Moore. Commun. Inst. For. Fenn. 45(4): 1—108.
VALMARI, A. 1956. Über die edaphische Bonität von Mooren Nordfinlands. Acta Agr. Fenn. 88(1): 1—126.
WEHRMANN, J. 1959. Die Mineralstoffernährung von Kiefernbeständen (*Pinus silvestris*) in Bayern. Forstw. Cbl. 78(516):129—149.
VEIJALAINEN, H. 1975. Kasvuhäiriöistä ja niiden syistä metsäojitusalueilla. Summary: Dieback and fertilization on drained peatlands. Suo 26(5): 87—92.
— 1977. Use of needle analysis for diagnosing micronutrient deficiensies of Scots pine on drained peatlands. Seloste: Neulasanalyysi männyn mikroravinnetilanteen määrityksessä turvemailla. Commun. Inst. For. Fenn. 92(4):1—32.
— 1980. Eräiden hivenlannoitteiden käyttökelpoisuus suometsien lannoituksessa. Neulasanalyysiin perustuva tarkastelu. Summary: Usability of some micronutrient fertilizers in peatland forests. Report basing on needle analysis. Folia For. 443:1—15.
— 1981. Hivenlannoituksen vaikutus istutusmännikön kehitykseen turvemaalla. Summary: Long-term responses of Scots pine to micronutrient fertilization on acid peat soil. Folia For. 477:1—15.
WESTMANN, C.J. 1981. Fertility of surface peat in relation to the site type and potential stand growth. Seloste: Pintaturpeen viljavuustunnukset suhteessa kasvupaikkatyyppiin ja puuston kasvupotentiaaliin. Acta For. Fenn. 172:1—77.
VIRO, P.J. 1974. Fertilization of birch. Seloste: Koivun lannoitus. Commun. Inst. For. Fenn. 81(4): 1—38.
WITTICH, W. 1957. Stand und Aussichten der forstlichen Düngung. Die Phosphorsäure, 17: 42—49.
VLASSAK, K. 1970. Total soil nitrogen and nitrogen mineralization. Plant and Soil 32(1):27—32.
ZEHETMAYER, J.W.L. 1954. Experiments in tree planting peat. For. Comm. Bull. 22:1—110.
ØDELIEN, M. & JERVEN, O. 1968. Gjødslingsforsøk in skogplantefelter på myr. Tidskr. Skogbr. 76(3):249—272.
— & JERVEN, O. 1971. Gjødslingsforsøk i skogplantefelter på myr. Naeringshusholding — vekst. Tidskr. Skogbr. 79(2):203—213.

SELOSTE

Männyn istutustaimien kehityksen riippuvuus eräistä turpeen ominaisuuksista sekä lannoituksesta, muokkauksesta ja kalkituksesta ojitetuilla avosoilla.

Tutkimuksessa tarkastellaan lannoituksen, muokkauksen, kalkituksen sekä eräiden turpeen ominaisuuksien (totaali-N, NH_4-N, pH, maatuneisuus ja turvekerroksen paksuus) vaikutusta männyn taimien kasvuun ja neulasten ravinnetilaan neljällä ravinteisuudeltaan erilaisille avosoille vuonna 1973 perustetulla koekentällä. Koekenttien ominaisuuksia on kuvattu taulukoissa 1—3. Tutkimussuunnitelmakaavio on esitetty taulukossa 4.

Turpeen ammoniumtypen määrä oli positiivisessa korrelaatiossa turpeen totaalityppipitoisuuden kanssa (liitetaulukko 1, kuva 1, taulukko 10). Turpeen totaali- ja NH_4-typpipitoisuuden sekä maatuneisuuden välillä oli kiinteä korrelaatio (taulukko 5, kuva 2). Lannoitus vähensi NH_4-typen määrää turpeessa ravinneyhdistelmästä riippumatta, mutta ei vaikuttanut turpeen pH:hon. Kalkitus kohotti turpeen pH:ta 0—5 ja 5—10 cm:n kerroksessa (taulukko 7) ja vähensi NH_4-N-typen määrää jonkin verran enemmän PK- kuin NPK-lannoitetuilla koealoilla (taulukko 8). Muokkaus ei vaikuttanut NH_4-typen määrään tai pH:hon.

Lannoitus alensi typpi-, kalsium-, kupari-, sinkki-, boori- ja mangaanipitoisuuksia ja lisäsi fosfori- ja kaliumpitoisuuksia neulasissa (kuvat 3 ja 4, liitetaulukko 2). Kalkitus alensi typpi-, kupari-, boori-, kalium-, fosfori- ja mangaanipitoisuuksia ja kohotti kalsium- ja sinkkipitoisuuksia neulasissa (kuva 5, liitetaulukko 3).

PK-lannoitukseen verrattuna NPK-lannoitus kohotti neulasten typen ja muiden ravinteiden välisiä suhteita. Samoin kohosivat suhteiden Ca/Mn ja P/Mn arvot. Sen sijaan suhteet K/Cu, K/Zn, P/Cu, Ca/Cu, Mn/Cu ja Mn/Zn aleni (kuva 6, liitetaulukko 3). Kalkitus kohotti keskimäärin suhteiden N/K, N/P, N/Mn, P/Mn, K/Mn, Ca/P ja Ca/Mn arvoja ja alensi suhteiden K/Ca, K/Cu, K/Zn, B/Zn, B/Cu, Mn/Cu ja Mn/Zn arvoja (kuva 7, liitetaulukko 3). Muokkaus pienensi suhteiden N/Mn, P/Mn, K/Mn, Ca/Mn, Cu/Mn ja Zn/Mn arvoja (taulukko 11).

PK-lannoitetuissa koejäsenissä neulasten typpipitoisuus korreloi kiinteimmin positiivisesti turpeen totaalityppipitoisuuden kanssa, mutta myös turpeen ammoniumtyppipitoisuuden ja maatuneisuuden kanssa (liitetaulukko 5). NPK-lannoitetuissa koejäsenissä neulasten typpipitoisuus ei korreloinut minkään maasta mitatun muuttujan kanssa.

Taimien kasvu korreloi yleensä positiivisesti turpeen totaalityppipitoisuuden, NH_4-typpipitoisuuden, maatuneisuuden ja pH:n kanssa PK-lannoitetuilla koealoilla, mutta negatiivisesti näiden muuttujien kanssa NPK-lannoitetuilla koealoilla (kuvat 8—14, liitetaulukot 6—14). Riippuvuus oli suoraviivainen. Parhaiten kasvua selitti turpeen totaalityppipitoisuus 5—10 cm:n kerroksessa. PK- ja NPK-lannoitetuille koejäsenille laskettujen suorien yhtälöiden perusteella laskettiin em. suorien leikkauspisteet, jotta saataisiin selville ne turpeen ominaisuuksien raja-arvot, joita suuremmilla arvoilla typpilannoitus fosfori- ja kaliumlannoituksen ohella oli tarpeeton. Raja-arvot vaihtelivat jonkin verran (taulukot 12 ja 13). Kokeella 1 raja-arvot olivat matalimmat: turpeen totaalitypelle 1,15 %:a, turpeen ammoniumtypelle 29 mg/l ja turpeen maatuneisuudelle 2,7 5 — 10 cm:n turvekerroksessa. Tulos näyttää viittaavan siihen, että ainakin joissakin tapauksissa typen mineralisoituminen taimien kannalta on riittävää, jos turpeen totaalityppipitoisuus 5—10 cm:n kerroksessa on n. 1,15 %:a. Koko aineistosta laskettu raja-arvo oli jonkin verran korkeampi (taulukko 12).

Lannoitus lisäsi taimien kasvua kaikissa kokeissa (kuva 15—16, liitetaulukot 16 ja 17). Typen lisäys fosforin ja kaliumin ohella lisäsi kasvua vähätyppisimmillä kokeilla (1, 2 ja 3), mutta vähensi kasvua runsastyppisemmällä koealueella (koe 4). Koealueilla 1—3 turpeen keskimääräinen totaalityppipitoisuus vaihteli 0,87 % — 1,12 % ja kokeella 4 turpeen keskimääräinen totaalityppipitoisuus oli 1,99 %:a.

Muokkaamattomaan suonpintaan levitettynä kalkitus vähensi taimien kasvua, mutta lisäsi sitä keskimäärin jonkin verran muokattuun turvekerrokseen sekoitettaessa (kuva 16, liitataulukko 18). Kalkituksen positiivinen vaikutus oli voimakkain vähätyppisimmällä (koe 3) ja toisaalta negatiivinen vaikutus runsastyppisimmällä (koe 4) koealueella. Viimemainitulla koealueella kalkitus huononsi aina taimien kasvua.

Muokkaus lisäsi taimien kasvua kaikissa olosuhteissa (kuva 17, liitetaulukko 18). Erityisesti ravinteiden sekoittaminen muokattuun turvekerrokseen edisti taimien kasvua.

Erikseen PK- ja NPK-lannoitetuille koejäsenille lasketut neulasten typpipitoisuuden ja kasvun väliset yhtälöt olivat suoria. Taimien kasvu parani neulasten typpipitoisuuden kohotessa enemmän PK- kuin NPK-lannoitetuilla koealoilla (liitetaulukko 19). PK- ja NPK-lannoitetuille koejäsenille laskettujen suorien leikkauspisteet vaihtelivat välillä 1,47 % — 1,67 %:a. NPK-lannoitetuilla vaikutus saattoi olla jopa negatiivinen. Kummatkin ravinneyhdistelmät sisältävissä kovarianssianalyyseissä osoittautuivat neulasten typpipitoisuuden ja kasvun väliset regressioyhtälöt alaspäin aukeaviksi parabeleiksi, joiden maksimi eri tapauksissa vaihteli välillä 1,47 % — 1,60 % (liitetaulukko 20, kuva 18). Yllämainittuja arvoja alemmilla neulasten typpipitoisuuksilla voidaan olettaa saatavan typpilannoituksella aikaan (fosforin ja kaliumin ohella annettuna) taimien kasvun lisäystä. Muut ravinteet tai ravinteiden suhteet eivät selittäneet taimien kasvua tilastollisesti merkitsevästi PK-lannoitetuilla koealoilla. Sen sijaan NPK-lannoitetuilla koealoilla kasvu oli positiivisessa korrelaatiossa suhteiden N/P, N/K, P/B ja K/Zn kanssa (liitetaulukot 21 ja 22). Sekä NPK-lannoitetuilla koealoilla että koko aineistossa inventointivuoden kasvu (1978) korreloi positiivisesti kaikkien muiden ravinteiden ja mangaanin välisen suhteen kanssa.

Kuolleisuus lisääntyi jonkin verran lisättäessä typpeä fosforin ja kaliumin ohella (kuva 19). Toisaalta kuolleisuus väheni turpeen ammoniumtyppipitoisuuden lisääntyessä (liitetaulukko 23).

NPK-lannoitus PK-lannoitukseen verrattuna lisäsi epänormaalien taimien määrää koealueilla 1, 2 ja 3 (taulukko 14). Muokkaus lisäsi epänormaalien taimien määrää (taulukko 15), mutta kalkitus vähensi sitä.

Turpeen pH:n ja normaalien taimien määrän välinen yhtälö oli ylöspäin aukeava parabeli (kuva 20), jonka minimi oli pH 4,2:ssa. Muut turpeesta mitatut suureet eivät vaikuttaneet normaalien taimien määrään. Epänormaalien taimien määrä lisääntyi neulasten typpipitoisuuden kohotessa (kuva 21).

KAUNISTO, S. 1982. Development of pine plantations on drained bogs as affected by some peat properties, fertilization, soil preparation and liming. Seloste: Männyn istutustaimien kehityksen riippuvuus eräistä turpeen ominaisuuksista sekä lannoituksesta, muokkauksesta ja kalkituksesta ojitetuilla avosoilla. Commun. Inst. For. Fenn. 109: 1—56.

Appendix 1. Dependence of peat NH_4 nitrogen on the total nitrogen content, pH and decomposition degree of peat. Equations calculated by the analysis of covariance. Coefficients of determination include also the effect of class variables.

Liitetaulukko 1. Turpeen NH_4-typen riippuvuus turpeen totaalityppipitoisuudesta, pH:sta ja maatuneisuudesta. Yhtälöt on laskettu kovarianssianalyysillä. Selitysasteet sisältävät myös luokkamuuttujien vaikutukset.

Experiment *Koe*	Indep. var. *Selittävä muuttuja*	Equation (5—10 cm) *Yhtälö*	F	Coeff. of. determ., % *Selitysaste, %*	Equation (15—20 cm) *Yhtälö*	F	Coeff. of determ. *Selitysaste, %*
1	Tot N 5—10	y = 28,92x — 8,65	48,48***	57,9	y = 19,27x + 4,20	24,71***	46,8
	Tot N 15—20	y = 17,05x — 1,62	7,42**	18,9	y = 18,34x — 1,01	16,39***	38,5
	pH_{5-10}	y = —0,11x + 20,19	0,08	8,0	y = —0,69x + 24,88	0,01	21,4
	pH_{15-20}	y = 22,88x — 66,34	3,11	23,1	y = 9,33x — 13,06	0,96	25,8
	Humific. 5—10	y = 9,226x + 0,40	18,45***	35,0	y = 5,78x + 11,04	9,70**	29,7
	Maatun. 15—20	y = 7,204x + 0,25	5,65*	15,5	y = 8,64x — 0,67	16,09***	31,2
2	Tot N 5—10	y = 21,64x + 0,73	8,55**	26,6	y = 33,25x — 5,58	29,96***	43,1
	Tot N 15—20	y = 9,29x + 9,09	3,18	18,0	y = 28,13x — 15,08	84,28***	67,4
	pH_{5-10}	y = 0,21x + 21,05	0,04	14,5	y = —0,22x + 26,85	0,41	21,3
	pH_{15-20}	y = 0,14x + 22,8	0,18	24,7	y = —0,29x + 25,90	0,32	20,4
	Humific. 5—10	y = 8,77x + 4,52	9,51**	27,9	y = 13,61x — 0,04	36,20***	47,6
	Maatun. 15—20	y = 3,09x + 14,05	3,18	18,5	y = 8,60x + 2,42	54,55***	57,4
3	Tot N 5—10	y = 31,06x — 10,30	21,30***	64,7	y = 23,25x — 4,28	6,28	54,3
	Tot N 10—20	y = 20,21x — 5,01	10,51**	51,0	y = 16,13x + 4,00	4,00	50,7
	pH 5—10	y = —12,82x + 62,03	0,21	23,3	y = 3,03x — 9,55	0,02	38,5
	pH 10—20	y = 12,63x — 28,70	0,76	4,8	y = 24,21x — 64,78	2,84	36,2
4	Tot N 5—10	y = 36,58x — 12,38	9,75**	51,6	y = 45,80x + 1,70	6,07*	52,0
	Tot N 15—20	y = 30,98x — 10,19	4,00	42,4	y = 22,99x + 36,33	0,88	41,6
	pH 5—10	y = 10,54x + 6,02	0,37	39,5	y = —10,78x + 130,08	0,17	40,4
	pH 15—20	y = 34,97x — 100,97	6,65*	47,8	y = 81,12x — 272,83	21,28***	65,4

Appendix 2. Effect of liming, soil preparation and fertilization on the foliar nitrogen levels, F values and statistical significance. Only PK and NPK fertilized plots included.

Liitetaulukko 2. Kalkituksen, muokkauksen ja lannoituksen vaikutus neulasten typpipitoisuuteen. F-arvot ja tilastollinen merkitsevyys. Mukana vain PK- ja NPK-lannoitetut koejäsenet.

Source of variation *Vaihtelun lähde*	F in experiment — F kokeessa 1[1)]	2	3	4[1)]	1—4[1)]
1 = Liming — *Kalkitus*	1,70	0,18	0,24	8,51*	6,88**
2 = Soil prep. — *Muokkaus*	0,24	3,37*	0,99	3,28	0,38
3 = Fertilization — *Lannoitus*	3,38	0,05	0,34	0,06	1,24
1 × 2	0,14	0,58	1,58	5,00*	0,39
1 × 3	0,08	0,31	0,32	6,68*	0,00
2 × 3	0,76	1,12	1,26	3,25	0,34

[1)] Analysis of covariance, corrected to regression in relation to total nitrogen content of peat at 5—10 cm.
[1)] Kovarianssianalyysi, kovarianssikorjaus turpeen totaalityppipitoisuuden suhteen 5-10 cm:n turvekerroksessa.

Appendix 3. F values and significances of class variables calculated for the different nutrients and nutrient ratios of needles. Calculations include only the PK and NPK fertilized plots.

Liitetaulukko 3. Neulasista analysoiduille ravinteille ja ravinnesuhteille lasketut luokkamuuttujien F-arvot ja merkitsevyydet. Laskennassa mukana vain PK- ja NPK-lannoitetut koejäsenet.

Source of variation *Vaihtelun lähde*	Element — *Alkuaine* N	P	K	Zn	Mn	Cu	B	Ca
1 = Experiment — *Koe*	13,75***	2,92	9,73***	15,04***	23,09***	6,02**	17,12***	28,95***
2 = Liming — *Kalkitus*	6,88**	0,41	16,80**	5,92*	8,44**	0,86	8,09**	3,83
3 = Soil prep. — *Maanvalm.*	0,38	0,33	0,61	0,01	2,89	0,60	1,89	0,96
4 = Fertilization — *Lannoitus*	1,24	1,81	2,83	0,16	5,79*	5,09*	0,02	0,48
Inter.-Yhdysv. 1 × 2	2,53	0,24	2,78	2,23	1,54	0,31	2,59	5,29**
" 1 × 3	1,53	1,02	1,49	1,12	1,37	0,37	2,43	0,20
" 1 × 4	1,65	0,53	8,72***	0,54	1,76	0,04	0,50	3,60*
" 2 × 3	0,39	4,90*	3,54*	4,14*	1,32	0,47	0,10	1,35
" 2 × 4	0,00	0,03	0,08	0,52	0,21	0,46	0,01	1,63
" 3 × 4	0,34	0,60	0,09	0,60	0,79	2,17	4,22*	1,84
Coefficient of determination — *Selitysaste, %*	93,7	56,3	80,8	78,3	84,0	61,7	82,0	85,7

	N/P	N/K	N/Ca	N/B	N/Cu	N/Zn	N/Mn	P/K	P/Ca	P/B	P/Cu	P/Zn	P/Mn	K/Ca
1 = Experiment — *Koe*	19,42***	51,04***	87,51***	22,44***	22,56***	59,78***	140,07***	0,77	4,91**	7,57**	2,21	1,92	36,55***	4,03*
2 = Liming — *Kalkitus*	0,02	5,72*	1,87	4,87*	0,78	3,11	13,85**	3,03	1,82	4,47*	1,94	2,32	8,08**	12,65**
3 = Soil prep. — *Muokkaus*	0,03	0,53	1,16	0,74	0,63	0,31	7,18**	0,22	0,54	0,75	0,75	0,24	3,77*	0,19
4 = Fertilization — *Lannoitus*	5,85*	13,14**	4,50*	0,27	0,33	1,81	19,51***	0,00	0,51	0,11	8,08**	1,13	3,94	1,04
Inter.-Yhdysv. 1 × 2	0,93	4,39*	2,68	1,55	0,85	0,83	1,16	0,52	2,01	1,22	0,38	0,97	1,13	4,52*
" 1 × 3	0,29	0,94	0,25	1,24	0,20	0,57	1,78	0,35	0,40	1,11	0,56	0,55	0,87	0,48
" 1 × 4	1,89	6,82**	11,04***	1,64	1,95	5,29**	3,74*	1,66	1,96	1,35	0,49	0,49	0,60	8,17***
" 2 × 3	1,74	0,52	1,85	1,18	1,09	3,71*	0,50	0,66	5,02*	1,77	4,45*	6,08**	1,02	4,01*
" 2 × 4	0,01	0,06	0,49	0,18	0,26	0,03	0,00	0,16	0,14	0,18	0,13	0,04	0,04	1,63
" 3 × 4	1,05	0,24	2,91	1,72	1,48	0,13	0,10	0,52	0,42	1,60	3,52*	0,95	0,03	1,14
Coefficient of determination — *Selitysaste, %*	78,7	90,6	94,0	82,6	80,44	91,2	95,5	44,6	67,5	70,5	65,6	60,2	85,9	78,8

	K/B	K/Cu	K/Zn	K/Mn	Ca/B	Ca/Cu	Ca/Zn	Ca/Mn	B/Cu	B/Zn	B/Mn	Cu/Zn	Cu/Mn	Zn/Mn
1 = Experiment — *Koe*	6,68**	1,88	1,75	47,44***	8,14***	1,11	0,87	34,65***	17,78***	10,03***	6,06**	0,29	27,26***	46,36***
2 = Liming — *Kalkitus*	2,39	10,10**	19,92***	7,59*	12,63**	0,04	0,18	21,14***	12,84**	10,89**	0,83	0,19	11,86**	24,46***
3 = Soil prep. — *Muokkaus*	1,19	0,17	0,18	4,83*	1,26	0,03	0,33	5,53*	1,55	1,30	3,80*	0,25	2,73	5,82**
4 = Fertilization — *Lannoitus*	0,26	10,56**	3,32	3,67	0,06	4,55*	0,39	8,83**	1,42	0,01	4,15*	2,49	11,31*	12,45**
Inter.-Yhdysv. 1 × 2	1,69	0,84	5,12**	2,21	0,94	0,76	1,40	4,04*	2,17	1,97	2,35	0,65	1,61	3,35*
" 1 × 3	1,14	0,71	1,31	1,61	2,11	0,20	0,75	2,02	2,76	2,02	2,21	0,50	0,94	1,51
" 1 × 4	3,84*	4,01*	5,28**	0,35	1,27	0,70	1,19	1,64	0,56	0,60	1,30	0,19	1,31	1,49
" 2 × 3	1,56	2,86	7,84**	0,84	0,42	0,33	0,54	1,99	0,03	0,49	0,56	0,87	1,63	2,53
" 2 × 4	0,08	0,65	0,36	0,00	0,60	0,06	0,06	0,01	0,60	0,31	0,17	0,03	0,00	0,02
" 3 × 4	2,19	2,65	0,66	0,07	4,85*	2,12	1,92	0,56	7,99**	3,35	0,78	0,73	0,73	0,22
Coefficient of determination — *Selitysaste, %*	—72,7	72,5	80,1	88,9	80,9	46,2	49,5	88,1	84,1	77,1	70,0	37,7	84,6	90,0

Appendix 4. Average needle nutrient ratios in different experiments.
Liitetaulukko 4. Neulasten keskimääräiset ravinnesuhteet eri kokeissa lannoitetuille koealoille.

Dividend *Jaettava*	Experiment *Koe*	Nutient ratio — *Ravinnesuhde* Divider — *Jakaja* P	K	Ca	B	Cu	Zn	Mn
N	1	10,5	3,34	5,0	186	3485	243	33
	2	9,8	3,30	4,9	248	3380	243	38
	3	9,1	3,00	4,1	215	2215	204	37
	4	13,1	4,52	7,0	367	4586	334	99
P	1		0,32	0,5	18	336	24	3,2
	2		0,34	0,5	25	346	25	4,0
	3		0,33	0,5	24	312	23	4,1
	4		0,34	0,5	28	353	26	7,6
K	1	3,1		1,5	55	1048	73	9,9
	2	2,9		1,5	75	1028	74	11,7
	3	3,0		1,4	72	950	69	12,4
	4	2,9		1,6	83	1033	75	22,0
Ca	1	2,0			38	716	50	6,6
	2	2,0			51	685	49	7,3
	3	2,0			53	700	50	9,4
	4	2,0			52	650	48	14,1
B	1					20,2	1,4	0,19
	2					14,3	1,0	0,17
	3					13,7	1,0	0,19
	4					12,9	0,9	0,28
Cu	1						0,07	0,0137
	2						0,07	0,0139
	3						0,07	0,0141
	4						0,07	0,0149
Zn	1					14,3		0,137
	2					14,3		0,160
	3					14,3		0,184
	4					14,3		0,296
Mn	1				5,3	73	7,3	
	2				5,9	72	6,3	
	3				5,3	71	5,4	
	4				3,6	67	3,38	

Appendix 5. Regression equations between the foliar nitrogen percentage of seedlings and peat characteristics calculated by the analysis of covariance, F values of regression coefficients and the coefficients of determination in different experiments. The coefficients of determination include also the effect of class variables.

Liitetaulukko 5. Kovarianssianalyysillä lasketut taimien neulasten typpipitoisuuden ja turpeen ominaisuuksien väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet eri kokeissa. Selitysaste sisältää myös luokkamuuttujien vaikutukset.

Exp. *Koe*	Independ. var. *Selittävä muuttuja*	PK-fertilization — *PK-lannoitus* Equation *Yhtälö*	F	Coeff. of. determ., % *Sel., %*	NPK-fertilization — *NPK-lannoitus* Equation *Yhtälö*	F	Coeff. of determ., % *Sel., %*
1	NH_4 5-10 cm	y = 0,006x + 1,25	9,62**	49,4	y = 0,004x + 1,42	1,04	24,3
	NH_4 15-20 cm	y = 0,008x + 1,19	6,99*	43,5	y = 0,001x + 1,47	0,07	18,2
	Tot N 5-10 cm	y = 0,256x + 1,15	8,63**	47,3	y = 0,114x + 1,38	0,69	22,4
	Tot N 15-20 cm	y = 0,304x + 1,00	10,34**	50,7	y = —0,091x + 1,62	0,36	20,2
	pH 5-10 cm	y = —0,074x + 1,68	0,47	30,2	y = 0,125x + 1,01	0,60	21,7
	pH 15-20 cm	y = 0,115x + 1,00	0,45	31,2	y = 0,378x + 0,06	1,08	24,5
	Humific.-Maatun. 5-10 cm	y = 0,104x + 1,16	7,79*	45,4	y = 0,103x + 1,27	4,58	40,6
	Humific.-Maatun. 15-20 cm	y = 0,010x + 1,12	3,83	34,5	y = 0,009x + 1,53	0,02	17,8
2	NH_4 5-10 cm	y = —0,001x + 1,35	0,12	2,4	y = —0,0036x + 1,42	4,83*	45,5
	NH_4 15-20 cm	y = —0,001x + 1,37	0,45	11,1	y = —0,0021x + 1,40	2,72	39,5
	Tot N 5-10 cm	y = 0,007x + 1,34	0,01	5,4	y = —0,026x + 1,37	0,11	30,1
	Tot N 15-20 cm	y = —0,017x + 1,37	0,20	9,9	y = —0,083x + 1,47	2,56	38,9
	pH 5-10 cm	y = 0,068x + 1,08	0,72	12,5	y = 0,086x + 1,01	0,42	31,2
	pH 15-20 cm	y = 0,075x + 1,06	0,50	11,4	y = 0,210x + 0,54	3,41	41,4
	Humific.-Maatun. 5-10 cm	y = —0,020x + 1,39	0,73	12,8	y = —0,039x + 1,42	1,52	35,7
	Humific.-Maatun. 15-20 cm	y = —0,013x + 1,39	0,93	13,3	y = —0,012x + 1,39	0,49	31,6
3	NH_4 5-10 cm	y = 0,004x + 1,32	2,28	39,8	y = 0,003x + 1,23	0,63	41,7
	NH_4 15-20 cm	y = —0,002x + 1,32	0,94	31,8	y = —0,001x + 1,30	0,07	36,3
	Tot N 5-10 cm	y = —0,198x + 1,43	0,19	37,4	y = —0,066x + 1,34	0,19	39,0
	Tot N 15—20 cm	y = —0,127x + 1,40	3,90	44,9	y = —0,035x + 1,32	0,04	38,9
	pH 5-10 cm	y = —0,394x + 2,69	3,08	43,0	y = 3,03x — 9,55	0,02	36,4
	pH 15-20 cm	y = 12,69x — 28,70	0,76	31,9	y = 0,367x — 0,01	0,53	35,6
4	NH_4 5-10 cm	y = 0,004x + 1,35	1,46	57,6	y = 0,002x + 1,47	1,93	62,7
	NH_4 15-20 cm	y = 0,004x + 1,26	3,38	67,4	y = 0,001x + 1,51	1,43	58,0
	Tot N 5-10 cm	y = 0,389x + 0,84	11,15*	82,9	y = 0,121x + 1,33	9,29*	83,3
	Tot N 15-20 cm	y = 0,050x + 1,46	0,46	45,4	y = 0,099x + 1,39	0,13	46,5
	pH 5-10 cm	y = —0,710x + 4,56	5,96	75,0	y = 0,149x + 0,94	2,56	64,4
	pH 15-20 cm	y = 0,38x — 0,01	8,55*	78,1	y = 0,104x + 1,16	0,65	55,5
1+2	NH_4 5-10 cm	y = 0,0023x + 1,32	5,39*	52,8	y = —0,0001x + 1,43	0,01	62,0
+3+4	NH_4 15-20 cm	y = 0,0026x + 1,29	5,94*	53,2	y = 0,0001x + 1,42	0,01	62,0
	Tot N 5-10 cm	y = 0,188x + 1,17	16,56***	60,2	y = 0,049x + 1,36	1,23	62,4
	Tot N 15-20 cm	y = 0,079x + 1,27	3,89	51,5	y = —0,088x + 1,56	3,62	64,7
	pH 5-10 cm	y = —0,073x + 1,67	1,33	45,5	y = 0,104x + 1,02	2,29	61,1
	pH 15-20 cm	y = 0,211x + 0,59	9,11**	55,5	y = 0,017x + 1,17	2,83	64,1

Appendix 6. Regression equation between seedling growth and the total nitrogen content of peat calculated by the analysis of covariance, F values of regression coefficients and the coefficients of determination in different experiments. The coefficients of determination include also the effect of class variables.

Liitetaulukko 6. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen totaalityppipitoisuuden väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet eri kokeissa. Selitysaste sisältää myös luokkamuuttujien vaikutukset.

Experiment *Koe*	Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1	5—10	Height						
		Pituus -78	y = 28,53x + 42,65	19,38***	67,8	y = —13,27x + 90,79	3,16	55,5
		Growth -74	y = 4,97x + 5,91	4,99*	48,9	y = —3,33x + 12,42	3,38	48,5
		Kasvu -75	y = 4,23x + 5,59	8,86**	57,6	y = —1,80x + 12,52	1,34	57,3
		-76	y = 4,36x + 6,94	7,93*	59,2	y = —1,52x + 13,41	0,84	33,9
		-77	y = 16,17x + 4,54	5,65*	49,6	y = —5,92x + 25,72	2,49	51,0
		-78	y = 10,30x + 7,31	16,60***	59,2	y = —2,74x + 22,32	1,16	56,0
	15—20	Height						
		Pituus -78	y = 26,68x + 35,30	9,82*	55,8	y = 0,10x + 74,88	0,00	43,8
		Growth -74	y = 0,81x + 6,68	0,53	35,1	y = 0,01x + 8,75	0,00	34,0
		Kasvu -75	y = 3,79x + 4,71	4,71*	49,0	y = 1,94x + 7,98	1,29	57,2
		-76	y = 3,88x + 6,07	4,21	51,7	y = 0,20x + 11,47	0,01	29,3
		-77	y = 18,10x — 3,32	5,60*	49,5	y = —4,79x + 25,53	1,24	46,4
		-78	y = 11,03x + 2,93	13,80**	55,4	y = —1,32x + 21,05	0,21	52,6
2	5—10	Height						
		Pituus -78	y = —10,34x + 100,86	1,52	49,2	y = 1,03x + 92,39	0,02	45,9
		Growth -74	y = —2,56x + 14,14	1,85	25,2	y = 1,45x + 12,07	0,46	32,4
		Kasvu -75	y = —1,22x + 13,61	0,74	36,0	y = 1,85x + 10,89	0,69	28,2
		-76	y = —0,66x + 15,59	0,15	56,9	y = 0,70x + 14,95	0,17	47,2
		-77	y = —4,52x + 23,50	4,78*	58,1	y = —0,96x + 20,29	0,22	43,9
		-78	y = —3,88x + 23,10	3,79	49,8	y = —0,63x + 20,18	0,48	44,6
	15—20	Height						
		Pituus -78	y = —1,82x + 92,70	0,13	45,1	y = —4,39x + 100,42	0,58	47,7
		Growth -74	y = 0,21x + 11,03	0,03	16,8	y = 1,47x + 11,31	0,94	40,9
		Kasvu -75	y = 0,26x + 11,86	0,09	33,3	y = 1,57x + 10,40	0,98	29,6
		-76	y = 0,67x + 13,78	0,44	58,0	y = 0,43x + 15,04	0,12	47,1
		-77	y = —1,69x + 21,40	1,69	51,4	y = —1,92x + 22,28	1,83	48,7
		-78	y = —1,86x + 21,98	2,39	46,2	y = —2,29x + 23,12	2,22	51,0
3	5—10	Height						
		Pituus -78	y = 22,63x + 67,60	1,28	73,6	y = 13,72x + 86,64	0,82	65,9
		Growth -74	y = 7,70x + 4,20	4,58	70,9	y = 4,37x + 9,07	2,25	77,9
		Kasvu -75	y = 9,50x + 4,94	11,97**	86,8	y = 4,15x + 11,09	0,55	42,4
		-76	y = 2,33x + 14,76	0,16	69,3	y = 1,89x + 17,11	0,25	66,4
		-77	y = —6,02x + 23,90	0,66	51,0	y = —2,15x + 22,72	3,69	90,9
		-78	y = —4,36x + 21,71	0,50	42,7	y = —3,40x + 22,74	1,07	65,7
	15—20	Height						
		Pituus -78	y = 7,61x + 78,22	0,36	71,0	y = 31,02x + 64,09	5,26	79,3
		Growth -74	y = 3,61x + 6,75	2,27	65,1	y = 5,41x + 7,36	2,79	79,5
		Kasvu -75	y = 5,58x + 6,92	10,50*	85,9	y = 9,09x + 5,47	2,61	56,6
		-76	y = —0,006x + 16,67	0,00	68,8	y = 5,87x + 12,82	2,50	75,9
		-77	y = —4,72x + 23,88	1,17	54,8	y = —1,99x + 22,88	1,99	89,0
		-78	y = —2,79x + 21,03	0,38	43,1	y = —1,30x + 21,12	0,10	60,9
4	5—10	Height						
		Pituus -78	y = 24,76x + 66,91	10,63*	94,5	y = —12,31x + 131,65	35,85**	96,4
		Growth -74	y = 0,11x + 13,05	0,00	90,5	y = —3,37x + 21,07	10,48*	77,7
		Kasvu -75	y = 3,62x + 9,86	31,33**	98,8	y = —2,12x + 20,22	3,98	64,6
		-76	y = 5,03 + 11,16	6,85*	93,7	y = —2,03x + 22,70	9,42*	88,5
		-77	y = 7,41x + 11,40	7,36*	86,4	y = —1,31x + 26,13	1,11	82,9
		-78	y = 11,48x + 5,26	41,81**	94,0	y = —0,75x + 25,79	0,43	86,2
	15—20	Height						
		Pituus -78	y = 11,88x + 87,77	0,71	85,0	y = —18,27x + 141,72	0,61	67,0
		Growth -74	y = 1,44x + 10,20	0,83	91,9	y = —9,08x + 31,95	2,15	47,0
		Kasvu -75	y = 1,63x + 13,12	0,81	93,2	y = —0,24x + 16,14	0,02	31,3
		-76	y = +0,41x + 19,62	0,02	85,6	y = —2,59x + 23,51	0,33	65,8
		-77	y = 2,02x + 20,90	0,18	67,6	y = 2,56x + 18,22	0,24	80,2
		-78	y = 5,08x + 15,83	0,80	51,9	y = 3,62x + 16,93	0,70	87,7

Appendix 7. Regression equations between seedling growth and the total nitrogen percentage of peat calculated by the analysis of covariance, F values of regression coefficients and coefficients of determination. The coefficients of determination include also the effect of class variables. Combined analysis of Exps. 1 and 4, and 1, 2, 3 and 4.
Liitetaulukko 7. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen totaalityppipitoisuuden (%) väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet. Selitysaste sisältää myös luokkamuuttujien vaikutukset. Kokeiden 1 ja koko aineiston yhdistetyt analyysit.

Experiment *Koe*	Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1+4	5—10	Height						
		Pituus -78	y = 29,44x + 50,23	48,66***	93,2	y = —11,97x + 110,41	13,04**	89,8
		Growth -74	y = 1,43x + 8,47	3,96	89,6	y = —2,48x + 15,31	5,94*	74,9
		Kasvu -75	y = 4,47x + 6,85	25,04***	89,7	y = —1,57x + 15,65	3,44	82,5
		-76	y = 4,34x + 9,70	16,82***	91,3	y = —1,94x + 18,11	6,48*	88,4
		-77	y = 8,19x + 10,90	9,62**	54,8	y = —2,34x + 25,17	1,62	61,7
		-78	y = 9,39x + 8,70	31,44***	82,9	y = —1,27x + 23,75	0,97	73,8
	15—20	Height						
		Pituus -78	y = 20,52x + 56,06	9,26**	86,6	y = —0,95x + 92,29	0,02	82,8
		Growth -74	y = 0,93x + 8,89	1,23	87,5	y = —0,93x + 12,91	0,18	65,7
		Kasvu -75	y = 3,03x + 7,88	5,82*	84,3	y = 1,55x + 10,56	0,94	79,9
		-76	y = 2,83x + 10,91	3,94	87,6	y = —0,59x + 15,97	0,14	84,3
		-77	y = 10,45x + 4,52	3,70	45,4	y = —3,08x + 26,39	0,92	58,6
		-78	y = 7,84x + 8,37	10,70**	73,8	y = —0,71x + 22,86	0,09	71,5
1+2+ 3+4	5—10	Height						
		Pituus -78	y = 15,05x + 71,94	11,06**	77,4	y = —6,29x + 100,65	3,17	68,2
		Growth -74	y = 0,97x + 10,15	0,37	64,4	y = —1,22x + 13,82	1,65	57,2
		Kasvu -75	y = 2,63x + 9,71	10,37**	73,0	y = —0,52x + 14,10	0,29	49,1
		-76	y = 2,25x + 13,13	4,92*	76,4	y = —1,01x + 17,41	1,83	75,1
		-77	y = 5,14x + 14,45	3,31	33,3	y = —1,88x + 23,13	2,83	48,2
		-78	y = 4,60x + 14,72	10,58**	62,3	y = —0,79x + 21,70	0,59	52,0
	15—20	Height						
		Pituus -78	y = 6,47x + 79,56	2,46	75,1	y = —1,12x + 94,21	0,07	70,5
		Growth -74	y = 0,68x + 9,67	1,09	69,7	y = 0,95x + 10,88	0,84	63,4
		Kasvu -75	y = 1,57x + 10,37	5,24*	76,5	y = 2,04x + 10,42	3,65	56,1
		-76	y = 1,35x + 13,68	2,43	78,8	y = 0,51x + 15,35	0,36	55,9
		-77	y = 2,26x + 17,06	0,84	37,6	y = —1,89x + 23,47	2,38	55,9
		-78	y = 1,62x + 17,61	1,43	57,6	y = —1,34x + 22,62	1,41	59,6

Appendix 8. Dependence of height and height growth of seedlings on the total nitrogen content of peat at 5—10 cm layer calculated with regression analysis for PK and NPK fertilized plots in differently arranged materials.
Liitetaulukko 8. Regressioanalyysillä laskettu taimien pituuden ja kasvun riippuvuus turpeen kokonaistyppipitoisuudesta 5-10 cm:n turvekerroksessa PK- ja NPK-lannoitetuilla koealoilla eri tavoin ryhmitellyissä aineistoissa.

Experiment *Koe*	Measured quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1	Height — *Pituus* -78	y = 25,29x + 45,16	12,83**	37,9	y = —0,03x + 76,30	0,57	0,9
	Growth — *Kasvu* -78	y = 9,47x + 7,97	16,68**	44,3	y = 0,01x + 19,42	0,02	0,1
1+4	Height — *Pituus* -78	y = 35,81x + 39,17	50,68***	60,6	y = 14,31x + 65,10	12,10**	30,2
	Growth — *Kasvu* -78	y = 9,18x + 8,68	56,36***	63,1	y = 2,54x + 17,20	6,27	18,3
1+2+ 3+4	Height — *Pituus* -78	y = 24,98x + 58,60	33,12***	31,2	y = 3,28x + 85,00	0,05	0,2
	Growth — *Kasvu* -78	y = 6,94x + 11,63	46,91***	38,1	y = 1,86x + 17,94	5,62*	7,8

Appendix 9. Regression equations, F values and significances describing dependence between seedling growth and total nitrogen content of peat at 5—10 cm calculated by the analysis of covariance. Both PK and NPK fertilized plots included.

Liitetaulukko 9. Kovarianssianalyysillä lasketut taimien kasvun riippuvuutta turpeen totaalityppipitoisuudesta 5-10 cm:n kerroksessa esittävät regressioyhtälöt, F-arvot ja merkitsevyydet. Aineisto sisältää sekä PK- että NPK-lannoitetut koealat.

Experim. *Koe*	Height and Height growth *Pituus ja pituuskasvu*	Year *Vuosi*	Equation — *Yhtälö*	F value — *F-arvo* X	X^2	Coeff. of determ., % *Selitysaste, %*
4	Height — *Pituus*	78	$y = 139{,}33x — 35{,}303x^2 — 20{,}65$	65,62***	67,64***	96,4
	Height growth	74	$y = 9{,}92x — 3{,}008x^2 + 6{,}40$	2,63	2,89	82,5
	Pituuskasvu	75	$y = 21{,}18x — 5{,}415x^2 — 3{,}38$	27,23***	28,59***	93,7
	”	76	$y = 28{,}83x — 7{,}312x^2 — 7{,}42$	56,53***	58,38***	96,7
	”	77	$y = 27{,}85x — 6{,}876x^2 — 2{,}43$	10,24**	10,02**	84,2
	”	78	$y = 35{,}27x — 8{,}407x^2 — 9{,}71$	14,37**	13,10**	83,0
1+4	Height — *Pituus*	78	$y = 52{,}25x — 15{,}00x^2 + 52{,}26$	21,09***	19,12***	79,2
	Height growth	74	$y = 2{,}56x — 0{,}96x^2 + 9{,}56$	1,38	2,16	67,2
	Pituuskasvu	75	$y = 7{,}55x — 2{,}18x^2 + 7{,}50$	10,81**	9,87**	73,7
	”	76	$y = 8{,}17x — 2{,}58x^2 + 9{,}97$	11,22**	12,34***	80,5
	”	77	$y = 19{,}36x — 5{,}16x^2 + 6{,}42$	6,65*	5,20*	35,7
	”	78	$y = 17{,}31x — 4{,}50x^2 + 7{,}68$	23,07***	17,16***	66,5
1+2+ 3+4	Height — *Pituus*	78	$y = 35{,}75x — 12{,}02x^2 + 68{,}96$	16,06***	16,35***	67,7
	Height growth	74	$y = 3{,}05x — 1{,}33x^2 + 10{,}16$	2,87	4,92*	59,9
	Pituuskasvu	75	$y = 6{,}11x — 1{,}94x^2 + 9{,}12$	10,67**	9,70**	59,3
	”	76	$y = 6{,}14x — 2{,}15x^2 + 12{,}29$	10,13**	11,22***	71,6
	”	77	$y = 9{,}43x — 2{,}98x^2 + 14{,}43$	4,26*	3,85*	26,4
	”	78	$y = 8{,}41x — 2{,}55x^2 + 14{,}70$	9,52**	7,91**	50,5

Appendix 10. Regression equations between seedling growth and NH_4 —N (mg/l) in peat calculated by the analysis of covariance, F values of regression coefficients and coefficients of determination in different experiments. **The coefficients of determination include also the effect class variables.**

Liitetaulukko 10. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen NH_4 - N (mg/l) väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet eri kokeissa. Selitysaste sisältää myös luokkamuuttujien vaikutukset.

Experiment *Koe*	Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1	5—10	Height						
		Pituus -78	y = 0,417x + 60,14	3,94	42,8	y = —0,407x + 84,64	3,55	56,6
		Growth -74	y = 0,032x + 7,06	1,89	40,0	y = —0,137x + 11,60	9,15*	62,6
		Kasvu -75	y = 0,043x + 8,55	1,07	38,2	y = —0,086x + 12,31	4,33	65,1
		-76	y = 0,055x + 9,79	1,54	44,4	y = —0,092x + 13,64	4,62	48,9
		-77	y = 0,361x + 11,99	4,51*	46,8	y = —0,124x + 21,76	1,15	46,0
		-78	y = 0,155x + 13,53	3,89	33,2	y = —0,008x + 19,48	0,01	51,8
		Height						
		Pituus -78	y = 0,886x + 48,80	11,99**	59,3	y = —0,344x + 84,48	2,15	52,3
		Growth -74	y = 0,069x + 6,15	5,06*	49,0	y = —0,074x + 10,52	1,58	41,7
		Kasvu -75	y = 0,118x + 6,80	4,63*	48,8	y = —0,037x + 11,43	0,59	54,8
		-76	y = 0,149x + 7,59	7,28*	58,1	y = —0,032x + 12,50	0,38	31,4
		-77	y = 0,805x + 1,34	17,62***	67,6	y = —0,206x + 24,16	3,50	54,2
		-78	y = 0,307x + 9,82	9,26**	47,4	y = —0,063x + 20,83	0,64	54,2
2	5—10	Height						
		Pituus -78	y = —0,014x + 90,04	0,01	44,7	y = 0,259x + 87,43	2,01	51,6
		Growth -74	y = 0,011x + 11,11	0,12	17,6	y = 0,085x + 11,64	3,22	47,7
		Kasvu -75	y = 0,013x + 11,98	0,32	34,6	y = 0,062x + 14,26	3,47	53,9
		-76	y = —0,001x + 14,90	0,00	56,8	y = 0,062x + 14,26	2,63	53,9
		-77	y = —0,036x + 19,52	1,07	49,4	y = 0,022x + 18,73	0,20	44,7
		-78	y = —0,036x + 19,80	1,19	42,7	y = —0,007x + 19,67	0,02	44,5
	15—20	Height						
		Pituus -78	y = —0,028x + 90,54	0,02	44,8	y = —0,105x + 96,68	0,53	47,5
		Growth -74	y = 0,037x + 10,24	0,74	20,5	y = 0,043x + 12,33	1,31	42,3
		Kasvu -75	y = 0,014x + 11,85	0,20	34,0	y = 0,049x + 11,40	1,57	31,7
		-76	y = 0,027x + 14,05	0,51	57,8	y = 0,002x + 15,66	0,00	46,7
		-77	y = —0,057x + 20,34	1,27	50,0	y = —0,056x + 20,95	2,64	50,8
		-78	y = —0,079x + 21,32	3,09	48,1	y = —0,077x + 21,82	4,44	55,9
3	5—10	Height						
		Pituus -78	y = 0,853x + 73,18	6,58*	82,6	y = 0,209x + 92,07	0,23	62,6
		Growth -74	y = 0,218x + 7,18	16,20**	84,9	y = 0,106x + 11,11	1,61	76,9
		Kasvu '75	y = 0,196x + 9,74	12,58**	87,2	y = 0,037x + 14,07	0,22	38,1
		-76	y = 0,141x + 14,52	1,67	74,0	y = 0,002x + 18,75	0,00	65,5
		-77	y = 0,043x + 18,32	0,08	47,9	y = —0,042x + 21,55	1,45	88,2
		-78	y = 0,064x + 17,17	0,17	42,0	y = —0,067x + 20,89	0,50	62,5
	15—20	Height						
		Pituus -78	y = 0,072x + 87,75	0,03	70,0	y = 0,844x + 79,82	18,17***	50,4
		Growth -74	y = 0,068x + 8,98	0,69	60,5	y = 0,110x + 10,79	2,41	78,2
		Kasvu -75	y = 0,073x + 11,10	0,91	72,5	y = 0,257x + 9,91	6,63*	70,8
		-76	y = 0,007x + 16,50	0,00	69,2	y = 0,159x + 15,81	5,27*	81,6
		-77	y = —0,147x + 22,26	1,14	53,5	y = —0,016x + 21,16	0,21	85,8
		-78	y = —0,158 + 21,67	1,36	48,4	y = 0,015x + 19,52	0,03	59,4
4	5—10	Height						
		Pituus -78	y = 0,431x + 92,60	5,18*	91,6	y = —0,133x + 111,81	0,55	66,6
		Growth -74	y = —0,016x + 14,02	0,30	91,1	y = —0,003x + 13,97	0,00	20,4
		Kasvu -75	y = 0,034x + 14,97	1,18	93,1	y = —0,018x + 16,56	0,17	31,9
		-76	y = 0,098x + 15,88	5,91*	93,4	y = —0,025x + 19,56	0,55	65,8
		-77	y = 0,095x + 20,69	1,59	74,7	y = —0,048x + 25,67	1,99	85,7
		-78	y = 0,100x + 21,88	1,00	53,2	y = —0,035x + 25,90	1,28	88,8
	15—20	Height						
		Pituus -78	y = 0,275x + 91,73	4,68	91,1	y = —0,082x + 112,35	1,28	71,2
		Growth -74	y = 0,009x + 12,59	0,18	90,9	y = —0,014x + 15,07	0,34	25,8
		Kasvu -75	y = 0,042x + 13,38	9,53*	97,1	y = —0,008x + 16,35	0,18	31,3
		-76	y = 0,046x + 16,99	1,88	89,3	y = —0,009x + 19,13	0,38	65,8
		-77	y = 0,084x + 18,74	3,85	81,9	y = —0,020x + 25,08	1,83	85,7
		-78	y = 0,126x + 16,90	8,09*	78,7	y = —0,011x + 25,08	0,51	86,7

Appendix 11. Regression equations between seedling growth and the amount of NH_4 nitrogen in peat (mg/l) calculated by the analysis of covariance F values and coefficients of determination. The coefficients of determination include also the effect of class variables. Combined analysis of Exp. 1 and 4 and Exp. 1, 2, 1 and 4.

Liitetaulukko 11. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen NH_4-typen määrän väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet. Selitysaste sisältää myös luokkamuuttujien vaikutukset. Kokeiden 1 ja 4 sekä kaikkien kokeiden yhteisanalyysi.

Expe-riment *Koe*	Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitys-aste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitys-aste, %*
1+4	5—10	Height						
		Pituus -78	y = 0,497x + 74,27	10,67**	87,2	y = —0,183x + 97,03	2,37	84,7
		Growth -74	y = 0,024x + 9,65	1,63	87,7	y = —0,056x + 13,32	2,93	70,1
		Kasvu -75	y = 0,053x + 11,22	3,08	82,7	y = —0,044x + 14,65	3,14	81,9
		-76	y = 0,071x + 13,35	4,76*	88,0	y = —0,032x + 16,09	1,62	85,4
		-77	y = 0,318x + 11,64	7,37*	52,0	y = —0,058x + 23,27	1,26	59,3
		-78	y = 0,133x + 17,17	4,93*	68,2	y = —0,010x + 22,02	0,07	71,5
	15—20	Height						
		Pituus -78	y = 0,445x + 68,75	11,29**	87,4	y = —0,070x + 94,55	1,40	84,0
		Growth -74	y = 0,031x + 8,93	3,67	88,6	y = —0,020x + 12,48	1,51	68,0
		Kasvu -75	y = 0,065x + 9,79	6,71**	84,7	y = —0,011x + 13,77	0,81	79,7
		-76	y = 0,066x + 12,43	5,50*	88,3	y = —0,008x + 15,43	0,42	84,5
		-77	y = 0,294x + 7,69	8,40**	53,6	y = —0,023x + 22,52	0,82	58,4
		-78	y = 0,153x + 14,05	9,87**	73,0	y = —0,007x + 22,07	0,15	71,6
1+2+ 3+4	5—10	Height						
		Pituus -78	y = 0,243x + 82,95	5,70*	76,4	y = 0,044x + 91,37	0,21	70,5
		Growth -74	y = 0,024x + 10,06	2,21	70,3	y = 0,007x + 12,10	0,07	62,9
		Kasvu -75	y = 0,036x + 11,80	4,21*	76,0	y = 0,024x + 12,77	0,88	53,7
		-76	y = 0,037x + 14,76	2,79	79,0	y = 0,011x + 15,80	0,30	77,1
		-77	y = 0,115x + 17,44	3,59	40,5	y = —0,018x + 21,16	0,36	54,1
		-78	y = 0,044x + 18,88	1,68	57,8	y =.0,005x + 20,51	0,03	58,5
	15—20	Height						
		Pituus -78	y = 0,274x + 79,01	6,61*	76,8	y = —0,045x + 94,33	0,62	70,8
		Growth -74	y = 0,031x + 9,53	3,32	70,8	y =—0,003x + 12,40	0,04	62,8
		Kasvu -75	y = 0,048x + 10,93	7,07*	77,2	y = 0,012x + 12,96	0,59	53,4
		-76	y = 0,049x + 13,88	4,62*	79,6	y = —0,001x + 16,13	0,00	77,0
		-77	y = 0,154x + 14,66	5,99*	42,8	y = —0,029x + 21,84	2,91	56,4
		-78	y = 0,072x + 17,33	4,17*	59,5	y = —0,018x + 21,35	1,22	59,5

Appendix 12. Regression equations between seedling growth and peat pH calculated by the analysis of covariance, F values of regression and coefficients of determination in different experiments. The coefficients of determination include also the effect of class variables.

Liitetaulukko 12. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen pH:n väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet eri kokeissa. Selitysaste sisältää myös luokkamuuttujien vaikutukset.

Experiment *Koe*	Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1	5—10	Height						
		Pituus -78	y = —6,167x + 93,27	0,40	30,4	y = 12,160x + 28,32	1,73	50,9
		Growth -74	y = —0,335x + 9,04	0,10	33,4	y = —0,731x + 11,63	0,09	34,5
		Kasvu -75	y = —2,802x + 20,72	2,78	43,8	y = 3,960x — 5,04	6.45*	69,1
		-76	y = —0,592x + 13,26	0,09	39,4	y = 2,734x + 0,97	2,17	40,1
		-77	y = —2,143x + 27,77	0,07	32,1	y = 7,570x — 10,60	3,05	52,8
		-78	y = —0,749x + 19,62	0,04	17,1	y = 6,444x — 6,07	6,52*	68,7
	15—20	Height						
		Pituus -78	y = 18,067x + 0,36	2,09	37,0	y = —12,847x + 125,13	0,33	45,2
		Growth -74	y = 1,253x + 2,97	0,85	36,3	y = —6,164x + 32,23	1,38	40,1
		Kasvu -75	y = 1,1406x + 4,11	0,34	35,3	y = 2,112x + 2,50	0,23	53,4
		-76	y = 3,323x — 1,63	1,81	45,2	y = —1,250x + 16,50	0,07	29,8
		-77	y = —0,722x + 21,83	0,04	31,9	y = —8,880x + 53,03	0,67	43,9
		-78	y = 7,894x — 13,11	2,99	30,0	y = 1,508x + 13,56	0,04	51,9
2	5—10	Height						
		Pituus -78	y = 17,52x + 21,60	3,01	53,0	y = —2,736x + 104,04	0,04	46,0
		Growth -74	y = —0,238x + 12,30	0,00	17,1	y = —4.612x + 31,40	1,64	43,5
		Kasvu -75	y = 1,689x + 5,73	0,92	36,6	y = —4,980x + 32,08	1,76	32,4
		-76	y = 2,533x + 5,03	1,46	60,0	y = —1,755x + 22,47	0,35	47,7
		-77	y = 3,140x + 6,42	1,23	50,0	y = 0,653x + 16,73	0,03	43,3
		-78	y = 4,987x — 0,47	4,05	50,5	y = 0,939x + 15,88	0,06	44,5
	15—20	Height						
		Pituus -78	y = 4,351x + 73,21	0,09	45,0	y = 16,725x + 30,09	1,80	51,0
		Growth -74	y = 0,139x + 10,85	0,00	16,8	y = —2,571x + 23,38	0,56	39,7
		Kasvu -75	y = 0,787x + 9,31	0,11	33,3	y = —3,556x + 26,36	0,99	29,6
		-76	y = 2,176x + 6,63	0,59	58,0	y = 0,070x + 15,44	0,00	46,6
		-77	y = 0,186x + 17,92	0,00	46,3	y = 7,113x — 7,718	6,13*	58,4
		-78	y = 0,186x + 18,92	0,00	40,8	y = 6,796x — 6,27	4,30	55,8
3	5—10	Height						
		Pituus -78	y = —18,070x + 151,3	0,18	70,4	y = 79,80x — 194,07	2,08	71,1
		Growth -74	y = —2,903x + 20,98	0,11	57,0	y = 18,46x — 53,98	2,65	78,8
		Kasvu -75	y = —4,194x + 27,86	0,25	70,6	y = 20,77x — 60,50	0,91	45,5
		-76	y = —7,421x + 43,44	0,41	70,2	y = 11,54x — 23,01	0,62	68,2
		-77	y = —13,549x + 67,87	0,83	51,6	y = —8,46x + 51,49	4,08	91,9
		-78	y = —13,227x + 65,87	0,79	45,7	y = —0,77x + 22,59	0,03	59,2
	15—20	Height						
		Pituus -78	y = 19,856x + 15,87	0,49	71,4	y = 8,330x + 66,18	0,02	61,3
		Growth -74	y = 8,571x — 13,83	2,65	66,3	y = —0,001x + 12,84	0,00	69,6
		Kasvu -75	y = 6,571x — 10,53	1,58	74,3	y = —1,667x + 20,53	0,01	37,2
		-76	y = 4,285x + 1,50	0,31	70,2	y = —0,001x + 18,75	0,00	65,1
		-77	y = —2,429x + 27,57	0,05	47,9	y = —0,001x + 20,86	0,00	48,1
		-78	y = —3,286x + 29,77	0,10	41,5	y = —13,334x + 66,70	1,54	68,1
4	5—10	Height						
		Pituus -78	y = —15,130x + 176,84	0,32	83,9	y = —14,734x + 169,59	3,64	80,1
		Growth -74	y = 4,102x — 4,08	2,64	93,8	y = —4,468x + 33,34	3,53	57,1
		Kasvu -75	y = —2,821x + 28,50	0,71	92,6	y = —2,340x + 25,89	1,15	46,9
		-76	y = —6,410x + 47,58	1,43	88,5	y = —2,128x + 27,62	1,58	72,5
		-77	y = —5,128x + 46,83	0,36	68,6	y = —0,798x + 26,82	0,12	78,8
		-78	y = —8,974x + 64,50	0,74	51,4	y = —0,106x + 24,63	0,00	85,7
	15—20	Height						
		Pituus -78	y = 25,840x + 7,39	11,27*	94,7	y = —10,803x + 149,99	0,92	69,1
		Growth -74	y = 0,320x + 11,92	0,04	90,6	y = —4,087x + 30,76	1,60	42,9
		Kasvu -75	y = 2,857x + 4,92	5,05	95,8	y = —2,26x + 11,07	0,72	40,6
		-76	y = 5,303x — 3,63	14,74*	96,2	y = —0,803x + 21,67	0,12	63,2
		-77	y = 7,727x — 6,39	7,65*	86,7	y = 0,803x + 20,01	0,09	79,1
		-78	y = 8,831x — 9,48	4,89	71,8	y = 1,168x + 19,33	0,27	85,7

Appendix 13. Regression equations between seedling growth and peat pH calculated by the analysis of covariance, F values of regression coefficients and coefficients of determination. The coefficients of determination include also the effect of class variables. Entire material.

Liitetaulukko 13. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen pH:n väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet. Selitysaste sisältää myös luokkamuuttujien vaikutukset. Koko aineisto.

Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % Selitysaste %
5—10	Height						
	Pituus -78	y = —1.81x + 96,46	0,08	74,0	y = 2,22x + 84,06	0,10	70,5
	Growth -74	y = —0,18x + 11,42	0,03	69,1	y = —2,63x + 22,33	2,16	64,4
	Kasvu -75	y = —1,77x + 19,73	2,72	75,4	y = —1,63x + 19,67	0,72	53,5
	-76	y = —0,18x + 16,46	0,02	77,9	y = —0,31x + 17,27	0,04	77,0
	-77	y = —2,45x + 30,11	0,42	37,1	y = 2,69x + 10,40	1,56	55,2
	-78	y = —0,27x + 21,12	0,02	56,5	y = 2,71x + 10,32	1,91	60,0
15—20	Height						
	Pituus -78	y = 18,70x + 18,48	6,79*	76,8	y = 13,72x + 37,58	2,11	67,2
	Growth -74	y = 1,32x + 5,69	1,25	69,8	y = —2,37x + 20,55	0,97	65,7
	Kasvu -75	y = 2,26x + 4,16	3,23	75,6	y = —1,47x + 18,15	0,29	46,5
	-76	y = 4,09x + 0,21	7,47**	80,5	y = 0,24x + 14,49	0,01	76,5
	-77	y = 3,29x + 7,98	0,55	37,3	y = 4,41x + 3,46	2,11	45,8
	-78	y = 5,76x — 1,78	6,02*	60,8	y = 4,69x + 2,14	3,13	49,6

Appendix 14. Regression equations between seedling growth and peat decomposition calculated by the analysis of covariance, F values of regression coefficients and coefficients of determination. The coefficients of determination include also the effect of class variables in Exp. 1 and 2.

Liitetaulukko 14. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen maatuneisuuden väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet. Selitysaste sisältää myös luokkamuuttujien vaikutukset kokeissa 1 ja 2.

Experiment *Koe*	Peat layer *Turvekerros*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1	5—10	Height						
		Pituus -78	y = 8,74x + 50,26	6,54*	49,4	y = —6,58x + 91,13	5,68*	61,8
		Growth -74	y = 0,48x + 6,68	1,43	38,4	y = —1,79x + 12,81	7,89*	60,2
		Kasvu -75	y = 1,58x + 6,12	6,29*	52,7	y = —1,04x + 12,92	3,24	62,7
		-76	y = 1,43x + 7,90	4,08	51,4	y = —0,89x + 13,77	1,98	39,2
		-77	y = 0,94x + 17,17	0,01	32,2	y = —2,50x + 24,87	2,84	52,2
		-78	y = 3,47x + 9,41	7,76*	44,0	y = —0,35x + 20,12	0,12	52,2
	15—20	Height						
		Pituus -78	y = 13,79x + 33,03	**13,80****	61,7	y = —4,00x + 88,45	0,94	47,8
		Growth -74	y = 0,94x + 5,28	3,91	46,1	y = —0,45x + 10,14	0,19	35,1
		Kasvu -75	y = 2,12x + 3,97	7,67**	55,4	y = —0,08x + 10,78	0,01	52,6
		-76	y = 2,67x + 4,03	13,10**	66,5	y = 0,01x + 11,21	0,04	29,5
		-77	y = 3,13x + 11,08	0,59	34,3	y = —0,77x + 21,59	0,14	41,5
		-78	y = 5,26x + 3,11	14,83**	56,9	y = —1,26x + 23,19	0,93	55,2
2	5—10	Height						
		Pituus -78	y = —4,22x + 99,77	2,01	50,6	y = 0,84x + 91,75	0,06	46,0
		Growth -74	y = —0,61x + 12,83	0,76	20,6	y = 1,26x + 11,01	2,08	44,6
		Kasvu -75	y = —0,27x + 12,94	0,27	34,3	y = —1,89x + 8,95	4,90*	42,0
		-76	y = —0,07x + 15,05	0,28	56,6	y = 0,85x + 13,94	1,46	50,9
		-77	y = —1,81x + 22,94	6,34*	60,9	y = —0,70x + 20,71	0,65	45,3
		-78	y = —1,90x + 23,46	8,76**	59,5	y = —1,01x + 21,60	1,16	47,9
	15—20	Height						
		Pituus -78	y = —1,33x + 94,13	0,55	46,4	y = —3,42x + 104,29	4,08	56,3
		Growth -74	y = 0,23x + 10,60	0,33	18,6	y = —0,07x + 13,85	0,02	37,9
		Kasvu -75	y = 0,03x + 12,18	0,01	33,3	y = 0,15x + 12,40	0,08	25,8
		-76	y = 0,12x + 14,45	0,12	56,9	y = —0,20x + 16,35	0,26	47,5
		-77	y = —0,77x + 21,21	2,98	54,3	y = —1,06x + 22,61	6,88*	59,5
		-78	y = —0,98x + 22,18	6,26*	55,2	y = —1,19x + 23,28	7,40*	61,2

Appendix 15. Regression equations between seedling growth and peat depth calculated by the analysis of covariance, F values of regression coefficients and coefficients of determination. The coefficients of determination include also the effect of class variables.

Liitetaulukko 15. Kovarianssianalyysillä lasketut taimien kasvun ja turpeen syvyyden väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet. Selitysaste sisältää myös luokkamuuttujien vaikutukset.

Experiment *Koe*	Quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % Selitysaste, %
1	Height —						
	Pituus -78	y = —0,209x+104,49	3,41	41,2	y = 0,182x + 49,40	6,78*	64,1
	Growth -74	y = 0,003x + 7,20	0,01	33,1	y = 0,029x + 4,53	2,12	44,0
	Kasvu -75	y = —0,024x+13,67	1,25	38,8	y = 0,032x + 5,81	5,00	66,5
	-76	y = —0,017x+13,77	0,48	40,8	y = 0,046x + 4,96	14,82**	68,3
	-77	y = —0,071x+31,99	0,49	33,8	y = 0,071x + 8,80	3,49	54,2
	-78	y = —0,092x+32,43	5,07*	36,9	y = 0,042x + 13,15	2,80	60,9
2	Height —						
	Pituus -78	y = —0,021x+93,78	0,50	46,3	y = 0,029x + 88,60	0,84	48,4
	Growth -74	y = —0,110x+13,49	2,99	29,5	y = 0,001x + 13,49	0,01	37,9
	Kasvu -75	y = —0,008x+13,93	3,43	44,4	y = —0,003x + 13,45	0,14	26,0
	-76	y = —0,008x+16,51	2,23	61,6	y = —0,005x + 16,54	0,53	48,3
	-77	y = —0,001x+18,91	0,03	46,4	y = 0,007x + 18,03	0,79	45,7
	-78	y = 0,004x+18,21	0,23	39,5	y = 0,001x + 19,37	0,01	44,4
4	Height —						
	Pituus -78	y=—0,353x+134,48	12,09*	95,0	y=—0,190x+115,56	1,09	70,1
	Growth -74	y = 0,002x+13,10	0,01	90,5	y = 0,003x + 13,66	0,00	19,5
	Kasvu -75	y = —0,043x+19,18	7,81*	96,7	y = —0,043x+17,98	1,01	43,6
	-76	y = —0,070x+24,75	6,55	93,6	y = —0,056x + 21,33	4,31	81,4
	-77	y = —0,094x+30,93	4,87	82,9	y = —0,082x+27,77	22,70***	96,7
	-78	y = —0,131x+34,58	7,32*	77,3	y = —0,075x+28,22	68,77***	99,2

Appendix 16. Seedling growth as affected by different treatments in the material with all fertilized plots calculated separately with the analyses of variance and covariance. F values, significances and coefficients of determination.

Liitetaulukko 16. Eri käsittelyjen vaikutus taimien kasvuun koko lannoitetut koealat käsittävästä arineistosta laskettuna erikseen varianssi- ja kovarianssianalyysillä. F-arvot, merkitsevyydet ja selitysasteet.

Analysis *Analyysi*	Source of variation *Vaihtelun lähde*	F value — *F-arvo*: Height *Pituus* 1978	Height growth — *Pituuskasvu* 1974	1975	1976	1977	1978
A. variance	1 = Experiment — *Koe*	61,23***	42,28***	30,34***	77,48***	5,51	26,99***
	2 = Liming — *Kalkitus*	2,88	1,10	0,35	2,31	3,13	4,15
	3 = Rotavation — *Jyrsintä*	33,54***	20,63***	24,99***	47,17***	11,22	17,98***
	4 = Fertilization — *Lannoitus*	2,99	16,69***	2,92	0,91	0,08	1,30
	1 × 2	2,72*	0,79	0,80	1,32	0,93	1,99
	1 × 4	3,41*	1,12	1,77	4,05*	0,46	3,54*
	2 × 3	3,31*	1,53	2,66	0,67	0,05	1,42
	Variation expl. — *Selitysaste, %*	71,8	64,2	62,6	75,8	34,1	56,8
A. covariance	*Tot. N*	9,67**	2,27	7,97	5,82	3,88	3,52
	Tot. N^2	8,88**	3,72	6,48	5,36	3,02	2,17
	1 = Experiment — *Koe*	43,84***	39,01***	28,7	65,92	2,41	8,35**
	2 = Liming — *Kalkitus*	2,93	0,90	0,36	2,29	3,18	4,38*
	3 = Rotavation — *Jyrsintä*	34,77***	19,74***	24,92	47,97	11,14	18,82***
	4 = Fertilization — *Lannoitus*	3,21	19,40***	2,68	0,97	0,04	0,84
	1 × 2	2,28	0,65	0,68	1,02	0,57	1,70
	1 × 3	1,73	0,87	1,14	2,73	1,39	2,32
	2 × 3	3,09*	1,54	2,38	0,40	0,33	1,00
	Variation expl. — *Selitysaste, %*	74,0	65,6	65,1	77,0	36,3	58,4

Appendix 17. F values and significances of class variables in the analyses of covariance of seedling height in different experiments. Only PK and NPK fertilized plots included.

Liitetaulukko 17. Luokittelumuuttujien F-arvot ja merkitsevyys taimien pituuskehitystä koskevissa kovarianssianalyyseissä eri kokeissa. Mukana vain PK- ja NPK-lannoitetut koealat.

Experiment *Koe*	Source of variation *Vaihtelun lähde*	F values — *F-arvot* Height *Pituus* 1978	Height growth — *Pituuskasvu* 1974	1975	1976	1977	1978
1	1. Liming — *Kalkitus*	0,04	0,08	0,19	0,19	0,47	0,02
	2. Rotavation — *Jyrsintä*	5,05*	0,73	4,96*	7,27**	3,92*	4,00*
	3. Nutr. combin. — *Ravinneyhdist.*	2,17	3,34	1,27	0,29	0,12	1,58
	1 × 2	0,85	0,81	1,38	0,07	0,41	0,37
	1 × 3	0,32	1,13	1,69	0,45	1,05	0,17
	2 × 3	0,62	1,04	1,26	1,21	1,21	0,23
2	1. Liming — *Kalkitus*	0,04	0,11	0,01	0,00	1,07	0,27
	2. Rotavation — *Jyrsintä*	14,07***	6,13**	6,78**	17,74***	10,08	10,93***
	3. Nutr. combin. — *Ravinneyhdist.*	1,59	9,07**	0,72	1,81	0,59	0,53
	1 × 2	0,04	0,23	0,03	1,26	0,06	0,25
	1 × 3	0,76	0,45	0,06	0,16	1,64	0,01
	2 × 3	0,18	1,02	0,27	0,17	1,28	1,49
3	1. Liming — *Kalkitus*	0,68	0,42	0,25	0,11	0,32	0,47
	2. Rotavation — *Jyrsintä*	11,87***	12,57***	7,55**	14,26***	5,83*	5,62*
	3. Nutr. combin. — *Ravinneyhdist.*	7,03*	11,48**	4,74*	4,97*	3,55	2,51
	1 × 2	4,44*	1,94	2,57	1,82	2,17	0,67
	1 × 3	0,00	0,13	0,24	0,12	0,08	0,02
	2 × 3	0,08	0,69	0,07	0,15	0,17	0,23
4	1. Liming — *Kalkitus*	33,01***	2,64	5,05*	13,93**	8,08*	10,22**
	2. Rotavation — *Jyrsintä*	55,59***	10,08**	32,21***	71,91***	11,32**	7,33**
	3. Nutr. combin. — *Ravinneyhdist.*	5,09*	4,05	0,61	11,97**	1,93	4,34
	1 × 2	4,67*	4,19	5,45*	2,76	0,50	0,04
	1 × 3	26,72***	0,88	14,16**	34,96***	5,15*	3,80
	2 × 3	16,57***	3,88	18,07***	29,69***	1,09	1,72

Appendix 18. F values of liming and soil preparation as obtained from the analyses of covariance calculated for each nutrient combination in different experiments. Treatment means adjusted to regression (total nitrogen 5—10 cm in Exp. 1 and 4 and NH_4 nitrogen 5—10 and 15—20 cm in Exp. 2 and 3 respectively).

Liitetaulukko 18. Kalkituksen ja muokkauksen F-arvot ravinneyhdistelmittäin lasketuissa kovarianssianalyyseissä eri kokeissa. Kovarianssikorjaus kokeessa 1 ja 4 kokonaistypen (5-10 cm) suhteen ja kokeissa 2 ja 3 NH_4-typen (5-10 ja 15-20 cm) suhteen.

Experiment *Koe*	Fertilization *Lannoitus*	Source of variation *Vaihtelun lähde*	F value — *F-arvo* Height *Pituus*	Height growth in — *Pituuskasvu vuonna* -74	-75	-76	-77	-78
1	PK	1=Liming—*Kalkitus*	0,01	0,88	0,05	0,12	0,01	0,57
		2=Soil prep.—*Muokkaus*	7.31**	4,98*	6,60**	8,75**	7,76**	3,26
		1 × 2	0,03	1,37	0,07	0,01	1,63	0,15
	NPK	*1*=Liming—*Kalkitus*	0,06	0,01	0,26	0,84	0,00	3,76
		2=Soilprep.—*Muokkaus*	4,62*	1,34	0,42	2,49	5,76	10,65**
		1 × 2	4,25*	5,87*	5,02*	0,31	3,06	1,94
2	PK	1=Liming—*Kalkitus*	0,23	0,32	0,11	0,28	3,51	1,03
		2=Soilprep.—*Muokkaus*	7,54**	1.98	4.39*	10,34**	8,81**	7,76**
		1 × 2	0,60	0,06	0,11	1,93	0,18	0,29
	NPK	1=Liming—*Kalkitus*	0,42	2,33	1,10	1,21	0,36	1,10
		2=Soilprep.—*Muokkaus*	8,09**	6,00*	4,07*	9,18**	6,80**	6,46**
		1 × 2	0,01	1,65	0,26	0,38	0,53	0,17
3	PK	1=Liming—*Kalkitus*	0,76	0,27	2,37	0,02	0,20	0,90
		2=Soilprep.—*Muokkaus*	5,17*	2,91	6,10*	5,96*	2,56	3,38
		1 × 2	8,21**	4,95*	8,05**	3,04	1,44	0,26
	NPK	1=Liming—*Kalkitus*	6,71*	1,55	0,98	1,91	0,22	0,30
		2=Soilprep.—*Muokkaus*	18,49**	8,88	3,37	10,84*	23,20**	3,54
		1 × 2	1,04	0,28	0,46	0,14	3,90	0,94
4	PK	1=Liming—*Kalkitus*	26,93**	4,56	65,95***	13,97**	5,96*	40,89**
		2=Soilprep.—*Muokkaus*	26,26**	16,19**	158,14***	42,06***	6,71*	17,09**
		1 × 2	0,01	1,59	1,67	0,63	0,55	5,79*
	NPK	1=Liming—*Kalkitus*	31,06**	1,69	0,70	3,35	3,54	11,18
		2=Soilprep.—*Muokkaus*	15,07*	1,21	1,01	4,77	4,02	2,77
		1 × 2	6,94*	0,71	0,48	4,83	4,88	7,40

Appendix 19. Dependence of seedling height and leader growth on the foliar nitrogen level (% in 1978) in different experiments as calculated with the analysis of covariance. Coefficients of determination include also effects of class variables.

Liitetaulukko 19. Kovarianssianalyysillä laskettu taimien pituuden (H) ja pituuskasvun (LG) riippuvuus neulasten typpipitoisuudesta (% v. 1978) eri kokeissa. Selitysaste sisältää myös luokkamuuttujien vaikutukset.

Experiment *Koe*	Measured quantity *Suure*	PK fertilization — *PK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*	NPK fertilization — *NPK-lannoitus* Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
1	Height -78						
	Pituus -78	y = 30,91x + 25,80	2,18	37,3	y = 6,15x + 66,97	0,13	44,4
	Growth -77	y = 12,92x + 1,33	0,51	33,9	y = 5,30x + 11,25	0,41	42,7
	Kasvu -78	y = 15,23x — 4,37	4,19	34,1	y = 10,36x + 3,76	5,13*	66,2
2	Height -78						
	Pituus -78	y=—17,16x + 112,79	0,28	45,6	y=—7,73x + 103,86	0,09	46,2
	Growth -77	y=—5,47x + 25,98	0,40	47,5	y=3,27x + 14,87	0,26	44,1
	Kasvu -78	y=8,19x + 7,90	1,06	42,2	y=6,01x + 11,45	0,74	46,9
3	Height -78						
	Pituus -78	y=—5,84x + 93,53	0,01	69,9	y=—15,73x+115,65	0,14	62,1
	Growth -77	y=33,05x — 22,90	3,89	63,4	y=—1,24x + 22,45	0,11	85,6
	Kasvu -78	y=24,75x — 13,21	1,85	51,1	y= 2,04x + 17,19	0,05	60,9
4	Height -78						
	Pituus -78	y=47,19x + 39,18	5,93	92,2	y=—79,97x+232,11	15,60*	92,3
	Growth -77	y=16,84x — 1,14	10,37*	89,3	y=—14,33x + 46,09	4,85	90,1
	Kasvu -78	y=21,15x — 6,46	9,96*	81,5	y=—11,99x + 43,20	4,20	92,6
1+4	Height -78						
	Pituus -78	y=95,34x — 54,07	22,67***	78,4	y=2,32x + 83,05	0,85	70,8
	Growth -77	y=19,57x — 7,37	3,98	43,3	y=1,14x + 19,00	1,15	56,5
	Kasvu -78	y=25,74x — 17,10	29,25***	70,5	y=12,60x — 1,72	5,86*	65,8
1+2+	Height -78						
3+4	*Pituus* -78	y=30,24x + 47,41	5,45*	76,3	y=—8,73x + 105,00	0,51	70,7
	Growth -77	y=12,03x + 3,80	2,36	39,2	y=1,37x + 18,72	0,13	53,8
	Kasvu -78	y=15,18x — 1,00	15,07***	65,8	y=4,98x + 13,55	2,16	60,2

Appendix 20. Regression equations between growth and foliar nitrogen percentage. Experiment 1 and the entire material.

Liitetaulukko 20. Kovarianssianalyysillä laskettu taimien pituuden ja pituuskasvun paraboloidinen riippuvuus neulasten typpipitoisuudesta kokeessa 1 sekä kaikkien kokeiden yhteisanalyysissä. Mukana kaikki lannoitetut koejäsenet.

Experiment *Koe*	Independ. var. *Selittävä muuttuja*		Equation — *Yhtälö*	F_x	F_{x^2}	Coeff. of determ., % *Selitysaste, %*	Maximum, % *Maksimi, %*
1	Height—*Pituus*	-78	$y = 670{,}39x - 226{,}0x^2 - 419{,}05$	12,22**	11,55**	57,6	1,48
	Growth—*Kasvu*	-77	$y = 426{,}19x - 145{,}34x^2 - 289{,}66$	6,69*	6,47*	40,9	1,47
	”	-78	$y = 242{,}10x - 79{,}56x^2 - 163{,}77$	14,80***	13,30***	61,8	1,52
1—4	Height—*Pituus*	-78	$y = 156{,}69x - 50{,}46x^2 - 28{,}36$	2,14	1,83	72,9	1,55
	Growth—*Kasvu*	-77	$y = 137{,}32x - 46{,}17x^2 - 80{,}06$	6,21*	5,76*	37,8	1,49
	”	-78	$y = 98{,}59x - 30{,}81x^2 - 56{,}54$	10,90***	8,75**	65,5	1,60

Appendix 21. Regression equations, F values and coefficients of determination between foliar nutrients and nutrient ratios and seedling growth calculated with the analysis of covariance for NPK fertilized seedlings. Coefficients of determination include also class variables. The fertilized test members of one replication of each experiment included.

Liitetaulukko 21. Kovarianssianalyysillä lasketut neulasten ravinteiden ja ravinnesuhteiden sekä taimien kasvun väliset regressioyhtälöt, F-arvot ja selitysasteet NPK-lannoitetuille taimille. Selitysasteet sisältävät myös luokkamuuttujien osuuden. Mukana kaikista kokeista yhden toiston lannoitetut koejäsenet.

Nutrient or nutrient ratio *Ravinne tai ravinnesuhde*	Height and leader growth *Pituus ja pituuskasvu*		Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
P	Height — *Pituus*	-78	y = 28,61x + 55,39	9,09*	97,6
	Growth — *Kasvu*	-77	y = 4,34x + 6,44	0,58	89,6
	"	-78	y = 9,68x + 8,42	2,20	86,0
Mn	Height — *Pituus*	-78	y = 0,007x + 90,73	0,02	94,6
	Growth — *Kasvu*	-77	y = 0,021x + 5,48	2,34	94,5
	"	-78	y = —0,040x + 33,20	4,38	90,7
N/P	Height — *Pituus*	-78	y = —2,384x + 119,55	6,98*	98,0
	Growth — *Kasvu*	-77	y = —0,365x 16,03	0,58	92,3
	"	-78	y = —0,571x + 27,54	0,58	82,9
N/K	Height — *Pituus*	-78	y = —19,67x + 166,66	2,93	96,9
	Growth — *Kasvu*	-77	y = —8,261x + 42,91	7,08*	96,8
	"	-78	y = 4,100x + 5,78	0,27	81,6
P/B	Height — *Pituus*	-78	y = 0,809x + 73,82	16,45*	98,9
	Growth — *Kasvu*	-77	y = 0,145x + 8,50	1,16	93,2
	"	-78	y = —0,049x + 19,99	0,04	80,6
K/Zn	Height — *Pituus*	-78	y = 0,606x + 50,44	1,09	95,8
	Growth — *Kasvu*	-77	y = 0,361x — 13,36	7,58*	97,0
	"	-78	y = —0,153x + 31,87	0,20	81,3
N/Mn	Height — *Pituus*	-78	y = 1,059x + 86,66	0,12	94,8
	Growth — *Kasvu*	-77	y = —1,571x + 21,19	4,76	96,0
	"	-78	y = 3.197x + 2.32	43,09**	98,3
P/Mn	Height — *Pituus*	-78	y = 0,238x + 80,66	1,69	96,2
	Growth — *Kasvu*	-77	y = —0,058x + 14,95	0,73	92,6
	"	-78	y = 0,211x + 10,34	17,60*	96,4
K/Mn	Height — *Pituus*	-78	y = 0,556x + 84,59	0,25	94,9
	Growth — *Kasvu*	-77	y = —0,461x + 18,81	2,13	94,2
	"	-78	y = 1,119x + 4,48	19,80*	96,7
Ca/Mn	Height — *Pituus*	-78	y = 0,368x + 88,99	0,07	94,7
	Growth — *Kasvu*	-77	y = —0,534x + 17,58	1,96	94,1
	"	-78	y = 1,265x + 7,80	11,90*	95,1
B/Mn	Height — *Pituus*	-78	y = —8,01x + 94,69	0,04	94,6
	Growth — *Kasvu*	-77	y = —12,58x + 14,80	1,01	93,0
	"	-78	y = 27,32x + 14,92	2,53	88,1
Cu/Mn	Height — *Pituus*	-78	y = 473,26x + 85,33	0,46	95,2
	Growth — *Kasvu*	-77	y = —267,55x + 16,20	1,56	93,7
	"	-78	y = 723,13x + 9,63	20,22*	96,8
Zn/Mn	Height — *Pituus*	-78	y = 16,51x + 89,29	0,05	94,7
	Growth — *Kasvu*	-77	y = —38,19x + 20,23	6,65	96,7
	"	-78	y = 70,30x + 5,90	24,69**	97,3

Appendix 22. Tree growth as depending on certain foliar nutrients. Material includes PK and NPK fertilized test members. Analysis of covariance and coefficients of determination include class variables: experiment, liming, fertilization and site preparation and their interactions.

Liitetaulukko 22. Puiden kasvun riippuvuus eräistä neulasten ravinteista. PK- ja NPK-lannoitetut koejäsenet käsittävän aineiston osana. Kovarianssianalyysissä ja selitysasteessa mukana luokkamuuttujat: koe, kalkitus, lannoitus ja muokkaus sekä näiden yhdysvaikutukset.

Nutrient or nutrient ratio *Ravinne tai ravinnesuhde*	Height and leader growth *Pituus ja pituuskasvu*		Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
B, ppm	Height — *Pituus*	-78	y = 0,200x + 78,73	1,92	91,9
	Growth — *Kasvu*	-77	y = 0,003x + 11,29	0,00	79,8
	”	-78	y = 0,099x + 14,51	4,40*	87,5
Cu, ppm	Height — *Pituus*	-78	y = 8,37x + 57,31	4,37*	92,3
	Growth — *Kasvu*	-77	y = 0,09x + 11,09	0,01	79,8
	”	-78	y = 4,23x + 3,48	12,72**	90,6
Mn, ppm	Height — *Pituus*	-78	y = —0,053x + 93,07	0,53	90,9
	Growth — *Kasvu*	-77	y = 0,078x + 8,86	2,00	81,4
	”	-78	y = —0,018x + 26,62	6,53*	88,5
N/Cu	Height — *Pituus*	-78	y = —0.0055x + 111,07	2,61	91,8
	Growth — *Kasvu*	-77	y = —0,0001x + 12,17	0,05	79,8
	”	-78	y = —0,0025x + 29,94	5,60*	88,1
N/Mn	Height — *Pituus*	-78	y = —0,0508x + 93,94	0,76	90,9
	Growth — *Kasvu*	-77	y = —0,0827x + 15,80	3,73	82,8
	”	-78	y = 0,1090x + 14,92	3,49	87,1
P/Mn	Height — *Pituus*	-78	y = 1,2386x + 85,36	0,53	91,1
	Growth — *Kasvu*	-77	y = —0,3919x + 13,33	0,86	80,6
	”	-78	y = 1,2486x + 14,69	5,74*	88,1
K/Mn	Height — *Pituus*	-78	y = 0,2913x + 87,13	0,16	90,9
	Growth — *Kasvu*	-77	y = —0,2224x + 14,62	1,64	81,2
	”	-78	y = 0,5958x + 12,17	8,12**	89,1
Ca/Mn	Height — *Pituus*	-78	y = 0,4169x + 87,23	0,17	90,9
	Growth — *Kasvu*	-77	y = —0,3222x + 14,58	1,68	81,3
	”	-78	y = 0,9304x + 11,63	10,45**	89,8
B/Mn	Height — *Pituus*	-78	y = 29,23x + 85,10	1,08	91,2
	Growth — *Kasvu*	-77	y = —4,11x + 12,32	0,33	80,2
	”	-78	y = 25,62x + 15,23	10,04**	89,8
Cu/Mn	Height — *Pituus*	-78	y = 411,36x + 85,36	0,63	91,1
	Growth — *Kasvu*	-77	y = —190,81x + 14,20	2,32	81,8
	”	-78	y = 570,63x + 12,45	19,08***	92,0
Zn/Mn	Height — *Pituus*	-78	y = 26,69x + 86,00	0,24	91,0
	Growth — *Kasvu*	-77	y = —23,02x + 16,00	3,32	82,5
	”	-78	y = 54,20x + 9,94	14,33***	90,9

Appendix 23. Regression equations between seedling mortality and peat characteristics calculated by the analysis of covariance, F values of regression coefficients and coefficients of determination in Exp. 4 as well as combined analyses of Exp. 1 and 4 and all experiments. The coefficients of determination include the effect of class variables in the entire material.

Liitetaulukko 23. Kovarianssianalyysillä lasketut taimien kuolleisuuden ja turpeen ominaisuuksien väliset regressioyhtälöt ja regressiomuuttujien F-arvot sekä mallien selitysasteet kokeessa 4 sekä kokeiden 1 ja 4 ja kaikkien kokeiden yhteisanalyyseissä. Selitysaste sisältää luokkamuuttujien vaikutukset koko aineistosta.

		PK fertilization — *PK-lannoitus*			NPK fertilization — *NPK-lannoitus*		
Experiments *Kokeet*	Indep. var. *Selittävä muuttuja*	Equation — *Yhtälö*	F	Coeff. of. determ., % *Selitysaste, %*	Equation — *Yhtälö*	F	Coeff. of determ., % *Selitysaste, %*
4	NH_4—N 5-10	y = —0,23x + 22,00	0,93	52,2	y = —0,10x + 16,17	1,40	55,7
	NH_4—N 15-20	y = —0,33x + 36,12	12,73*	84,0	y = —0,02x + 13,35	0,31	44,9
	Tot N 5-10	y = —25,56x + 58,50	16,32**	86,7	y = 1,64x + 7,91	0,28	44,0
	Tot N 15-20	y = —19,31x + 51,85	2,64	62,8	y = —5,92x + 23,24	0,24	43,8
	pH 5-10	y = 11,02x — 35,58	0,17	45,2	y = —0,37x + 13,04	0,01	40,3
	pH 15-20	y = —17,92x + 84,18	2,71	63,2	y = 0,66x + 8,70	0,01	38,0
1 ja 4	NH_4—N 5-10	y = —0,23x + 18,40	3,65	31,6	y = —0,71+16,48	0,22	33,3
	NH_4—N 15-20	y = —0,34x + 27,48	14,44***	51,3	y = 0,01x + 13,23	0,03	32,7
	Tot N 5-10	y = —12,75x + 28,34	7,44*	40,1	y = 3,75x + 7,88	0,49	34,3
	Tot N 15-20	y = —3,93x + 17,48	0,50	22,5	y = —5,62x + 23,36	0,36	33,9
	pH 5-10	y = —1,15x + 15,30	0,05	20,9	y = 15,22x — 36,72	0,69	21,4
	pH 15-20	y = 1,96x + 3,38	0,05	20,9	y = —13,73x + 74,03	0,65	21,2
1—4	NH_4—N 5-10	y = —0,14x + 15,05	3,34	38,3	y = —0,001x + 14,73	0,00	32,2
	NH_4—N 15-20	y = —0,17x + 18,12	5,18*	40,2	y = 0,005x + 14,48	0,01	32,3
	Tot N 5-10	y = —5,38x + 17,63	2,21	24,5	y = 2,67x + 11,15	0,35	25,1
	Tot N 15-20	y = 0,90x + 10,10	0,01	34,6	y = 0,93x + 13,32	0,03	32,3
	pH 5-10	y = —1,11x + 15,83	0,06	34,6	y = —4,87x + 39,23	0,25	32,5
	pH 15-20	y = —8,32x + 42,97	2,41	37,3	y = —5,95x + 37,43	0,46	32,9

ODC 2--114.444+237+160.2+161.4
ISBN 951-40-0597-X
ISSN 0358-9609

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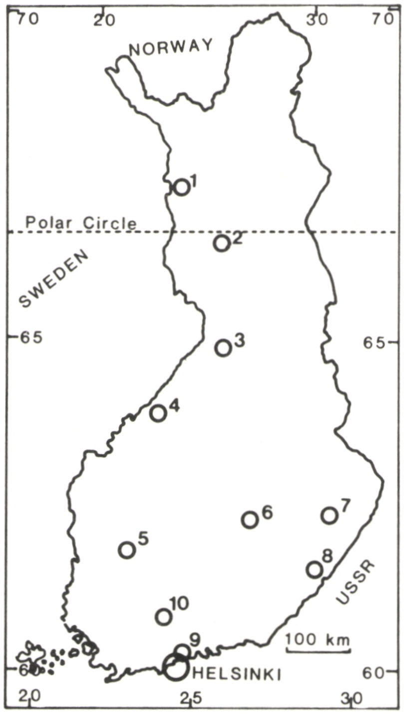

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FACTS ABOUT FINLAND

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

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

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

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