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EFFECT OF FERTILIZATION AND THINNING ON RADIAL GROWTH OF SCOTS PINE

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SELOSTE:

LANNOITUKSEN JA HARVENNUKSEN VAIKUTUS MÄNNYN SÄDEKASVUUN

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The radial growth of Scots pine stands at the age of 30—60 years has been measured five years after fertilizing and thinning the stands. The effect of fertilization culminated sharply 3—4 years after treatment. The effect of thinning increased throughout the measuring period. In thinned and fertilized stands the effect of thinning was almost completely hidden by the effect of fertilization, fertilization and thinning together giving a larger growth response than the application of fertilization or thinning separately.

INTRODUCTION

Empirical results about the effects of forest fertilization have been substantially available since the early 1950's (cf. for exampe Paavilainen 1972, Viro 1972). It has been shown that fertilization plays a role of primary importance in increasing timber production. It is, however, rather difficult to determine the effect of fertilization alone since variations in growth response are also caused by climate, soil fertility, stage of development of the trees etc. For example, the weather pattern during fertilizing is of importance as regards the availability of nutrients to tree growth. In addition, thinning and similar measures affect the interpretation of the results of fertilization. Methods should therefore be developed for distinguishing between the role of different factors affecting the growth response of fertilized stands.

The aim of the study is to evaluate the applicability of radial growth analysis for determining the effect of fertilization. Our hypothesis is that radial growth analysis possesses great potential for determining the precise effect of fertilization and the eliminate the effect of climatic factors. In addition, the effect of thinning and its interaction with fertilization is studied.

Enso-Gutzeit and Kemira companies are acknowledged for providing the facilities needed to carry out this study and to utilize their fertilization experiments. Especially, Tauno Turunen, Head of the Silvicultural Department of Enso-Gutzeit, has helped us, and his activity has been important.

MATERIAL

Table 1. Some characteristics of the stands. For symbols of treatments see Table 2.

Area and its number		Treatment	Age,	Mean diameter cm	Basal area area m²/h	Volume, m³/ha	Stem number/ha
Huplinkangas (7)	1	A	48	12,0	17,8	91,81	2 408
	2	B	50	10,7	16,9	73,42	2 608
	3	C	45	10,3	21,7	98,12	3 800
	4	D	52	11,0	20,4	94,77	2 917
	5	E	54	11,1	24,3	122,29	3 783
	6	F	46	10,5	21,3	103,05	3 167
Huplinkangas (9)	1	A	42	13,8	16,1	83,18	1 483
	2	B	45	10,1	18,6	81,76	2 900
	3	C	52	12,4	24,6	130,30	3 008
	4	D	62	13,0	19,6	103,37	2 083
	5	E	54	11,6	25,9	130,37	3 683
	6	F	58	13,4	19,8	113,04	1 933
Sarajärventie (8)	1	A	43	12,2	14,6	73,72	1 958
	2	B	48	10,9	19,1	96,34	2 708
	3	C	54	11,1	21,7	104,28	3 375
	4	D	45	9,6	18,1	85,25	3 133
	5	E	48	10,0	24,6	121,59	4 417
	6	F	45	10,5	20,7	99,32	3 050
Sarvikumpu (6)	1	A	48	13,2	26,1	168,55	2 392
	2	B	48	15,0	23,6	164,14	1 633
	3	C	47	13,6	26,6	165,45	2 267
	4	D	47	13,4	29,1	190,32	2 733
	5	E	47	13,3	27,6	171,47	2 658
	6	F	46	14,5	31,3	216,45	2 350
Pankasalo (3)	3	A	64	12,0	22,9	135,57	2 742
	6	B	54	12,4	16,9	87,52	1 825
	2	C	58	12,0	26,4	147,13	3 200
	4	D	50	10,9	18,7	101,15	2 692
	5	E	61	14,8	23,9	155,65	2 208
	1	F	61	13,8	22,9	153,76	1 933
Juuka (4)	5	A	53	10,3	29,6	150,67	5 983
	1	B	52	12,9	16,6	96,16	1 508
	2	C	55	10,8	29,3	156,10	5 483
	3	A	55	13,7	19,1	113,81	1 542
	4	E	56	10,4	31,2	155,10	6 242
	6	F	53	14,3	23,3	139,54	1 800
Maanselkä (2)	1	A	30	12,0	19,5	75,42	2 075
	2	B	30	10,5	16,4	55,20	2 200
	3	C	30	11,1	20,5	75,06	2 953
	4	D	33	10,9	19,9	70,60	2 450
	5	E	32	11,2	23,6	92,63	3 150
	6	F	28	11,5	18,3	59,91	2 258
Pyhäsalmi (1)	2	A	50	9,4	24,8	100,71	6 600
	5	B	40	8,1	13,6	50,41	3 725
	1	C	50	9,8	19,9	86,58	4 658
	3	D	41	8,1	18,3	67,47	5 017
	6	E	50	8,2	23,4	87,97	7 467
	4	F	42	9,8	19,5	75,00	4 008
Lakomäki (5)	1	A	46	9,8	16,0	69,97	2 758
	6	B	54	13,1	14,3	75,87	1 475
	2	C	50	10,0	20,8	98,75	3 500
	3	D	46	11,6	15,9	78,37	1 983
	4	E	44	10,8	19,6	88,14	3 300
	5	F	44	12,4	15,9	82,58	1 675

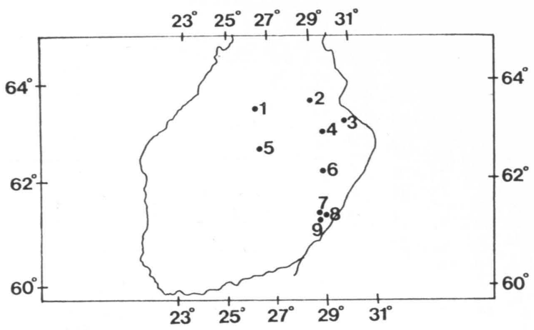

Fig. 1. Location of study areas. For numbers of the areas see Table 1.

Table 2. Treatment of sample plots.

Symbol	Treatment	Fertilizing
A	No thinnig No fertilization	
B	Thinning No fertilization	
C	No thinning Fertilization	N 145 kg/ha as NH_4NO_3
D	Thinning Fertilization	N 145 kg/ha as NH_4NO_3
E	No thinning Fertilization	N 187 kg/ha, P 95 kg/ha as NH_4NO_3 and as super-phosphate
F	Thinning Fertilization	N 187 kg/ha, P 95 kg/ha as NH_4NO_3 and superphosphate

The material consists of eight areas in southern Finland (cf. Fig. 1). The sample plots were of the *Vaccinium* site type with a cover of Scots pine *(Pinus sylvestris* L.) stand, at the age of 30 – 60 years (cf. Table 1). The areas were situated mainly on soils of sand and sand morain. The relief in study areas was flat with no particular aspects.

The study plots were established in 1970. There were six plots representing thinning and fertilization treatments in each area as shown in Table 2. No replicates were used but each treatment was represented by one plot. The size of the plots was 30 × 40 m with a buffer zone 10 m wide. The fertilization and thinning treatments were completed before the snow melted in spring 1970.

The material was collected in summer 1976 during the period June 8. – August 13. Inventory of the plots was carried out using the MISS-system developed in the Department of Forest Mensuration, the University of Helsinki, as reported by Mielikäinen (1972). Tree sampling was performed in such a way that there was minimum of one sample tree representing each diameter class. In sampling the role of large trees was empasized.

Standard methods were used in the measuring of sample trees in order to obtain the information necessary to calculate the volume of the standing crop and growth of the tree stand. Particular emphasis was laid on measuring radial growth as it was needed for testing our hypothesis. Measuring was done at the height of 1.3 m from ground level. The measurements covered the preceding ten years period, *i.e.* five years before treatment and five years after. The annual radial growth was determined to an accuracy of 0.001 mm with a microscope in the laboratory.

RESULTS

The mean annual radial growth values for each treatment are depicted in Fig. 2 A. The pronounced effect of weather on radial growth affects the interpretation of the results. The effect of fertilization and thinning becomes much more evident, if instead of annual increments the ratio between the annual increment of the treated and control plots is studied, as demonstrated in Fig. 2 B. The disturbing

effects of other factors as that of weather have nearly disappeared and the differences between the treatments are easily recognised.

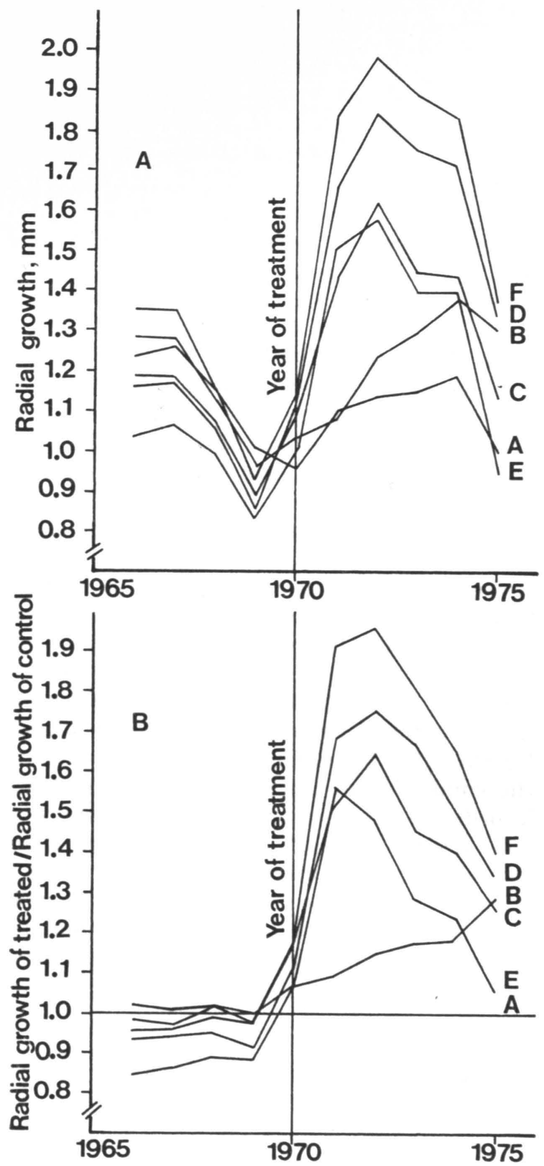

Fig. 2. Effect of fertilization and thinning on radial growth of Scots pine.

A: Radial growth of treated and untreated trees in absolute terms.

B: Radial growth of treated trees as related to radial growth of untreated trees.

For treatment symbols see Table 2.

DISCUSSION

The effect of fertilization on tree growth is frequently studied by following volume growth during a prolonged period, for instance five years. Information about the effect of fertilization is then ommitted, *eg.* the latent time response and the duration of the response, which may obscure the interpretation of the results. In addition, the heterogenity of the area often generates additional variance, which might cover the effect of fertilization. These disadvantages are essentially reduced when the effect of fertilization on annual growth is studied as a time series instead (cf. Jonsson and Sundberg 1972). This approach can be applied to reduce the variance in annual radial growth generated by a changing weather pattern. The disturbing effects of other factors as that of weather are drastically reduced when the ratio between the treated and control plots is determined. This can be seen by comparing Figs 2 A and 2 B.

A small positive response to fertilization can be seen already during the summer following treatment at the same spring. The maximum response, however, occured during the third year following fertilization. The culmination of growth is abrupt, and 3 – 4 years after fertilization growth is considerably decreased. The decrease in growth seems to be as fast as the increase in growth. This result agrees well with the findings of Brantseg *et al.* (1970). According to their results the culmination of growth takes place 3 – 4 years after fertilization. The effect of fertilization, however, is still recognizable even six years later. There are no significant differences between different fertilizing treatments, but the application of nitrogen and phosphorus appears to give a greater response than nitrogen only.

The magnitude of the fertilizer effect is dependent on the physiological and ecological effects of the fertilizers on the functions of trees and stands. In particular, two basic processes can be mentioned: the effect of fertilization on the photosynthetic rate and on the characteristics of the crown system. Both factors make their own contribution to the photosynthetic capacity of the fertilized tree and have an effect on the productivity of the stand.

According to HELMS (1964), BRIX and EBELL (1969) and BRIX (1971), the application of nitrogen at a dosage of 200–500 kg N/ha increases the photosynthetic rate of Douglas fir *Pseudozuga menziesii* by 10–20 % compared to nonfertilized trees. In experiments carried out by KEAY *et al.* (1968) the photosynthetic rate of *Pinus pinaster* increased by 100–150 %, when nitrogen (100 kg N/ha) and phosphorus (30 kg/ha) were applied. Also the study by ÅGREN *et al.* (1977) suggests that fertilization may increase the photosynthetic rate more than can be assumed on the basis of results obtained with Douglas fir. On the other hand, the application of nitrogen may have a direct effect on the photosynthetic rate, if the supply of other nutrients is sufficient (cf. FAGERSTRÖM and LOHM). The greater response to applications of nitrogen and phosphorus than to nitrogen only may be due to this fact.

According to HELMS (1964) the increase in the needle mass plays the decisive role in increasing the photosynthetic capacity. Numerous researchers have published results which agree with HELMS (1964) conclusions (cf. for example BRIX 1971, FAGERSTRÖM and LOHM 1977). According to MILLER and MILLER (1976), the leaf area of *Pinus nigra* increased by 100 % when nitrogen was applied (500 kg N/ha) to the stand. Especially, the retarding of needle fall increases the leaf area during the first couple of years after fertilization as indicated by the present study. In addition, the number of needles per shoot, the size of needles and the number of lateral shoots increase as a result of fertilization. All these factors increase the leaf area of fertilized stands compared to nonfertilized stands.

The duration of the fertilizer effect also suggests that the crown system plays a dominant role in increasing the photosynthetic capacity of fertilized trees. According to MILLER and MILLER (1976) and MILLER *et al.* (1976), the dynamics of needle mass in fertilized *Pinus nigra* was the same as in nonfertilized trees 3–4 years after fertilizing. This coincides with the culmination of the growth response as indicated by radial growth. The abrupt decrease in growth also supports this assumption. In addition, the photosynthetic rate decrease as the needles age and for this reason the photosynthetic capacity returns to the level prevailing before fertilization (cf. BRIX 1971, WOODMAN 1971).

Thinning also had a recognisible effect on radial growth. During the whole measuring period the effect of thinning was, however, increasing and did not culminate during the measuring period. The low reaction to thinning may be associated with the low adaptive ability of trees subjected to new ecological conditions. Adaptation to a new light climate is especially slow and takes place through the renewal of needle mass. It normally takes 3–5 years for a pine to complete its adaptation to new conditions, *i.e.* the period for renewal of the needle mass. On the other hand, BRIX (1971) recommends the combining of thinning with fertilization in order to decrease mutual shading of trees and needles. BRIX (1971) supposes that thinned and fertilized stands are better able to utilize solar radiation than thinned or fertilized stands. This assumption is supported by the present material (cf. also WEETMAN 1975).

REFERENCES

BRANTSEG, A., BREKKA, A. & BRAASTAD, H. 1970. Gjodslingsførsøk i gran — og furuskog. Med. Norske Skogfordkøksv. 100: 540–603.

BRIX, H. 1971. Effect of nitrogen fertilization on photosynthesis and respiration of Douglas-fir. Can. J. For. Res. 2: 467–478.

— » — & EBELL, L. F. 1969. Effect of nitrogen fertilization on growth, leaf area, and photosynthesis rate in Douglas-fir. For. Sci. 15: 189–196.

FAGERSTRÖM, T. & LOHM, V. 1977. Growth of Scots pine (*Pinus silvestris* L.). Mechanism of response to nitrogen. Oecologia (Berl.) 26: 305–315.

HELMS, J. A. 1964. Apparent photosynthesis of Douglas-fir in relation to silvicultural treatment. For. Sci. 10: 432–442.

JONSSON & SUNDBERG, R. 1972. Has the acidification by atmospheric pollution caused a growth reduction in Swedish forests. Department of forest yield research, Royal college of forestry. Research Notes 20.

KEAY, J., TURTON, A. G. & CAMBELL, A. N. 1968. Some effects of nitrogen and phosphorus fertilization of *Pinus pinaster* in Western Australia. Forest Sci. 14: 408–417.

MIELIKÄINEN, K. 1972. MISS-Metsän inventoinnin ja suunnittelun systeemi. Summary: Miss-a forest inventary and planning system. University of Helsinki. Department of forest mensuration and management. Research Reports 1.

MILLER, H. G., COOPER, J. M. & MILLER, J. D. 1976. Effect of nitrogen supply on nutrients in litter fall and crown leaching in a stand of Corsican pine. J. appl. Ecol. 13: 233–248.

— » — & MILLER, J. D. 1976. Effect of nitrogen supply on net primary production in Corsican pine. J. appl. Ecol. 13: 249–256.

PAAVILAINEN, E. 1972. Reaction of Scots pine on various nitrogen fertilizers on drained peatland. Commun. Inst. For. Fenn. 77.3.

WEETMAN, G. F. 1975. Ten-year growth response of Black spruce to thinning and fertilization treatments. Can. J. For. Res. 5: 302–309.

WOODMAN, J. N. 1971. Variation of net photosynthesis within the crown of a large forest grown conifer. Photosynthetica, 5: 50–54.

VIRO, P. J. 1972. Die Walddüngung auf finnischen Mineralböden. Folia For. 138.

SELOSTE:

LANNOITUKSEN JA HARVENNUKSEN VAIKUTUS MÄNNYN SÄDEKASVUUN

Tutkimuksessa on selvitetty lannoituksen ja harvennuksen vaikutusta kasvatusvaiheessa olevien männiköiden sädekasvuun. Lannoitus aiheutti nopean sädekasvun lisääntymisen, joka kulminoitui 3–4 vuotta lannoituksen jälkeen. Harvennuksen vaikutus sen sijaan jatkui koko tutkitun jakson ajan. Lannoitetuissa ja harvennetuissa metsiköissä lannoituksen vaikutus oli selvästi suurempi kuin harvennuksen. Lannoitus ja harvennus vaikuttivat kuitenkin yhdessä voimaakkaammin sädekasvuun kuin kumpikaan käsittely erikseen.