

DURATION OF THE HEIGHT GROWTH RESPONSE OF YOUNG PINE STANDS TO NPK-FERTILIZATION ON OLIGOTROPHIC PINE BOGS IN FINLAND

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Seloste

NPK-LANNOITUSVAIKUTUKSEN KESTOAIKA KARUJEN RÄMEIDEN TAIMIKOISSA

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This is the latest report in a series of publications from an on-going investigation which is concerned with the influence of different fertilization treatments and ditch spacings on the growth of pine (*Pinus sylvestris*) seedlings and transplants growing on nutrient poor bogs in different parts of Finland. In particular, this paper concentrates upon the results concerning the duration of the growth response to NPK-fertilization on the experimental plots. The experiment was established and the treatments performed in 1965-66.

The results show that climate, expressed as effective temperature sum (dd°C, threshold +5 °C) has a clear influence on the duration of the fertilization effect. In South Finland (>1200 dd°C) the duration was at least 15 years, in Middle Finland (1200-1000 dd°C) it appears to be almost 10 years and in North Finland (<1000 dd°C) slightly shorter.

The amount of fertilizer applied clearly influenced the duration of the fertilization effect. The dosage of 500 kg/ha (N 14, P 7.8, K 8.3 per cent) had, on average, a shorter duration than the greater dosages of 1000 and 1500 kg/ha. However, there was no clear difference between these latter two dosages.

1. INTRODUCTION

The question of how long an application of fertilizer continues to evoke a growth response is of great relevance in practical forestry. In the case of drained peatlands it is a question of in which cases it is necessary to add expensive nitrogen which has a short-lasting influence, and in which cases will the mobilization of organic nitrogen or resources of mineralized nitrogen be adequate and lead to a long-lasting and thus an economic effect of PK-fertilization

This paper deals with the duration of the influence of NPK-fertilization on the height

growth of Scots pine seedling stands growing on oligotrophic pine bogs in different parts of Finland. This study aims to produce some answers to the questions posed above.

It is difficult to separate the role of each author in this co-authored paper. However, following joint discussions Prof. Heikurainen was largely responsible for the preparation of the manuscript while Dr. Laine performed the statistical analyses. The authors are grateful to Mr. Juhani Tuominen M.Sc. for advise concerning statistical methods and to Dr. Michael Starr for linguistic polishing of the manuscript.

2. EXPERIMENTAL SITES AND FIELD MEASUREMENTS

The experimental design and location of the experimental sites has been described in detail earlier (Heikurainen et al. 1983). The experiments were established and the treatments carried out in 1965–66. For the purposes of this paper it suffices to present only some of the main features. The original site type of the experimental sites ranged from low-shrub pine bog to cottongrass pine bog, although some of the sites showed features of tall-sedge pine swamps or spruce-pine swamps (Heikurainen and Pakarinen 1982). The mean values for some peat properties and main nutrient contents in the surface peat layer at the beginning of the experiment are: pH 3.5, ash 2.8 %, N 0.94 %, K 0.052 %, P 0.027 % and Ca 0.24 %.

There are 22 experimental sites distributed throughout the region defined by the 865 and 1330 dd°C limits. At each site there are three ditch spacings, 10, 20 and 30 m, and four levels of fertilization, 0, 500, 1000 and 1500 kg of NPK-fertilizer per hectare (N 14 %, P 7.8 % and K 8.3 %). Half of the sample plots at

each site were planted with 2+1 transplants and the rest were naturally regenerated. Each treatment has two replications, giving 48 plots per experimental site. There is thus a total of 1056 plots in the whole material.

In each plot the height of trees in autumn 1981 and the annual height growth for years 1974–81 of ten sample trees were measured. The height growth values for the period 1971–73 had been measured in 1974 and this material is also included in the present study. The same sampling principle was applied in both inventories (1974 and 1981), but the sample trees selected were not the same. Selection of the 10 sample trees was according to the following criteria: healthy appearance, no top changes during the measuring period (1974–81), etc. (Heikurainen and Laine 1976, Heikurainen et al. 1983). In cases where there were less than 3 such trees fulfilling the above criteria, the plot was not used in the analyses. After this limitation was applied there were 1011 plots remaining.

3. STATISTICAL TREATMENT OF THE MATERIAL

The experimental sites were grouped into three climatic regions according to effective temperature sum as follows: South Finland (>1200 dd°C), Middle Finland (1200–1000 dd°C) and North Finland (<1000dd°C). The location of the experimental sites together with their temperature sums are presented in Table 1.

The height growth of the trees in each year was separately analysed to study the duration of the fertilization effect. The concept of a fertilization effect is used in this paper in the meaning of a significantly different height growth of the trees in one or more of the three fertilization levels from that of the control plots. The fertilization effect for a certain year also includes the earlier accumulated fertilization effect which may indirectly influence the growth in the year under study (i.e. auto-

correlative effect). Because of the nature of the experimental design a fixed-effects analysis of variance model with experimental site and ditch spacing treatment as grouping factors and seedling type and fertilization treatment as within (or trial) factors was applied to the data in the first phase of analysis (BMDP 2V, BMDP Statistical... 1983). This analysis of variance model was not, however, valid in all cases because of the large proportion of missing values (i.e. treeless plots) in some of the groups; this was especially so in the data for North Finland. In these cases (results presented in Table 1) an ordinary fixed-effects model in which main effects and interactions are linked together was subsequently used.

In the next phase of analysis the influence of the fertilizer dosage upon the duration of

Table 1. The duration of the fertilization effect on the experimental sites expressed as F-values of covariance analyses between fertilized and non-fertilized sample plots in 1971–76.

Taulukko 1. Lannoitusvaikutuksen kesto aika koelueilla ilmaistuna lannoitettujen ja lannoittamattomien kesken tehdyn kovarianssianalyysin F-arvoina vuosina 1971–76.

The location parish of the experim. sites Koealueen sijaintikunta	dd °C	Planted trees – <i>Istutetut</i>				Natural trees – <i>Luontaiset</i>			
		1971–73	–74	–75	–76	1971–73	–74	–75	–76
		F-values – <i>F-arvot</i> ⁽¹⁾				F-values – <i>F-arvot</i> ⁽¹⁾			
South-Finland									
Savitaipale	1328	0.69	0.36	0.49	0.97	10.44 ^b	6.43 ^c	5.04 ^c	10.88 ^b
Sippola	1323	5.17 ^c	0.59	0.89	1.41	7.27 ^c	5.79 ^c	4.91 ^c	2.92
Yläne	1283	7.73 ^c	3.74	1.99	1.72	17.39 ^b	15.25 ^b	15.04 ^b	8.91 ^{c(2)}
Gottby	1250	4.20	4.38	3.20	2.36	11.90 ^b	1.90	1.20	3.44
Hammarland	1250	36.67 ^a	7.21 ^c	8.68 ^c	7.11 ^c	73.88 ^a	21.04 ^b	13.88 ^b	7.94 ^c
Loppi	1227	1.23	10.95 ^{b(2)}	3.69	1.19	–	–	–	–
Virtasalmi	1203	11.67 ^b	4.26	1.14	1.78	10.43 ^b	5.31 ^c	8.17 ^{c(2)}	4.49
Middle-Finland									
Orivesi	1164	1.74	5.57 ^c	3.53	2.29	0.50	0.26	0.55	0.76
Uurainen	1105	1.78	3.14 ^c	0.55	0.55	1.23	1.24	3.44 ^c	3.07
Virrat	1086	0.66	1.03	1.03	2.36	0.40	1.10	0.35	0.59
Eno	1078	0.20	0.75	0.24	0.34	10.46 ^b	8.02 ^{c(2)}	2.92	2.53
Viitasaari	1064	0.39	0.49	0.37	0.22	0.66	0.14	1.13	0.11
Sonkajärvi	1047	0.07	0.31	0.57	2.82	1.20	0.05	0.29	1.61
Multia	1029	1.04	0.92	0.04	0.75	6.23 ^c	6.13 ^c	2.71	5.36 ^c
Muhos	1002								
North-Finland									
Kuhmo	984		b(2)		c(2)			c(2)	
Paltamo	983								
Pudasjärvi	982								
Pyhäjoki	978								
Pello	925								
Suomussalmi	923								
Rovaniemi	865				c(2)			c(2)	

⁽¹⁾ risk levels: a – 0.1 %, b – 1 %, c – 5 %, *riskitasot: a – 0.1 %, b – 1 %, c – 5 %.*

⁽²⁾ Statistically significant interaction with other experimental factors, as described in section 4. *Tilastollisesti merkitsevä yhdysvaikutus muiden koejäsenten kanssa; selitykset luvussa 4.*

the fertilization effect was studied by comparing each fertilizer level separately with the control using the appropriate ANOVA-model described in the above paragraph. Additionally the analyses were performed on the data for 10 m and 30 m ditch spacing treatments separately in order to study the influence of differing hydrological conditions on the duration of the growth response. The influence of climate on the growth response duration was investigated by performing the

analyses separately in the three climatological regions.

The analyses of variance results are presented as F-values which express the effect of the fertilization treatment on height growth. Occasional significant interactions between fertilization treatments and other studied factors indicate that the fertilization effect in a particular year was not uniform in all experimental sites and ditch spacings, or natural and planted stands reacted differently.

4. GENERAL DESCRIPTION OF THE TREE STANDS

The characteristics of the studied tree stands are analysed in detail in Heikurainen et al. (1983). The height (in 1981) and annual height growth (1977–81) of the planted and naturally regenerated stands, grouped according to study treatments in the three climatic regions, are presented in Figures 1 and 2.

It is observed that both height and height growth are the greatest in South Finland and the smallest in the North. In the natural stands the regional differences in the height are not large. This is the result of maintenance cuttings performed in 1975, in which a large number of holdover trees were removed. These cuttings were heavy in South Finland but were only slight in Middle Finland and not at all carried out in the North. The reduction in the average height of the natural stands due to thinning in South Finland was about 30 cm but in Middle Finland only a few

centimetres (Heikurainen et al. 1983). Concerning the annual height growth the regional differences are clear, although the cuttings in 1975 may have influenced the growth level of the natural stands in South Finland.

The influence of ditch spacing is also clear. Height and height growth of the trees are clearly the greatest at the spacing of 10 m and the smallest at the spacing of 30 m. The influence of fertilization on tree height is also clear; in South Finland the difference between control and the higher fertilizer dosages is more than 1 m, whereas in North Finland the difference is only about 20 cm. Differences between dosages are generally small except for natural stands in South Finland. A similar pattern is observed in the results concerning the height growth response to fertilization. These results are discussed in more detail in Heikurainen et al. (1983).

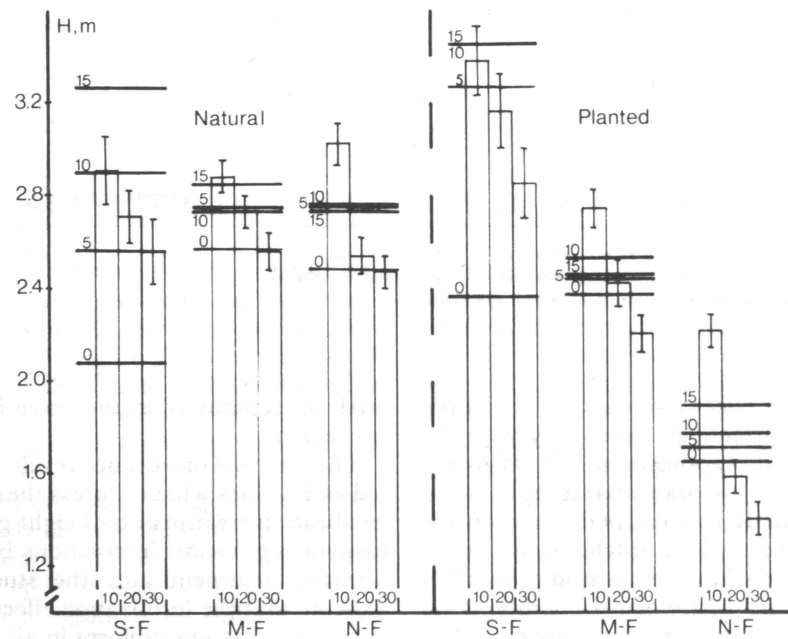


Fig. 1. The mean height of seedling stands in 1981 described in different spacings (10, 20 and 30 m) and fertilizer levels (0, 500, 1000 and 1500 kg/ha) in different regions. The bar indicates the standard error of the mean.

Kuva 1. Taimikoiden keskipituus v. 1981 eri sarkaleveysillä (10, 20 ja 30) ja eri lannoituksilla (0, 500, 1000 ja 1500 kg/ha) alueittain.

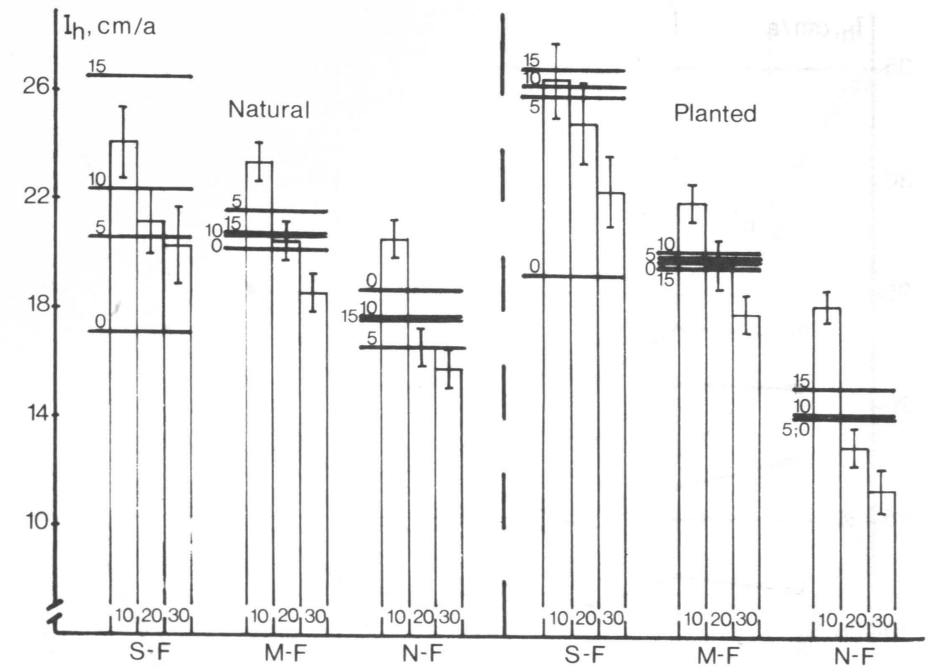


Fig. 2. The mean height growth of seedling stands in the period of 1977–81 described in the different treatment groups (see Fig. 1).

Kuva 2. Taimikoiden pituuskasvu vuosina 1977–81 eri käsittelyryhmissä (ks. Kuva 1).

5. DURATION OF GROWTH RESPONSE TO FERTILIZATION

5.1. Regional differences

The results concerning the duration of the fertilization effect in different experimental sites during the years 1971–76 can be seen in Table 1. The variation between the experimental sites is large, but it is clear that in South Finland, especially in natural stands, the influence of fertilization has lasted longer than in Middle Finland. In North Finland all the test values, excluding those with significant interactions with other studied factors, were below the 5% significance level and thus the F-values are not included in the table.

The regional differences are better seen in Table 2, in which the F-values of the fertilization effect on the annual height growth are

presented separately for the three climatic regions. In each region the F-values tend to progressively decrease year after year. In South Finland the F-values remain significant throughout the measuring period, i.e. a growth response of at least 15 years duration. For Middle and North Finland, however, the test values are not significant after 1973, i.e. a growth response of some 8 years duration.

These results are also seen in Figures 3 and 4. For South Finland the duration of the fertilization effect is rather similar in planted and natural stands, whereas for Middle Finland the duration seems to be slightly longer in natural stands, where it appears to be marginally longer than in North Finland.

It can be seen from Figure 3 that the height growth of the control plots of the naturally

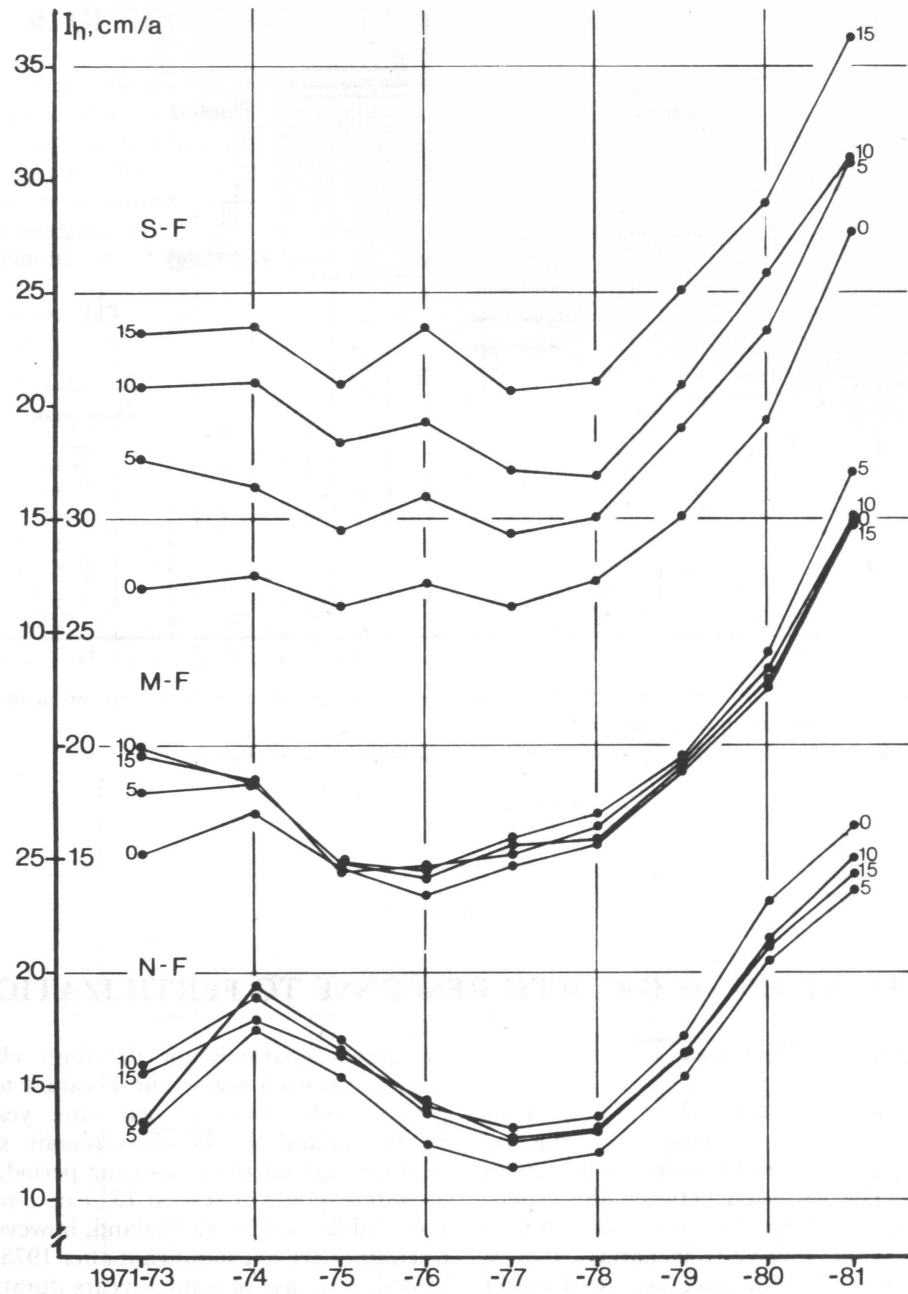


Fig. 3. The height growth of natural seedling stands in the period of 1971-81 in different regions and different fertilizer levels.

Kuva 3. Luonnontaimikoiden pituuskasvu vuosina 1971-81 eri alueilla ja eri lannoituskäsittelyillä.

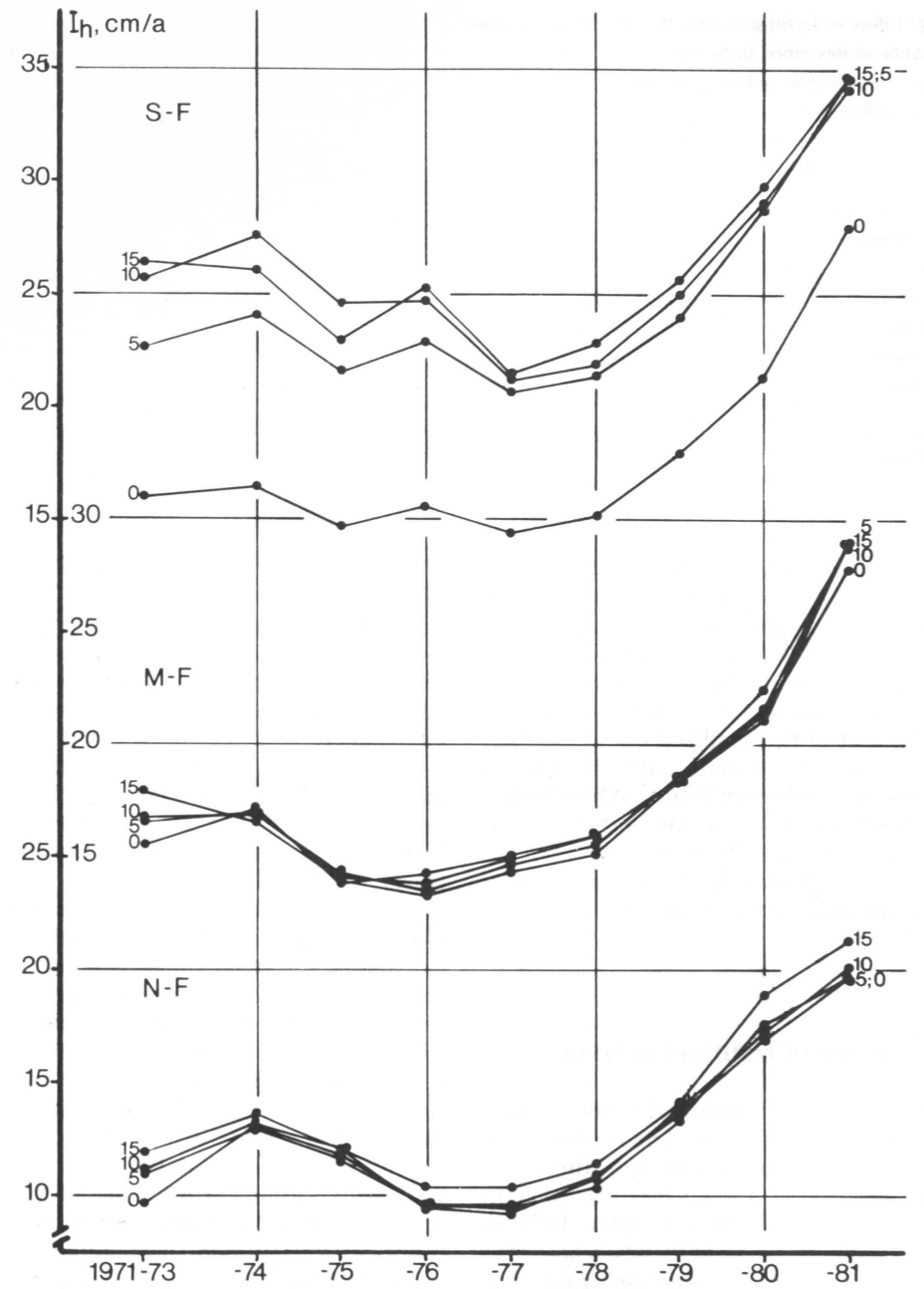


Fig. 4. The height growth of planted seedling stands in the period of 1971-81 in different regions and fertilizer levels.

Kuva 4. Istutustaimikoiden pituuskasvu vuosina 1971-81 eri alueilla ja eri lannoituskäsittelyillä.

Table 2. Effect of fertilization on the height growth during 1971–81. F-values presented are from the analyses of variance as described in Section 4.

Taulukko 2. Lannoituksen vaikutus pituuskasvuun vuosina 1971–81. F-arvot varianssianalyysistä, joiden yksityiskohtainen selostus on esitetty luvussa 4.

	1971–73	-74	-75	-76	-77	-78	-79	-80	-81
	F-values ⁽¹⁾ – F-arvot ⁽¹⁾								
South Finland									
<i>Etelä-Suomi</i>	99.84 ^a	33.08 ^a	41.42 ^a	31.64 ^{a(2)}	27.49 ^{a(2)}	28.34 ^a	23.27 ^a	24.13 ^a	14.13 ^a
Middle Finland									
<i>Keski-Suomi</i>	11.86 ^{a(2)}	0.40	0.26	0.05	0.36	0.32	0.19	0.32	0.71
North Finland									
<i>Pohjois-Suomi</i>	17.51 ^{a(2)}	–	–	–	–	–	–	–	–

⁽¹⁾ Risk levels as in Table 1.
Riskitasot kuten taulukossa 1.

⁽²⁾ Statistically significant interaction with other experimental factors, as described in section 4.
Tilastollisesti merkitsevä yhdysvaikutus muiden kojäsenten kanssa; selitykset luvussa 4.

regenerated stands in North Finland became greater, compared to fertilized plots, in 1974. This feature became more pronounced towards the end of the measuring period. In the last year of the period the better growth of the non-fertilized stands (26.4 cm/a) when compared to that of the fertilized ones (1500 kg/ha: 24.3 cm/a) is evident, and the growth difference is nearly significant. When testing the differences between the fertilized and control plots in the 20 m spacing material alone the height growth of the control plots was significantly greater in the years 1980 and 1981.

5.2. Influence of fertilization level

The height growth during the study period is seen in Figures 3 and 4. The course of the height growth is unusual in that after 1974 there is a period of a few years when height growth decreases. However, after 1977 in Middle Finland and 1978 elsewhere the height growth begins to increase again. The decrease in growth is the result of exceptional climatic conditions (i.e. excess summer precipitation) in 1974. The phenomenon is not discussed further and it is considered not to have affected the main results of this study – the duration of the fertilization effect.

It can be concluded from the figures that the height growth of planted trees in South Finland has been higher than that of natural-

ly regenerated trees, especially in the beginning of the measuring period. In North Finland, on the contrary the natural stands have been superior to the planted ones. These differences between the naturally regenerated and planted stands are further discussed in a later paper.

The response to different fertilizer levels differ from each other clearly in South Finland: the greater the dosage the greater and longer lasting is the increase in height growth (Figs. 3 and 4). This result is also clearly seen in Table 3, where significance testing of the differences in the height growth between treated and non-treated plots in South Finland are presented. The values show that the greater the dosage the longer the duration of fertilization effect. The smallest dosage (500 kg/ha) had a significant influence on natural stands only up until 1976 and close to significance in the period 1976–80. In other words, the duration was about 10 years. In planted stands the significant influence of the lowest dosage seems to be longer, i.e. to the end of the measuring period. The influence of the higher dosages (1000 and 1500 kg/ha) is still significant in 1981, i.e. the duration is at least 15 years (Table 3).

The statistical analyses concerning the influence of the fertilization level on the duration of the growth response were performed only in the data for South Finland because the other regions did not yield significant test values for the overall fertilization effect after the period 1971–73 (Table 2).

Table 3. Effect of fertilization on the height growth during 1971–81 for different fertilizer levels in naturally regenerated and planted stands in the data for South Finland. Each fertilizer level is separately compared with the control in the analyses of variance.

Taulukko 3. Lannoituksen vaikutus pituuskasvuun vuosina 1971–81 eri lannoitustasoilla Etelä-Suomessa. Kutakin lannoitustasoa on erikseen verrattu nollatasoon varianssianalyysissä.

Year vuosi	NPK-fertilizer, kg/ha – NPK-lannoite, kg/ha					
	500		1000		1500	
	natural	planted	natural	planted	natural	planted
	F-values ⁽¹⁾ – F-arvot ⁽¹⁾					
1971–73	41.73 ^{a(2)}	39.90 ^a	241.62 ^{a(2)}	181.82 ^a	324.07 ^{a(2)}	48.07 ^a
1974	5.93 ^c	31.70 ^a	79.66 ^a	80.22 ^a	153.21 ^{a(2)}	30.21 ^a
1975	4.95 ^c	26.81 ^a	34.47 ^a	75.37 ^a	90.84 ^a	26.02 ^a
1976	5.27 ^c	29.91 ^a	23.47 ^a	62.85 ^a	97.73 ^a	26.68 ^a
1977	3.94	23.48 ^a	17.31 ^b	46.65 ^{a(2)}	76.93 ^a	19.96 ^a
1978	3.95	22.01 ^a	9.77 ^b	49.54 ^{a(2)}	51.59 ^a	23.56 ^a
1979	4.15	19.18 ^a	13.28 ^b	42.28 ^{a(2)}	39.17 ^a	31.32 ^a
1980	3.82	17.79 ^a	17.68 ^b	40.96 ^{a(2)}	30.60 ^a	21.98 ^a
1981	1.40	12.04 ^b	5.76 ^c	22.13 ^a	16.66 ^a	13.32 ^b

⁽¹⁾ Risk levels as in Table 1.
Riskitasot kuten taulukossa 1.

⁽²⁾ Statistically significant interaction with other experimental factors, as described in section 4.
Tilastollisesti merkitsevä yhdysvaikutus muiden kojäsenten kanssa; selitykset luvussa 4.

Table 4. Effect of fertilization on the height growth during 1971–81 at different ditch spacing treatments in the data for South Finland.

Taulukko 4. Lannoituksen vaikutus pituuskasvuun vuosina 1971–81 eri sarkaleveysillä Etelä-Suomen aineistossa.

Ditch spacing, m Sarkaleveys, m	1971–73	-74	-75	-76	-77	-78	-79	-80	-81
	F-values ⁽¹⁾ – F-arvot ⁽¹⁾								
10	29.84 ^a	24.63 ^{a(2)}	19.58 ^a	9.79 ^{b(2)}	9.74 ^b	9.60 ^b	7.57 ^b	7.50 ^b	4.21 ^c
30	34.36 ^a	5.75 ^b	11.60 ^a	14.08 ^{a(2)}	12.07 ^{a(2)}	15.82 ^{a(2)}	12.56 ^a	12.55 ^a	9.71 ^b

⁽¹⁾ Risk levels as in Table 1.
Riskitasot kuten taulukossa 1.

⁽²⁾ Statistically significant interaction with other experimental factors, as described in section 4.
Tilastollisesti merkitsevä yhdysvaikutus muiden kojäsenten kanssa; selitykset luvussa 4.

5.3. Influence of ditch spacing

The influence of ditch spacing on the duration of the fertilization effect was analysed only in the data for South Finland and the results are given in Table 4. It is seen that there is no consistent difference between the

narrowest and widest ditch spacing treatments. Even though the ditch spacing treatments do not appear to have influenced the duration of the fertilization effect, the height growth level of 10 m spacing stands is much higher than in greater ditch spacing stands (Fig. 2).

6. CONCLUSIONS AND CONSIDERATIONS

The variation in the duration of the fertilization effect between the experimental sites was great, but in general the duration was longer in the southern sites. When grouping the sites into South, Middle and North Finland it was seen that the effect in South Finland continues until the end of the study period, i.e. a duration effect lasting at least 15 years. In Middle Finland the duration of the fertilization effect appears to be almost 10 years, and in North Finland only marginally shorter.

The role of nitrogen mineralization may be important in explaining the differences found in the duration of the fertilization effect in the different regions of Finland. In South Finland the mineralization of nitrogen is possibly sufficient to maintain a relatively long-lasting effect of added potassium and phosphorus, even in relatively nutrient poor peatlands (Huikari 1973). Results of some fertilization trials in southern Sweden are in accordance with this interpretation (Möller 1978). The mineralization of the peat's nitrogen reserve in oligotrophic pine bogs after drainage and NPK-fertilization would thus explain the longer duration of the fertilization effect in South Finland as found in this material. In Middle Finland the mineralization of nitrogen would be slower and nitrogen will become a limiting factor when the initial strong effect of applied nutrients is over. The lack of mineralized nitrogen is even more limiting in North Finland.

These conclusions are supported by the results presented by Seppälä and Westman (1976) and Härkönen (1982), according to which nitrogen, together with phosphorus, is necessary in order to obtain a clear growth response in North Finland, even in fairly nitrogen rich peatland sites. Results by Paavilainen (1984) also indicate that the need for nitrogen in the refertilization of peatlands may be greater in northern Finland, although earlier results (Paavilainen 1978) indicated that PK-fertilization alone evokes a satisfactory growth response in nitrogen rich North Finnish drained peatlands.

Another possible explanation for the aforementioned regional differences in the duration of the fertilization effect may be the

uneven distribution of nitrogen deposition from air. The deposition rates are clearly higher in South Finland than in the North (e.g. Järvinen and Haapala 1980). It has been suggested that these nitrogen compounds may be readily available as nutrients for trees (e.g. Energiäntuotannosta . . . 1983).

It is known that greater dosages will result in a longer lasting response. The results concerning the influence of the different levels of fertilization in South Finland support this experience. Using 1000 kg of fertilizer per hectare, the duration increased quite significantly in comparison to the case where only 500 kg was used. The increase in time was 4–5 years in the case of naturally regenerated stands. The greatest dosage (1500 kg/ha), however, did not increase the response time significantly above that of the 1000 kg/ha dosage. Why this was so is not clear but increased leaching of K and increased binding of P in the ground vegetation could be the reasons. It may also be related to toxicity, especially in the case of the planted stands. High dosages of fertilizer have been shown to increase seedling mortality (Heikurainen and Laine 1976), and the correlation between mortality and the height growth of surviving trees is negative (Päivänen 1975). Similar results have been presented also by Kaunisto and Paavilainen (1977). Finally, it must also be noted that the tree stands in this survey are young, the nutrient requirements of older stands would be higher. The optimum dosage according to the results of this study is 1000 kg/ha, which corresponds to 140 kg N, 78 kg P and 83 kg K per hectare. These amounts of nutrients, however, are already slightly greater than present practical recommendations (Heikurainen 1978, Paavilainen 1979).

It is of interest to note that in North Finland after the initial positive effect of fertilization, the effect becomes negative in the course of time (see also Karsisto 1974, Paavilainen 1978). It is generally considered that tree growth will return to the pre-treatment level after the response to fertilization has ceased. In the results for North Finland in our study this was not, however, true, but after the fertilization effect had ceased the height growth of the fertilized natural stands fell

below that of the non-fertilized ones. The decrease in height growth was not great, but in some subgroups significant and it appears to increase towards the end of the measuring period. This result was not found in the material for Middle Finland and it is possible that the observed depression in the growth is typi-

cal only in North Finland. The cause of this phenomenon is not clear and needs more attention and the authors assume that the increased biomass of tree stand and ground vegetation may inhibit height growth when the direct positive influence of added nutrients has ceased.

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SELOSTE

NPK-LANNOITUSVAIKUTUKSEN KESTOAIKA KARUJEN RÄMEIDEN TAIMIKOISSA

Johdantoa

Vuosina 1965 ja 1966 perustettiin eri puolille maata karuille rämeile 25 koekenttää, joissa vaihdeltiin ravinnetaloutta antamalla 0, 500, 1000 ja 1500 kg/ha NPK-lannosta (N 14 %, P 7,9 % ja K 8,3 %) ja kuivatusta käyttämällä sarkaleveyksiä 10, 20 ja 30 m. Lämpösumman (dd°C, 1941–70) vaihtelu on aineistossa 865–1328 dd°C. Puolet koelajoista on istutettu 2+1 vuotiailla mätymäntaimilla ja puolet on uudistettu luontaisesti pääasiasa vaihtuvalla taimiaineeksella. Aikaisemmin esitettyjen kuvauksien (esim. Heikurainen ja Laine 1976, Heikurainen et al. 1984) lisäksi todettakoon tässä, että tutkimuksessa on käytetty kaikkiaan 22 koekenttää, joissa kussakin on ollut 48 kappaletta aarin suuruisia koelajoja, yhteensä siis 1056 koelajaa. Näistä tosin 45 oli hylättävä, koska mittauskelpoisten puiden lukumäärä jäi liian pieneksi.

Tutkimusmenetelmistä

Koepuiden vuotuinen pituuskasvu mitattiin vuosilta 1974–81. Lisäksi aineistoon otettiin aikaisemmista inventoinneista jakson 1971–73 pituuskasvu. Laskemalla keskiarvoja tarkasteltavien selittäjien (lämpösumma, lannoitustaso ja sarkaleveys) ryhmissä ja vertaamalla näitä keskiarvoja saadun aikasarjan puitteissa lannoittamattoman keskiarvoihin on pyritty muodostamaan kuvaa siitä, kuinka pitkään lannoitusvaikutus on kestänyt ja miten siihen edellä mainitut tekijät ovat vaikuttaneet. Erojen testaus on tapahtunut varianssianalyysillä.

Ilmaston vaikutus

Koekenttien välinen hajonta on suurta (taul. 1), mutta Etelä-Suomessa lannoitusvaikutus on keskimäärin kestänyt selvästi pitempään (ainakin 15 vuotta) kuin Keski- ja Pohjois-Suomessa (alle 10 vuotta) (taul. 2). Mittausjakson loppuvuosina lannoittamattomien taimien pituuskasvu on Pohjois-Suomen aineistossa suurempi kuin lannoitettujen.

Lannoitemäärän vaikutus

Pituuskasvu on Etelä-Suomessa koko tutkittavan ajan ollut sitä suurempi mitä suurempi on ollut lannoiteannos (kuvat 3 ja 4). Suurimmat annostukset ovat lisänneet kasvua merkittävästi vuoteen 1981 asti eli siis ainakin 15 vuotta, mutta 500 kg/ha-annostuksen vaikutus näyttää luonnontaimikoissa loppuvan jo mittausjakson alkuvuosina (taul. 3). Istutustaimikoissa pieninkin annostus on vaikuttanut mittausjakson loppuun asti, tosin koko ajan heiketen. Kasvun taso on suuremmilla annostuksilla sitä paitsi ollut korkeampi (Heikurainen et al. 1984).

Keski-Suomessa ja Pohjois-Suomessa lannoitusvaikutus näyttää myös sitä voimakkaammalta mitä suurempi on ollut lannoiteannostus. Erot eivät tosin ole selviä ja häviävät jo mittausjakson alussa, näin erityisesti Pohjois-Suomessa (kuvat 3 ja 4).

Sarkaleveyden vaikutus

Sarkaleveys ei näytä vaikuttavan lannoitusvaikutuksen kestoon Etelä-Suomessa (taul. 4). Muilla alueilla tulos oli sama. Tässä yhteydessä on paikallaan todeta, että sarkaleveyden vaikutus kasvun tasoon oli erittäin selvä kaikilla ilmastoalueilla (kuva 2).

Tulosten yhdistelmä ja pohdintaa

Tulosten perusteella on pääteltävissä, että ilmasto vaikuttaa NPK-lannoituksen kestoon karujen soiden taimikoissa ratkaisevasti. Selitys löytynee eri alueiden erilaisesta typen mobilisaatiosta. Tässä todettu NPK-lannoituksen verrattain pitkä vaikutusaika Etelä-Suomessa merkinnee sitä, että typen mobilisaatio on siellä riittävä takaamaan fosforin ja kalin tunnetusti pitkän vaikutusajan. Pohjoisempina typen mobilisaation heikkous aiheuttaa sen, että tyypeistä tulee minimitekijä aikaisemmin kuin etelämpänä.

Toinen mahdollinen selitys lannoituksen kestoajan alueellisiin eroihin on maahan tulevan typpilaskeuman selvä pieneneminen etelästä pohjoiseen (esim. Järvinen ja Haapala 1980).

Lannoitemäärien lisääminen lisäsi lannoitusvaikutuksen kestoaa. Käytännön lannoitusosuudesta jonkin verran lievämpi annostus (500 kg/ha: 70 kg N, 39 kg P ja 42 kg K) aiheutti lyhyemmän lannoitusvaikutuksen keston kuin kaksinkertainen ja kolminkertainen annostus. Viimemainittujen välillä ei istutustaimikoissa ollut eroja. Luonnontaimikoissa ero oli ilmeinen ei vain kasvun tasossa vaan myös vaikutuksen kestossa. Tulos lienee yhdensuuntainen sen aikaisemmin todetun tämän koekenttäaineiston tuloksen kanssa, jonka mukaan suurin annostus on aiheuttanut voimakasta istutustaimien kuolleisuuden lisääntymistä (Heikurainen ja Laine 1976).

Pohjois-Suomessa todettu lannoitettujen luonnontaimikoiden kasvun taantuminen kaipaa pohdintaa. Ilmiö ei liene kovin yleinen, mutta viitteitä tämän laatuista tuloksista on esitetty aikaisemminkin (Paavilainen 1978).

Ilmeisesti lannoituksesta lisääntynyt biomassa, josta melkoinen osa on pintakasvillisuutta, saattaa välittömän lannoitusvaikutuksen loputtua johtaa tilanteeseen, jossa sillä on vaikeuksia tyydyttää ylisuuren biomassan tarpeet.

Käytännön johtopäätösten teko esitetyistä tutkimustuloksista on vaikea, sillä tässä käytettiin käytännössä harvoin suositeltavaa taimikoiden hajalannoitusta metsittämisvaiheessa. Varttuneempien taimikoiden hajalannoitukseen sovellettuna näyttäisi tämä tutkimus osoittavan, että NPK-lannoituksen vaikutusaika on Etelä-Suomessa yli 15 vuotta, Keski- ja Pohjois-Suomessa vaajaat 10 vuotta. Tulos korostaa lämpösumman merkitystä arvioitaessa metsäojitusalueiden lannoittamisen taloudellisuutta.