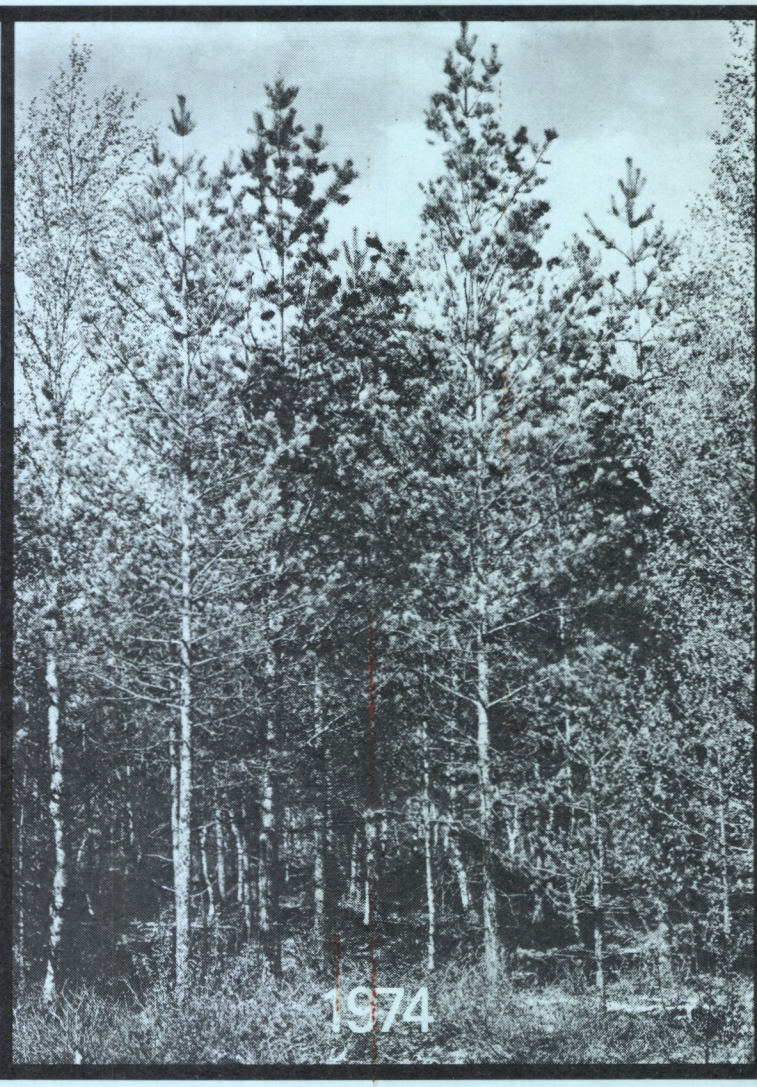
METSÄNTUTKIMUSLAITOS

PYHÄKOSKEN TUTKIMUSASEMAN TIEDONANTOJA 12



KALEVI KARSISTO

PEATLAND FORESTRY EXPERIMENTS IN PYHÄKOSKI EXPERIMENTAL AREA

MUHOS 1974

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FOREWORD

An English copy, introducing the Pyhäkoski Experimental Forest and its most important points, was written for the excursion of the International Symposium on Forest Drainage. As the most recent results are also generally applicable, the copy was later worked into a report of the Pyhäkoski Research Station. On the other hand, this publication, which at the same time is an introductory quide for the experimental area, is useful especially for foreign visitors.

In addition to the undersigned, Seppo Kaunisto, Lic. of Sci. in For., contributed with a paper dealing with the afforestation of peatlands and Kimmo Paarlahti, Lic. of Sci. in For., introducing two results concerning the fertilization of swamp forests. The names are attached to their papers. The translation was performed by Leena Kaunisto, M. A. The staff of the Pyhäkoski Research Station, especially Jorma Issakainen and Kauko Kylmänen, has aided remarkably in the establishment and measurement of the experiments and in the treatment of the results. I wish to extend my best thanks to all the contributors.

In Muhos December 22nd, 1974

Kalevi Karsisto

Suomenkieliselle lukijalle:

Kansainvälisen metsäojitussymposiumin retkeilyä varten laadittiin syksyllä 1974 Pyhäkosken kokeilualuetta ja tärkeimpiä kohteita esittelevä englanninkielinen moniste. Koska tässä yhteydessä mitatut uusimmat koetulokset ovat käyttökelpoisia yleisemminkin ottaen, on monisteesta edelleen muokattu Pyhäkosken tutkimusaseman tiedonanto.
Toisaalta tällä englanninkielisellä tuloksia sisältävällä julkaisulla, joka samalla on kokeilualuetta esittelevä opaslehtinen, on käyttöä erityisesti ulkolaisia retkeilijöitä ajatellen. Suomenkielisiä vierailijoita varten laadittu retkeilyopas tullaan uusimaan lähiaikoina.

CONTENTS

EXPERIMENTAL ACTIVITY IN PYHÄKOSKI EXPERIMENTAL AREA

The total area of Pyhäkoski Experimental Forest, after some recent enlargements, is about 4100 hectares. From this, more than 90 % is peatland. In the case of peatlands, the altitude varies between 70 - 75 metres and in the case of mineral soils about 75 - 80 metres above sea level. This means that a comparatively even area is in question. The annual precipitation is about 550 mm, which is rather little. The average sum of daily mean temperature ($>+ 5^{\circ}C$) is 1020 d.d., and the duration of the growing season ($\geq + 5^{\circ}C$) about 145 days.

The research activities in the station are characterized by problems urgent at a particular period of time. By presenting these periods, a clear picture of the development of the experimental activity as well as the changing of the problems within peatland forestry in the course of decades can be given.

In the 1930´s, the emphasis was put upon investigations on peatland afforestation. Besides methods of natural regeneration, artificial seeding methods, especially with pine, were studied.

Yield investigations on peatlands were started in the 1930´s, as the so-called permanent plot series were established. Among other things, the influence of different silvicultural treatments on yield has been studied on these plots.

The first fertilization experiments, using wood ash as a fertilizer, were established in the 1940´s. The actual basic research on the fundamentals of fertilization did not start until the beginning of the 1950´s, as the use of commercial fertilizers in forests increased.

Investigations on new ditching methods started in the 1950's after mechanized ditching had become a common practice. At that time, the first field experiments on the use of plastic pipes in forest drainage were established in the experimental forest. Later, this work has been continued by investigations on rotary ditching and work output.

Investigations on different fertilizer forms became actual at the beginning of the 1960's. At this time, it was already known which nutrients and how much of each should be applied when fertilizing peatlands. Since nutrients are applicable in various chemical forms, extensive experiments with different nitrogen and phosphorus fertilizers were set up to find out the most profitable form for common use.

In the 1960's, the development of seeding and planting methods started again. Simultaneously, the value of different ditch types in afforestation was studied. It was found out that a good planting result and an effective drainage are achieved at the same time if the furrowing method is used. Mechanized afforestation with soil preparation has been studied, too.

Good facilities for studying the need for repeated fertiliration and supplementary ditching were provided by old fertiliration experiments established some 20 years ago in the experimental forest. Soon after the activity of the research station started, old plots were divided into smaller units by ditches. The possibilities for intensive forestry by using effective ditching and frequently repeated fertiliations have been the main object of research at the beginning of the 1970's.

INDEX MAP OF PYHÄKOSKI EXPERIMENTAL FOREST

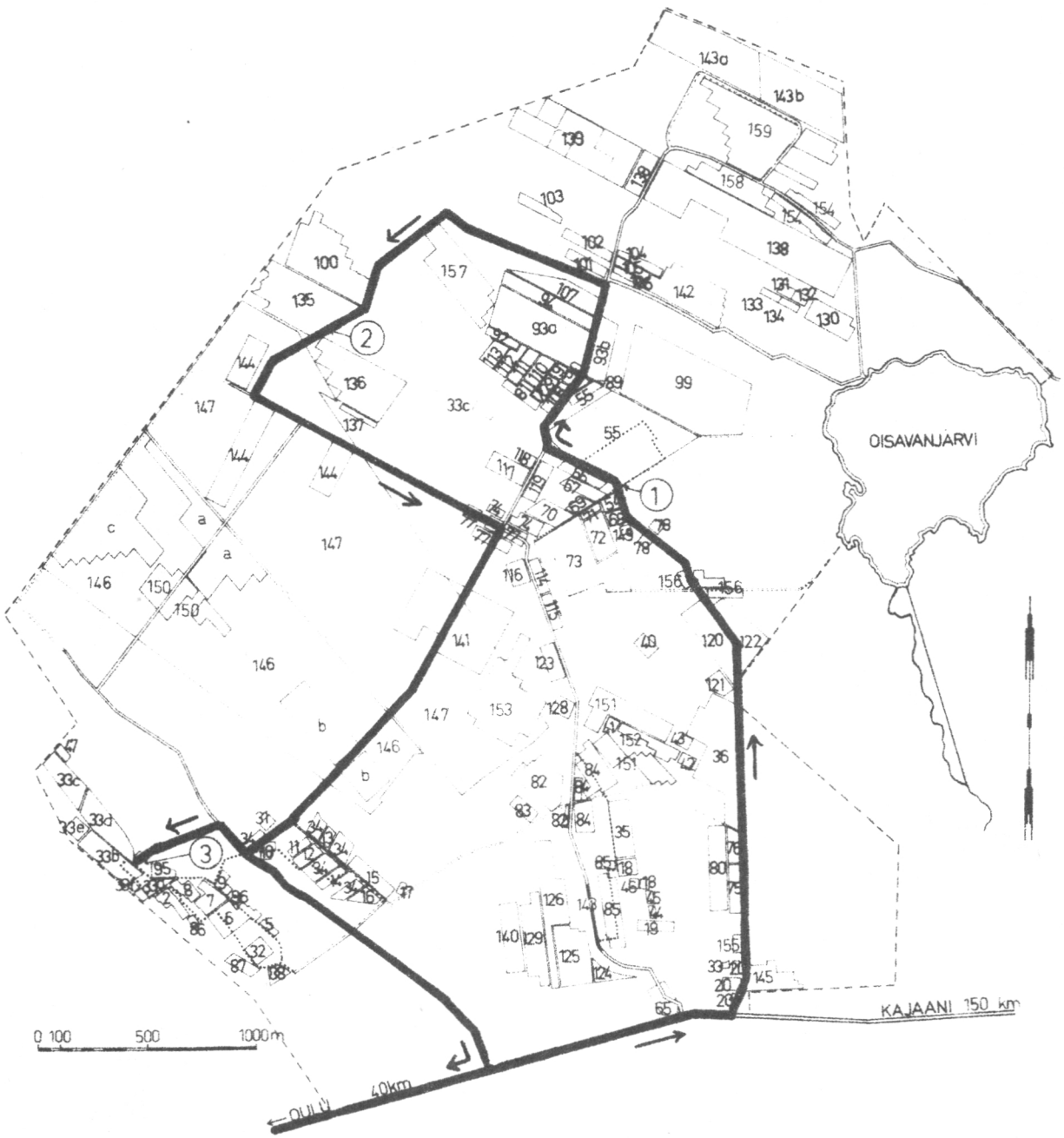
Detailed excursion route on lot 2

can be seen on page 4

Lots:

1.	Research Station	4 ha
2.	Northern lot	1 550 ha
3.	Southern lot	630 ha
4.	Kantosuo	280 ha
5.	Tahvola and Häikiö	1 100 ha
6.	Other lots	500 ha
	Total about	4 100 ha

SURVEY MAP OF LOT 2



Excursion route on lot 2

Points:

1. Fertilization experiments on an originally open swamp
2. Experiments on afforestation of open peatlands
3. Various fertilization experiments on an old drainage area

Experiments and results on the way to point 1

Near the forest road leading from the main road to the first excursion point there are several experiments dealing with fertilization and liming of swamp forests.

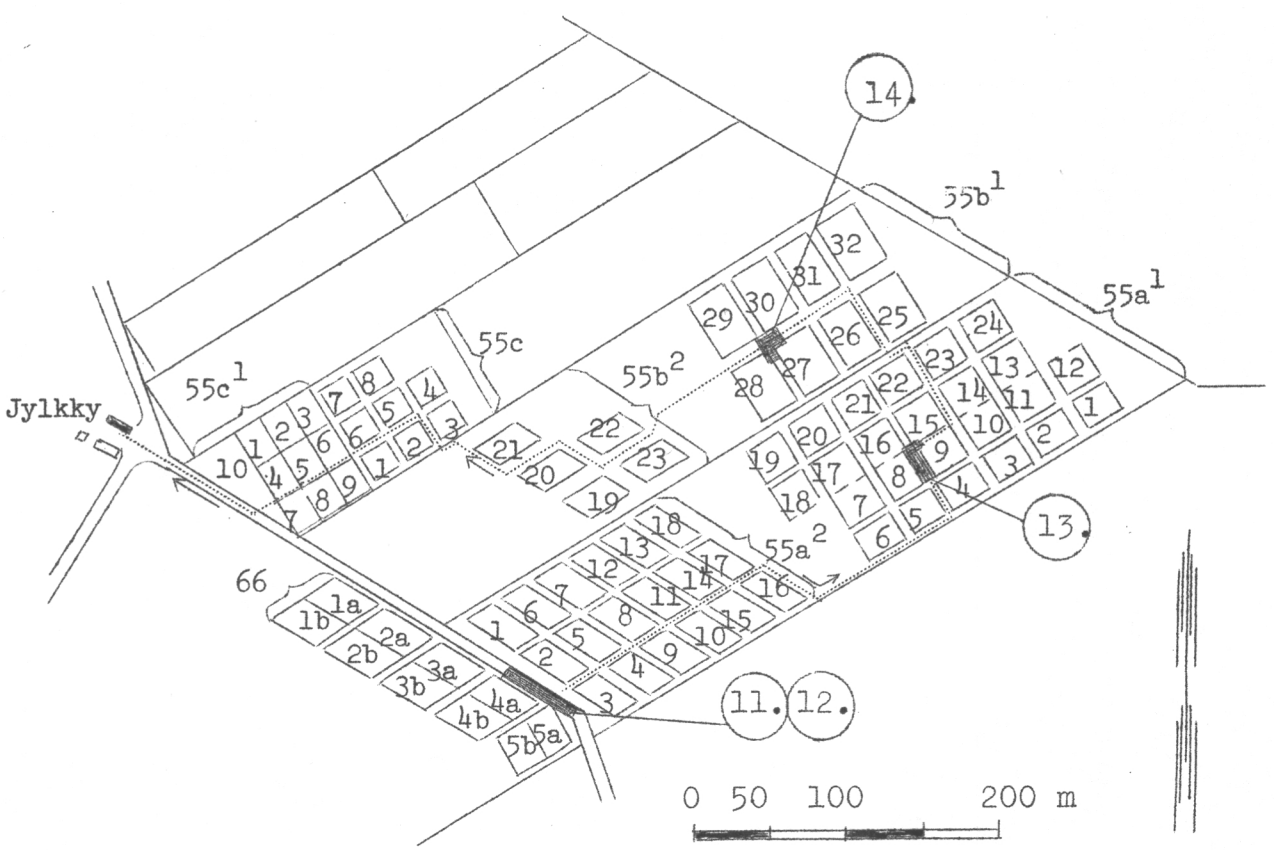
Experiment No. 20 deals with the yield of swamp forests. It is a permanent plot drained in 1932 - 33. Originally, planting and seeding (1934) with spruce under differently thinned shelterwood were investigated. A fertilization experiment (No. 145) with 10 treatments was established in 1971 on the other side of the road in a naturally regenerated birch (Betula pubescens) stand. The various blocks were thinned into three different densities in connection with fertilization. Experiment 155, established in 1973, likewise deals with the fertilization of Betula pubescens.

After this we shall move over to a former treeless bog, which can be seen in its original state on the right beyond the influence of the main ditch on the road side. The stands left to the road have been established by seeding and planting pine in 1953 - 54 (fertilization and liming experiments 75 and 76). The experimental area No. 36 was originally seeded in 1936. Not until 1960 was the area fertilized, eight different nitrogen fertilizers with phosphorus and potassium were used among other things. Refertilization occurred in 1972 - 73.

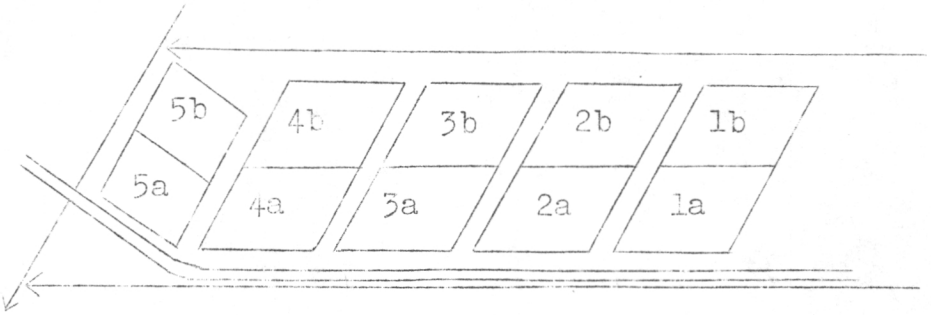
Experiments 120, 121, 122 were treated with PK fertilization in 1967. Later on the way, there are stands brought about by mere drainage (1938). The cubic volume of the stands is about 200 solid m^3/ha. A fertilization experiment with Betula pubescens (No. 156) was established in this stand in 1973. The experiments 78, 68 and 54 before the first stop are dealing with different seeding and planting methods with pine.

POINT 1. FERTILIZATION EXPERIMENTS ON AN ORIGINALLY TREELESS SWAMP

The route consists of originally herbrich sedge bogs which underwent basic drainage in the 1930's and were later afforested either by seeding or planting. The area has been redrained since in connection with the establishment of fertilization experiments. Additional drains have been employed for dividing the plots into new treatment units at the time of refertilization.



11. High rates of phosphorus and potassium



Experiment No. 66 contains 10 plots. The acreage of all the plots is 0.065 ha, excluding the plots 5 a and 5 b with their 0.049 ha. The area was drained in 1934 - 37. Supplementary drainage of the border areas and the untreated strips between the plots was performed in 1971. The tree stand was established in 1941 by planting with pine. Basic fertilizations were carried out from 12th to 16th December in 1953 on snow. Refertilization took place on 11th June, 1973. The enclosed map shows the location of the plots. The treatments can be seen in enclosed Table.

The fertilizer amounts kg/ha

	Basic fertilization in 1953					Refertilization in 1973		
No.	K	P	Ca	B	Cu	U	Rf	Ks
1 a	1154		3461	11,54	34,61	-	500	-
b	577		3461	-	-	-	-	-
2 a	-	1154	3461	11,54	34,61	-	-	-
b	-	577	3461	-	-	-	-	500
3 a	577	1154	3461	11,54	34,61	-	1000	500
b	577	1154	3461	-	-	-	-	-
4 a	1154	2308	3461	11,54	34,61	-	-	-
b	1154	2308	3461	-	-	400	-	-
5 a	-	-	-	-	-	-	1000	500
b	-	-	-	-	-	-	-	-

K = muriate of potash (50 %)
P = ground rock phosphate (33,5 %)
Ca = lime stone (54 %)
Cu = byproduct of copper calcination (20-30 %)
B = fertilizer borax (14 %)
U = urea (46 %)
Rf = raw phosphate (33 %)
Ks = muriate of potash (60 %)

The part "a" on each plot received boron and copper in fertilization. When examining the total cubic volume and especially the growth, it seems that the plots 3 and 4 which received PK and Ca fertilizers had benefited from the fertilization with microelements. High rates of phosphorus and potassium seem, in this case, to have resulted in a particularly long-lasting influence, since the original swamp type was adequately rich in nitrogen. The negative reaction often brought about by liming remained apparently small owing to the high application rates of phosphorus and potassium.

The annual growth and cubic volume in 1974 is shown by enclosed Table:

	5 a-b	1 a	1 b	2 a	2 b	3 a	3 b	4 a	4 b
Total cubic volume in 1974, m^3/ha	6,5	17,7	24,8	42,7	42,5	88,0	69,9	81,9	54,5
Annual growth m^3/ha (1971 - 74)	0,4	1,2	1,4	2,7	3,4	8,8	4,5	6,5	4,1

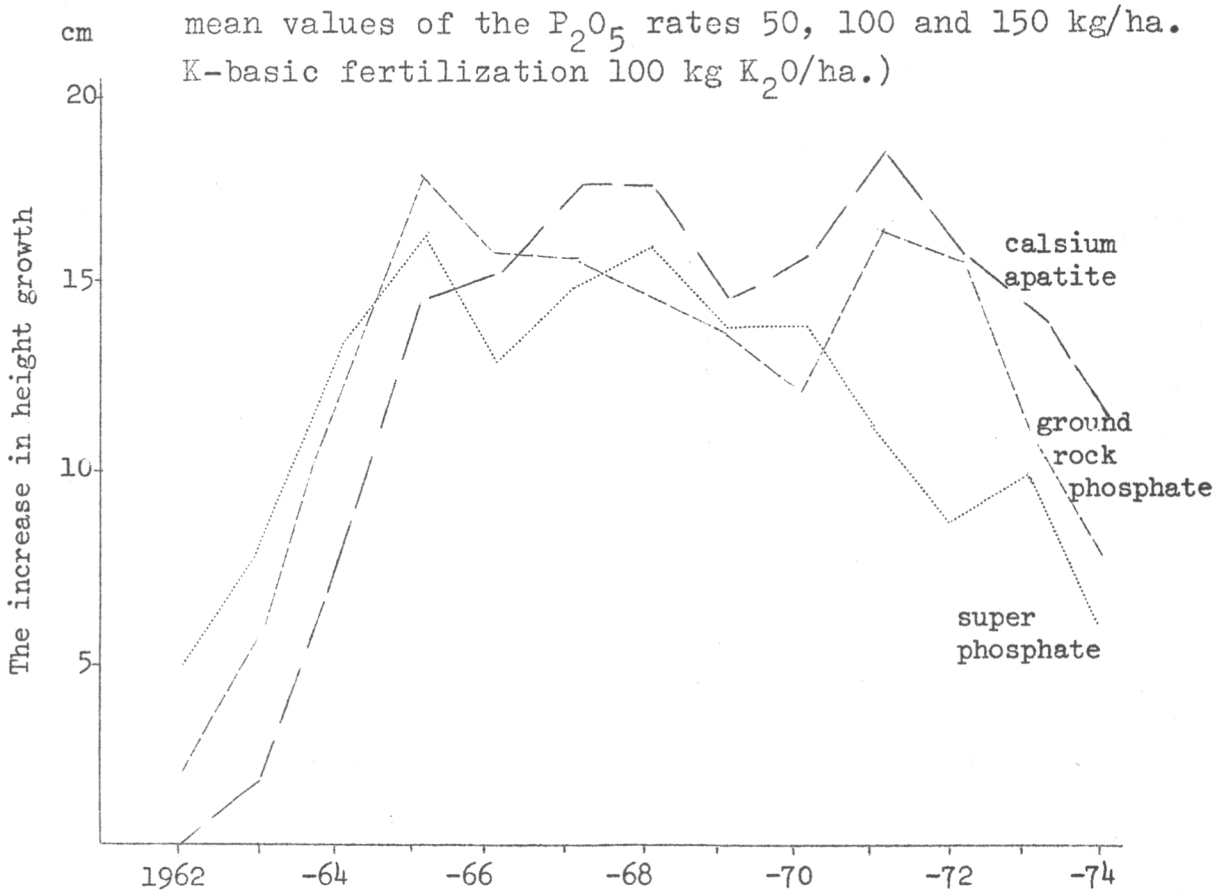
12. An experiment with different phosphorus fertilizers

The experiment with different phosphorus fertilizers dating back to 1961 (No. 55 a and b/2) involved 23 plots, whose locations are seen on the enclosed map (page 6). The experimental area is part of a more extensive series of experiments with different phosphorus fertilizers, the establishment of which was initiated in 1961. This experiment is replicated in Parkano. Another experiment established in 1961 is in Kivisuo. More detailed information on the number of experiments with different phosphorus fertilizers and on their locations is available on the map in the paper by Mr. Karsisto (1974).

Originally treeless swamp was drained in 1934 and afforested by pine seeding in 1939. The experimental area had flarks in some parts of it. In August 1961 it was fertilized with different phosphorus fertilizers: super, ground rock, Kotka (mixture of super and ground rock phosphates), or Thomas phosphates. All plots received muriate of potash 100 kg as K_2O/ha.

It is very interesting to compare the various durations of fertilization influence caused by different phosphorus fertilirers. The following page (Figure 1) presents the annual height growth of trees during the 13 growing seasons after fertilization. At first, the response given by apatite was slow, but in the sixth growing season its influence on growth surpassed that caused by other fertilizers. Correspondingly the response by super phosphate distinctly weakened after the eighth growing season. The ground rock phosphate, which comes between the two fertilizers mentioned above as regards its chemical properties, yields a mediocre response.

Figure 1. The annual increase in height growth caused by fertilization with reference to calsium apatite, ground rock phosphate and super phosphate. (As the mean values of the P_2O_5 rates 50, 100 and 150 kg/ha. K-basic fertilization 100 kg K_2O/ha.)

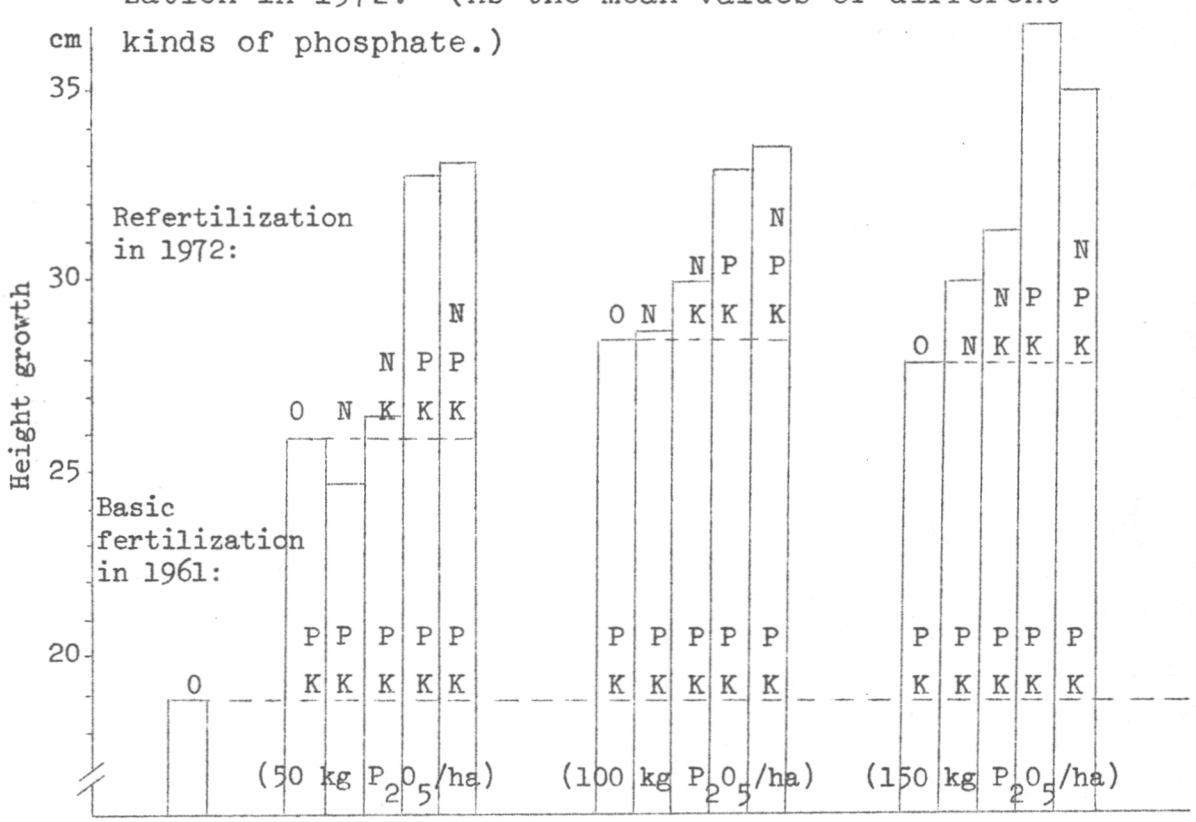


The long-lasting fertilization influence obtained in this experiment is based on the fact that nitrogen was not required owing to the naturally nutritious state of the site. Nitrogen had not yet become a growth limiting agent. On the corresponding experimental area in Parkano already mentioned, nitrogen had to be used from the very beginning since the area was naturally deficient in nutrients. Even the duration of influence was the same as in nitrogen fertilization. On the other hand, the influence of apatite did not as distinctly surpass the others as in Muhos, although it proved the best in the past few years. In order to investigate the differences caused by the various phosphorus fertilizers, no other factor should inhibit the growth.

The area was refertilized 22nd through 29th of June, 1972, in order to clarify the differences between the various phosphorus fertilizers and to reveal the possible weakening in the fertilization influence. The plots were then divided into six parts by means of ditches (except plots 19 - 23 which were divided into four parts). Two parts of the shared plots were left unchanged. The other ones were fertilized so that one part received the same PK fertilization as in 1961, the second mere nitrogen fertilization, the third NK fertilization and the fourth NPK fertilization.

The results from refertilization experiments indicate that the site still suffered from phosphorus and potassium shortage. Not even 13 years after the first PK fertilization was nitrogen needed. Later on excursion point 3 we shall see a swamp which is nutritionally two degrees poorer. On that site as early as seven growing seasons after the first fertilization the nitrogen shortage had become a growth inhibiting factor despite the originally applied NPK fertilization.

Figure 2. The annual height growth in 1974 after refertilization in 1972. (As the mean values of different kinds of phosphate.)



13. A refertilized basic fertilization series (Paarlahti)

Drainage, afforestation and fertilization experiment No. 55 a and b/1 is situated on an area with a thich peat-layer where the original peatland site type was sedge-rich open swamp. Drainage was carried out in 1934 and boadcast sowing with pine seeds in 1939. The fertilization experiment was established in 1957.

The primary aim of the fertilization experiment was to clarify the fertilization requirements of pine stands for the main nutrients and the effect and duration of the growth reaction given by different dosages. The layout used in this experiment was a balanced incomplete factorial design, where the main nutrients N, P and K were applied at 5 levels. The results showed that the most necessary fertilizers on this site were phosphorus and potassium, fertilization with nitrogen did not cause any increase in growth.

A clear positive correlation was found between the increase of potassium and phosphorus dosages and the duration of the growth reaction.

This experiment formed part of a wide investigation carried out by the Department of Peatland Forestry, the Finnish Forest Research Institute, in which an attempt was made to clarify the possibilities of using needle and soil analyses for determining fertilization requirements. The total material consists of 226 sample plots where different fertilization treatments have been carried out at sites situated in different parts of Finland. Needle and soil samples were collected in 1967 and the results were published in Comm. Inst. For. Fenn. 74.5 by the authors Paarlahti - Reinikainen - Veijalainen.

It is not possible to give any detailed information concerning the results, but as a rough conclusion it can be said that nitrogen fertilization is required if the N-content of the needles is under 1.3 % and the phosphorus-potassium status is good. It appears that phosphorus fertilization is required if the P-content of the needles is under 1.7 o/oo and the nitrogen-potassium status is satisfactory, and potassium fertilization is required if the K-content is under 4.00 o/oo when the nitrogen-phosphorus status is favourable.

As an example the stepwise regression analysis for all the data collected from Muhos, classified according to the N-, P- and K-content of the needles gave the following equations:

1) $P_n \geq 1.40$ o/oo, $K_n \geq 3.50$ o/oo

Height growth $_{-67} = 47.520^{***} N_n + 21.288^{**} P_n - 9.045^{*} Ca_n + 7.834^{*} K_n - 86.872^{***}$; $R = 0.84^{***}$, $100\ R^2 = 70.1$ %

2) $N \geq 1.30$ %, $K_n \geq 3.50$ o/oo

Height growth $_{-67} = 20.964^{***} P_n - 16.273^{***} Ca_n + 26.115^{**}$;

$R = 0.86^{***}$, $100\ R^2 = 74.5$ %

In order to test the fertilization recommendations based on needle analyses, some of the plots of this experiment were divided in 1972 into four parts. One part from each plot was refertilized with a dosage determined on the basis of needle analyses and the limit values of nutrient contents mentioned above.

The data concerning these plots is shown in the appendix Table. The figures show that the height growth of pine clearly increased after refertilization indicating that the diagnosis in this case was correct.

Fertilizations, nutrient content of needles and height growth
on some sample plots of experiment 55 a-b, Muhos

Plot No.	Fertilized in 1957 with			Nutrient content of needles in 1967			Refertilized in 1972 with			Height growth (cm)		
	N	P	K	N	P	K	N	P	K	in 1967	in 1974	
	kg/ha			%			kg/ha				not refertilized	refertilized in 1972
5	-	-	-	1.62	0.115	0.315	-	87	83	13.3	17.2	37.3
8	-	24	-	1.30	0.155	0.225	100	44	166	28.0	19.3	36.1
9	-	49	-	1.46	0.225	0.250	-	-	166	27.0	22.6	37.5
10	-	73	-	1.64	0.238	0.225	-	-	166	24.0	24.9	35.6
11	-	122	-	1.37	0.245	0.250	-	-	166	25.6	25.7	32.2
2	-	-	66	1.50	0.110	0.400	-	87	-	22.4	19.3	34.7
3	-	-	100	1.62	0.103	0.375	-	87	83	24.1	21.0	33.8
4	-	-	166	1.46	0.103	0.375	-	87	83	19.1	23.5	39.1
20	-	24	100	1.42	0.120	0.345	-	87	83	28.1	14.0	31.2
21	-	49	100	1.39	0.145	0.425	-	44	-	36.3	16.9	31.4
22	-	73	100	1.32	0.178	0.400	-	-	-	42.3	23.9	-

Nutrient content of needles in 1972 and increase in height growth caused by refertilization.
Experiment 55 a-b, Ruhos

Plot No.	Nutrient content of needles in 1972						Increase in height growth caused by refertilization (cm)		
	N		P		K				
	not ref.	ref.	not ref.	ref.	not ref.	ref.	in 1972	in 1973	in 1974
5	2.00	1.67	0.080	0.110	0.290	0.400	-1.3	+9.6	+20.1
8	1.72	1.89	0.090	0.100	0.220	0.450	2.7	9.7	16.8
9	1.53	1.45	0.140	0.120	0.230	0.510	0.5	12.3	14.9
10	1.67	1.47	0.150	0.140	0.240	0.550	-2.9	11.4	10.7
11	1.53	1.61	0.160	0.180	0.230	0.270	-1.3	2.1	6.5
2	1.96	1.81	0.090	0.100	0.320	0.450	2.6	8.2	15.4
3	1.85	1.53	0.090	0.130	0.300	0.480	-0.4	7.7	12.8
4	1.65	1.43	0.090	0.130	0.320	0.490	-0.5	2.5	15.6
20	1.97	1.85	0.080	0.120	0.300	0.400	-6.9	1.9	17.2
21	1.89	1.63	0.100	0.130	0.330	0.340	3.3	9.2	14.5
22	1.62	-	0.120	-	0.280	-	-	-	-
Average height growth on not refertilized plots (cm)							21.4	23.9	20.7

14. Cubic results

The next stop on point 1 is situated on an unfertilized control plot No. 30. On the right there is an almost treeless limed plot No. 28 and a well-growing plot No. 29 with NPK fertilization. Right ahead is the plot No. 27 also directly fertilized with NPK. The area was drained in 1934 and afforested by pine seeding in 1939. The fertilization treatments were carried out in 1957. In addition to the above-mentioned well-growing NPK plots it is worth while paying attention to the plot 31 fertilized with mere PK. The enclosed Table shows the total cubic volumes and annual growth on the plots in question.

No.	Fertilization in 1957 (kg/ha)	Total cubic volume in 1974 (m^3/ha)	Annual growth in 1974 (m^3/ha)
30	0	4,23	0,07
28	Ca 2600	3,92	0,20
26	N 50 + P_2O_5 168 + K_2O 150	40,65	2,16
31	P_2O_5 220 + K_2O 200	41,09	2,05
27	N 100 + P_2O_5 168 + K_2O 150	58,63	4,31
29	N 150 + P_2O_5 168 + K_2O 150	55,36	3,98

Experiments and results on the way to point 2

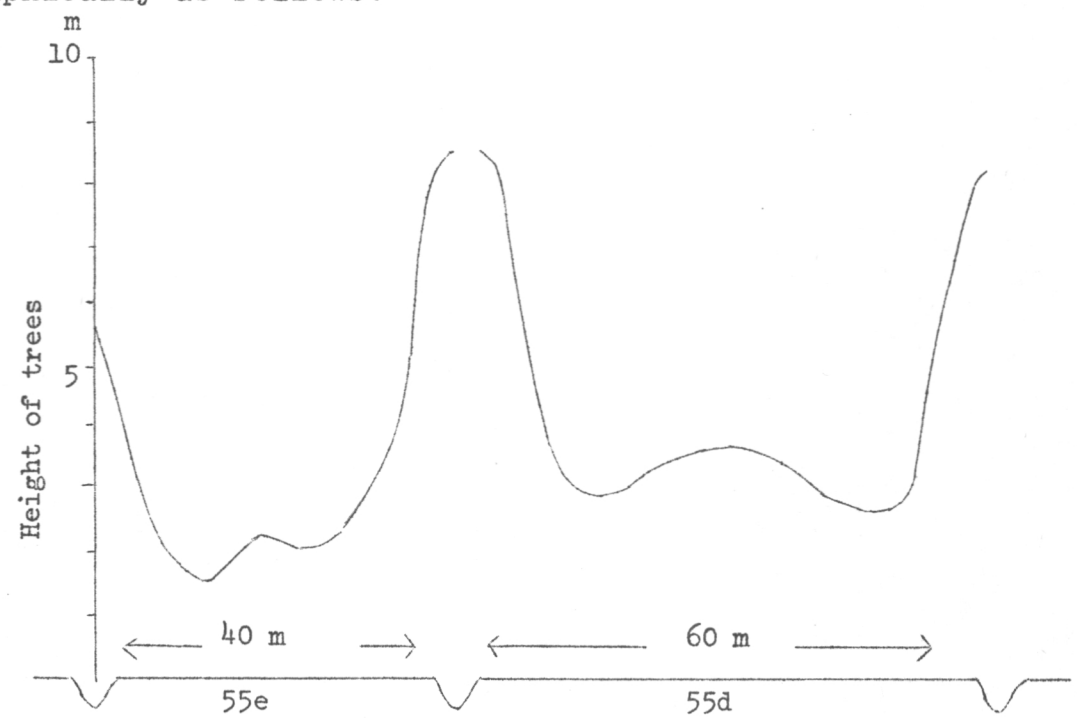
On the way from the last stop on point 1 to Jylkky-cottage refertilized plots belonging to the experiment with different phosphorus fertilizers on point 1 can be seen. Among them on the fertilized part of the plot No. 21, which was originally an unfertilized control plot, trees have responded very strongly in fertilization.

When moving over to the next strip, 55 c, the route goes through a fertilization experiment set up in 1952. This area suffering from poor drainage in 1934 was treated with supplementary drainage in 1970 and with various fertilizer treatments in 1972. Then the original plots were divided into two parts. The annual height growth can be seen on the Table.

The height growth of pine in 1974. Experiment 55 c.

Basic fertilization in 1952	Refertilization in 1972		$\bar{x}$
	PK	NPK	
0	-	-	24.7
N	35.8	41.8	38.8
P	26.9	37.9	32.4
K	31.0	37.3	34.2
NP	33.8	33.8	33.8
NK	39.9	39.4	39.7
PK	31.7	38.2	35.0
NPK	32.0	35.2	33.6
$\bar{x}$	32.2	35.8	

The areas east of the Jylkky cottage belong to the former treeless Oisava bog characterized by abundant spring floods. When coming to the cottage we visited fertilization experiments which were on the strips 55 a, 55 b and 55 c. The strips seen from the front yard are 55 d and 55 e. They were drained in 1934 and afforested by direct pine seeding in 1939. The original ditch spacing was too wide, which resulted in a slow growth of trees. Only in the immediate vicinity of the ditches have the trees grown fairly well. It can be simplified graphically as follows:



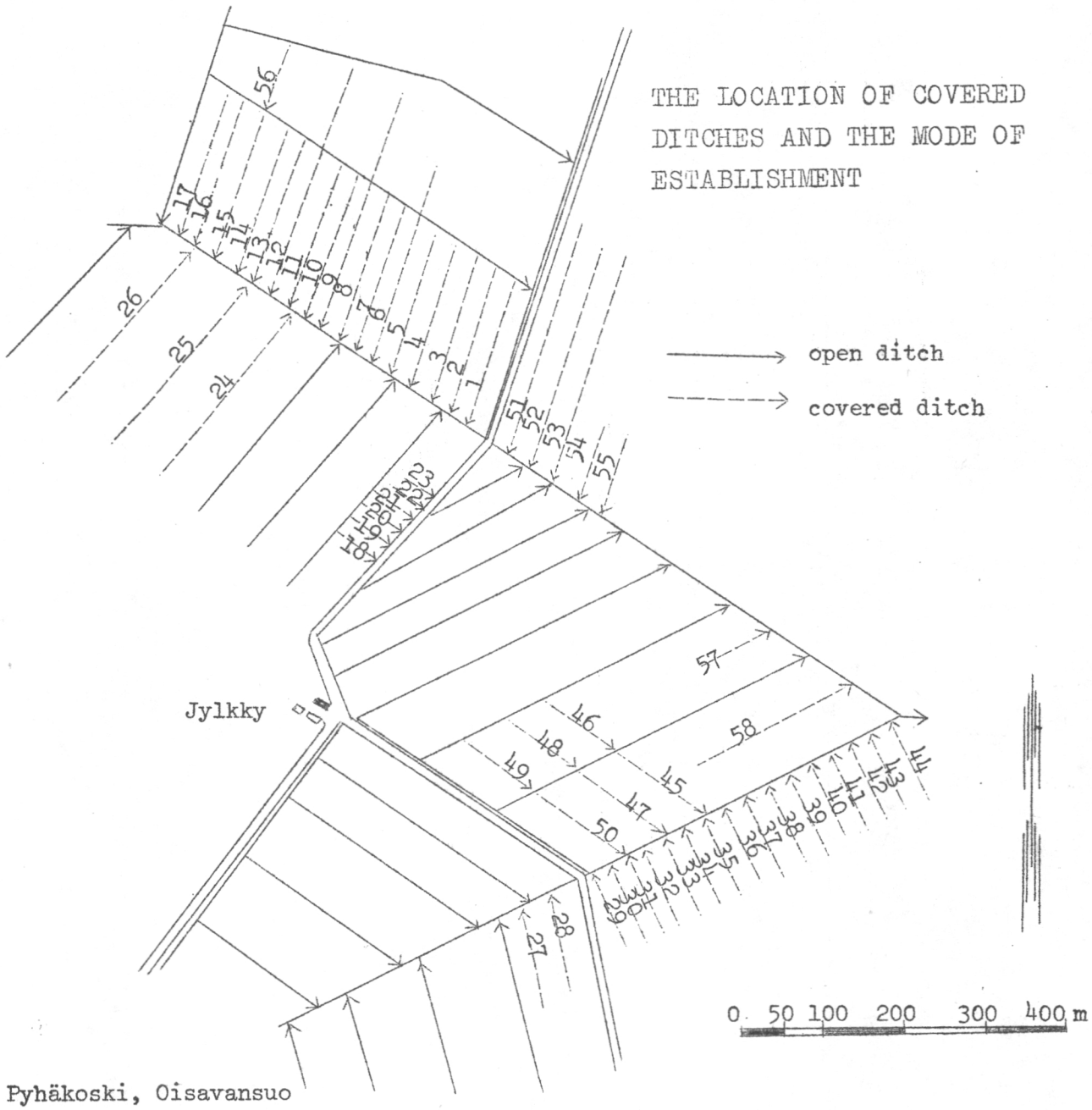
Both strips were fertilized in 1967, 55 e with mere Kotka phosphate 400 kg/ha and 55 d with PK fertilizer for swamp forest 600 kg/ha. In order to intensify the drainage effect, two additional ditches were made lengthwise on both strips by means of a rotary ditcher in 1969. A refertilization experiment was set up in 1972 on the strips. The experiment involved 10 different treatments with 8 replicates. The differences caused by the originally inadequate drainage have started to acquire a more uniform level. This is demonstrated by the colour of trees and the growth of the latest leading shoots.

When driving from the Jylkky cottage, there is a mound of mineral soil on the left, which was burnt in 1955. After burning, the area was sown with pine. In Jylkynsaari (Jylkky island) there are fertilization experiments on mineral soil and series of thinnings in the young stand. (Typical of the Experimental Forest is the great number of previously wet swamps, which have made the local people call all the patches of mineral soil with the suffix "island". The total area contains 6 % of "islands" and 94 % of peatland.)

The drainage of experiments 108, 90, 93 a and 93 b has been carried out by means of covered ditches. The oldest covered ditches date back to 1951. In connection with underdrainage different types of covered ditches and their properties have been studied. Subsequent investigations on their condition have dealt with their operation and capacity of avoiding clogging up. It is worth mentioning that plastic pipes were used for making covered ditches in swamp forests before they were taken into use in agriculture. There is a detailed map (next page) showing the different kinds of covered ditches on the whole area of Oisavansuo.

In 1962 pine was planted on an underdrained area (experiments 93 a and 93 b), and the transplants were spot fertilized with NPK. In 1967 various parts of the afforestation field were broadcast fertilized with phosphorus and potassium, both separately and together. The afforestation experiment 94 and the fertilization experiments on a naturally regenerated young stand 107 (NPK, PK in 1967) are outside the actual underdrained field. The whole of the northern lot (1550 ha) was photographed with infrared from the height of 9 km. These photographs reveal very clearly the covered ditches, for example, although it is very difficult to actually see them in the field.

THE LOCATION OF COVERED DITCHES AND THE MODE OF ESTABLISHMENT



Pyhäkoski, Oisavansuo

No.	Ditch type		No.	Ditch type		No.	Ditch type	
1	plastic sheet	1961	20	plastic pipe	1961	39	plastic pipe	1961
2	"	"	21	"	"	40	"	"
3	vault	1951	22	"	"	41	hole	"
4	plastic sheet	1961	23	"	"	42	"	"
5	"	"	24	hole	1953	43	plastic pipe	"
6	vault	1951	25	vault	"	44	"	"
7	plastic sheet	1961	26	"	"	45	hole	1953
8	"	"	27	plastic pipe	1961	46	"	"
9	vault	1951	28	"	"	47	wood pipe	"
10	plastic sheet	1961	29	plastic sheet	"	48	"	"
11	"	"	30	"	"	49	vault	"
12	wood pipe	1953	31	"	"	50	"	"
13	plastic sheet	1961	32	"	"	51	plastic pipe	1961
14	"	"	33	plastic pipe	"	52	"	"
15	hole	1953	34	"	"	53	"	"
16	plastic sheet	1961	35	hole	"	54	"	1962
17	"	"	36	"	"	55	"	"
18	plastic pipe	"	37	plastic pipe	"	56	hole	1954
19	"	"	38	"	"	57	vault	1953
						58	hole	"

POINT 2. AFFORESTATION OF OPEN PEATLANDS

The most important species in afforestation of open bogs in Finland is Scots pine (Pinus silvestris). Some other coniferous species under study in the Finnish Forest Research Institute are Pinus contorta, Picea abies and Larix sibirica. The most important hard-wood species are Betula verrucosa and Betula pubescens.

21. Afforestation with betula species (Kaunisto)

Experiment No. 135 at Muhos experiment station was established in 1969. It is dealing with the afforestation of peat soils by B. verrucosa. The goal was to find out the growing requirements of B. verrucosa on peat. B. verrucosa naturally occurs almost exclusively on mineral soils. However, after drainage and fertilization it also appears on peat soils, even on quite poor sites. There, however, seems to be a number of difficulties when growing it on peat. It is easily attacked by a certain fungus Godronia multispora, whereas this is not a problem on mineral soils. On peat this tree species usually has a bushlike habitus.

This experiment is one of the five similar ones in five different locations in Finland. The treatments included are as follows:

1. Fertilization
   - Nutrient combination NPK or PK
   - Nutrient level 0, 500 kg/ha of PK fertilizer (0-24-15) plus - minus 300 kg/ha of oulusaltpetre (26-0-0) or the amounts above doubled.
2. Site preparation no site preparation or rotavation by means of Lamu III
3. Liming 0, 4000 or 8000 kg/ha of agricultural limestone.

In prepared treatments all of the combinations of the other variables were studied. In unprepared treatments only the first level of liming and fertilization was included.

An otherwise similar experiment was performed at Alkkia (400 km southwest of Muhos), but in addition B. pubescens was included. B. pubescens naturally occurs on peat soils but at least on mineral soils is less profitable than B. verrucosa. Comparison was made between the growth of these species. The results showed that B. verrucosa was slightly better-growing than B. pubescens (Tables 1 and 2). Fertilization was necessary in all cases. Nutrient combination or level didn´t affect tree growth in unlimed treatments. However, in connection with liming growth somewhat increased with increased nutrient application. This was obvious especially with B. pubescens. Growth was improved also by site preparation with Lamu II. On the other hand liming diminished growth drastically.

The results indicate that B. verrucosa has grown quite well in fertilized prepared peat so far. However, last spring revealed a number of frost damages in trees (Table 3). It is not known whether the damages occurred in the previous fall or during the winter. Frost damages were heavier with B. verrucosa than B. pubescens, but damages with the latter species were greatly increased by fertilization and liming. With B. verrucosa the effect of these treatments was not as clear, except probably in connection with the heaviest lime application.

Table 1. Height of B. verrucosa and B. pubescens in the fall of 1974 at Alkkia. Exp. No. 79.

Tree species	Site preparation	Liming	Fertilization				
			0	PK_1	PK_2	NPK_1	NPK_2
B. verrucoaa	Yes	0	105	213	201	194	217
		4000	110	129	162	169	172
		8000	115	131	182	131	153
	No	0	114	175		186	
		4000	63	141		128	
B. pubescens	Yes	0	92	186	160	185	210
		4000	83	112	128	161	156
		8000	80	105	119	138	136
	No	0	92	151		144	
		4000	66	126		110	

Table 2. Height of B. verrucosa in the fall of 1974 at Muhos.

Tree species	Site preparation	Liming	Fertilization				
			0	PK_1	PK_2	NPK_1	NPK_2
B. verrucosa	Yes	0	104	202	211	197	214
		4000	113	144	142	161	138
		8000	107	120	168	130	150
	No	0	83	141		187	
		4000	99	130		126	

Table 3. Number of frost damaged trees per plot in the fall of 1974 at Alkkia. Exp. No. 79.

Tree species	Site preparation	Liming	Fertilization				
			0	PK_1	PK_2	NPK_1	NPK_2
B. verrucosa	Yes	0	16	11	20	18	17
		4000	16	21	15	21	21
		8000	16	18	18	21	26
	No	0	9	6		19	
		4000	7	12		20	
B. pubescens	Yes	0	3	5	11	10	16
		4000	9	7	7	10	16
		8000	6	10	13	21	25
	No	0	3	2		13	
		4000	4	6		11	

22. Afforestation with Scots pine (Kaunisto)

The research activity in the Finnish Forest Research Institute concerning afforestation with Scots pine is today mainly focused on site preparation and fertilization. The main site preparation methods used in Finland are schematically shown in Figure 3.

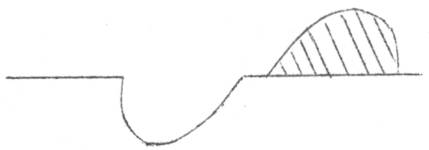
For various reasons site preparation has proved necessary for good tree growth. The physical condition of the substratum is improved. E.g. temperature in milled turf ridges made by LAMU IV is somewhat higher than in undisturbed peat (Table 1). This, of course, results in enhanced microbial and chemical activity.

Competition by other vegetation is negligible for some years (Table 2), which means that a considerable amount of nutrients remains in peat instead of being fixed in the vegetation (Table 3). Mechanical competition of aerial parts of plants is lowered as well. However, after six growing seasons there is not much difference in the biomass of growing stock between prepared and unprepared treatments (Table 4) on a low-sedge open bog.

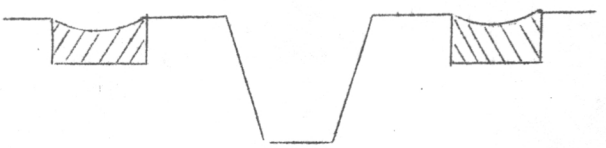
Experiment No. 136 at Muhos concerning afforestation of a small-sedge bog with pine was established in 1969. Site preparation was made by means of LAMU II. In addition, the treatments involved broadcast fertilization with P and K or with N, P and K at the levels of 52, 104 or 208 kg/ha of nitrogen, 42, 62 or 124 kg/ha of phosphorus, and 25, 50 or 100 kg/ha of potassium spread evenly before the site preparation. Strip-widths of 5, 10 or 20 meters were used in the experiment. Afforestation was made by direct seeding.

Because of the difficulties in drainage most of the seedlings born in the first year were distroyed. The area was reseeded in the following year. Broadcast fertilization with NPK caused fast growth of Chamaenerion angustifolium and Eriophorum vaginatum. Higher amounts of PK than 31 and 25 kg/ha correspondingly resulted in enhanced growth of vegetation as well. In these conditions only seedlings on plots of the lowest level of PK fertilization had some chances for survival and growth. It is important to point out that strip fertiliration is used in the normal pre-fer-seed -machine procedure and consequently the reaction of vegetation is not as pronounced as in this case.

Some research also deals with the fertilizer placement in the connection with site preparation. So far the results have been encouraging (Tables 5 and 6). At least on poor sites fertilizer placement improves tree growth especially in connection with direct seeding.

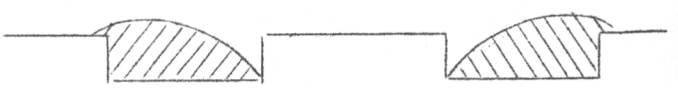


Fiskars
One winged plough

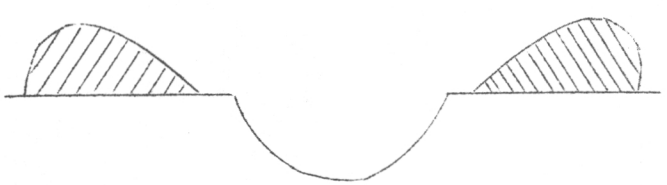


Lamu I
Pre-fer-seed machine

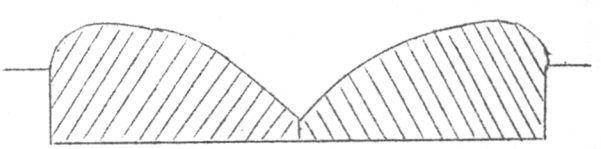
Raittila
Two winged front plough



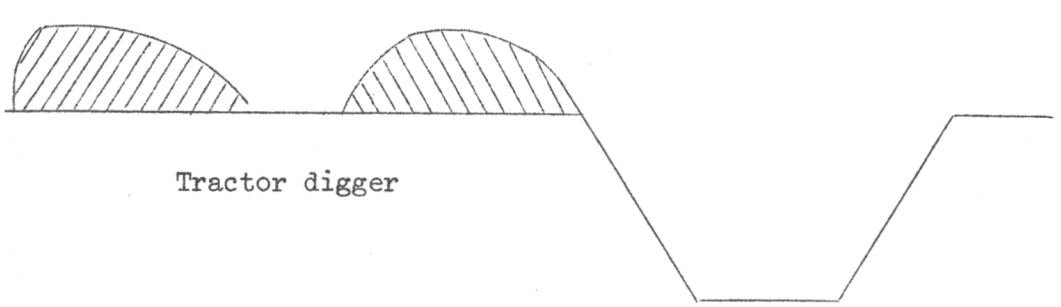
Lamu II
Pre-fer-seed machine



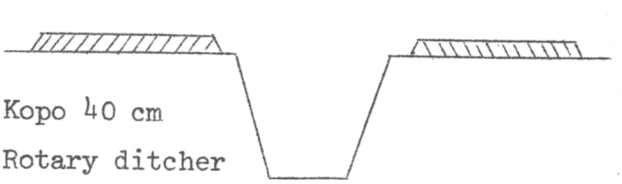
Vikeid
Two winged plough



Lamu IV and V
Pre-fer-seed machine



Tractor digger



Kopo 40 cm
Rotary ditcher

Figure 3. Some site preparation methods used in Finland.

Table 1. Average maximum and minimum temperatures (°C) 19th, June through 18th, August in 1972 in prepared and unprepared peat at Alkkia.

Surface form	Depth, cm	Maximum			Minimum		
		Prepared	Unprepared	Difference	Prepared	Unprepared	Difference
Even surface	5	20	18	2	13	13	Δ
	15	17	15	2	14	13	1
Hummock	5	19	18	1	12	12	Δ
	15	17	15	2	13	13	Δ

Table 2. The dry weight ratio (%) tree shoots/tree shoots + other vegetation as affected by site preparation and fertilizer placement during 3 growing periods in greenhouse.

Site Preparation	Fertilizer placement	Peat type		
		S-p	CS-p	WSC-p
Unprepared	Topdress fert.	7	43	29
Prepared	Topdress fert.	96	96	84
Prepared	Placement	97	97	78

Table 3. The amount of nutrients remained in peat due to site preparation.

Peat type	Fertilization level N, P_2O_5, K_2O	Nutrient, kg/ha		
		N	P_2O_5	K_2O
S-p	0	22	5	21
	75	36	17	34
	150	50	22	53
CS-p	0	22	3	14
	75	20	5	24
	150	64	18	87
WSC-p	0	19	4	19
	75	27	7	31
	150	33	12	62

Table 4. The dry weight of the field layer of the vegetation on open low-sedge bog 5 growing seasons after fertilir-ation and site preparation.

Site preparation	Fertilization			
	0	PK	NPK	$\bar{x}$
Yes	126	1317	1393	945
No	354	995	1651	1000
$\bar{x}$	240	1156	1522	973

Table 5. Height of pine trees 6 growing seasons after seeding in connection with different site preparation treatments.

Site preparation	Topdress fert.			Placement		
	Strip width					
	25	50	100	25	50	100
One winged plough	40	39	31	-	-	-
Lamu I rotavator	38	33	29	50	40	43
Lamu II rotavator	46	38	34	63	55	47
Kopo rotary cutter	34	36	28	33	37	34
Two winged front plough	50	37	43	48	59	59
Two winged plough	48	32	42	51	54	56

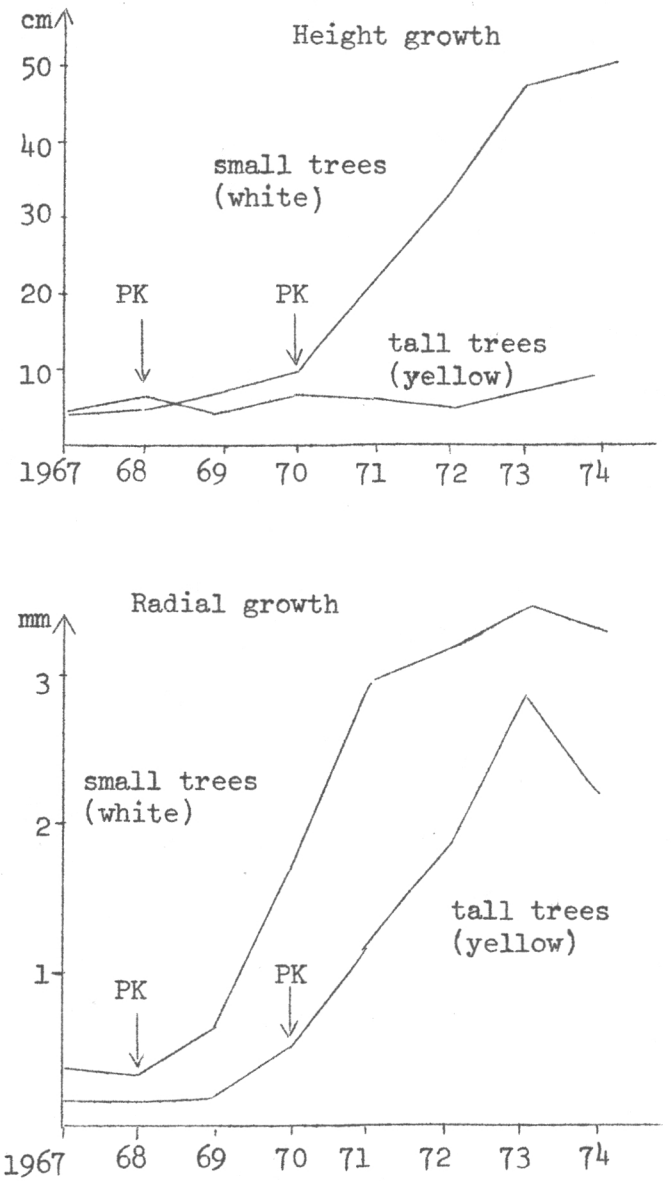
Table 6. Growth of transplants and seedlings during the third growing season in the field. Exp. No. 101 in Alkkia.

Site preparation	Placement	Seedlings				Transplants			
		Nutrient combination							
		0	P	PK	NPK	0	P	PK	NPK
+	+		12	13	19		17	22	24
+	-	3	9	11	14	12	18	21	24
-	-	2	3	4	5	8	9	11	12

Experiments and results on the way to point 3

In 1968 and 1969 the total of 300 ha was prepared for the coming refertilization experiment (No. 147 and 146). In order to simplify the practical procedure, the whole strip randomly chosen was fertilized in the same manner. Unfertilized control strips were left between the fertilized ones. Then several experiments dealing with the time for refertilir-ation, nutrient rates and different kinds of nutrients were set up.

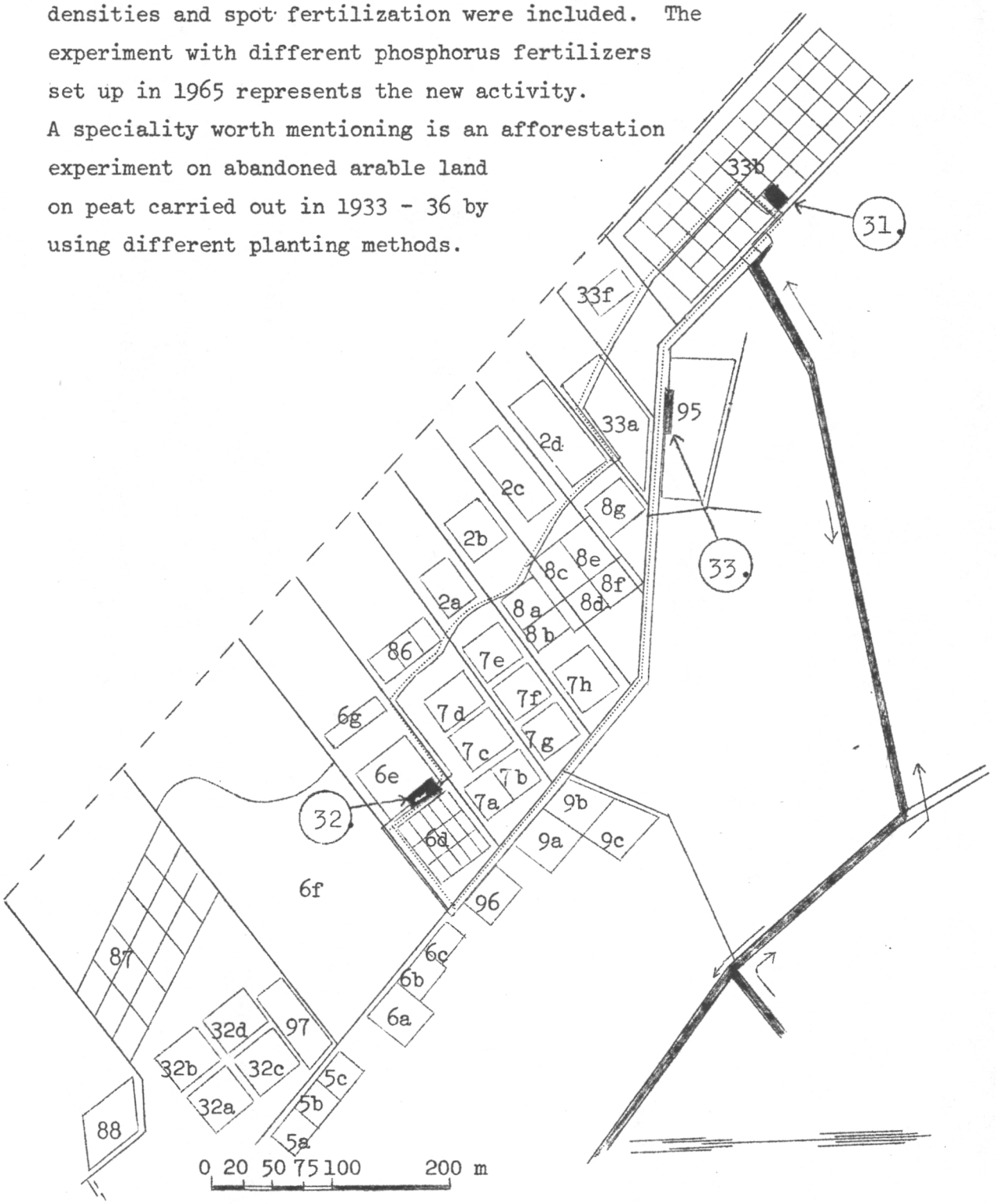
On the southern side of the road sample trees belonging to experiment 141 have been marked as examples of revival on a pine swamp. The area was drained in 1967 and fertilized for the first time in 1968. Considerably more uneven stands with many openings are acceptable on swamps than on mineral soils for wood production. Height growth is the best indi-cator for predicting the reviving capacity of a stand after fertilization, according to previous investigations. In other words, the pines with clearly distinguishable leading shoots are more responsive to treatment than the trees with flat crowns.



In 1968 the small trees were very short indeed, their height averaged 2.3 m and the breast height diameter 3.8 cm. The corresponding figures of the trees with flat crowns were 4.9 m and 10.3 cm. It is surprising that the absolute height growth (3 cm) of small trees is not at all larger on the average than that of tall trees (4.0 cm), but even weaker. Yet there is a tremendous difference in the height growth reaction. On the other hand, the trees with flat crowns have been able to heavily increase the radial growth, although not as much as the smaller, younger and "more vital" trees.

POINT 3. AN OLD DRAINAGE AREA

The excursion route contains permanent experimental plots of old drainage areas. Some of them were fertilized in 1965 and afforestation experiments have been established since the 1930's. Later such experiments as the planting of spruce under shelterwood with varying densities and spot fertilization were included. The experiment with different phosphorus fertilizers set up in 1965 represents the new activity.
A speciality worth mentioning is an afforestation experiment on abandoned arable land on peat carried out in 1933 - 36 by using different planting methods.



31. An experiment with different phosphorus fertilizers

As raw phosphate became available, the Department of Peatland Forestry in the Forest Research Institute established 12 experiments in all using different phosphorus fertilizers all over the country. Three different rates of raw phosphate were compared to corresponding amounts of ground rock phosphate and superphosphate. Also potassium metaphosphate fron Israel was included. It contains both potassium and phosphorus, its total nutrient content being over 90 %.

The plots were formed by making crosswise 40 cm deep furrows at a distance of 20 m from each other. All the plots received as basic fertilization nitrogen 100 kg N/ha and potassium either 33, 66 or 99 kg K_2O/ha depending on the level of phosphorus applied 50, 100 or 150 kg P_2O_5/ha.

The original peatland was nutritionally of a low-sedge type. The area was drained in 1932, when the main drain between the experiment and the parking lot was made. Afforestation was carried out in 1935 by broadcast seeding with pine. Conplementary ditching was performed at the time when the experiment and the plots were set up.

At the time of fertilization the young stand was poorly growing. This can be seen when examining the height growth of trees in 1963-64 (4-5 cm). The strong response at first created by fertilization has virtually passed in 7-8 growing seasons, as effective drainage had vigorously increased the growth on control plots. In 1972, when various kinds of refertilization treatments took place, the young stand was by no means growing poorly, but losing, in fact, the impact caused by the originally applied nutrients. This is demonstrated in Figure 4.

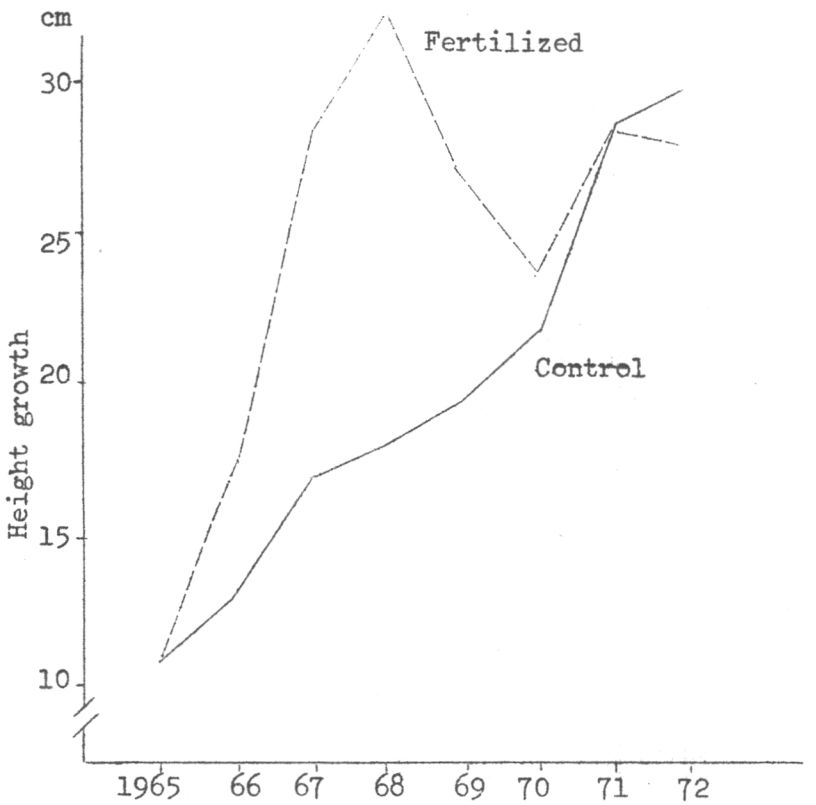


Figure 4. The annual height growths from the experiment with different phosphorus fertilizers established in 1965 in Muhos. Results as the mean values of all the fertilized and control plots.

When planning refertilization and looking for reasons which might have caused the growth decrease, it was observed first of all that the high rates of phosphorus applied in 1965 did not increase growth in the last few years. It was noticed that the occurrence of various damages in the crown was most frequent on the trees which had received 150 kg P_2O_5/ha of superphosphate. The following Table shows the influence of phosphorus rates on the growth:

P_2O_5 amount/ha with NK fertilization	Annual increase in height growth produced by fertilization		
	1970	1971	1972
50	11.4	5.0	1.1
100	7.1	3.7	-0.8
150	7.3	2.6	-1.6

The reaction caused by more unbalanced fertilization, where phosphorus was abundant, had turned out to be negative. As potassium rates were applied according to the phosphorus rates, potassium deficiency is not probably the reason. The results rather refer to nitrogen shortage.

In refertilization the experimental area received different treatments as regards the fertilizer type and amount. In the first place, it was investigated if nitrogen shortage had become a growth limiting factor. On the other hand, the goal was to show that mere PK fertilization will not yield the desired result on a swamp nutritionally of a low-sedge type at the time of refertilization. Furthermore, the aim was to show that a more frequent application of small nutrient rates was more beneficial than to apply only once big amounts of nutrients, which may even disturb the growth. Some of the former 0 plots were fertilized in order to investigate how the time of drainage affects in comparison with fertilization. In other words, the stand which has been revived by effective drainage is better capable of benefiting from the applied nutrients than a poorly growing stand.

Simultaneous investigation of all these themes in one experimental area naturally requires plenty of scientific criticalness. As this experiment is one in twelve corresponding ones, most of which are in remote and not easily accessible parts of the country, this area was "sacrificed" in order to introduce the experiments and theories.

Figure 5:

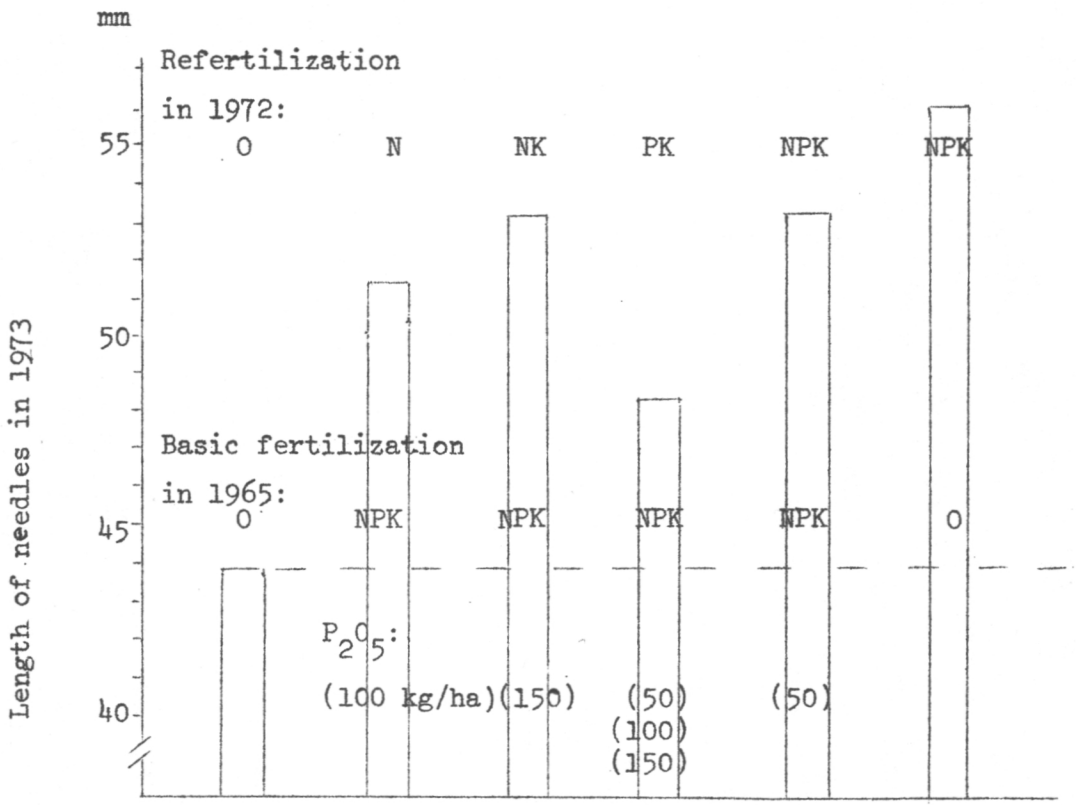


Figure 6:

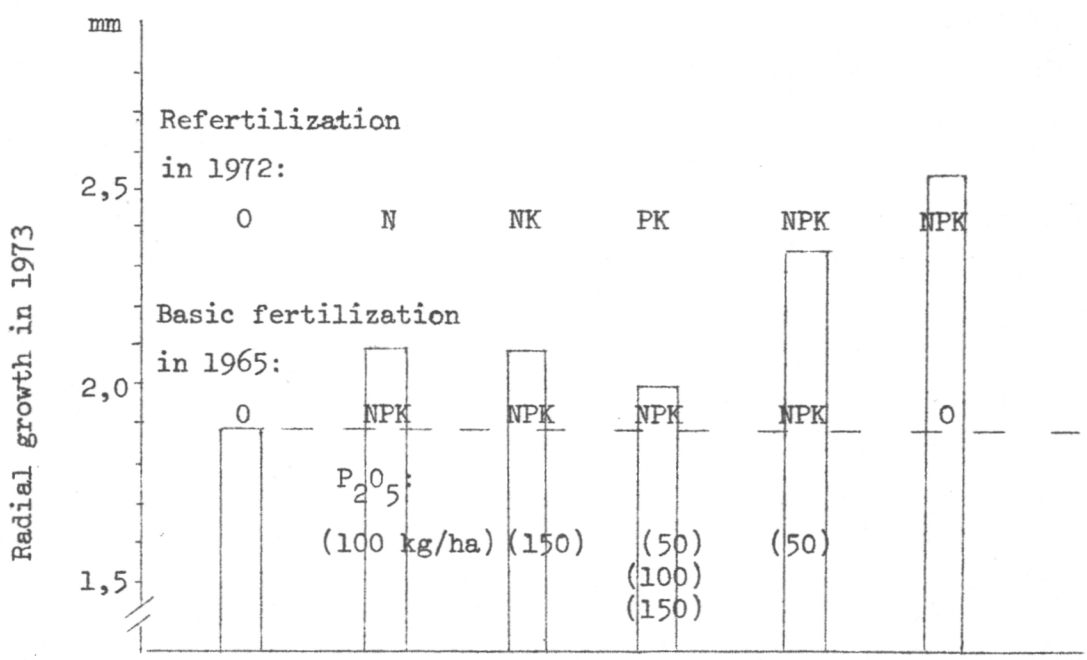
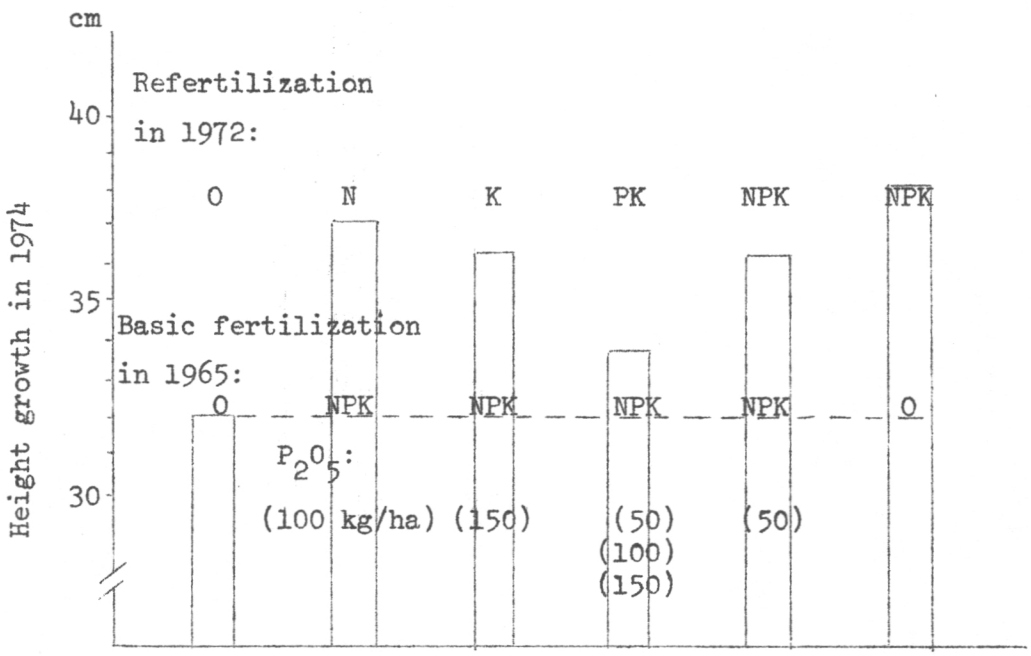


Figure 7:



The results from the comparision between different phosphorus fertilizers, one of the original aims of the study, strengthened the notion that the price is the most determining factor when choosing the various products for practical use. The quickly soluble fertilizers are not as beneficial in forestry as in agriculture, for the trees grow for decades on the same site. Not until 3-4 years after nutrient application does the maximum growth increase become apparent owing to the response mechanism and growth characteristics.

32. An afforestation experiment on abandoned arable peatland

The afforestation experiment on abandoned arable peatland 6 d was set up in 1932. In 1933 it was planted with spruce at the intervals of 1.5 x 1.5 m. Despite the damages caused by spring frosts the stand has gradually acquired a complete crown cover and achieved a moderately good level of growth. Changing into Polytricum heath is typical in adequately drained abandoned burnt-over fields which have been regenerated either artificially or naturally. This implies usually also a strong potassium shortage. Thus owing to insufficient drainage and potassium shortage the stand with groups of entirely yellow trees was about to die in 1970.

In the spring of 1971 the drainage on the stand was improved by dividing the strips into three parts. An experiment which included five different fertilization treatments with three replicates was set up. At first, the aim was to save the stand by mere potassium fertilization. On the other hand, phosphorus was applied in three different forms. One of them was from the newest Finnish Sokli deposit. In addition, the possible nitrogen deficiency was investigated to improve the growth of quite a tall swamp stand as much as possible.

The results concerning the radial growth (mm) in 1971-74 are shown by the Table below:

Year	0	K muriate of potash 75 kg K_2O/ha	PK_1 Sokli phosphorite + muriate of potash 120 kg P_2O_5 + 75 kg K_2O/ha	PK_2 raw phosphate + muriate of phosphate 120 kg P_2O_5 + 75 kg K_2O/ha	NPK fertilizer poor in nitrogen 50 N + 75 P_2O_5 + 75 K_2O/ha
1974	0.86	1.90	1.63	2.02	2.20
1973	0.70	1.44	1.12	1.36	1.69
1972	0.95	1.28	1.23	1.37	1.47
1971	1.03	0.94	1.01	1.07	0.97

The mere potassium application decisively improved the growth of trees, which was anticipated according to the symptoms of potassium deficiency. The use of phosphorus also increased growth, although the Sokli phosphorite is obviously so slowly soluble that it causes reactions resembling those received by using the Siilinjärvi apatite. Thus it will not reach its maximum until the 4th or 5th year. NPK fertilizer includes besides nitrogen also a quickly soluble superphosphate, which yields a fast response. So far it is impossible to be sure whether the presence of nitrogen or phosphorus in its quickly affecting form in the NPK fertilizer has brought about the vigorous growth response. Probably both of them contribute to the outcome. The result is normal; usually the best response when only interested in growth increase in received by adding all the main nutrients. Considering the profitability, often only PK fertilization is used for swamp forests in practice. In this case the mere potassium application considerably improved the nutritional status of trees. This procedure, however, somewhat deviates from the usual practice on peatland.

33. Planting of spruce under birch shelterwood (Paarlahti)

The afforestation of swamps with spruce is not usually successful without shelterwood, which protects seedlings against frost. Spruce, as a species susceptible to frost, is especially liable to damages by spring frosts. Birch is very often shelterwood, particularly on originally open swamps, on which birch is the first tree generation. In order to investigate the seeding and planting methods for spruce several experiments have been set up. The present experiment is one among those investigating the planting of spruce when employing different spot fertilization treatments under birch shelterwood with varying densities.

The spruce seedlings were planted in the autumn of 1961 (or 1963) and spot fertilized (by using spots of 0.25 m^2) in the spring of 1962 (or 1964, plots No. 95 and 96). The experimental design was 34 factorial experiment with three levels of N, P, K and Ca fertilizers. The experiment was replicated 32 times. The experimental units amounted to 2592, and each unit was formed by five seedlings.

Three different kinds of shelterwood are seen on this point: plot No. 86 overdense, plot No. 95 slightly thinned and plot No. 96 no shelterwood at all.

The results indicate that the growth of spruce transplants under shelterwood had decreased with increased spot fertiliration. The reason is supposed to be that shelterwood had developed a competitive root system on the spots capable of a vigorous uptake of nutrients. As a result the small amount of nutrients applied in spot fertilization was used up in few years. Thus the progress of transplants was impeded by increased root competition.

Influence of forest improvement activity on living conditions of the game

The research station and the Department of Peatland Forestry in the Finnish Forest Research Institute have initiated investigations on the multiple use of forests and the influence of forest improvement measures on berry and mushroom crops and the living conditions of the game.

This so-called northern lot of 1550 ha, which has almost totally been drained in connection with research activities and over half of which is fertilized, is still despite normal hunting activity considerably richer in game than the other parts of the country on the average. According to the inventory carried out in the early spring of 1974 (Karsisto 1974) the stocks of game were found to be as follows: 24 capercaillies, 60 black grouse, 15 partridges, 70 white ptarmigan and 50 snow hares. The stocks of game birds are three or four times more numerous than elsewhere in late winter. As late as in the 1930's the lot was still mainly a treeless open swamp offering game animals little shelter or food.

The black grouse, in particular, seems to have benefited from the lush clusters of birch on ditch sides. The capercaillie likes fertilized young pine stands as well. On point 13 (experiments 55 a and b/1) an inventory revealed how often the capercaillie ate on different plots. On the most favourable plots it had visited 25-30 trees in the early spring, whereas some plots were left entirely untouched. The various nutrients applied in the original or repeated fertilization treatments did not affect the outcome. The most important factor was that the stand had been fertilized and was well-growing. It was obvious that birds regarded shelter and security important when choosing the eating place.

Veijalainen (1974) has aimed at investigating the suitability of the old drainage areas on point 3 for the snow hare living place in winter. The investigation was performed by inventorying the footprints after snow fall. A virgin privately owned land bordering the experimental area was used as a control area. The occurrence of footprints was six times higher on the area where forest improvement measures had taken place than on the virgin control area, although both areas had originally the same background. The biggest problem on the experimental area was the great number of footprints.

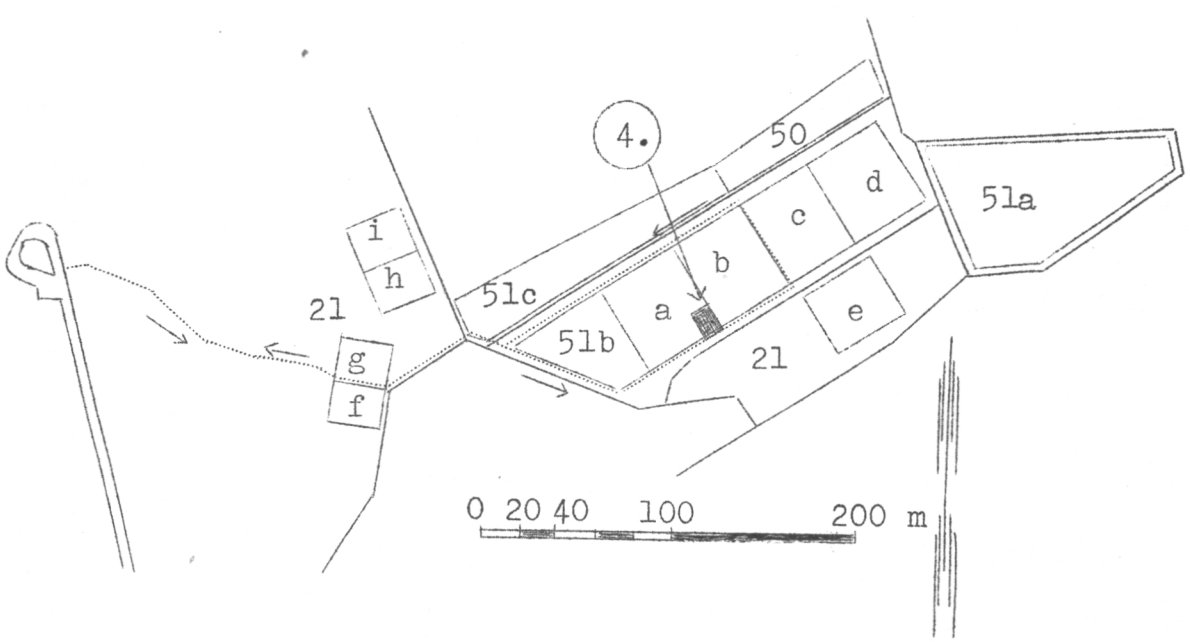
In order to take an active part in game protection, game fields have been established in different parts of the lot. They help to judge the properties of various kinds of feeds and how game animals use them. An experiment set up in 1972 included seven different Swedish feed mixtures for the use of game fields. The name of one of them was "Delicacy of roe deer". As it is well-known that there do not occur wild roe deer in our country, we supposed that the feed was eaten by other animals. However, in December there appeared five roe deer in the field which the excursion route crossed, and immediately devoured "the Delicacy of roe deer". The roe deer, which evidently must have come from Sweden along the coast of the Gulf of Bothnia, lived for three months near the field, before possibly sensing a new delicacy elsewhere. Food, not snow or cold weather, poses the problem for most game animals for surviving the winter. Areas improved for forestry offer shelter and food to a great number of game at the most critical time, in the early spring.

POINT 4. A WOOD ASH FERTILIZATION EXPERIMENT

The last excursion point is not on land owned by the Forest Research Institute. When the power station on the river Oulu was being built, the required land on both sides of the river was given to the Oulujoki Company. Efforts have been made to preserve all the established experiments.

The name of the Experimental forest derives from the famous Pyhäkoski rapids, which before the building of the power station was an excellent place for salmon fishing and a beautiful tourist attraction. The official residence of the forest technician of the Research Institute was in the middle of the present dam basin on a high cape which is now covered with 12 m deep water.

In the 1930's experiments dealing with the afforestation of drained peatlands and soil improvement were established in this area which previously belonged to the Forest Research Institute. Sand with varying amounts, calcium and later wood ash were used for soil improvement. The area was drained in 1933 and afforested in 1934 and 1937.



An experiment investigating the effect of wood ash was set up on this originally treeless open swamp, whose nutritional status resembles cottongrass - sedge type. In 1932-34 the area was drained using 60 m wide drain spacings and afforested partly by seeding and partly by planting in 1934-36. The afforestation failed so that in 1947 there was an uneven, less than 0.5 m tall young stand.

Including the wood lost in thinnings the total wood production (inc. 1974) on the plot was 145 solid m^3 without bark/ha and on the plot c about 180 solid m^3/ha. The yield surpasses that obtained on the best mineral soils (the Oxalis-Myrtillus type) in southern Finland in the same period of time.

With the aid of these experimental plots, serving mainly as demonstration plots, the following things may be observed:

- The amount of radiation energy from the sun is not, in these latitudes (65°), the main growth limiting factor. By soil improvement measures it is possible to reach a very high production level per hectare.

- The present results do not yet represent the maximum possible leve, since the employed drain spacing, 60 m, is too wide. This is demonstrated by a distinct decrease in the total height of trees when moving towards the middle of the strip. The experimental plots do not touch the ditch side, which would be the best site.

- By draining a nutritionally poor swamp the desired result will not be achieved. While the nutrient deficiency is limiting the growth, mere drainage is inadequate. If nutritionally poor swamps are drained, the task should be completed by fertilization as well.

- Despite the high nutrient rates used, running of nutrients into ditches and thus contributing to pollution has not been detected. Even 26 growing seasons after the fertilization there is a clearly discernible difference in ground vegetation, even on borders running in the direction of the ditches. Furthermore, the nutrients have not penetrated deep into the soil. The investigations show that in 15 years the change brought about by ash have affected only the surface peat layer down to 13 cm.

- When the nutritional status and water relationships are well maintained, the present recommendation for pulp production, 1600 stems/ha, can be considerably exceeded. At the moment plot c contains 4200 stems fulfilling the requirements for pulp wood.

- The long-lasting influence has been produced by adding nutrients and by improving the soil, which have ensured a continuous nutrient mobilization. The large amounts of ash have not, in fact, contained high nutrient rates. For example, plot b received 240 kg/ha of phosphorus. In another ash fertilization experiment (No. 14) within the experimental area 3000 kg of ash/ha produced the same yield.

- If other virgin swamps in corresponding climatic conditions were made as productive as on plot c, it would be possible to provide the large wood processing industry in Oulu, for example with the needed 1.2 million m^3 from the distance of only 20 km. (Now the wood is partly brought even from the distance of 200 km.) The example set by the ash fertilization experiment shows that the biological possibilities for wood production, not utilized today, are boundless.

Experimental activity on fertilization of peatlands

Since the Research Station began its operation in the autumn of 1969 till the present day, the cooperation between the Department of Peatland Forestry and the Experimental Forest Office, which operates among practical forestry, has produced 45 fertilization experiments on the experimental area in Muhos. The experiments include 1742 plots with a net area of 432 ha. At the same time 50 refertilization experiments including 1748 plots with the net area of 336 ha have been established. At present there are altogether 154 different fertilization experiments and 4368 plots with various treatments at the Pyhäkoski Experimental Forest. The total net area amounts to 1192 hectares.

The activity is not limited to the forests owned by the Research Institute in Muhos, but 47 experiments, out of which 15 deal with refertilization, have been established in other experimental forests possessed by the Research Institute. Moreover, 204 hectares of privately owned forests in Muhos have been used for establishing 133 fertilization experiments. Recently also many fertilization experiments have been set up on land owned by the State Forest Service. For example, in the Pohjanmaa district 55 experiments totalling 180 hectares will be ready in 1974.

The projects mentioned above have been realized by linking the experimental activity with the practical work of various organizations. The problem will be the measurement and treatment of the results.

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