DET FORSTLIGE FORSØGSVÆSEN I DANMARK

THE DANISH FOREST EXPERIMENT STATION
STATION DE RECHERCHES FORESTIÈRES DE DANEMARK
DAS FORSTLICHE VERSUCHSWESEN IN DÄNEMARK

BERETNINGER UDGIVNE VED
DEN FORSTLIGE FORSØGSKOMMISSION

REPORTS — RAPPORTS — BERICHTE

BIND XXXI

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KØBENHAVN
TRYKT I KANDRUP & WUNSCH'S BOGTRYKKERI
1969

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10 YEARS' FERTILIZING EXPERIMENTS IN NORWAY SPRUCE AND BEECH REPRESENTING THE MAIN VARIATIONS IN GROWTH CONDITIONS IN DENMARK

10 ÅRS GØDNINGSFORSØG I RØDGRAN OG BØG

BY

CARL MAR:MØLLER, OLE SCHARFF AND
JENS R. DRAGSTED

The existing literature on fertilization of forests is immense, as will appear, for example, from two compilatory works published by the University of Syracuse: "Forestry Fertilization" by *White & Leaf* in 1957, treating 700 reports — and "Forest Fertilization Research 1957—64" by *Mustanoja & Leaf.*

The majority of the experiments have given positive results, but this should not be taken as a proof of the possibility of obtaining similar results by fertilization in general practice, as there will always be a tendency to conduct experiments where the forest seems to be in need of fertilization, and also, when possible, to publish positive results.

Furthermore, a large number of the experiments are not satisfactory, from a mathematical-statistical point of view, to allow any real conclusion to be drawn.

Finally, the natural nutritional conditions are most often not sufficiently defined — if defined at all. The amount of accessible minerals and nitrogen before the start of the experiments may not have been measured, and so on.

Even though the large number of different observations do, naturally, provide a great amount of knowledge about the nature of problems in general, this enormous amount of material still affords only a limited possibility of evaluating fertilization as an integral part of a country's silviculture.

In recognition of this fact, a rather comprehensive system of fertilizing experiments was laid out in Denmark in 1953 and the following years, covering the whole country, so that the main variations in climate and soil, resulting in different site classes, were well represented in respect of the two species covered in our experiments, viz. beech (Fagus silvatica L.) and Norway spruce (Picea Abies (L.) Karst), of which beech covers about 23 % and Norway spruce about 33 % of the forested area of Denmark.

As in agriculture, the fertilizers were to be applied annually, and the experiments were to continue for 10 years.

The material obtained has been treated in the following sections*):

A. Fertilizing experiments with the fertilizers most commonly used in agriculture, viz. 15.5 % calcium nitrate, 50 % potassium muriate, and 18 % superphosphate, applied annually to cultures of spruce and beech, normally in the state before closing, the soil not being worked since culture (p. 90).

B. Fertilizing experiments with the same fertilizers in middle-aged stands of spruce and beech, the soil not being worked (p. 201).

C. Combined fertilizing and soil-working experiments in cultures of spruce on heathland soil, with application of the above-mentioned fertilizers — with the object of comparing the effect of fertilizers with or without simultaneous soil-working (p. 217).

D. A fertilizing experiment with urea in a typical middle-aged spruce stand on heathland soil, the soil not being worked (p. 225).

E. Analyses of needles (p. 236).
Hereto comes:

F. Total summary and discussion (p. 245).

In the following, each type will be treated separately in sections A, B, C, a. s. o.

It is noteworthy, and fundamental, that the three main fertilizers applied, viz.: 15 % calcium nitrate, 18 % superphosphate, and 50 % potassium muriate, are the fertilizers until recently used almost exclusively in Danish agriculture, and that, in good farming, they are generally given in quantities corresponding to the full doses administered in our experiments, and with very satisfactory results.

On the heathland which is being transformed into agricultural land these fertilizers are normally used jointly with intensive

*) Møller has planned, started and supervised the experiments. Scharff is responsible for the statistical methods used in the making up of results at the conclusion of the investigation and for the programming of the electronic data processing. Dragsted carried out the field work in 1963—64. All three authors worked jointly at the final treatment of results.

working of the soil and with the application of considerable amounts of lime.

In many cases, this treatment was also used for a few years preparatory to the transformation of heathland into coniferous plantations, and, as might be expected, the result was always good — in so far as the plantation always got a good start. But without this treatment a period of stagnation would generally follow some years after planting and long before the closing of the cultures. Harrowing or ploughing between the rows would then give the yellow, short-shooted spruces a better colour and growth, not only because any competing flora of heather and grasses was killed, but probably also because the working of the soil resulted in a new decomposition, as might be concluded from the fact that improvement could be observed also where no competing flora had yet come into existence.

Agriculturally prepared cultures are represented in our material (the "Frederikshåb", "Skygge", "Haraldslund" and, partially, "Harreskov" plantations). But in no case had the soil been worked for the last 5 years preceding the start of the experiments, so that the soil carried a dense vegetation of heather, etc. or — in the case of the better soils — of grasses mixed with various herbs or shrubs.

The main object of the investigation of Type A was to get an answer to the question of the isolated effect of the common agricultural fertilizers given to cultures in the state just before, or shortly after closing, the fertilization being repeated annually, as in agriculture, for 10 years, and no working of the soil taking place.

The effect of soil-working — isolated or combined with fertilization, — has been elucidated in the Type C experiments.

A. INVESTIGATION OF THE EFFECT OF SOME TYPICAL AGRICULTURAL FERTILIZERS ON BEECH AND NORWAY SPRUCE CULTURES, THE TREATMENT STARTING JUST BEFORE (OR IN SOME CASES AFTER) THE CLOSING OF THE CULTURE. NO SOIL-WORKING.

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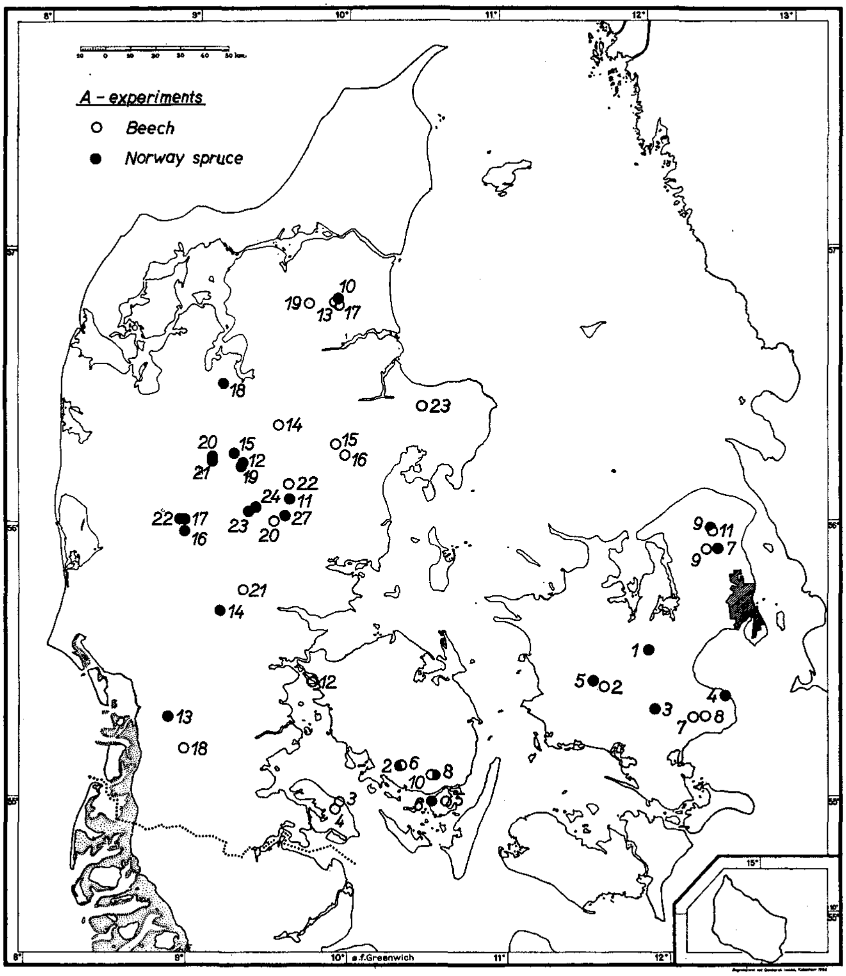

F i g. 1. Geographical position of A-experiments. The numbering of the experiments refers to that used in Tables 1 and 2, which provide more detailed information about the experiments.

F i g. 1. Geografisk placering af A-forsøg. Den anvendte nummerering af forsøgene refererer til den, der er anvendt i tabel 1 og 2, hvor nærmere oplysninger om forsøgene findes.

I. SURVEY OF EXPERIMENTAL MATERIAL. LAYOUT OF EXPERIMENT

The aggregate material consists of 25 experiments in Norway spruce (Picea abies (L.) Karst.) and 23 experiments in beech (Fagus sylvatica L.). One beech experiment has, however, been left out from the final total. Apart from Experiment No. 23 in beech (see Table 2), all the experiments were established in the spring of 1953 and fertilized each year for ten years, i.e. up to and including 1962. The experiments are scattered over the greater part of Denmark, as can be seen from Fig. 1.

At the time of the establishment, the age from seed of the spruce and beech cultures in which experiments were established, ranged from 6 to 17 years, with the exception of Experiment No. 20 in beech, which was older. The beech cultures were produced by planting in rows spaced (1.0)—1.3—(2.0) m apart, in a few cases by natural regeneration. The spruce cultures were produced by planting in rows spaced (1.0)—1.3—(2.0) m apart. Thinning of the cultures has been performed only in a few cases, viz. in beech experiments Nos. 6, 7, 14, 18, and 20 (see Table 2).

A standard experiment comprises 15 plots, each about 50 m long and containing 7—11 rows of plants (always an uneven number planted in the lengthwise direction of the plot). The experiment thus covers an area of about 0.7 hectare. The plots were marked by timber or concrete posts placed at the corners.

The standard experiment included 7 different treatments with fertilizers (cfr. Fig. 2), viz.:

N:	300 kg	15.5 %	calcium nitrate per ha/year	(46 kg N per ha/year)
K:	100 -	50 %	potassic muriate - - -	(42 kg K - - -)
P:	200 -	18 %	superphosphate - - -	(15 kg P - - -)
	300 -	15.5 %	calcium nitrate - - -	(46 kg N + 42 kg K + 15 kg P) per ha/year
NKP:	100 -	50 %	potassic muriate - - -	
	200 -	18 %	superphosphate - - -	
N/2	150 -	15.5 %	calcium nitrate - - -	(23 kg N per ha/year)
K/2	50 -	50 %	potassic muriate - - -	(21 kg K - - -)
P/2	100 -	18 %	superphosphate - - -	(7.5 kg P - - -)

The fertilizer was spread on the ground manually in April-May. Often, K + P was spread first, and later N.

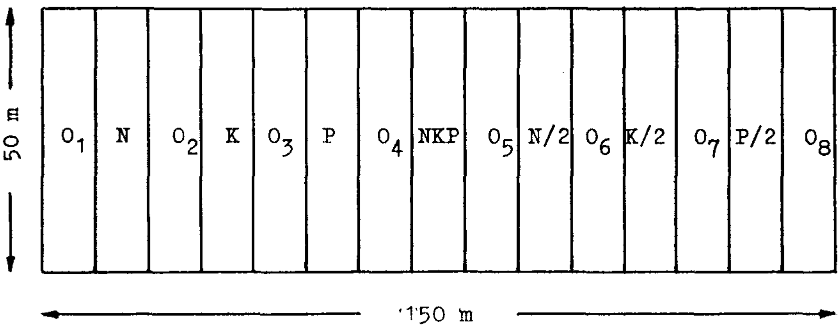

Fig. 2. A-experiments (standard experiment). Diagram of the typical structure of 15 plots situated beside each other. From this structure there are a few deviations, regarding which see text.

Fig. 2. A-forsøg (normalforsøg). Diagram over den typiske opbygning i 15 parceller, der ligger ved siden af hinanden. Fra denne opbygning findes enkelte afvigelser, hvorom henvises til teksten.

The 8 untreated plots have been interposed between the treated plots as controls.

In a number of cases the standard experiments have been supplemented by one or more fertilizing treatments in order to watch the effect of qualities and quantities of fertilizers differing from those of the standard experiment, in which cases the standard experiment was extended by the addition of fertilized plots and controls. The treatments tested in this way were NKP/2, non-chlorous potassium (K_2SO_4), ammonium sulphate, and dicalcium phosphate in spruce; urea in beech; nitrophoska and $3 \times$ P in both spruce and beech. Further details will appear from the description of the individual experiments on pages 103—123, as well as from Tables A 19 and A 35.

II. DESCRIPTION OF THE INDIVIDUAL EXPERIMENTS

a. Synoptic description.

The first column of Tables 1 and 2 contains the numbers of the experiments. By means of these numbers, the texts describing the experiments can easily be found, as the descriptions appear in the same sequence as in the two tables.

Next, the tables contain one column for forest district, one for forest — or ranger district, and one for compartment number.

The adjacent column indicates the age of the experiment from seeds. In Table 1 (Norway spruce) this age applies to the stage in the spring of 1963, as most of the experiments were measured at a time in 1963 when it was impossible to measure the increment for 1963 (see further on). In Table 2 (beech) the age applies to the stage in the autumn of 1963, because all experiments were measured at the end of 1963 or the beginning of 1964.

The additional columns indicate the site-class groups in which the experiments are placed. Site-classification was made at the start of the experiments (for each experiment) with the aid of Carl Mar: Møller's yield tables, neighbouring stands forming the basis for the site-classification. The experiments were then placed in a number of site-class groups (cfr. *Møller* 1954, p. 176—179).*) Due to the inaccurary with which such a site-classification is attended, the authors of this paper have preferred after having stated the site-class of the single experiments then to condense the result by grouping the site-class figures obtained into fewer and wider site class groups, f. inst. for beech site-classes 0.0—2.0 and 2.1—4.0.

The column for number of plots contains the number of plots included in the final measurement. This number may deviate from the original number of plots, as some plots have had to be given up, or control plots have had to be added where experiments were divided. Then follows a column for number of rows per plot. This number is normally constant throughout an experiment, but may vary in a few cases, which then appears from the verbal description of the experiment.

The columns following these indicate the time (month and year) for the final measurement, i.e. the measurement forming the basis for the present paper.

Table 1 then has two special columns stating more precisely how the measurement has been made. The former of these two columns indicates whether height measurement has been made to the top formed in 1962, which applies to experiments measured

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*) The Danish site class system is most simply characterized as follows: At 100 years from seed site-class I of beech is 32 m high, class II 28 m, class III 24 m, class IV 20 m and class V 16 m.

At 50 years from seed site class I of Norway spruce is 24 m high, class II 21 m, class III 18 m, class IV 15 m, class V 12 m, class VI 9 m and class VII 6 m. (See further Carl Mar: Møller 1933) by August 20, 1963, or to the top formed in 1963, which applies to experiments measured after August 20, 1963. Such a problem does not exist for the beech experiments, as these were all measured in the winter of 1963/64 and so are height-measured to the top formed in 1963. — The second of the two columns indicates the height above the ground at which the diameter was measured, seeing that a number of experiments have been sufficiently high to permit of diameter-measuring at the normal measuring height (i.e. 1.3 m above ground), while in a number of experiments, especially on old heathland soil, the height has been so small that the place for the measuring of the diameter has had to be fixed at 0.5 m above ground. This problem does not exist for the beech experiments, all of which have been calipered at 1.3 m above ground.

These columns are succeeded by 7 columns, which are identical for Tables 1 and 2, and contain results of a soil investigation made in 1953 — immediately before the first treatment with fertilizers.

Details about the soil investigation.

In forestry, evaluation of the practical importance of the different index figures is extremely difficult. In agriculture, however, thousands of fertilizing experiments have been made for many years, providing a wealth of experience for all types of soil. As to numerical expressions characterising the various experimental soils the following may be said: —

1. pH has been determined on the Kinhydron method (KCl number + 1): In agriculture, Danish experiments have indicated that he following values should be suitable for field crops in general:

Heavy clay soil	above 7.5
Clayey soil	7.0—7.5
Sandy soil	6.5—7.0
Sandy soil or sandy heathland soil rich in humus	6.0—6.5
Low-level bog	5.5—6.0
Raised bog	5.0—5.5

The best values for forest soil are difficult to ascertain at the moment, but, generally, far lower optimum values may be

Table 1. A-Experiments in Norway Spruce.
For explanatory notes regarding the various columns, see the text.

Experiment No.	Forest district	Forest or ranger district	Compartment No.	Age from seed spring 1963	Site class group	No. of plots	No. of rows per plot
01	Bidstrup	Hejede Overdrev	214	23	1.1—3.0	15	9
02	Brahetrolleborg	Storskoven	93	20		15	7
03	Bregentved	Haslev Orned	I 42	20		15	7
04	Gjorslev	Magleby	99	20		18	9
05	Sorø I	Vindelbro	31 A	16—17		8	7
05	Sorø I	Vindelbro	31 A	16—17		16	7
06	Valdemar Slot	Vornæs	XXI 14	16		16	7
07	Frederiksborg	St. Dyrehave	233	20		15	7
08	Hvidkilde	Hedeskovene	69 c	19		15	7
09	Nødebo	Strøgårdsvang	324	20—21		15	7
10	Lindenborg	Fræer	768	22	3.1—4.0	16	9
11	Silkeborg	Østerskov	175	20		16	7
27	Løndal	Salten ådal	185 b	25		15	7
12	Viborg	Kompedal	404	21		17	7
13	Lindet	Varming	513	21	4.1—7.0	18	9
14	Randbøl	Frederikshåb	184	17		15	7
15	Viborg	Kompedal	197	20		17	7
16	Heath Soc. 5.	Hesselvig	5	22		15	9
17	Heath Soc. 5.	Birkebæk	109	27		15	11
18	Heath Soc. 3.	Liebe	16—17	22—24		17	7
19	Heath Soc.	Skygge	13	20		17	7
20	Heath Soc. 4.	Agerskov	14—15	14—15		17	7
21	Heath Soc. 4.	Haraldslund	8	21		15	7
22	Heath Soc. 5.	Harreskov	65	22		15	7
23	Palsgård	Gludsted	52	25		15	9
24	Palsgård	Gludsted	142	21		15	9

Table 1 (continued).

Final measurement, month and year	Measurement to top formed autumn	Diameter measured at height, above soil m	Soil data, 1953							
			Heath Society Laboratory					State Laboratory of Plant Culture		
			pH	Ft	Fot	Kt	Nitrate figure	pH	Ft	Kt
October, 1963	1963	1.3	4.5	1.4	0.3	8.1	0	4.4	1.0	7.5
September, 1963	1963	1.3	5.1	2.1	1.5	15.3	0	4.8	1.5	12.3
October, 1963	1963	1.3	—	—	—	—	—	4.1	0.7	6.1
October, 1963	1963	1.3	7.3	3.2	0.5	3.1	10	7.1	4.4	8.1
October, 1963	1963	1.3	4.6	3.1	1.1	13.6	10	6.5	2.2	12.5
October, 1963	1963	1.3	6.6	2.4	1.3	12.8	15	6.7	2.0	10.3
September, 1963	1963	1.3	5.1	2.3	0.9	8.0	0	5.0	1.6	8.4
June, 1963	1962	0.5	4.5	1.2	0.4	4.5	0	4.4	0.9	4.4
September, 1963	1963	1.3	4.6	1.7	0.8	5.8	0	4.7	1.7	5.3
July, 1963	1962	0.5	—	—	—	—	—	3.8	1.3	8.4
August, 1963	1963	1.3	5.0	0.9	0.4	5.8	0	4.8	0.5	4.7
August, 1963	1962	1.3	4.3	0.6	0.2	4.1	0	4.2	0.2	3.9
September, 1963	1963	1.3	4.4	0.1	0.3	3.6	3	4.4	0.6	4.5
July, 1963	1962	1.3	4.4	0.8	0.5	2.7	0	4.4	0.3	2.5
August, 1963	1962	0.5	4.2	0.5	0.2	3.3	0	4.2	0.2	1.9
August, 1963	1962	1.3	5.7	0.9	0.6	1.6	—	5.6	0.7	2.0
July, 1963	1962	0.5	4.9	1.0	0.5	2.0	0	4.7	0.8	2.5
June, 1963	1962	0.5	4.2	0.6	0.4	1.7	0	—	—	—
June, 1963	1962	0.5	3.9	0.6	0.4	3.7	0	—	—	—
June, 1963	1962	0.5	4.3	0.7	0.5	4.1	0	—	—	—
June, 1963	1962	0.5	5.8	1.5	1.1	2.3	0	—	—	—
May, 1963	1962	0.5	4.6	0.8	0.4	4.7	0	—	—	—
May, 1963	1962	0.5	5.7	0.8	0.4	2.8	0	—	—	—
September, 1962	1962	0.5	4.9	0.3	0.3	2.5	0	—	—	—
July, 1963	1962	0.5	4.5	0.2	0.2	3.4	0	4.5	0.7	2.5
July, 1963	1962	1.3	4.6	0.3	0.2	2.3	0	4.6	0.7	3.6

Table 2. A-Experiments in Beech.
For explanatory notes regarding the various columns, see the text.

Experiment No.	Forest district	Forest or ranger district	Compartment No.	Age from seed autumn 1963	Site class group	No. of plots	No. of rows per plot
02	Sorø Akademi I	Alsted	12 B	19	0—2.0	15	—
03	Sønderborg	Nygård	50, 17	20		16	11
04	Sønderborg	Øvelgunde	341, 336	19—23		17	11
05	Valdemar Slot	Holme	XII, 3	19		15	7
06	Brahetrolleborg	Storskoven	104	23		15	—
07	Bregentved	Ganneskov	XXII,23	20		15	7
08	Bregentved	Boelskov	XXXIII,21	19		16	7
09	Frederiksborg	Brøde	56 B	18		9	9
10	Hvidkilde	Hedeskovene	89 a	21		15	7
11	Nødebo	Strøgårdsvang	312	19		16	7
12	Wedellsborg	Sparretorn	18	20		9	7
13	Buderupholm	Sønderskov	151	19	2.1—4.0	16	6
14	Viborg	Vindum	94	24		13	7
15	Frijsenborg	Tårup	11	25		15	7
16	Frijsenborg	Sønderskov	54	20		15	7
17	Lindenborg	St. Arden	488	22		15	—
18	Lindet	Lindet	76	27		17	9
19	Nørlund		I 5	24		19	7
20	Palsgård	Velling	186	55		15	7
21	Randbøl	Refstrup	147	18—23		16	—
22	Silkeborg	Nordskov	68 C	23		15	7
23	Løvenholm	Eldrup	205	13		12	7

Table 2 (continued).

Final measurement, month and year	Soil data 1953							
	Heath Society Laboratory					State Laboratory of Plant Culture		
	pH	Ft	Fot	Kt	Nitrate figure	pH	Ft	Kt
February, 1964	4.5	1.4	0.7	8.1	0	4.5	1.3	7.5
January, 1964	—	—	—	—	—	5.0	1.2	17.3
January, 1964	—	—	—	—	—	5.0	2.1	11.2
January, 1964	5.0	1.4	0.7	14.2	5	4.9	1.5	13.6
March, 1964	5.0	1.5	0.5	9.7	0	4.8	2.2	10.1
January, 1964	—	—	—	—	—	5.6	2.2	10.6
Februar, 1964	—	—	—	—	—	4.9	2.0	6.7
December, 1963	4.8	2.9	0.6	5.3	0	4.8	2.9	5.6
January, 1964	4.6	1.5	0.4	5.3	5	4.5	1.2	4.8
February, 1964	—	—	—	—	—	7.0	0.7	7.0
January, 1964	5.6	1.0	0.4	13.1	0	5.7	1.9	12.9
November, 1963	—	—	—	—	—	4.3	0.3	3.7
November, 1963	4.4	0.9	0.5	6.9	0	4.5	0.7	6.6
December, 1963	—	—	—	—	—	5.0	0.7	9.2
December, 1963	—	—	—	—	—	4.9	1.2	6.4
November, 1963	4.8	0.9	0.4	5.0	5	4.7	0.6	4.5
January, 1964	4.0	0.6	0.2	5.9	0	3.9	0.3	9.2
November, 1963	4.5	1.0	0.5	8.9	0	4.3	0.7	8.6
Winter 1963/64	5.0	0.6	0.1	2.8	0	5.0	0.5	4.1
January, 1964	5.1	0.9	0.3	9.7	—	5.1	0.7	7.8
December, 1963	4.4	0.6	0.3	2.7	5	4.4	0.3	3.1
December, 1963	—	—	—	—	—	—	—	—

figured on in forestry than in agriculture. For example, *Weiss* (1924) found pH = 4 in many of the best beech stands in Denmark.

2. The *phosphoric acid figure,* Ft, varies in agriculture between 0 and 20 — most frequently between 4 and 7. In forest soil which has never been fertilized it seems to range between 0 and 3, and it is probable that forest trees would be able to obtain the optimum yield at far lower values of Ft than apply to agricultural crops.

   The phosphoric acid figure, Ft, has been found by shaking 10 g air-dry earth for 3 hours in 250 cm^3 standard sulphuric acid, followed by a colorimetric determination in the filtrate after precipitation with ammonium molybdate.

   The *phosphate figure,* Fot, is another expression for control of P, and has been found by means of a cation exchanger, sodium zeolite (cfr *Jørgen Møller* and *Thorkil Mogensen,* 1953).

   The analysis is carried out by shaking 10 g air-dry soil in 10 g Na zeolite and 250 cm^3 distilled water for 6 hours, after which the phosphate concentration is determined colorimetrically in the filtrate, expressed as mg PO_4 per litre. This figure is then multiplied by a factor (0.2336) in order to become directly comparable to the Ft mentioned above.

   The ion exchanger method was adopted in order to avoid interfering with the actual state of the soil, and to try to imitate the process which, presumably, is taking place in the soil between the cation-occupied soil colloids and the phosphates precipitated, and thus interfere as little as possible with the colloid-chemical state of the soil.

   In a large number of experiments with Danish and foreign index methods the Fot figure has given the best correlation between index number and the growth obtained, namely a correlation coefficient r = 0.68. Nearest this value was the Dutch citrate figure, r = 0.60, while Ft had r = 0.35. (*K. A. Bondorff,* 1948).

3. The *potassium figures,* Kt, were determined by the Danish Plant Laboratory on Damsgaard-Sørensen's titration method, while the Danish Heath Society's laboratory used Beckman's flame spectrophotometer, which, fundamentally, should give the same result because the same solvent is used.

   In agriculture, Kt most frequently varies between 5 and 10; in forest soil most often between 2 and 6.

4. The *nitrate figures* have been determined colorimetrically on the diphenylamine sulphuric-acid method.*)

5. *The analytical accuracy in the determination of pH, phosphoric-acid figure (Ft) and Potassium figure (Kt):*

   In order to find out what degree of accuracy one should attach to the individual results from the soil analyses, a calculation of the standard deviation of the individual analysis has been made for the pH, the phosphoric-acid figure and the potassium figure. This has been possible by a double determination of pH, Ft and Kt, as these figures were determined for the same 32 samples by both the Danish State Laboratory of Plant Culture and the Heath Society's laboratory using the same methods. (As regards Kt, see above).

   The standard deviation of the individual analysis is, approximately, as follows:

   For pH: ± 0.1 For Ft: ± 0.3 For Kt: ± 0.9

   In the calculation of the standard deviation on Ft, a correction had previously to be made, as the figures of the Plant Laboratory for Ft are on an average 10 % lower than those of the Heath Society.

   The analytical accuracy found is fully satisfactory only for pH, though for the other factors usable.

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*) For the individual index numbers the unit has the following values in mg per kg air-dry soil at 20°C:

Phosphoric-acid number (Ft) and phosphate number (Fot): 30 mg P per kg air-dry soil.

Potassium number (Kt): 10 mg K per kg air-dry soil.

Nitrate number (Nit): 1 mg NO_3-nitrogen per kg air-dry soil.

6. *Relation between site class and Ft, Fot, Kt and pH.*

Tabulation of the statistical mean for each site class of the soil analysis gives the following result:

Site Class	Heath Society's Laboratory					Plant Culture Laboratory		
	pH	Ft	Kt	Fot	Nit	pH	Ft	Kt
			Beech					
0.0—2.0	4.9	1.6	9.3	0.6	1.7	5.2	1.7	9.8
2.1—4.0	4.6	0.8	6.0	0.3	1.7	4.6	0.6	6.3
			Norway Spruce					
1.1—3.0	5.3	2.3	8.9	0.8	4.4	5.2	1.7	8.3
3.1—4.0	4.6	0.8	4.2	0.4	0	4.5	0.3	3.7
4.1—7.0	4.8	0.7	2.9	0.4	0	4.7	0.6	2.5

It will be seen that all index figures tend to increase with improvement of site class. Here it should be borne in mind, that improvement of site class is most often accompanied by higher clay content, and that the greater part of our clay originates from minerals which are rich in bases and thus easily disintegratable. Accordingly higher water-absorption capacity is combined with a bigger content of basic minerals and thus of plant nutrients.

The nitrate figures are not very informative. For Norway spruce, nitrate is observed only in the best site class; for beech, sporadically scattered throughout the site classes.

7. *Variation of growth conditions within the individual experiment.*

Usually, the index figures are the mean figures for a complete experimental area, 20 soil samples taken all over the area (ab. 0.7 ha) having been mixed in the same way as is usual in agriculture. In order to obtain an indication of the variation within a single experimental plot, we have in 4 experiments taken mixed samples from each plot, and these plot figures appear to fluctuate rather greatly.

In the most extreme case of the four pH of the single plots of an experiment might fluctuate between 5.6 and 7.8. Ft might fluctuate between 0.5 and 1.2, and Kt between 4.2 and 12.6.

Add to this the inevitable differences in ground levels, etc., and it is obvious that even though efforts have been made to select areas as uniform as possible, our experimental areas must be far more heterogeneous than those normally found in agricultural or horticultural experiments. This is due, primarily, to the fact that, as far as dimensions are concerned, tree growth is of a higher order of magnitude than agricultural crops, and demands larger plot areas, and also to the fact, that the homogenisation of the soil which has taken place for decades or centuries in agriculture and horticulture, has generally not taken place in forests and heath plantations. Finally, in the old forestal regions of the country the forests generally stand on rougher ground than that occupied by agriculture.

It should be added that the 4 experimental areas referred to were old forest soil corresponding to a beech site class of 1—3 (i.e. experiments Nos 03, 04 and 11 in beech, and 09 in spruce).

The heathland experimental areas were more uniform in respect of ground and nutrient content.

Incidentally, variations in ground, soil and other items of experimental importance will appear from the following:

b. Detailed Description of the Individual Experiments.

Although the experimental areas selected, with the assistance of the forest supervisors, were among the most uniform cultures in the districts, the heterogeneous soil and ground conditions of the forests, as compared with those of agriculture, have given rise to some irregularities, as will appear from the very exhaustive descriptions following.

In several of the experiments there have been standards, which were entirely or partially removed in the experimental period. In many experiments there were ditches, which may have affected the diameter increment of the boundary trees, and in a few cases several plots were intersected by logging tracks. In certain plots the withering-away of plants has created small clearings, or natural reproduction of other tree species has obscured the picture. The ground is often somewhat broken, which has been accounted for in great detail in the description, e.g. by indication of the maximum difference in ground levels.

Plots, or groups of plots have been left out of the experiment in cases where the growth conditions have been deemed too irregular.

Altogether, the material is as good as has been possible to obtain from the available cultures.

The unavoidable deficiencies have been compensated for by the great number of replications, and also by the system adopted, by which a treated plot always has two untreated neighbouring plots.

NORWAY SPRUCE

Unless otherwise noted, the tree species of the preceding generation in experiments 01—09 was beech (or other broad-leaved trees). The preceding species in the other experiments will be mentioned in the following.

Plant spacing has normally been 1.3 × 1.3 m. Exceptions are mentioned below.

Experiment No. 01. Bidstrup District, Hejede Overdrev, compt. 214. Almost all sample trees cut and measured on the ground.

Soil: About 10 cm brown forest soil on rather sandy or gravelly loam. In the direction from plot No. 15 to plot No. 1 the subsoil becomes steadily heavier. At 50-cm depth there is a slight intermixing with lime.

Experimental area fairly flat in the longitudinal direction of the plots, but rising rather steeply from plot No 1 to plot No. 15. Difference in levels, about 12 m.

There have been beech standards in the experiment; most of them were removed in 1947/48, the remainder in 1953/54. At the establishment of the culture, every 3rd plant in every 3rd row was a Douglas fir. Some Douglas firs still remain, but are not included in the measurements.

Experiment No. 02. Brahetrolleborg District, Storskoven, compt. 93. Almost all sample trees cut and measured on the ground.

Soil: About 20 cm brown forest soil on slightly sandy clay.

The experiment was divided into two sub-experiments. Plots 1—6 (treatments N, K and P) are situated on ground falling by a little over 1 m from plot No. 1 to plot No. 6, obliquely in relation to the longitudinal direction of the plots. Plots 7—15 (treatments NKP, N/2, K/2 and P/2) are situated on ground having a fall of about 2.5 m in the longitudinal direction of the plots.

Plots 7—15 are 70 % longer, on an average, than plots 1—6.

Experiment No. 03. Bregentved District, Haslev Orned, compt. I, 42.

After old beech and nurse crop of birch.

All sample trees cut and measured on the ground.

Soil: About 20 cm brown forest soil on sandy clay. At greater depth (60—70 cm) loamy sand is found. Around plots 1—2 the subsoil is interspersed with coarse gravel.

The experimental area is plane. Equally scattered over the area are several ditches, which are no longer in use, but which have given rise to interior fringes.

A few birch stumps from nurse trees removed in the early 1950s.

Experiment No. 04. Gjorslev District, Magleby forest, compt. 99.

Afforested woodland meadow, where hay had been harvested.

Almost all sample trees cut and measured on the ground.

Soil: 20—50 cm almost peaty topsoil — rich in humus — on sandy clay. At greater depth interspersed with gravel and lime grains.

Experimental area almost plane, with a fall of about ¼ m in the longitudinal direction of the plots.

The experiment was split up*) into plots 1—9 (treatments N, K, P and NKP), and plots 10—18 (treatments N/2, K/2, P/2 and NKP/2). A ditch passes through one end of plot 8 (NKP-fertilized) and the centre of plot 9. At the centre of plot 5 (unfertilized) a gap, producing interior fringes in the plot. A ditch passes right through one end of plots 10—18.

The experimental area is somewhat moist, for which reason some Norway spruces have died, being replaced with Sitka spruce, which are not included in the measurements.

Experiment No. 05. Sorø, District I, Vindelbro forest, compt. 31 A.

Almost all sample trees measured standing.

Soil. Raised site. About 10 cm brown forest soil on sandy clay.

Experimental area plane.

Experiment split up into plots 1—3 (N) and plots 4—8 (K and P).

Experiment No. 05. Sorø, District I, Vindelbro forest, compt. 31 A.

All sample trees measured standing.

Soil: About 30 cm topsoil, rich in humus, on sandy clay.

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*) "Split up" here and in the following means, that it has not been possible to place all plots in a single uninterrupted row. But the plot groups are always kept close together.

Experimental area almost plane with a difference in levels in the longitudinal direction of the plots of about 0.5 m. Area moist. At the time of measurement (Oct. 1963) the ground water was about 10 cm below the surface. Some spruces have died, often in groups. Experiment split up into 1—9 (N, K, P and NKP fertilizing) and plots 10—16 (N/2, K/2 and P/2).

On the area standards of 75-year-old birches 2.6 birches, on an average, per plot.

Experiment No. 06. Valdemar Slot District, Vornæs forest, compt. XXI 14.

Most of the sample trees cut and measured on the ground.

Soil: About 40 cm brown forest soil on slightly sandy clay.

Experimental area almost plane.

Plot No. 1 one year younger than the rest of the experiment. At one end of plot 10 (N/2-fertilized) a bare gap of about 5 × 7 m. Between plot 11 (unfertilized) and plot 12 (K/2-fertilized) a 2.5 m wide track. Plot 15 (unfertilized) tapers at one end to 2 rows.

Experiment No. 07. Frederiksborg District, Store Dyrehave, compt. 233.

Previous generation: 75-year-old Norway spruce, site class 2.0.

About ¼ of the sample trees cut and measured on the ground.

Soil: About 20 cm brown forest soil on slightly loamy yellow sand, which, at about 50 cm depth, changes into light, yellowish-grey sand, rather solidly cemented together.

Experimental area dominated by a somewhat higher portion stretching across the plots and sloping towards their ends. A hollow with a ditch, passes through one end of plots 1—4 (N and K fertilizing). The mortality in the hollow is high, and so the surviving trees are standing isolated, tapering markedly.

Experiment No. 08. Hvidkilde District, Hedeskovene, compt. 69 c.

About ¾ of the sample trees cut and measured on the ground.

Soil: About 30 cm brown forest soil in slightly loamy sand with many stones.

Experimental area slightly hilly, with a downgrade in the longitudinal direction of the plots of about 3 m, on an average.

The experiment is split up: Plots 1—9 (N, K, P and NKP fertilizing) are situated with one end against a track, the other end adjoining plots 10—16. In plot 2 (N-fertilized) a small gap. Plots 10—16 (N/2, K/2 and P/2) are situated with one end adjoining plots 1—9, and the other adjoining a middleaged beech stand (to the south) influencing the spruces. An about 4 m wide track passes obliquely through plots 10—16.

Plant spacing throughout the experiment, 2.00 m. The spruces have been planted under a nurse crop of birch. Cutting of the shelter was concluded in 1952/53.

Experiment No. 09. Nødebo District, Strøgårdsvang, compt. 324.

Preceding generation: Beech on northern half, Norway spruce on southern half.

Allmost all sample trees cut and measured on the ground.

Soil: About 30 cm brown forest soil on loamy sand. Plot length varying. The plant spacing being constant, the number of plants per row increases from about 50 to 75 from plot 1 to plot 9. From plot 10 to plot 13 the number of plants decreases from about 75 to 40, and plots 14 and 15 have about 40 plants per row. (Here, number of plants refers to time of planting). This fact has resulted in varying representation in the measurement.

Experimental area slightly sloping towards the ends of the plots. At the same time there is a transverse fall, so that the difference in levels between plots 1 and 15 is about 6 m. Through plots 3 and 4 the ground is declining, then rising through plots 5 and 6, so that plots 7, 8, 9 and, partially, 10, are at a higher level. From plot 10 through plots 11 and 12, there is a downgrade, so that the latter plot is situated in a pronounced hollow with many dead plants. Through plot 13 a slight upgrade to plots 14 and 15.

Plot 11 (unfertilized) contains 2 Norway spruce trees essentially older than the experiment, and plot 12 (K/2-fertilized) has 1, and these older trees exert a pressure on the surrounding spruces.

Experiment No. 10. Lindenborg District, Fræer, compt. 768.

1st generation on heathland partially covered with shrub.

Most of the trees measured standing.

Soil: Greatly bleached brown forest soil on slightly loamy sand. At several points the humus layer is very sparse. This is the case at one end of plot No. 6 (P-fertilized) and the opposite end of plot 11 (N/2-fertilized).

Experimental area somewhat hilly. In the longitudinal direction of the plots there is an average difference in levels between the plot ends of about 3 m. Irregular variations in the crosswise direction of the plots.

The experiment is split up. Plots 1—7 (N, K and P fertilizing) are situated on one side of a moist hollow; plots 8—16 (NKP, N/2, K/2 and P/2) on the other side. Furthermore, all potash-fertilized plots have been divided crosswise, one half being given the usual dose of 50 % potash fertilizer (KCl), while the other half was given an equivalent dose of chlorine-free potash (K_2SO_4). In the measurement and statistical treatment of the experiment, the 2 plot halves of the potash-fertilized plots have been treated partly separately (Table

A19—20), and, partly, as one unit (Table A9—12). Plot 8 (unfertilized) is only half as long as plot 9 (NKP-fertilized), and covers that portion of plot 9 which has been fertilized with potash in the form of KCl. The portion of plot 9 where potash has been administered in the form of K_2SO_4 has therefore not been included in the tabulation of the material. A 3—4 m wide track passes from one end of plot 4 (K-fertilized), through 5 and 6 (P-fertilized), to the opposite end of plot 7.

Experiment No. 11. Silkeborg District, Østerskov, compt. 175.

Planted culture after old clear-cut beech.

All trees measured standing.

Soil: Podsol with 10—20 cm bleached sand, including a humus-coloured layer of 2—3 cm, under which fine, yellow sand. No hardpan.

Experimental area very level.

Experiment split up into plots 1—9 (N, K, P and NKP fertilizing) and plots 10—16 (N/2, K/2 and P/2 fertilizing).

Beating up with Douglas fir not included in the measurement. In most plots from 0 to 5 Douglas firs; in plot 11 (N/2), however, 17 Douglas firs.

Experiment No. 27. Løndal District, Salten river valley, compt. 185 b.

All trees measured standing.

Soil: Under humus layer, grey sand at top, yellowing with depth, in places with hardpan.

The area was originally agricultural fields, which had become overgrown with heather. After an unsuccessful Norway spruce culture, it was planted with Pinus Banksiana, which was thinned and underplanted with Norway spruce. Standards removed in 1950. At the establishment of the experiment in 1953 the culture was not yet closed; growth retarded, some gaps.

The experimental area rises by 5—6 m from plot 1 to plot 12, and falls by 4.7 m from plot 12 to plot 15. Longitudinally, the differences in the levels of the plots are considerably smaller.

In 1954 no fertilizer was spread. In 1955, a double dose was spread.

In plot 8 (NKP-fertilized) the mortality was unusually high. Many trees died even a time after the closing of the culture, the cause, no doubt, being the extra large supply of fertilizers in 1955, which may have weakened the trees by increasing the conductivity factor of the soil. The effect of the debilitating parasite, Rhizosphaera Kalkhoffii on needles and twigs of diseased spruces was demonstrated by Dr. Yde Andersen. The summer of 1952 was very dry.

Experiment No. 12. Viborg District. Kompedal Plantation, compt. 404.

Trench-ploughed heathland, planted in 1947. Around 1950 the area was heavily overgrown with grass, and was therefore harrowed with good effect (unlike compt. 197).

The usual experimental area was supplemented by plot 16 (unfertilized) and plot 17 (fertilized with ammonium sulphate).

All trees measured standing.

Soil: Partially drifting sand. Under the mor layer bleached sand rich in humus, under which again dark, ochre-yellow sand changing to lighter, yellow sand with depth. A 60—70 cm high ridge stretches about 23 m into plot 17 (ammonium sulphate fertilizing) from one end. From plot 17 to plot 7 the ridge narrows evenly until it barely touches plot 7. The differences in levels in the experimental area are very small (about 1 m).

When the culture was established, every 3rd plant was a Mountain pine, mainly cut or overgrown before 1953. In plot 8 (NKP-fertilizing) the centre row was felled in January of 1963.

Experiment No. 13. Lindet District, Varming Plantation, compt. 513. 1st generation on meagre heathland soil, sporadically covered with drifting sand.

All trees measured standing.

Soil: About 5 cm heather-mor; about 20 cm humus-coloured bleached sand; about 10 cm loose humus hardpan; about 30 cm reddish brown sand, dark-flamed at top, on a subsoil of rather sharp brown sand.

The experimental area is rather level, the difference in levels being only 0.5 m. However, a hollow about 20 m wide stretches obliquely across plots 1—9, the greatest depth of the hollow in relation to the surrounding ground being about 2 m.

The experiment was split up into plots 1—9 (N, K, P and NKP fertilizing) and plots 10—18 (N/2, K/2, P/2 and Nitrophosca).

At the time of establishment of the culture, every 3rd plant was a multi-stem Mountain pine. The pines, which have not been measured, are now of almost the same height as the spruces. The experiment is exposed towards the west, and the tree height decreases from east to west (from plot 1 to plot 9, and from plot 18 to plot 10). The height of the spruces falls relatively more than that of the pines.

Experiment No. 14. Randbøl District, Frederikshåb Plantation, compt. 184.

All trees measured standing.

Soil: Under the needle-mor, bleached sand rich in humus, to a depth of about 20 cm. Under this layer, dark yellow coarse sand, under which again lighter, yellow sand. No hardpan.

The culture was established on old, exhausted agricultural soil.

The experimental area is level. At the northern end the plots adjoin a track, on the northern side of which there is a white-spruce hedge sheltering the experiment. When the culture was started, one Mountain pine was planted together with every 3rd Norway spruce in plots 10—15. The pines were later removed from the centre rows of the plots. In plot 8 (NKP-fertilizing) the mortality was very high, aggravated by the severe drought in 1955 in conjunction with a vigorous vegetation of Agropyrum repens (cfr *Møller and Schaffalitzsky*, 1957, p. 418).

Experiment No. 15. Viborg District, Kompedal Plantation, compt. 197. The area (heath) was deep-ploughed in 1901—02, and then planted with Mountain pine, which, after a hard thinning, was underplanted with Norway spruce in 1944.

On June 1, 1947, the whole area burned. In the autumn of 1947 the scorched Mountain pines were again underplanted with Norway spruce. On the area scattered ridges of drift sand. During the fire, almost all organic matter was burnt away, including the humus layer, so that planting in 1947 took place in almost pure mineral soil. This has no doubt been of importance with regard to the high mortality in 1955 (see below).

Soil: Dark-yellow, reddish, coarse gravel with many stones. The ridges consist of fine sand. A description has been made of their location, but is not included here.

Greatest difference in levels: about 1 m.

The usual experimental area has been supplemented by plot 16 (fertilized with ammonium sulphate) and plot 17 (unfertilized).

From 1955, every second unfertilized plot has been harrowed, i.e. plots 3, 7, 11 and 15, though without effect, since the floor had only a very sparse vegetation, apart from the conifer plants. In 1955, which was a year with severe drought, many plants died, especially in plots fertilized with N. As in particular the small plants died, a statistical increase of the height has taken place, favouring the N-fertilized plots more than the neighbouring unfertilized plots. (Cfr *Møller and Schaffalitzsky*, 1957).

Experiment No. 16. The Danish Heath Society, 5th District, Hesselvig Plantation, compt. 5.

All trees measured standing.

Soil: About 20 cm greatly leached sand, under which dark-coloured sand and as a rule no hardpan.

The experimental area, which was originally meagre heathland soil, is level.

Planting took place in 1941 under a screen of Mountain pine, which is 67 years old today and has a breast-height diameter of 10—20 cm. There are from 6 (plot 8) to 18 (plot 12) Mountain pines per plot, the average number of Mountain pines per plot being 12.

There are some selfsown pines, and remnants of interspersed silver fir.

There are several tracks*) of 2.5—3 m width, e.g. between plots 1 and 2, between plots 3 and 4, between plots 5 and 6, through plot 8 with 3 rows on one side and 6 on the other, through plot 12 with 2 rows on one side and 7 on the other, and through plot 14 with 4 rows on one side and 5 on the other.

In general, the mortality in the experiment is very high, and the surviving trees are often very branchy. To the southwest of the experiment low, old Mountain pine.

Experiment No. 17. The Danish Heath Society, 5th district, Birkebæk Plantation, compt. 109.

Pit-planting after single-stemmed Mountain pines planted direct into meagre heathland soil.

All trees measured standing.

Soil: 10—30 cm dark grey bleached sand, under which a blackish sediment, and underneath this layer a 10—20 cm deep ochre-yellow sediment; which, in the highest portion of the experiment (plots 10—15) is solidly cemented together (hardpan). Under the sediments, light, yellowish-grey sand.

The experimental area rises about 4 m from plot 1 to plot 9 — steeply from plot 1 to plot 6, and slightly from plot 7 to plot 9. The area is level from plot 10 to plot 15. In the following plots the number of plant rows deviate from 11: Plots 3, 13, 14 and 15 have 9 rows, and plot 10 has 15.

The row- and plant-spacings of the plots vary. Plots 1—8, 10 and 12 have a row-spacing of 1.0 m and a plant-spacing in the row of 1.3 m. Plots 9 and 11 have a row-spacing of 0.9 m and a plant-spacing of 1.3 m. Plots 13, 14 and 15 have row-spacings of 1.35 m, 1.20 m and 1.40 m, respectively, and they have all a plant-spacing of 1.0 m.

The culture is interspersed with silver fir, generally every 3rd plant. The growth of the silver fir is weak, and many plants have died. The experiment contains some naturally reproduced Mountain pines, which, however, have not affected the growth of the spruce.

There are several 2.5—3 m wide tracks, viz. one through plot 3, with 7 rows on one side and 2 on the other; one through plot 5 with 8 rows on one side and 3 on the other; one through plot 7 with 9 rows on one side and 2 on the other; one through plot 10 with 5 rows on one side and 10 on the other; one through plot 12 with 10 rows on one side and 1 on the other; and one through plot 14 with 6 rows on one side and 3 on the other.

Experiment No. 18. The Danish Heath Society, 3rd district, Liebe Plantation, compts 16—17.

The usual experimental area has been supplemented by plot 16 (dicalciumphosphate fertilizing) and plot 17 (unfertilized).

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*) Tracks here and elsewhere in this description most often means unplanted rows allowing room for later logging.

All trees measured standing.

Soil: About 25 cm humus-embedded bleached sand, under which a dark-coloured sediment. Next, brownish-yellow sand of about 50 cm thickness. Under this layer gravel.

The experimental area has differences in level of about 1 m longitudinally. The culture was established by planting in pits dug under shelter of single-stemmed Mountain pines planted in meagre heathland soil. All Mountain pines had been felled at the time of measurement — the last ones in the winter of 1961—62. A count of the fresh stumps shows that there have been from 4 (plot 14) to 11 (plot 12) pines per plot, i.e. 7.5 pines on an average per plot. Stump diameter, 20—30 cm. During the felling of the pines, several spruces lost their tops. Furthermore, the screen was thinned twice in the experimental period.

A track passes through plots 13 and 14.

Experiment No. 19. Viborg County Plantation at Skygge, compt. 13. Supervised by the head office of The Danish Heath Society.

The usual experimental area was supplemented by plot 16 (dicalcium-phosphate fertilizing) and plot 17 (unfertilized).

All trees measured standing.

Soil: 10—40 cm bleached sand, under which a blackish sediment layer, under which again ochre-coloured hardpan consisting of coarse sand (at least 20 cm).

The experimental area is level, apart from a small hollow about 1 m deep at one end of plots 15, 16 and 17, in which the mortality seems to be greater than in the rest of the experiment.

The culture was established on old agricultural soil, which was furrow-ploughed and grubbed. Every 5th plant was a silver fir with a Scotch pine nurse tree. The silver fir vegetates, while the Scotch pine is often so high as to compete with the Norway spruce. A count of the Scotch pine trees which are thought to affect the development of the Norway spruce trees (pine trees over 1.5—2 m high) shows from 6 (plot 4) to 23 (plot 10) Scotch pine trees per plot, i.e. about 14, on an average, per plot. The corresponding number of Norway spruce trees per plot is about 250. The pines were not measured.

One end of the plots borders onto a track, along which a row of larch trees has been planted, which are generally a little higher than the spruces.

Experiment No. 20. The Danish Heath Society, 4th district, Agerskov Plantation, compts. 14—15.

All trees measured standing.

Soil: Bleached sand of varying depth on dark yellow, coarse sand (weathered hardpan).

The experimental area is rather level, the difference in levels in the longitudinal direction of the plots being about 0.5 m.

The culture was preceded by meagre heathland soil. Method of cultivation: Ordinary ploughing, then treatment with a disc-harrow and, finally, re-ploughing. The area was then left for some years (too long!); in 1941 it was drill-ploughed with an ordinary tractor-plough, and grubbed, after which planting was done in the drills. In 1950 cleaned with a disc-harrow, and in 1952 with an agricultural harrow; then untouched.

The experiment was split up into plots 1—9 (N, K, P and NKP fertilizing) and plots 10—17 (N/2, K/2, P/2 and 3-P). The plot ends of the two sub-experiments face each other on either side of a track.

Plant spacing in the rows: 1.25 m. In every 2nd plant space a multi-stemmed mountain pine has been planted. Throughout the experiment the mountain pines are very vigorous. Their height is almost the same as that of the spruces. Only in plot 8 (NKP-fertilizing) do the spruces really dominate.

At one end of plots 10 (unfertilized), 11 (N/2 fertilizing) and 12 (unfertilized) there has been an unusually high mortality (at least 75 %), of both spruce and pine.

A track runs between plot 12 (unfertilized) and plot 13 (K/2).

Experiment No. 21. The Danish Heath Society, 4th district, Haraldslund Plantation, compt. 8.

All trees measured standing.

Soil: About 40 cm bleached sand (rich in humus at the top) on ochre-yellow gravel.

Hardpan not found.

Experimental area level — very slightly undulating.

Prior to the culture meagre heathland soil dominated by grasses, with sporadic patches of heather. Method of cultivation: Deep-ploughing, disc-harrowing, marling and rye-growing for 3 years with fertilizers supplied. In 1942 drilled with a Bovlund plough, and planted with pure Norway spruce in the drills. In 1952 cleaned with an agricultural harrow. Then untouched.

The longitudinal axis of the plots is orientated south-west/north-east. At the southwesterly end of the plots the growth is generally inferior to that of the northeasterly end. Local foresters are of the opinion that this is due to the fact that on the southwesterly portion of the plots there is a ridge, so that any hardpan may not have been broken by the deep-ploughing, because it has been lying too deeply.

Experiment No. 22. The Danish Heath Society, 5th district, Harreskov Plantation, compt. 65.

All trees measured standing.

Soil: Poor heathland soil with heather.

Method of cultivation: Ploughing with agricultural plough; harrowing;

subsoiling. Next, planting of Norway spruce (1941) and mountain pine (1943).

The experimental area has a difference in levels across the plots of about 0.50 m. The culture was established with Norway spruce and Mountain pine altermating. Some of the experiment is situated on former heath, and some on old agricultural soil. Plots 1, 2, 10 and 11 are on former forest soil. Plots 3—9 are mostly situated on old agricultural soil (more than one-half). Plots 12—15 are situated, partially, on old agricultural soil (less than one-half).

Experiment No. 23. Palsgaard district, Gludsted Plantation, compt. 52. All trees measured standing.

Soil: About 30 cm bleached sand, under which 20—30 cm dark yellow coarse sand, under which again light yellow sand and some hardpan. Prior to the establishment of the culture the heath was ploughed and disc-harrowed for 2—3 years, after which it was trench-ploughed. The area therefore contains splittings and gatherings. — In the splittings the soil differs from what is specified above in that the uppermost 30 cm are almost missing. The spruces develop poorly here. On the other hand, in the gatherings there is a layer of bleached sand of about 50—60 cm embedded with humus. Under this layer, a thin layer of humus hardpan, under which densely deposited coarse sand. Splittings are found between plots 3 and 4 as well as in plot 10 in the side facing plot 11. No measurements have been made in the rows planted on the gatherings or splittings.

The experimental area is level.

A track passes between plots 4 and 5 (plot 4 contains only 8 rows) and between plots 10 and 11. Along the track, there are 6 extra rows along with plot 10 and one along with plot 11. Row-spacing 1.5 m; plant-spacing 1.0 m. A mountain pine has been planted in the space between every second spruce. The pines fill all gaps between the spruces but are not dominating.

Experiment No. 24. Palsgård District, Gludsted Plantation, compt. 142. All trees measured standing.

Soil: About 30 cm bleached sand, under which 20—30 cm dark brownish-yellow, coarse sand, under which again dark yellow, coarse sand. Cultivation of the soil before planting as in compt. 52. The area therefore contains splittings and gatherings of the same appearance as described under experiment No. 23.

The splittings are found in plot 4, in the side facing plot 5, as well as between plots 10 and 11. No measurements have been made in the rows planted on the gatherings or splittings.

The experimental area is level.

There is a track between plots 9 and 10 with 4 extra rows facing plot 9, and 5 facing plot 10.

Row-spacing 1.5 m; plant-spacing 1.0 m.

A mountain pine has been planted in the spaces between every second spruce. Most pines are suppressed by spruces, though a few are on a level with the latter. Mortality in the spruces is very small. Height, as well as health, decreases slightly from plot 1 towards plot 15. Some trees have been damaged by deer.

BEECH

Unless otherwise noted, the preceding generation was beech, possibly interspersed with other broadleaved trees. With some exceptions (natural reproduction), the cultures are plantings, usually with a row spacing of 1.0—1.3 m, and with 3—10 plants per linear row metre.

Experiment No. 02. Sorø Academy, District I, Alsted Forest, compt. 12 B.

All trees measured standing.

Soil: 40—50 cm brown forest soil, rich in humus, on clay to very gravelly loam, mixed with stones. The clay content seems to decrease from plot 1 to plot 15. At the time of measuring (winter) the ground water table was at a depth of about 40 cm.

The experimental area is level.

The experiment was established in a natural reproduction. Plots of the same size as in plantings were marked.

The experiment still contains beech standards (diameter at 1.3 m height, 60—70 cm), viz. from 1 beech (plots 2, 6, 7, 13 and 15) to 4 beeches (plot 8) per plot, i.e. a little more than 2 beeches per plot, on an average.

In connection with the natural reproduction, some ash plants have occurred. Slight to fair interspersion of ash on plots 1—7 and 14; fair to heavy interspersion on plots 8—11; heavy interspersion on plots 12, 13 and 15. Only beech was measured.

Beating up was made with Norway spruce. Isolated trees or small groups are found on plots 4—6; a Norway spruce strip (a 2-metre wide track planted up) stretches from one end of plot 7 obliquely across the plots to the opposite end of plot 15, with extra width on plots 13 and 15. No spruces were measured.

The experiment was measured by placing 4 base lines in each plot, and systematic selection of sample trees along these lines.

Between plots 4 and 5 a track about 3 m wide.

Experiment No. 03. Sønderborg District, Nygård Forest, compts. 50 and 17.

All trees measured standing.

Soil: About 40 cm topsoil of slightly loamy sand, on slightly sandy loam (compt. 50). The soil in compt. 17 is a little stiffer.

The experimental area is level.

The experiment was divided into plots 1—11 (N, K, P, NKP and N/2 fertilizing), and plots 12—16 (K/2 and P/2).

The experiment was established in a very dense culture produced by strip sowing. In compt. 50 one beech standard in each of plots 2, 5 and 11. In compt. 50 a 5 m wide track between plots 4 and 5 and plots 8 and 9. In compt. 17 a track between plot 12 (unfertilized) and plot 13 (K/2-fertilized).

Experiment No. 04. Sønderborg District, Øvelgunde Forest, compts. 341 and 336.

All trees measured standing.

Soil: About 30—40 cm dark topsoil on sandy loam to loamy sand, with a slight intermixing of gravel.

The experimental area is rather level.

The experiment was split up into plots 1—9 (N, K, P and NKP fertilizing) situated in compt. 341, plots 10—14 (N/2 and K/2) in compt. 336, and plots 15—17 (P/2-fertilized) in compt. 341, the two compartments being neighbours.

Culture produced, partly, by planting and, partly, by strip sowing, resulting in age variations, which were inconsequential, however.*)

In plot 2 one elm standard; in plots 7, 13, 14 and 17 one oak standard; in plots 5 and 15 two oak standards; in plot 8 one beech standard; in plot 9 one oak standard and one beech standard. To the west of plot 14 open field, at the border of which a few old oak trees.

A ditch runs across plots 10—14, at about ⅓ from one end.

Experiment No. 05. Valdemar Slot District, Holme Forest, compt. XII 3.

All trees measured standing.

Soil: About 40 cm brown forest soil on slightly sandy loam. At the time of measurement (January 1964) the ground water table was at a depth of 20—70 cm.

The experimental area is level. With the exception of traces of old agricultural use in the form of parallel ridges ab. 10 m apart and 0.5 m high. High ground water table. In plots 1, 3 and 7 one beech standard. Immediately outside plots 10 and 12/13 one beech standard. Obliquely across plot 1 and at the end of plot 2 a ditch.

Experiment No. 06. Brahetrolleborg District, Storskoven, compt. 104.

All trees measured standing.

Soil: 10—15 cm brown forest soil on slightly sandy loam.

Experimental area rather level. From plot 1 to plot 5 a rise of about 2.5 m. Plots 6 and 7 unchanged. From plot 8 to plot 12 a fall of about

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*) The plants used in Danish beech plantings are 1—2 years old.

3 m, steepest for plots 8 and 9. Plots 13 and 14 unchanged. A slight rise through plot 15. In addition, a slight slope in the longitudinal direction of the plots. Width of plots, 13 m.

The experiment was split up into plots 1—12 (N, K, P, NKP, N/2 and K/2) and plots 13—15 (P/2).

The experiment was established in a complete natural reproduction. Through the plots and between them linear swaths were cut, so that in each plot there are five strips ab. 2 m wide with plants. In plot 12, however, there are 7 strips. Plant density seems very constant from plot to plot — however clearly below average in plot 8 and above average in plot 1.

In 1956 the whole experiment was thinned according to the usual practice of the district, during which the swaths mentioned above were cut.

The standards were all felled before the establishment of the experiment.

Experiment No. 07. Bregentved District, Ganneskov, compt. XXII 23. All trees measured standing.

The culture established after old beech followed by a nurse-planting of birch.

Soil: About 30 cm brown forest soil, rich in humus, on loam with a very slight sand content. A few big boulders.

The experimental area is level, with a difference in levels of about 1 m.

The area is cut by some ditches, which, however, contain little water. On the experimental area a nurse crop of birch from about 1930. In the winter of 1957/58 the screen was thinned, leaving from 0 (plot 14) to 5 (plot 1) birch trees per plot — a little over 2 birch trees per plot, on an average. The rest of the birch trees were cut in the winter of 1959/60.

The culture was established by dense planting, with a row spacing of 1 m. At least 2 thinnings have been made in the experiment, the last one in 1962.

Experiment No. 08. Bregentved District, Boelskov, compt. XXIII 21.

After old beech and then nurses of birch.

All trees measured standing.

Soil: About 40 cm brown forest soil, rich in humus, on loamy sand, with areas containing more loam. The colour is yellowish grey, with ochre-yellow spots. In places, larger areas with slightly sandy or gravelly loam. At the time of measurement (winter) the ground water table was at a depth of 60—70 cm.

The experimental area is completely level.

The experiment was divided into plots 1—9 (N, K, P and NKP) and plots 10—16 (N/2, K/2 and P/2).

The area is cut by some ditches, which now carried no water.

There has been a nurse crop of birch on the experiment, but the last nurses were cut in the winter of 1960/61.

The culture was established by planting, with 3 plants per m and 1.3 m row spacing.

The culture has not been thinned during the experimental period.

Experiment No. 09. Frederiksborg District, Brøde Forest, compt. 56 B.

All trees measured standing.

Soil: 70—80 cm homogeneous, loamy sand, under which sand with less loam, of a lighter colour.

The experimental area is fairly level, with a difference in levels of up to 80 cm.

The experiment was fertilized with N, K, P and NKP.

The experiment was seriously damaged by rodents. Replanting was done with sycamore, the height of which is now equal to that of the beech. Sycamores not measured. The experiment makes a heterogeneous impression. A track runs across all plots, at about ⅓ from one end.

There has been a nurse crop of birch on the experiment, the last birch trees being removed around 1961/62. Plot 8 contains 10 rows against 9 in the other plots.

Experiment No. 10. Hvidkilde District, Hedeskovene, compt. 89a.

All trees measured standing.

Soil: 40—50 cm brown forest soil, sandy and slightly degraded. Under the topsoil slightly loamy, yellow or yellowish-red, coarse sand — often with many stones.

The experimental area is rough, with differences in levels of 10—12 m. A detailed description has been made, but only the main points are given here: Crosswise to plots 1—8 there is a hill crest, which is particularly pronounced in plots 6—8. The crest rises from plot 1 to plot 8. At the same time there are more or less steep slopes from the top of the crest to the plot ends, i.e. lengthwise to the plots. As far as plots 9 to 15 are concerned, one end of plots 10—14 and the centre of plot 15 are fairly level, and from there there is a more or less steep fall towards the other end — in plot 15 to both ends. From plot 9 to plot 11 a more or less steep rise across the plots.

The experiment was split up into plots 1—8 (N, K, P and NKP) and plots 9—15 (N/2, K/2 and P/2).

There have been minor attacks by rodents in the experiment.

The beech planting was established under shelter of silver fir, which was clear-cut in 1951/52. Some beating up was done with Douglas fir, which are not measured.

Experiment No. 11. Nødebo District, Strøgårdsvang forest, compt. 312. All trees measured standing.

Soil: About 20 cm brown forest soil, slightly degraded, on slightly loamy, ochre-yellow sand with many stones.

The experimental area is rough, with differences in levels of about 10 m. A detailed description has been made, but only the main points are given here. Across plots 1—11 there is a ridge at one end, which gives rise to variations in the crosswise direction of the plots, but, particularly, falls towards the plot ends. Crosswise to plots 12—12 there is a ridge, which is situated almost at the middle of plot 12, but moves towards one end of the following plots. This ridge gives rise to falls towards the plot ends. At the same time, it has a fall transversely through plots 15 and 16.

The experiment was split up into plots 1—11 (N, K, P, NKP and N/2) and plots 12—16 (K/2, and P/2).

The beech was planted densily under a nurse crop of birch, the last birch being cut immediately before the final measurement.

A few naturally reproduced oaks and Norway spruces.

Experiment No. 12. Wedellsborg District, Sparretorn forest, compt. 18. All trees measured standing.

Soil: About 40 cm brown forest soil, rich in humus, on pure loam.

The experimental area is almost level.

The culture is interspersed with selfsown ash. Originally, the experiment consisted of 15 plots, laid out on the usual system. In the final measurement, 6 plots had to be given up due to the heavy interspersion with ash. The remaining plots were fertilized with K, P, NKP and N/2. The plots measured contained from 0 to 42 ash trees in the 5 sample rows, on an average about 14 per plot. The average content of beech trees is about 120. Care has been taken to avoid measuring beeches suppressed by ash.

The beeches have been attacked by rodents.

Experiment No. 13. Buderupholm District, Sønderskov, compt. 151. All trees measured standing.

Soil: About 10 cm greatly degraded sand, under which 10 cm sediment of an ochre-yellow colour. Under this layer, slightly loamy sand.

The experimental area is fairly level, with a fall in the longitudinal direction of the plots of about 1.5 m, and minor slopes across the plots.

The experiment was split up into plots 1—9 (N, K, P and NKP) and plots 10—16 (N/2, K/2 and P/2).

In the experiment, there have been nurse trees of birch and Alnus spuria, almost all of which had been removed. The culture was established with a row spacing of 1.3 m, and a plant spacing of 0.4 m.

Experiment No. 14. Viborg District, Vindum Forest, compt. 94.

Planting in rows spaced 1.3 m apart, after 78-year-old clear-felled Norway spruce of site class 2.6.

All trees measured standing.

Soil: 5—15 cm medium-heavily degraded brown forest soil on slightly loamy sand, which has a darker colour at top.

The experimental area is characterised by a bog-like depression between plots 5 and 6, separating these two plots from each other by a 20 m wide belt. From plot 1 to plot 5 the ground slopes about 3 m, and from plot 13 to plot 6 about 2.5 m.

The experiment was originally laid out in 15 plots on the usual system. Due to greatly irregular growth conditions in plot 14 (P/2-fertilized) and plot 15 (unfertilized), these plots were left out from the final measuring.

The bog between plots 5 and 6 contains naturally reproduced Norway spruce, spreading into the two plots. Plots 4 and 7—11 have sporadic occurrence of naturally reproduced Norway spruce, and plots 10 and 11 also contain a few small larch trees. In plots 12 and 13 the growth conditions are unfavourable. There is in these plots a moist hollow, and several large, naturally reproduced Norway spruces and birches. In this portion, there is a ditch.

The experiment was thinned at some time around 1958 and in April 1962 and September 1963.

Experiment No. 15. Frijsenborg District, Tårup Forest, compt. 11.

All trees measured standing.

Soil: About 20 cm brown forest soil on sand with a rather slight content of loam.

The experimental area is rough. In the longitudinal direction of the plots a fall of about 6 m, 3 m of which on ¼ plot length at one end of the plots. Crosswise to the plots, a slight fall from plot 1 to plot 6, a steep rise through plot 7, and a less steep rise through plots 8 and 9. Standards of old beech and oak, namely from 0 (plot 3) to 4 (plots 6, 9, 10 and 15) per plot, i.e. an average of more than 2 per plot, with diameters of about 40—60 cm at 1.3 m height. On plots 5 and 6 there are 6 and 1 birch respectively with diameters of 20—25 cm at 1.3 m height. On plot 13 a small, moist area, from where a ditch runs through plot 12 to plot 11, on which there is a ditch in the longitudinal direction.

Experiment No. 16. Frijsenborg District, Sønderskov, compt. 54.

After old beech and nurse crop of birch.

All trees measured standing.

Soil: Brown forest soil on slightly sandy loam. In December 1963 ground water was found at a depth of 50 cm on plot 8, but elsewhere at a depth of 70 cm or even more.

The experimental area is almost level. A minor slope, of not more than 0.5 m, across the plots.

Crosswise to the plots, and almost near their centre, there is a track about 3 m wide. Crosswise to the plots, and about 10—15 m from one end, there is a ditch.

In plot 3, a ditch about 15 m long runs on the site of the centre row at one end of the plot.

There were young standards of birch on the experiment, originating from broadcast-sowing of birch seeds. The last birch trees were removed in 1960/61.

The plot length increases from 75 to 110 m from plot 1 to plot 15.

Experiment No. 17. Lindenborg District, Store Arden forest, compt. 488.

Successful natural reproduction.

All trees were cut and measured on the ground.

Soil: 20—25 cm brown forest soil, greatly degraded. Underneath, dark-yellow, slightly loamy, sand.

The experimental area is fairly level, with a fall from plot 1 to plot 15 of 10—11 m (6.5 %).

The experiment was established in a natural reproduction. The plots are 11 m wide strips, between which small passages have been cut, marking boundaries. A count in 15 randomly chosen 1-sq.m areas, one in each plot, shows the average number of plants per sq.m to be about 7.

The large number of plants has made it necessary to select sample trees along base lines, cut these trees, drag them out from the experiment, and measure them on the ground.

The experiment was originally established with the use of two kinds of potash fertilizer, in the same way as for Norway spruce experiment No. 10. In the evaluation, distinction between the two kinds of fertilizer was given up, however.

A few beech standards on the experiment. On plots 2, 4, 9 and 12 no standards; on the rest of the plots one standard on each.

A track runs through one end of plots 11 to 15.

Experiment No. 18. Lindet District, Lindet Forest, compt. 76.

All trees measured standing.

Soil: 30—50 cm greatly degraded, brown forest soil on yellow, fine sand, with little or no loam.

The experimental area is very level, with a slight slope across the plots, of about 2 m.

The experiment was split up into plots 1—10 (N, K, P, NKP and N/2 fertilizing) and plots 11—17 (K/2, P/2 and nitrophosca).

Normally dense planting with a row distance of 1.3 m.
On plots 1—15 a Czechoslovak provenance was used, on plots 16—17 Sønderborg provenance of the same age.
There have been beech standards on the experiment, altogether 10, which were removed in 1952/53. In an area at the middle of plot 8 (NKP-fertilizing) the beeches are very branchy.
Thinning of the experiment was carried out at least once.

Experiment No. 19. Nørlund District, compt. I 5.
Transplanting after old spruce.
All trees measured standing.
Soil: 30—40 cm highly degraded brown forest soil on slightly loamy sand.
The experimental area is rather level, with slight undulations. Greatest difference in levels, about 1 m.
The fertilizing treatments provided for by the experimental plan were supplemented by 3 × P, with one repetition. The NKP-fertilized plot was partially ruined by rodents, and had to be left out from the evaluation of the experiment. Slighter attacks were found in other plots.
Birch nurses were found scattered evenly on the experiment; the nurses were finally removed in the spring of 1960.
The plot length varied somewhat (from 20 to 40 m). On a few plots a little naturally reproduced Norway spruce at one end.

Experiment No. 20. Palsgård District, Velling Forest, compt. 186.
All trees measured standing. Height-measuring of standing trees was made with Løvengreen's hypsometer.
Soil: 40—50 cm brown forest soil on slightly loamy sand.
The experimental area is slightly hilly.
The experiment was split up into plots 1—6 (N, K and P fertilizing) and plots 7—15 (NKP, K/2 and P/2).
Because of the size of the trees measurement was made only in 3 of 7 rows in each plot.
The experiment was thinned 2 or 3 times in the experimental period. In cases where trees from fertilized plots had fallen on to unfertilized plots, slash from fertilized trees may have been transferred to unfertilized plots.

Experiment No. 21. Randbøl District, Refstrup Forest, compt. 147.
All trees measured standing.
Soil: About 40 cm brown forest soil on sandy loam.
The experimental area almost level.
The experiment was split up into plots 1—9 (N, K, P and NKP fertiliinzg) and plots 10—16 (N/2, K/2 and P/2).

Plots 4—9 and 12—16 are 10 m wide strips, on which beech seeds were sown after harrowing. Each of plots 1—3 and 10—11 contains 8 rows in which beech plants were transplanted after ploughing and grubbing. Parts of such rows are, however, also found in several of the other plots. The differences in age are inconsequential.

There have been some standards of beech, which were cut during the experimental period.

A little interspersion of naturally reproduced ash, oak, hornbeam and willow. On plot 15 (P/2-fertilized) a narrow gap of 10 m length.

Experiment No. 22. Silkeborg District, Nordskov, compt. 68 C.

All trees measured standing.

Soil: On the highest part of the plots, 30—40 cm highly degraded brown forest soil, under which a thin, black sediment, an ochre-yellow sand layer, sometimes with a slight content of loam, under which again light, coarse sand. On the lowest parts of the plots 70—80 cm degraded, brown forest soil, under which a black sediment. Here, the ground water table was found at a depth of 80—90 cm (December 1963).

The experimental area greatly, though uniformly, sloping to the north in the longitudinal direction of the plots. Difference in levels between the plot ends, about 15 m (about 25 % slope).

The culture was established with birch nurses, which were removed in the experimental period or earlier. Beech planted in irregular lines, so that the spacing between two rows varies from 1 to 2 m.

On plots 13—15 a little birch interspersed, as well as a few naturally reproduced spruce and mountain ash trees.

Experiment No. 23. Løvenholm District, Eldrup Forest, compt. 205.

All trees measured standing.

Soil: 20—30 cm highly degraded, brown forest soil on yellowish-grey sand.

The experimental area has a uniform slope in the crosswise direction of the plots, of about 5.5 m. At the same time, a very slight slope in the longitudinal direction, especially on the plots with the lowest numbers.

The experimental plan deviates from the normal. Plots 2, 4, 5, 7, 9 and 11 were fertilized with K, N, P, NKP, urea and N/2, respectively. 100 kg urea was given per hectare. The rest of the plots were not fertilized.

The experiment was not started until the spring of 1957, and has thus been fertilized only for 6 years.

Standards of silver fir with 30—40 cm diameter at 1.3 m height. There are from 1 (plot 12) to 6 (plot 1) standards, on an average 3.5 standards, per plot. Thinning of standards was done in 1957 and 1962.

III. METHODS

With its seven different fertilizing treatments, a typical A-experiment (Fig. 2) may be regarded as 7 *sub-experiments.* Each sub-experiment consists of one fertilized plot flanked by two unfertilized control plots (Fig. 3). The fertilizing effect in a sub-experiment may be expressed by the following difference:—

Fertilizing effect = (the growth in the fertilized plot) — (the average growth in the two controls)

The growth is determined by measuring the heights and diameters of a representative section of the individual trees in a plot.

"Growth" means the total growth from seeds.

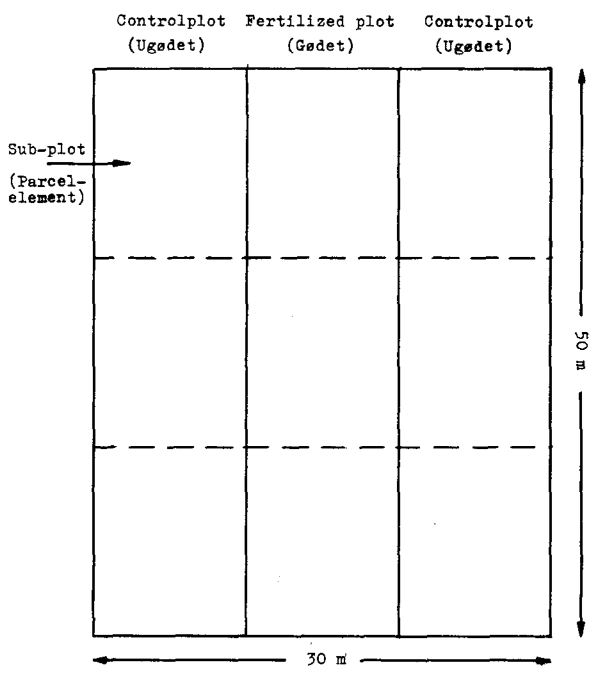


Fig. 3. Sub-experiment. In the statistical treatment of measurements from A-experiments the sub-experiment constitutes a unit of treatment on which analysis of variance is carried out. The object of splitting up each plot into 3 sub-plots is to reduce the effect of growth variations in the longitudinal direction of the plot.

Fig. 3. Delforsøg. Ved den statistiske bearbejdning af måletal fra A-forsøg udgør delforsøget en behandlingsenhed, på hvilken der udføres variansanalyse. Opdeling af hver parcel i tre parcelelementer har til formål at mindske effekten af vækstvariationer i parcellens længderetning.

When the experiment started in 1953, the average age from the establishment of the cultures was as follows:
Beech: about 8 years (with the exception of Velling forest 186).
Norway spruce: about 7 years.

Consequently, it is not the last ten years' growth which is indicated by the measurements made, but the last 18 or 17 years' growth, respectively.

As a height determination was made at the start of the experiment in the spring of 1953, by means of the plants in the centre row of each plot (cfr Möller 1954, p. 174), it was possible, by deducting this starting height from the height found at the conclusion of the experiment, to obtain values for the height increment in the experimental period proper.

The same was not possible for the diameter, however, since measurements from the start of the experiment were not available in this case.

Furthermore, sample measurements in some cultures had shown that in many cases the mean height of the centre row is an unreliable expression for the mean height of the whole plot, especially where the site class is low.

Consequently, the total height and diameter obtained were chosen as expressions for the growth, on the following grounds:

1. As far as the diameter was concerned, this was the only procedure possible.
2. As far as the height was concerned, determination of the growth in the experimental period proper might well have been possible, but its accuracy would have been affected by the inaccuracy of the height determination in 1953, and a direct comparison of the height growth and the diameter growth would no longer have been possible.
3. Any effect of a fertilizing treatment must be expected to have the same absolute average value, irrespective of whether a comparison is made of the height increments in the 10-year period or of the total heights obtained, as these are $= H_{1953} +$ height increment.

In each A-experiment a particular fertilizing treatment occurs only once. The lack of repetitions calls for circumspection in the evaluation of the effect in each individual sub-experiment. The evaluation becomes especially difficult if the natural site class varies within the experiment. An apparent effect may then be due to differences between the site classes of the fertilized plot and the two control plots. If the growth of the control plots agrees, there is, however, little probability of the 10 m wide and 50 m long intermediate, fertilized plots having a unilateral deviating natural site class. On the assumption that the two control plots have grown equally much, a deviating growth in the fertilized plot may therefore reasonably be interpreted as a real, fertilizing effect. A fertilizing effect can, however, only be recognised with absolute certainty when sub-experiments with the same fertilizing treatment from several A-experiments are compared.

Although endeavours have been made to place each A-experiment on uniform soil, it is unavoidable that the natural site class varies somewhat within a single plot (10 m × 50 m) — especially in the longitudinal direction. It is therefore natural to divide the three plots of a sub-experiment crosswise to the longitudinal direction. As shown in Fig. 3, this has been done by trisecting the plots, so that a sub-experiment consists of, altogether, 9 *sub-plots,* i.e. 3 fertilized and 6 unfertilized units. By comparing the growth in each of the 3 fertilized sub-plots with that of the 2 adjoining, unfertilized sub-plots, three values for the fertilizing effect in a sub-experiment are thus obtained. In this way, the greater part of the variation in the natural site class in the longitudinal direction of the plots can be eliminated during the later data-processing.

a. Measurement of Sample Trees.

In each sub-plot, the height and diameter were measured on sample trees selected representatively.

In the case of tree heights up to 8 metres, the *height* measurement was made on standing trees by means of an articulated rod of bamboo, scaled in decimetres. In spruce experiments with sample trees higher than 8 metres, the sample trees were felled, and their height from soil measured with a steel band rule. In one beech experiment (No. 20) all the sample trees were measured with J. A. Løvengreen's hypsometer (large model). All readings were taken in decimetres. The height was measured from the projection of the tree top on the ground surface to the tree top. In the Norway spruce experiments, which were measured in the summer season of 1963, measurements before August 20 were made to the 1962-top, and after August 20 to the 1963-top. In the beech experiments, which were measured in the winter season of 1963/64, all measurements were made to the 1963-top.

Diameter measurement was made with a steel caliper manufactured by Bjørnrud & Arnestad, Oslo, the rule of which had been shortened to 20 cm, and the sleeve of which was provided with a recess and a corresponding millimetre scale. The diameter was measured at 1.3 m height in most A-experiments. In A-experiments in spruce cultures on low site classes, where many single trees are smaller than 1.3 m, it was necessary to measure the diameter at 0.5 m height. The diameter was measured by single-calipering and read in millimetres.

b. Selection of Sample Trees.

In the selection of sample trees, endeavours were made to have these distributed equally throughout each sub-plot. Along the boundary between a fertilized plot and an unfertilized plot, an isolating belt, consisting of 1 + 1 rows, was interposed, no sample trees being measured in that belt. The width of the isolating belt was determined on the basis of a special investigation of the neighbour effect between NKP plots and neighbouring control plots (see p. 135).

Endeavours have been made to measure a fairly constant number of sample trees per sub-plot in all the A-experiments. However, in fertilized sub-plots a greater number of sample trees were measured (about 15 per unit) than in unfertilized sub-plots (about 10 per unit), one fertilized sub-plot being compared to two unfertilized ones. As the stem number per sub-plot varies from experiment to experiment, the degree of representation, i.e. that fraction of the total stem number which is represented by the sample trees measured, must vary. In the spruce experiments, the average degree of representation for fertilized plots is 17 % — for unfertilized plots 11 %. In the beech experiments, the degrees of representation are considerably smaller (for fertilized plots about 5 %, and for unfertilized plots about 3 %), on account of the larger number of stems per sub-plot.

The selection of sample trees was done as follows: —

Spruce experiments. The degree of representation for fertilized and unfertilized plots was fixed with a view to the abovementioned conditions. Let the degree of representation for a plot be 1:n. The first sample tree to be selected is the second tree in the first row of plants to be measured starting with a row neighbouring the isolation belt, the first tree of the row, which is generally a boundary tree, being avoided. The next sample tree is found by counting n tree positions ahead in the same row of plants. Tree positions mean both live and dead trees. The selection continues in this way, every nth tree being picked. At the boundary between the sub-plot and the next one, the counting is carried on into the second row of plants a.s.o. In that way the sample trees are distributed evenly throughout the sub-plot (less the isolation belts), the plant spacings in the spruce cultures being rather constant. Dead plants are not measured.

The counting is then continued in the next sub-plot.

In several experiments there has been a rather high mortality rate. In such experiments the number of sample trees per subplot will be smaller than in intact experiments. In order to maintain a fairly constant number of sample trees per sub-plot, it is necessary to find substitutes for any sample trees missing. If, therefore, it is found during the count that the nth tree (the sample tree) is dead or missing, the next live tree in the plant row (or the next row) is chosen instead. The counting on to the next sample tree starts from the original nth tree position. Of course, in sub-plots with rather considerable dead gaps, this method cannot prevent the number of sample trees from being smaller. In such sub-plots there is a tendency for the sample trees to accumulate at the boundary of the dead gaps. In order to avoid too large a representation of boundary trees, the sample trees are in such cases chosen among the trees next to the outermost ones at the boundary.

Beech experiments. In those experiments where the plants are in rows, the procedure of selecting sample trees is almost the same as in the spruce experiments. Instead of finding the sample trees by counting tree positions, the sample trees are here found by measurement in the rows. If the representation is fixed at 1:n, a sample tree is selected for every nth linear metre.

In natural regenerations or broadcast cultures without plant rows, the same procedure has been adopted, after a suitable number of base lines have been laid out along which the sample trees were selected.

Unlike the spruce experiments, where all sizes of trees have been accepted as sample trees, it has been necessary in the beech experiments to exclude trees which were completely suppressed. This category includes trees of less than 1.3 m height, or trees which have no vertical shoot axis at 1.3 m height. If the counting strikes a suppressed tree, the nearest not suppressed tree is chosen instead.

c. Processing of the Data Material.

The majority of the computations have been made on a digital computer (IBM 7070 and 7074) at the I/S Datacentralen, Copenhagen. Two special processing programmes were worked out (FORTRAN language): one for the main investigation, and one for the neighbour effect investigation (cfr below and p. 135).

The heights and diameters measured on the sample trees are entered on a special schedule (Fig. 4), from which these data, together with a numeral code for tree species, number designations of experiments, plots and sub-plots, etc., are easily transferred to punched cards. Each sub-plot occupies two lines of the schedule, corresponding to two punched cards, viz. one for the heights and one for the diameters.

Individual sub-experiments.

Heights and diameters from each individual sub-experiment (cfr Fig. 3) are comprised by analyses of variance of their own. The data material from a typical A-experiment is thus subjected to 7 mutually independent analyses of variance, comprising the height observations, viz. one analysis for each fertilizing treatment, and, similarly, 7 analyses comprising the diameter observations.

From a mathematical point-of-view, a sub-experiment may be regarded as consisting of 3 rows stretching crosswise to the longitudinal direction of the plots (each row consists of one fertilized and two unfertilized sub-plots) and 3 columns (plots). Consequently, the sub-experiment may be included in an analysis of variance with a two-way classification of the observations

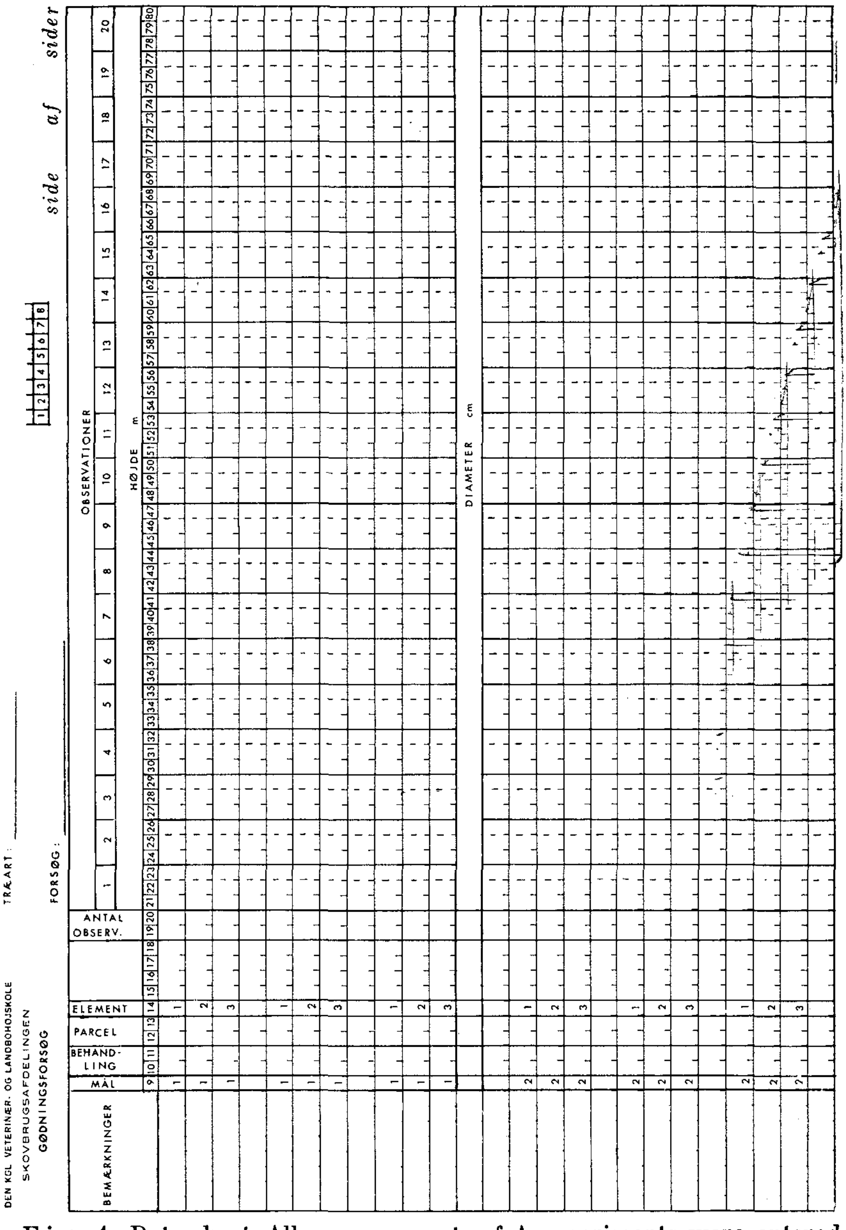


Fig. 4. Data sheet. All measurements of A-experiments were entered on data sheets during measuring. One data sheet holds measurements from 3 plots, each divided in 3 sub-plots.

Fig. 4. Måleark. Alle målinger af A-forsøg er indført på måleark under målingens udførelse. På ét måleark er plads til måledata fra tre parceller, hver delt i tre parcelelementer.

(Hald 1962), provided that the data material satisfies the necessary conditions. These are: the observations must be (1) mutually independent, (2) normally distributed, and (3) have a common standard deviation.

re (1): Random tests show that the heights and diameters, respectively, of the sample trees vary accidentally in magnitude without dependence on the chronological order of the measurements. As, furthermore, the selection of sample trees takes place independently of the size of sample trees previously measured, point (1) must be considered fulfilled.

re (2): Random tests (fractile diagrams) show that the observations may be regarded as normally distributed. There is a tendency for the distribution to be somewhat biased, so that rather the logarithms of the observations are normally distributed. However, the standard deviation is only about one-third of the distribution mean, i.e. both the observations and the logarithms of these may be regarded as normally distributed (Hald 1962). No transformation of the material has, therefore, been made.

re (3): In confirmity with the foregoing, there is a tendency for the standard deviation to grow in direct proportion to the mean value. v^2-tests, carried out in a number of sub-experiments, show, however, that the variance of the fertilized plot does not deviate significantly from that of the two control plots. In the individual sub-experiment, condition (3) may therefore be considered satisfied.

If the total number of sample trees in the 9 sub-plots of a sub-experiment are equal to N, the total variation of the obser-

No.	Designation of variation	Degrees of freedom	Variance	Variance ratio
1	Interior	N - 9	s_1^2	
2	Interaction between rows and columns	4	s_2^2	$v_a^2 = s_2^2/s_1^2$
3	Between 3 rows	2	s_3^2	
4	Between 2 control plots	1	s_4^2	$v_b^2 = s_4^2/s_1^2$
5	Between fertilized plot and control plots	1	s_5^2	$v_c^2 = s_5^2/s_1^2$
	Total	N - 1		

vations will be split up by the analyses of variance, as shown in the table. It is especially notable that the variation between the 3 columns is divided into variation between the 2 control plots and variation between the fertilized plot and the controls.

In the majority of the sub-experiments there is no interaction between rows and columns. In sub-experiments with interaction, the trisection of the plots has been given up, so that the total variation is split up only into variation between columns (plots) and interior variation. The latter then comprises variations No. 1, 2 and 3 from the above table.

In support of the evaluation of the fertilizing effects, the least significant difference (L.S.D.) between the mean value of the growth of the fertilized plot (height or diameter) and the mean value of the growth of the control plots, has been calculated for each sub-experiment:

$$\text{L.S.D. } (5\ \%) = s \sqrt{\frac{1}{N_B} + \frac{1}{N_K}} \cdot t_{05}$$

s being the standard deviation calculated from the interior variation (cfr the table above). If there is no interaction between the rows and columns of the analysis of variance, $s = s_1$ is determined by N - 9 degrees of freedom. If there is an interaction, s is determined by N - 3 degrees of freedom. (If there is an interaction, s is greater than s_1, as the interaction and the row variation are then included in the interior variation). N_B and N_K are the number of observations in a fertilized plot and its control plots, respectively. t_{05} is the 97.5 % fractile in the t-distribution corresponding to the number of degrees of freedom by which s is determined.

As a *criterion of significance* the 5 % level has been used all-over. In the analyses of variance, this corresponds to the 95 % fractile of the v^2-distribution, the 5 % being cut off only at the upper end of the distribution. In a t-test (including calculation of L.S.D.) the 5 % level corresponds to the 97.5 % fractile of the t-distribution, 2.5 % being cut off at either end of the distribution.

The analysis of variance of a sub-experiment makes it possible to compare the growth in the two control plots. If the two mean heights (respectively, mean diameters) of these are significantly different (the variation between the control plots exceeding the interior variation in the sub-plots), this is taken as a sign of the natural site class varying so much that a fertilizing effect cannot be recognised, and the sub-experiment is then given up as an individual experiment. If, on the other hand, the mean values do not differ significantly, this is taken as a sign of agreement between the growth of the control plots.

If the mean height (respectively, mean diameter) in the fertilized plot is significantly different from the common mean in the two control plots (i.e. the variation between the fertilized plot and the control plots exceeds the interior variation), the difference between the mean values is interpreted as a fertilizing effect — positive or negative, dependent on which mean value is the larger. If the two mean values are not significantly different, no fertilizing effect is demonstrable in the sub-experiment.

The analysis of the observations described above makes possible only an evaluation of each sub-experiment separately. A more general evaluation of the different fertilizing treatments might be had by comparing the fertilizing effect of several sub-experiments. It appears, however, that the interior variations of the sub-experiments differ. (A Bartlett's Test of the diameter variances in the NKP-sub-experiments in the spruce site class groups 3—4 and 4—7 thus shows that the variances are significantly different (the 5 % level)). It is therefore impracticable to extend the analysis of variance to comprise several sub-experiments.

Instead, a complementary point of view is adopted.

Contraction of sub-experiments.

The fertilizing effects of the sub-experiments (height or diameter) are now regarded as original observations, and each site-class croup is regarded as one experiment comprising the fertilizing effects of the respective sub-experiments. For each site-class group in spruce and beech experiments, respectively, a Student's t-test is now made on the basis of the diameter effects.

The conditions for making the t-test are that the fertilizing effects (1) are mutually independent, (2) are normally distributed, and (3) have a common standard deviation.

re (1): This requirement has been satisfied, as the sub-experiments are situated in different localities, and the observations are made independently of each other.

re (2) and (3): Simultaneous mean heights (mean diameters) from control plots and fertilized plots, respectively, within each tree species and site-class group are plotted in a diagram with H_K (D_K) as abscissa and H_B (D_B) as ordinate (cfr Tables 5 and 6). The dots of the diagram are randomly distributed, with a constant variation about a line with the slope 1. Requirements (2) and (3) may thus be regarded as satisfied. (Hald 1962).

In each site-class group a mean ($\bar{U}$) of the fertilizing effects is calculated. The standard deviation s is calculated from

$$s = \sqrt{\frac{\sum_{i=1}^{n} (U_i - \bar{U})^2}{n - 1}}$$

where U_i is an arbitrary fertilizing effect (for the height observations, $U = H_B\text{-}H_K$; for the diameter observations, $U = D_B\text{-}D_K$, cfr tables 5—8), and n is the number of sub-experiments in the site-class group. The t of the t-test is calculated from

$$t = \frac{(\bar{U} - 0)\sqrt{n}}{s} = \frac{\bar{U}\sqrt{n}}{s}$$

the t-test being used to ascertain whether the calculated t is compatible with the hypothesis that the fertilizing effect is nil. The calculated t is compared with t_{05}, which is the 97.5 % fractile in the t distribution with (n - 1) degrees of freedom. Furthermore, the least significant effect is calculated:

$$\text{L.S.D. } (5\ \%) = s\sqrt{\frac{1}{n}} \cdot t_{05}\ .$$

By means of the t-test it is investigated whether the mean value of the fertilizing effects in the site-class group is significantly different from zero. If the fertilizing effect is significant and the mean value positive, this is interpreted to mean that the fertilizing has had a positive effect for the site-class group as a whole. Similarly, a negative mean value is interpreted as a negative effect. If the mean value is not significantly different from zero, no fertilizing effect is demonstrable in the site-class group.

IV. NEIGHBOUR EFFECT IN A-EXPERIMENTS

As mentioned, the fertilizing effects of the A-experiments are determined by comparing a fertilized plot with the two unfertilized neighbouring plots. Owing to the small width of the plots (about 10 m), there is the possibility that any effect of the treatment extends across the boundaries of the fertilized plot into the control plots. Furthermore, the outermost plant rows in the fertilized plot may be imagined to be less influenced by the treatment than the centre plant rows. Such *neighbour effects* will disturb the determination of fertilizing effects.

A preliminary detailed investigation in spruce experiment No. 22 did not indicate that neighbour effect played any great part. But within a given plot there were often great differences in the growth of the individual plant rows. The variations between the rows were often greater than the variation within the rows. It might therefore seem reasonable to include as many plant rows as possible in the determination of the growth of a plot. If the growth of the plot were determined by the growth of a single plant row it would be difficult to compare the fertilized plot with the two adjacent controls.

In the measuring of the A-experiments the outermost two rows in each plot, were, however, left out from the measuring from the start in order to eliminate the majority of any neighbour effects. But at the same time, an investigation was commenced of the extent of any neighbour effects in a number of NKP sub-experiments in spruce, as well as in a single NKP sub-experiment in beech. The NKP sub-experiments were chosen because the greatest fertilizing effects, and consequently the most vigorous neighbour effects, might be expected there.

a. Methods.

In 19 NKP sub-experiments in spruce, the rows were measured separately in different groups, in addition to the measurements outlined in Sect. 3. E.g. sub-experiments with 7 rows of plants per plot were measured in the following groups:

1st row-group:	The 3 central rows of the NKP plot.
2nd row-group:	The 2 next-outermost rows of the NKP plot.
3rd row-group:	The 2 outermost rows of the NKP plot.
4th row-group:	The first row of each control plot (O_4 and O_5, Fig. 2) on either side of the NKP plot, 2 rows in all.
5th row-group:	The second row of each control plot (O_4 and O_5, Fig. 2) on either side of the NKP plot, 2 rows in all.
6th row-group:	The 3 central rows of each control plot on either side of the NKP plot, i.e. 6 in all.

In each of the 6 row-groups, the heights and diameters of representatively selected trees were measured as described in Sect. 3. The degree of representation was fixed so that 15—20 trees were measured in each row-group, and, consequently, it varies with the number of stems.

In 5 of the NKP sub-experiments investigated there are 9 or more rows of plants per plot. In these experiments also the 3rd *outermost row* was measured separately in both NKP plot and control plots. These 5 experiments were thus sub-divided into 8 row-groups.

The criteria chosen for neighbour effect were:

(α) *In the NKP plot:*	The outer rows (in the example with 7 rows per plot: the 2nd and/or 3rd row-groups) have obtained significantly *smaller* heights and diameters than the central rows (1st row-group).
(β) *In the control plots:*	(O_4 and O_5): The outer rows (4th and/or 5th row-groups in the example) have obtained significantly *greater* heights and diameters than the central rows (6th row-group).

Thus, the central rows in NKP plot and control plots, respectively, are used as basis for comparison. It is then an assumption that they themselves are not influenced by the neighbouring plot.

In order to ascertain whether this assumption has been satisfied, the two control plots, O_3 and O_4, surrounding the P-plot have been compared (cf. Fig. 2). The basis for the comparison are the height and diameter measurements in the total number of rows of the control plots, with the exception of the outermost 2 rows bordering on the fertilized plots (see later). If the fertilization of the NKP plots is capable of extending its effect to the central rows of the O_4-plot, the average growth of plot O_4 may be assumed to deviate from that of plot O_3, on the following grounds:

(a) The P-plot has the possibility of influencing the O_3 and O_4 control plots equally. As, in the majority of the 19 A-experiments investigated no effect of the P-fertilization has been found, this influence is probably slight. (b) Correspondingly there is no effect in the K-plot. Consequently, the fertilization of the K-plot cannot have influenced the O_3-plot, whereas in the majority of the A-experiments there is a great, positive growth effect in the NKP plot.

If there is no difference in growth between plots O_3 and O_4, the assumption of the central rows in control plot O_4 (and, analogously, control plot O_5) not being influenced by the treatment of the NKP-plot, may therefore be considered satisfied.

Table 3. A-experiment. Spruce. The growth difference between the two control plots surounding the P-plot (figure 2). The mean of 18 experiments. L.S.D. (5 %) is the least significant difference between the means of the heights and between the means of the diameters according to the t-test.

Measure		Control plots O_3	Control plots O_4	Growth difference $O_4 - O_3$	L.S.D. (5 %)
Height	m	3.21	3.36	0.15	0.14
Diameter	cm	4.51	4.61	0.10	0.26

Table 3 shows that the growth in the O_4-plot is a little greater than that in the 0_3-plot. The difference in growth is, however, only significant for the height, and is actually small compared with the growth differences between the NKP-plot and its control plots (O_4 and O_5) (see the NKP sub-experiments, Table A17 and A18). The L.S.D. (5 %) has been calculated in analogy with the procedure described in Sect. 3c. The assumption for the neighbour-effect investigation proper may therefore be regarded as satisfied in practice.

Certainly, it is impossible to carry out a similar investigation of a reducing effect of the control plots on the fertilizing effect in the central rows of the NKP-plot. Such an effect, however, does not seem probable, though it may not be excluded.

The two criteria for neighbour effect (α and β) are investigated by means of analyses of variance. One analysis of variance is made for each NKP sub-experiment, and comprises the height observations from the 6 (or 8) row-groups (cf. p. 136), a similar analysis being made for the diameter observations. The analyses of variance have been supplemented by calculations of the least significant differences (calculated by means of Student's t-test) between the mean values of central and outer row-groups. The calculations were carried out on an electronic computer (cfr. Sect. 3).

In each analysis of variance a two-way classification of the observations into columns and rows (not to be confused with rows of plants) has been made. The observations from the 6 (or 8) plant-row groups are covered by 6 (or 8) columns. As in the main investigation (sect. 3), the plots are trisected into sub-plots, whereby each plant-row group is divided into 3 units. Furthermore, each plant-row group (with the exception of the 1st row-group) is composed of plant rows from two different halves of the NKP plot or from two different control plots. Each row-group may therefore be regarded as composed of $3 \times 2 = 6$ units. Each unit now enters into its row of the analysis of variance, which thus consists of 6 rows and 6 or 8 columns. On grounds of symmetry, the three units from the 1st row-group may also be divided into 6 units. (A formal error is then committed, which, however, is of no consequence in practice, as the number of degrees of freedom are adjusted afterwards so that the number of observations are included only once).

The variation between columns (row-groups) is divided into three variations, viz.:

(a) between fertilized and unfertilized row-groups,
(b) between fertilized row-groups,
(c) between unfertilized row-groups.

These variations are compared to the variation within the row-group units (interior variation).

It is a prerequisite for a neighbour effect that the NKP-fertilizing has had an effect, i.e. the variation (a) is significantly larger (the 5 % level) than the interior variation. If variation (b) is significantly larger than the interior variation, there is the possibility that some of the outer row-groups of the NKP-plot may have been neighbour-affected. In order to decide which row-groups are neighbour-affected, the differences between the mean values of the central row-group and the outer row-groups are compared with the least significant difference (L.S.D. (5 %)) between these. The standard deviation is calculated on the basis of the interior variation, and L.S.D. is calculated as described in Sect. 3c. A similar examination is made to see whether the outer row-groups of the control plots are neighbour-affected if variation (c) is significantly larger than the interior variation.

If the analysis of variance shows that the mean values of the row-groups are significantly different, and that the difference between a central row-group and a corresponding outer row-group is larger than the least significant difference (L.S.D. (5 %)), one of the criteria of neighbour effect is satisfied. If, e.g., the difference between the 4th and 6th row-groups is larger than L.S.D., and the difference between the 5th and 6th row-groups smaller than L.S.D., the conclusion is that the outermost rows of the control plots are affected by the fertilization of the NKP-plot, while the next-outermost rows are unaffected.

b. Results.

Tables A1, A2, A3 and A4*) contain the mean heights and mean diameters of the row-groups as well as the least significant differences between the row-groups. They further indicate the outer row-groups in which a neighbour effect has been ascertained. At the foot of the tables, the number of experiments with neighbour effect have been summed up for each of these row-groups. In Table 4 the summations for the outermost and next-outermost row groups are found together.

c. Discussion.

When comparing the results of the neighbour effect investigation with the results of the NKP sub-experiments of the main investigation (Tables A17 and A18), it should be borne in mind

*) Tables A1, A2 ... a. s. o. will be found assembled in a special tabular work on p. 163.

that the data materials are not identical. For one thing, the degrees of representation are greater in the neighbour effect investigation (a larger number of single trees measured), and for another, unlike the main investigation, the neighbour effect investigation does not comprise the two next-outermost rows of the control plots, O_4 and O_5, which are situated farthest away from the NKP-plot.

Table 4. A-experiment. Spruce. NKP-sub-experiments with neighbour effect. Outermost and next-outermost rows. Summary of tables A1, A2, A3 and A4.

	Measure	Number of experiments with effect of NKP	Number of experiments with neighbour effect			
			NKP-plots		Control plots	
			Next-autermost	Outer-most	Next-outermost	Outer-most
Number	Height	14	3	4	3	11
	Diameter	13	2	5	1	7
Relative	Height	100	21	29	21	79
	Diameter	100	15	38	8	54

Table 4 shows clearly that the outermost rows of the plots are more often neighbour-affected than the next-outermost rows. The outermost rows of the control plots, which are nearest the NKP-plot, seem especially to have been affected by the fertilizing of the NKP-plot. Obviously, a large part of the neighbour effect can be eliminated by excluding the outermost rows of the plots from the measurements. But, are the next-outermost rows also to be excluded? This will depend on the reaction in relation to the third-outermost rows of the plots.

However, the number of NKP sub-experiments with 9 or more plant rows per plot is too small to allow safe conclusions to be drawn as to any neighbour effect of the third-outermost rows. Tables A3 and A4 rather seem to indicate that there is no great difference between the reactions of the next-outermost and the third-outermost rows, and do not encourage elimination of the 2nd-outermost rows.

If the outermost rows only are left out, the determination of the fertilizing effect in some experiments may still be disturbed by neighbour effects. But the neighbour effects are undoubtedly reduced by the omission of the outermost rows. In all cases where neighbour effect has been ascertained in the 2nd and 3rd outermost rows, the neighbour effect is smaller than in the outermost rows (Tables A1, A2, A3 and A4).

In the only beech experiment (Silkeborg No. 22) where a neighbour effect investigation could be and was made as in the spruce experiments, only the outermost rows of the control plots are neighbour-affected, while the rows of the NKP-plot are unaffected.

As the row spacing in most experiments is from 1.0 to 1.3 metres, the main impression of the investigation is that the neighbour effect extends at most only a few metres. This impression is in agreement with more recent investigations, which show that the concentration of fine roots and, consequently, probably the nutrient-absorbing capacity, decreases rapidly with increasing distance from the tree (see, e.g. *Holstener-Jørgensen,* 1959 on Norway spruce and beech).

d. Conclusion.

In all A-experiments, isolation belts in which the trees are not measured, are interposed between fertilized plots and control plots. An isolation belt comprises the outermost rows of the fertilized plot and the outermost row of the control plot.

The investigation shows that this procedure is justifiable.

V. GENERAL RESULTS OF A-EXPERIMENTS

As mentioned in Sect. 3, all sub-experiments with one definite fertilizing treatment (e.g. all NKP sub-experiments in spruce), are regarded in two complementary ways. According to the former point-of-view the sub-experiments are a number of individual experiments, each assessed separately, and not mutually comparable. According to the latter point-of-view the sub-experiments (properly speaking, the fertilizing effects of the sub-experiments) are *single observations* which are included in *a common experiment* comprising all sub-experiments which belong to the same site-class group and tree species with the same fertilizing treatment. The spruce sub-experiments are divided into three site-class groups; the beech sub-experiments into two site-class groups (cfr tables 1 and 2 on p. 96—99).

a. Individual Sub-experiments.

Detailed information about the experimental results is given in Tables A5—A18 (spruce experiments) and Tables A21—A34 (beech experiments). Sub-experiments with the same fertilizing treatment are found in one table. The tables contain information about mean heights and mean diameters in fertilized plots and control plots, and about absolute and relative fertilizing effects. The minimum limit for significant effect, calculated by means of the t-test (L.S.D. (5 %)), has been indicated in support of the evaluation of the absolute effects (cfr Methods, Sect. 3c). Finally, the significance column indicates whether the fertilizing effects are significant according to the analyses of variance. Mean values from the two control plots of a sub-experiment have been added up to form a common mean, including cases where the control plots are significantly different in respect of growth. When the control plots are different, the individual sub-experiment does not, however, give any information about fertilizing effects. For such sub-experiments, the table columns "L.S.D. (5 %)" and "Significant Effect" are therefore empty. Furthermore, the number of stems in fertilized plots have been stated in relation to the number of stems of the control plots in order to make possible a comparison with the relative fertilizing effects. The crosswise lines divide the spruce experiments into three site-class groups, and the beech experiments into two.

In the evaluation of the results of the individual sub-experiments, account must be taken of the fact that a significant effect of a definite fertilizing treatment in an individual sub-experiment does not immediately prove that the fertilizing has influenced the growth of the trees in this experiment. The choice of the 0.05 significance level means that, on an average, in 5 % of a large number of sub-experiments a significant effect of a treatment will be recorded, even if the treatment has actually had no effect on the growth of the trees. Such accidental effects are found, e.g. in the K-fertilizing of spruce (Tables A9 and A10). Only when a treatment shows effect in several sub-experiments may the treatment be regarded as definitely effectual, e.g. the NKP-fertilizing of spruce of low site classes (Tables A17 and A18).

1. Spruce Experiments.

N- and N/2-fertilizing. From Tables A5 and A6 it appears that N-fertilizing has influenced both height and diameter growth in site-class group 4—7, while site-class groups 0—3 and 3—4 have not been influenced significantly. The most important effects are apparently on the diameter. There is even a tendency to small positive diameter effects for site-class group 0—4.

As might be expected, the effect of the N/2-fertilizing is smaller than that of the N-fertilizing (Tables A7 and A8), and not univocal — especially not as far as the height growth is concerned. The diameter effects are, however, positive in several experiments — and, surprisingly, also in experiments in better site classes.

K- and K/2-fertilizing. These two treatments seem to have influenced the growth equivocally (Tables A9, A10, A11, and A12). The individual significant effect are now positive, now negative.

P- and P/2-fertilizing. Nor do these two treatments seem to have had any great effect on the growth (Tables A13, A14, A15 and A16).

NKP-fertilizing. In the site-class groups 3—4 and 4—7 there are positive effects in the majority of sub-experiments, both for height and diameter growth (Tables A17 and A18). There is a tendency to positive diameter effects in the site-class group 0—3 (many positive fertilizing effects, — but not significant), although there is no tendency to a height effect here.

Special fertilizing treatments (Tables A19 and A20). In general, the effects of these treatments agree with the above-mentioned results. The positive effect of the 1/2 NKP-fertilizing in Experiment No. 04 is contrary to the 1/1 NKP-fertilizing in the same experiment which had no effect. The nitrophosca-fertilizing in Experiment No. 13 has given positive effect in conformity with the positive effect of the NKP-fertilizing in this experiment (Tables A17 and A18). In the K- and K/2-treatments, Experiment No. 10, there was no result either from the fertilizers containing chlorine or from those without chlorine. Ammonium sulphate in Experiments Nos. 12 and 15 has had no effect in conformity with the low N-content (14 kg N/hectare) in this treatment as compared with the N/2-fertilizing (23 kg N/ha). As with the P-fertilizing, dicalcium-phosphate fertilizing has had no effect.

On the other hand, there is reason to emphasize the positive effect of the 3 P-fertilizing in Experiment No. 20. In this experiment P and P/2 had no effect.

2. *Beech Experiments.*

N- and N/2-fertilizing. The general impression of Tables A21, A22, A23 and A24 is that the two treatments had no effect. In a single experiment, No. 06, both height and diameter growth

Table 5. A-experiment. Spruce. Height. Contraction of sub-experiments. L.S.D. (5 %) is the least significant difference between the mean heights of the fertilized plots and the mean heights of the corresponding control plots. + indicates significant positive effect, 0 no significant effect, and — significant negative effect according to the t-test (cf. section 3c).

Fertilizer	Site-class group	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	Fertilizing effect: L.S.D. (5 %) m	Fertilizing effect: Significance	Fertilizing effect: $\frac{H_B}{H_K}$ 100	Number of experiments in site-class group
N	0—3	6.94	6.85	0.09	0.26	0	101	10
	3—4	4.90	4.93	—0.03	0.30	0	99	4
	4—7	3.22	2.95	0.27	0.27	+	109	12
N/2	0—3	7.21	7.14	0.07	0.27	0	101	9
	3—4	4.94	4.91	0.03	0.67	0	101	4
	4—7	2.90	2.80	0.10	0.20	0	104	12
K	0—3	7.08	6.88	0.20	0.25	0	103	10
	3—4	5.00	5.03	—0.03	0.32	0	99	4
	4—7	2.93	2.85	0.08	0.16	0	103	12
K/2	0—3	7.18	7.18	0.00	0.27	0	100	9
	3—4	4.88	4.61	0.27	0.26	+	106	4
	4—7	2.81	2.77	0.04	0.35	0	101	12
P	0—3	6.77	6.94	—0.17	0.28	0	98	10
	3—4	4.87	4.97	—0.10	0.17	0	98	4
	4—7	2.91	2.83	0.08	0.20	0	103	12
P/2	0—3	7.18	7.15	0.03	0.25	0	100	9
	3—4	4.86	4.69	0.17	0.39	0	104	4
	4—7	3.04	2.89	0.15	0.11	+	105	12
NKP	0—3	7.23	7.22	0.01	0.31	0	100	9
	3—4	5.33	4.94	0.39	0.50	0	108	3
	4—7	3.95	2.96	0.99	0.33	+	133	12

T a b l e 6. A-experiment. Spruce. Diameter. Contraction of sub-experiments. Further explanation in table 5.

Fertilizer	Site-class group	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	Number of experiments in site-class group
N	0—3	7.89	7.64	0.25	0.38	0	103	10
	3—4	6.35	6.06	0.29	0.30	0	105	4
	4—7	5.11	4.60	0.51	0.45	+	111	12
N/2	0—3	8.16	7.88	0.28	0.49	0	104	9
	3—4	6.21	5.83	0.38	1.07	0	107	4
	4—7	4.64	4.31	0.33	0.31	+	108	12
K	0—3	7.84	7.64	0.20	0.25	0	103	10
	3—4	5.88	6.08	—0.20	0.57	0	97	4
	4—7	4.55	4.56	—0.01	0.26	0	100	12
K/2	0—3	7.91	7.91	0.00	0.27	0	100	9
	3—4	5.64	5.36	0.28	0.25	+	105	4
	4—7	4.27	4.34	—0.07	0.55	0	98	12
P	0—3	7.64	7.68	—0.04	0.49	0	99	10
	3—4	5.75	6.02	—0.27	0.22	—	96	4
	4—7	4.43	4.38	0.05	0.33	0	101	12
P/2	0—3	7.96	8.01	—0.05	0.38	0	99	9
	3—4	5.75	5.54	0.21	0.47	0	104	4
	4—7	4.77	4.58	0.19	0.17	+	104	12
NKP	0—3	8.42	8.04	0.38	0.50	0	105	9
	3—4	6.99	6.08	0.91	0.45	+	115	3
	4—7	6.26	4.52	1.74	0.49	+	138	12

were positively influenced by both N and N/2. Positive effects are also found in Experiment No. 13, while other effects seem rather accidental.

K- and K/2-fertilizing. In the majority of the sub-experiments no effect of the two treatments seems traceable (Tables A25, A26, A27 and A28). In Experiment No. 15 there is a positive effect of K, but only tendencies for K/2. In Experiments No. 13, 17 and 19, all of which are situated in the vast Roldskov complex, the diameter growth seems to have responded positively to K/2 and, partially, K.

P- and P/2-fertilizing. (Tables A29, A30, A31 and A32). These two treatments have hardly had any effect on the growth.

T a b l e 7. A-experiment. Beech. Height. Contraction of sub-experiments. Further explanation in table 5.

Fertilizer	Site-class group	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}$ 100	Number of experiments in site-class group
N	0—2	5.86	5.88	—0.02	0.37	0	100	10
	2—4	5.10	5.10	0	0.26	0	100	10
N/2	0—2	6.24	6.23	0.01	0.31	0	100	10
	2—4	4.92	4.77	0.15	0.23	0	103	10
K	0—2	5.86	6.00	—0.14	0.13	—	98	11
	2—4	4.93	4.98	—0.05	0.22	0	99	10
K/2	0—2	5.76	5.85	—0.09	0.23	0	98	9
	2—4	5.01	4.99	0.02	0.28	0	100	9
P	0—2	6.05	5.97	0.08	0.15	0	101	11
	2—4	4.74	4.93	—0.19	0.25	0	96	10
P/2	0—2	6.01	5.97	0.04	0.25	0	101	9
	2—4	4.78	4.85	—0.07	0.30	0	99	8
NKP	0—2	6.04	5.96	0.08	0.18	0	101	11
	2—4	4.78	4.91	—0.13	0.46	0	97	9

NKP-fertilizing. The height growth does not seem influenced by NKP (Table A33), but there is a tendency for the diameter growth to be positively influenced (Table A34). It is especially noteworthy that Experiments 13 and 17 in the Roldskov complex have positive diameter effects (cfr. the effect of K). Unfortunately, Experiment No. 19 is not represented. Experiment No. 06, which showed effect of N, shows a positive diameter effect.

Special fertilizing treatments. (Tables A35 and A36). These treatments do not seem to have any effect. The positive tendency of the nitrophosca treatment in Experiment No. 18 is outweighed by the negative tendency of the NKP-treatment.

b. Contraction of sub-experiments.

Mean values of heights, diameters and of the absolute fertilizing effects have been calculated for each tree species and site-class group. The mean values will appear from Tables 5 and 6

Table 8. A-experiment. Beech. Diameter. Contraction of sub-experiments. Further explanation in table 5.

Fertilizer	Site-class group	Fertilized plot	Control plots	Fertilizing effect				Number of experiments in site-class group
				Effect	L.S.D. (5 %)	Significance	$\frac{D_B}{D_K} 100$	
		D_B cm	D_K cm	$D_B - D_K$ cm	cm			
N	0—2	4.38	4.34	0.04	0.32	0	101	10
	2—4	4.17	3.98	0.19	0.28	0	105	10
N/2	0—2	4.85	4.78	0.07	0.40	0	101	10
	2—4	3.91	3.64	0.27	0.33	0	107	10
K	0—2	4.33	4.54	—0.21	0.23	0	95	11
	2—4	3.93	3.86	0.07	0.38	0	102	10
K/2	0—2	4.21	4.35	—0.14	0.19	0	97	9
	2—4	4.06	3.88	0.18	0.48	0	105	9
P	0—2	4.56	4.56	0.00	0.23	0	100	11
	2—4	3.64	3.79	—0.15	0.35	0	96	10
P/2	0—2	4.26	4.29	—0.03	0.22	0	99	9
	2—4	3.63	3.73	—0.10	0.36	0	97	8
NKP	0—2	4.91	4.59	0.32	0.23	+	107	11
	2—4	4.16	3.87	0.29	0.31	0	107	9

(spruce experiments) and Tables 7 and 8 (beech experiments). The tables also indicate the smallest effect which differs significantly from zero (L.S.D. (5 %)), and a note has been added regarding the significance of the fertilizing effect. Finally, the relative magnitude of the fertilizing effect has been stated. The atypical beech experiment, No. 20, has been left out from the comparison in Tables 7 and 8.

1. Spruce experiments.

The results indicated in Tables 5 and 6 and illustrated by Figs. 5 and 6 largely confirm the general impression of the results of the individual sub-experiments (Tables A5—A18). *In site-class group 4—7 the N- and NKP-fertilizing has influenced the height and diameter growth. The diameter growth is also affected by N/2. The 4 experiments in site-class group 3—4 have responded positively to NKP* and apparently also to K/2-fertilizing, though not to the K-fertilizing. There is a small, positive effect of the P/2-fertilizing in site-class group 4—7, though not

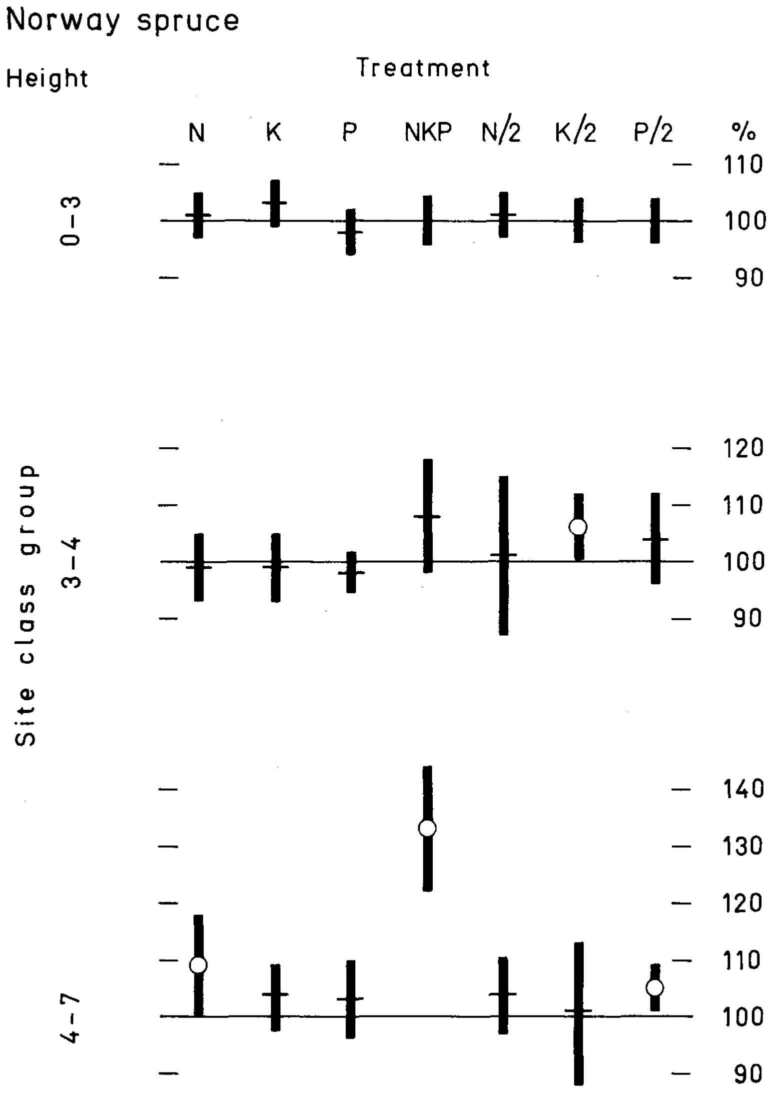


Fig. 5. Height effects in Norway spruce resulting from the fertilization. The effects are indicated by a circle or a cross bar in per cent. of unfertilized plots. Circle means significant effect, cross bar non-significant effect. Vertical columns indicate confidence intervals (twice L.S.D. (5 %), cf. page 134).

Fig. 5. Højdeudslag i rødgran som følge af gødningsbehandling. Udslag er angivet ved en cirkel eller en tværstreg i procent af ubehandlede parceller. Cirkel betyder signifikant udslag, tværstreg ikke signifikant udslag. Til bedømmelse af den statistiske sikkerhed er både over og under hvert udslag tegnet en søjle, hvis længde angiver minimumsstørrelsen for udslag, der er signifikante.

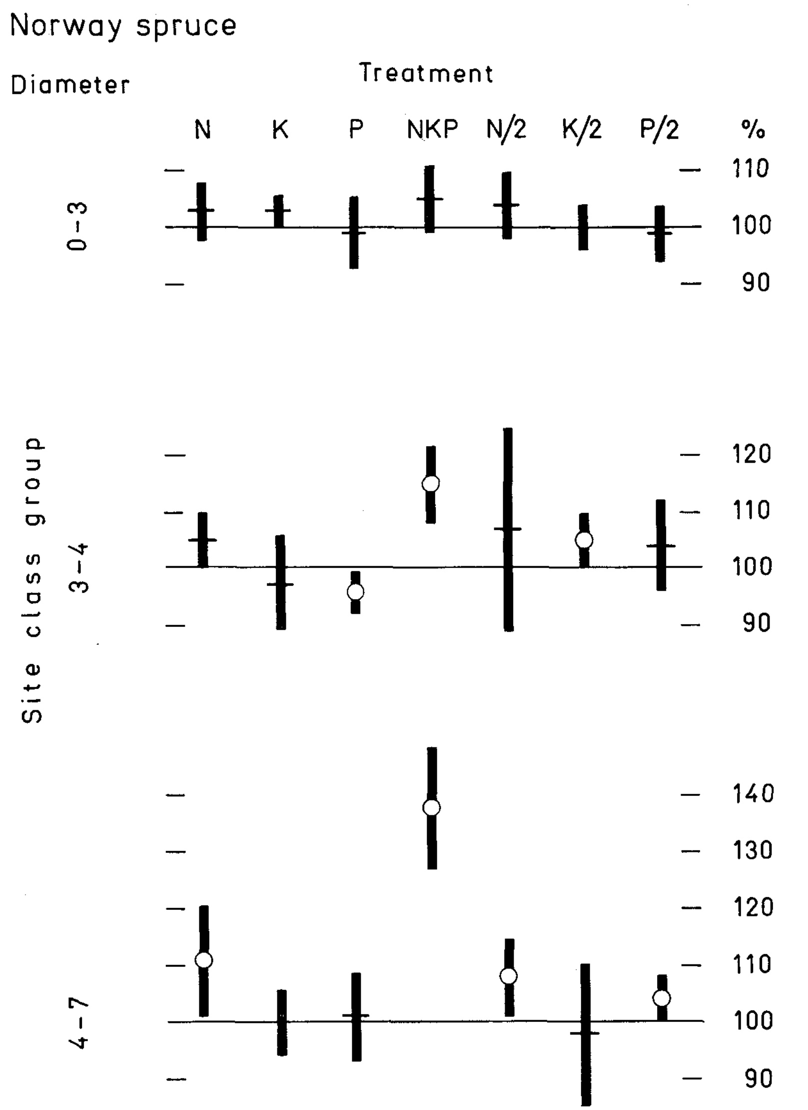


Fig. 6. Diameter effects in Norway spruce resulting from the fertilization. The effects are indicated in per cent. of unfertilized plots. Also see text of Fig. 5.

Fig. 6. Diameterudslag i rødgran som følge af gødningsbehandling. Udslag er angivet i procent af ubehandlede parceller. Se iøvrigt tekst til fig. 5.

Table 9. A-experiment. Beech. Summary of experiments No. 13, 17, and 19 situated in the Rold forest. Further explanation in table 5.

Fertilizer	Fertilized plot	Control plots	Fertilizing effect				Number of experiments
			Effect	L.S.D. (5 %)	Significance		
	H_B	H_K	$H_B - H_K$			$\frac{100 H_B}{H_K}$	
	m	m	m	m			
N	4.72	4.40	0.32	0.79	0	107	3
N/2	4.57	4.28	0.29	0.28	+	107	3
K	4.61	4.47	0.14	0.35	0	103	3
K/2	4.47	4.23	0.24	0.31	0	106	3
NKP	4.32	3.88	0.44	3.26	0	111	2
	D_B	D_K	$D_B - D_K$			$\frac{100 D_B}{D_K}$	
	cm	cm	cm	cm			
N	3.21	2.79	0.42	0.94	0	115	3
N/2	3.30	2.96	0.34	0.24	+	111	3
K	3.43	2.93	0.50	0.33	+	117	3
K/2	3.59	2.83	0.76	0.88	0	127	3
NKP	3.14	2.59	0.55	4.36	0	121	2

of the P-fertilizing. The diameter growth in the 4 experiments in site-class group 3—4 seems even to have been inhibited by the P-fertilizing.

In site class-group 0—3 no significant fertilizing effect is found but perhaps a weak, positive trend for N-containing fertilizers (below 5 %).

It appears from Tables 5 and 6 that the effects of the NKP-fertilizing are much greater than the sum of the effects of the N-, K- and P-treatments individually. Most often, the relative fertilizing effects on the diameter growth are a little greater than on the height increment.

2. *Beech experiments.*

Largely, the beech experiments do not seem to have responded to any treatment (Tables 7 and 8 and Fig. 7). The small negative effect of the K-fertilizing in site-class group 0—2 may hardly be considered of any importance. Inversely, there is a tendency for the NKP-fertilizing to have enhanced the diameter growth a little (much smaller effect than in the spruce experiments).

In Table 9 the results of the nitrogen and potassium fertilizations in the Roldskov experiments (Nos. 13, 17 and 19) have

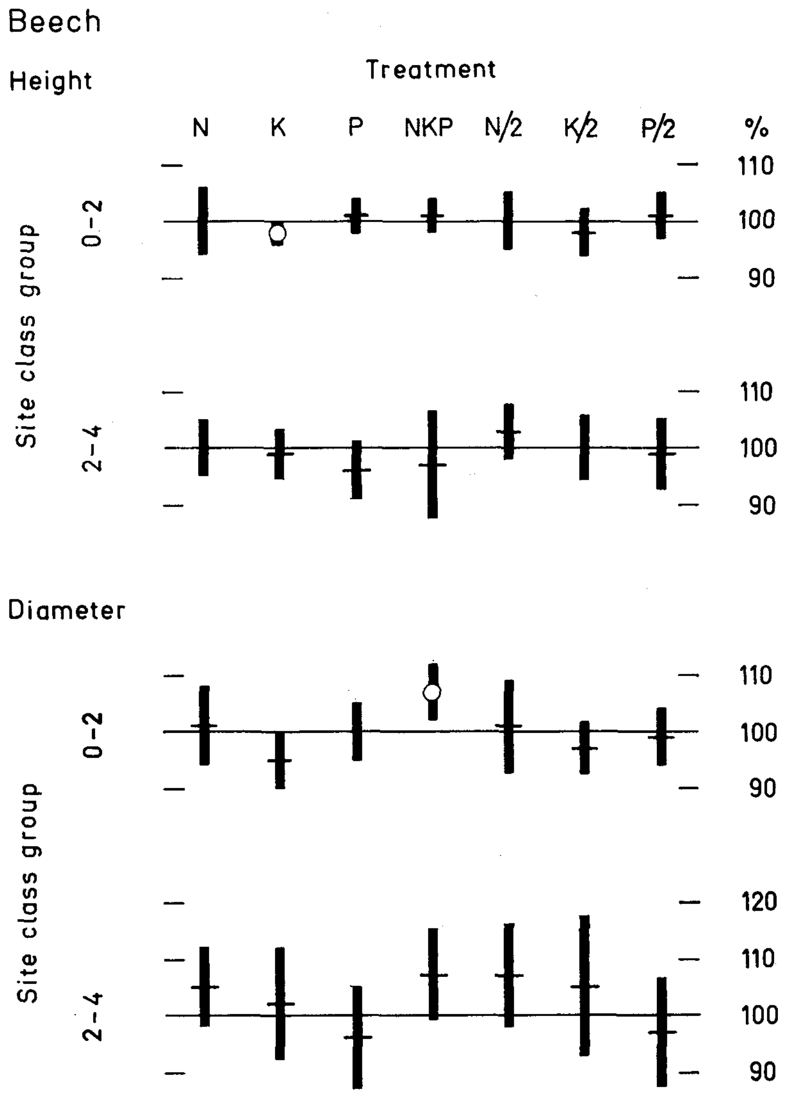


Fig. 7. Height and diameter effects in beech resulting from the fertilization. The effects are indicated in per cent. of unfertilized plots. Also, see text of Fig. 5.

Fig. 7. Højde- og diameterudslag i bøg som følge af gødningsbehandling. Udslag er angivet i procent af ubehandlede parceller. Se iøvrigt teksten til fig. 5.

been summarized. The absolute fertilizing effects vary greatly within the three experiments. This results in large L.S.D. values for some of the treatments. In these cases no significant effect (e.g. of the N- and K/2-treatments) is recorded, in spite of marked trends. It should be observed that the effects of the treatments on the diameter growth are greater than on the height growth. This tendency is met with again when comparing Tables 7 and 8. A part of it may be explained by the fact that the diameter is measured at a fixed height above soil, cf. p. 247 below and table 11 on p. 161.

VI. INFLUENCE OF NUMBER OF STEMS IN A-EXPERIMENTS

During the measuring of the A-experiments it appeared that the number of stems in fertilized plots sometimes deviates from the number of stems in the respective control plots. If, for example, the number of stems of a fertilized plot is essentially lower than that of the control plot, this may be imagined to have the same effect as a thinning, furthering the diameter growth of the fertilized plot in relation to that of the control plots. Such cases might erroneously be recorded as sub-experiments with a positive fertilizing effect.

In order to find out whether this is the case, the number of stems in the plots of the A-experiments were counted, and relative stem numbers were calculated for each sub-experiment (100 $\times$ (number of stems in fertilized plot)/(mean of stem number in the two control plots)). These relative stem numbers have been listed in Tables A5—A20 (spruce experiments) and Tables A21—A36 (beech experiments) beside the relative fertilizing effects of the sub-experiment concerned (cfr Sect. 5). It will appear from the tables that in several sub-experiments the relative number of stems is far below 100, corresponding to a reduction in the number of stems of the fertilized plots. In many cases the stem number reduction is due to accidental causes, while in others the fertilization is no doubt a contributory cause. This, for instance, is the case in many NKP sub-experiments in spruce.

As any thinning effect may be assumed to have the greatest influence on the diameter, a number of correlation analyses have been made, with the relative number of stems as the independent variable and the relative diameter effect ($100 \times D_B/D_K$) as the dependent variable. Such analyses have thus been made of the K/2-sub-experiments, N/2-sub-experiments, N-sub-experiments and NKP-sub-experiments of the spruce experiments. Furthermore, an analysis has been made, comprising the diameter effects from the K/2-, K-, P/2- and P-sub-experiments, as well as a corresponding analysis comprising the height effects ($100 \times H_B/\bar{H}_K$). However, no significant correlation coefficients were found in a single one of these cases (the 5 % level). The tendencies are now toward positive correlations and now toward negative ones. A thinning effect should give a negative correlation.

Table 10. A-experiment. Spruce. Site-class group 4—7. Number of stems and relative fertilizing effect of NKP on the diameter. The reduction of the stem number is considered significant when the relative number of stems is below 90.

Experiment		Number of stems			Relative stem number in NKP-plot Control plots = 100	Relative fertilizing effect $\frac{D_B}{D_K}$ 100	
Designation	No.	NKP-plot	Control plot O_4	Control plot O_5		No significant reduction of stem number	Significant reduction of stem number
Lindet	13	254	248	233	106	176	
Randbøl	14	124	238	201	56		134
Kompedal, 197	15	188	285	294	65		173
Hesselvig	16	119	163	166	72		143
Birkebæk	17	167	202	197	84		141
Liebe	18	160	186	164	91	103	
Skygge	19	282	280	294	98	127	
Agerskov	20	200	208	232	91	157	
Haraldslund	21	258	260	230	105	121	
Harreskov	22	246	250	280	93	182	
Gludsted, 52	23	368	385	388	95	119	
Gludsted, 142	24	335	349	344	97	142	

In Table 10, for example, the NKP-sub-experiments in spruce site-class group 4—7 have been divided up into experiments with stem number reduction and experiments without stem number reduction. It will be seen immediately that the relative diameter effects are not correlated to the number of stems.

It may concluded that the fertilizing effects are not demonstrably disturbed by the fluctuating numbers of stems, even *where the number of stems drops essentially* as in the NKP sub-experiments in spruce. The explanation of this phenomenon may be that the reduction in the stem numbers has often taken place in the way that whole groups of trees have died (see, e.g. the mention of the individual experiments on pages 108 and 110), and that trees growing along the margin og gaps in the stands have been avoided when sample trees have been selected.

On the other hand, there is no doubt that fertilizing, and especially NKP-fertilizing, may cause plant deaths (see further Total Summary and Discussion p. 254).

VII. COMPARISON WITH AN EARLIER MAKING UP OF THE EXPERIMENT IN NORWAY SPRUCE, AFTER 3 YEARS' FERTILIZING

In 1957, Carl Mar: Møller and M. Schaffalitzsky de Muckadell accounted for a preliminary experimental survey for Norway spruce based on 3 years' height growth after the initial fertilization.

At this early time after the start of the experiment it was thought that the procedure adopted for the final survey of the A-experiments, in which the effects are assessed on the basis of the total height and total diameter obtained in the plots, was less applicable.

Instead, the following three methods were used simultaneously for the height increment, on the assumption that they would check each other:

The material comprised figures for

H_{1952}, ΔH_{1952}, ΔH_{1953}, ΔH_{1954} and
ΔH_{1955}, ΔH being height increment.

Method 1. The absolute height increments in each of the fertilized plots were compared with the absolute height increments in the two adjoining unfertilized control plots.

But, as there may be one-sided condition-dependent differences in height increments from plot to plot, even in an apparently rather uniform and uniformly treated culture, this method may lead to unreasonable results.

If, say, the fertilized plot has so far had an essentially lesser height increment (and, consequently, now a lesser H_{1952}) than its unfertilized neighbours, a negative effect of the fertilizing may easily be arrived at, even though the effect has, in fact, been positive. At any rate, the impression of the positive effect will be greatly reduced.

It seemed natural, therefore, to assess the height increment of the plots by comparison with their growth so far.

Method 2. This was done by expressing the annual ΔH of the individual plot after the fertilizing as a percentage of the ΔH_{1952} of the plot, i.e. the height increment in the year before the initial supply of fertilizer.

The background for this method is the assumption that ΔH_{1952} would normally be a good indicator of the growth capacity of the plot at that time.

It is thus assumed that the relation between the height increments in 1953—55 of all the unfertilized control plots is the same as in 1952. This may certainly seem a reasonable assumption, but the method may have its drawbacks — especially in cultures having a pronounced stay-in-check period. If the whole culture enters or leaves this period simultaneously, or if this period is directly dependent on special conditions which will continue to exercise their effect on the said parts of the culture, the method is not attended with any fundamental errors. Different parts of the culture will, however, often have different stay-in-check periods, but this need not necessarily mean that these parts will continue to have a different power of growth throughout the life of the stand.

Let us assume, for example, that in 1953 to 1955 the fertilized plot would normally still be in a period of staying in check, while the adjoining two control plots with the same H_{1952} are just getting over that period in those years. In that case it may happen that any positive effect of the fertilization is hidden — or even becomes apparent as a negative effect.

Method 3. Finally, the H of the individual plot after the fertilizing period was expressed as a percentage of the H_{1952} of the plot. Whereas, as mentioned, method (2) is a correction for different height increments at the start of the experiment, method 3 is a correction for different starting height. The background for the method is that H_{1952} must normally be a good indicator of the growth of the plot so far. This method has the advantage that $\Delta H_{1952-55}$ is put in relation to the height increment in a number of years, and not — as according to method (2) — to the height increment in a single year.

On the other hand, it is an advantage of method (2) that, fundamentally, it gives a more conspicuous impression of the change in the power of growth caused by the fertilization.

In the same way as described under method (2), method (3) may give rise to difficulties in cultures parts of which have different periods of staying in check.

In completely uniform cultures, method (1) may give good results in spite of the short observation period, but in most of the experiments method (2) or (3) was considered preferable. Normally, there was good agreement between the results of methods (2) and (3).

The said publication from 1957 contains a graphical representation of the result of method (2) for each individual experiment. Additionally, it contains the same graphical picture of the average of each of the same three site-class groups, which are used in this publication.

These three graphs from 1957 are reproduced below (Figs. 8, 9, 10), as it may be of interest to see to what extent it is possible to obtain usable experimental results after only three years' experiment, calculated in a simpler way. These figures should be compared with the preceding fig. 5.

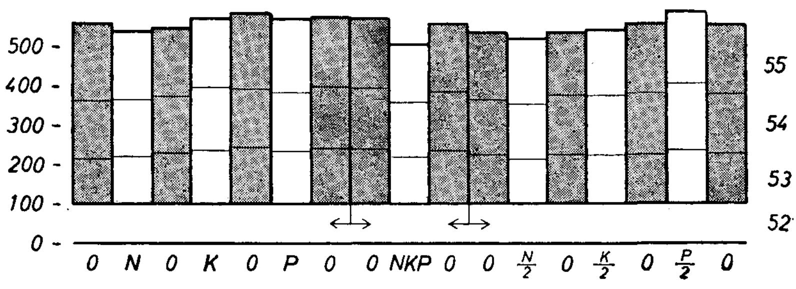


Fig. 8. Relative height increments. Autumn-1955-average of the 9 experiments in site class group 0—3. At the start in 1952, the mean deviation of a fertilized plot from the average of its 2 neighbouring controls was 3 %.

Fig. 8. Relative højdetilvækster. Gennemsnit efterår 1955 for de 9 forsøg på bonitet 0—3. Ved starten 1952 var middelafvigelsen af en behandlet parcel fra gennemsnittet af dens 2 ubehandlede naboparceller 3 %.

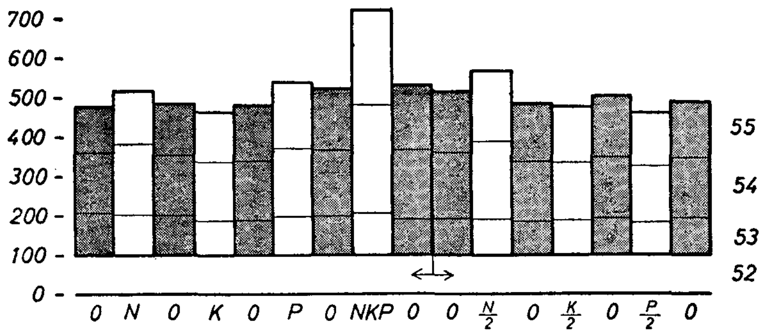


Fig. 9. Relative height increments. Autumn-1955-average of the 4 experiments in site class group 3—4. At the start in 1952, the mean deviation of a fertilized plot from the average of its 2 neighbouring controls was 6 %.

Fig. 9. Relative højdetilvækster. Gennemsnit efterår 1955 for de 4 forsøg på bonitet 3—4. Ved starten 1952 var middelafvigelsen af en behandlet parcel fra gennemsnittet af dens 2 ubehandlede naboer 6 %.

For the sake of clarity, the O-plots have been hatched in the graphical representations. Their variation illustrates the part of the experimental inaccuracy which originates from the variation of the growth conditions among the plots.

The figures to the right of the diagram represent the years, and those to the left are relative figures, meaning that for each individual plot 100 is an expression of the height increment in

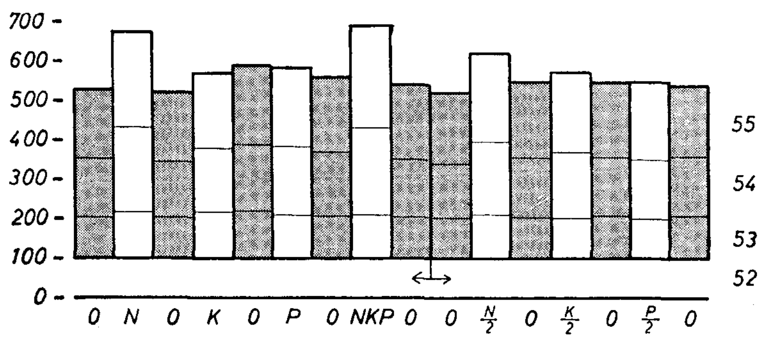


Fig. 10. Relative height increments. Autumn-1955-average of the 12 experiments in site class group 4—7. At the start in 1952, the mean deviation of a fertilized plot from the average of its 2 neighbouring controls was 5 %.

Fig. 10. Relative højdetilvækster. Gennemsnit efterår 1955 for de 12 forsøg på bonitet 4—7. Ved starten 1952 var middelafvigelsen af én behandlet parcel fra gennemsnittet af dens 2 ubehandlede naboer 5 %.

1952. According to method (2) mentioned above, the height increments of the following 3 years are then expressed in percentages of the height increments in 1952 and graphically summed up.

For each individual treatment, i.e. O, N, O, K, etc., the figure used in the graphical representation is a simple mean of the figures from all the individual plots of the site-class group at this place in the common system.

The symbol ←┴→ means that there the experimental area has been split up into groups, made necessary by field conditions.

The fact that simple mean figures have been used in the graphical representation means that no regard has been paid to the undoubtedly different confidences of the individual mean figures, whereas this was done in the final experimental survey.

Compared with the height figures for Norway spruce in the final experimental survey, as shown in Fig. 5, we find good agreement for the site classes 0—3, where no effect is ascertained.

For site-classes 3—4, the positive effects of the NKP-fertilizing in the two surveys are in agreement, although the effect is not significant in the final survey.

But, whereas the 1955-survey showed a smaller positive effect of N and N/2, and none of P and K, the 1963-survey has no effect of N and N/2 and a positive effect of, at any rate, K/2.

Since in both cases the effect of NKP is greater than the sum of the other effects, the question must no doubt be one of an interaction, and it is therefore probable that both of the graphical representations compared may be expressions for realities. On the other hand, it should be emphasised that the site class group covers only 4 experiments, which may lead to inaccurate mean values.

For site class group 4—7, there is a fundamental agreement between the two graphical pictures, the tendency being toward positive effects for all treatments and so that the NKP effect is greatest; next follows N. However, in 1963 the NKP effect is far more dominating than in 1957, while the independent effect of N is more moderate than in 1957.

The general conclusion of the comparison made must be that while in 1957 the results pointed to N as by far the most effective fertilizer on poor soils, the final survey indicates that in the long *run the effect of N is dependent on the simultaneous supply of K and P.*

It seems probable that the trees respond most quickly to N, but that the increased growth rather soon induces a deficiency of K and P — and, possibly, several other materials, which are not included in this investigation.

VIII. DISCUSSION

Spruce Experiments.

The effect of nitrogen fertilizing on height growth in spruce cultures has been found in other experiments in Danish heath plantations. In Sønder Omme Plantation *Olsen, Rafn* and *Scheurer* (1960) found a positive effect from full fertilization consisting of ammonium nitrate, phosphoric acid and various metallic salts, including potassium salts. If the nitrogen component, a quantity of 175 kg N/ha spread over 2 years, was left out, the fertilizing effect was negligible. In the Klosterheden and Gludsted Plantations, *Holstener-Jørgensen* (1963 and 1965) obtained increased height growth in spruce cultures by fertilization with calcium nitrate (corresponding to 90 kg N/ha/year), administered both alone and together with superphosphate and potassic fertilizer respectively. The quantities of nitrogen supplied were thus two times larger than in the present investigation. These differences in dosage, as well as the shorter periods of treatment (1—3 years) in the investigations cited, make comparison of the magnitude of the fertilizing effects difficult.

In both the Klosterheden Plantation and the Gludsted Plantation Holstener-Jørgensen found that the height growth of the spruce cultures was increased by the application of superphosphate (corresponding to about 75 kg P/ha). In the present investigation, fertilizing with superphosphate has been ineffectual, probably because in this case the P and P/2 doses have been too small (i.e. corresponding to 15 and 7.5 kg P/ha, respectively). Only in a single experiment of the present investigation (No. 20) was a larger dose of superphosphate administered (corresponding to 45 kg P/ha), and this treatment has promoted the height growth (Table A19, the 3 P-fertilizing). On the other hand, the 3 P-fertilizing has not influenced the diameter growth significantly (Table A20). Olsen et al. found that the fertilizing effect was negligible if the phosphoric-acid component (corresponding to 25 kg P/ha) was left out from the full fertilization (cfr above). This does not mean, however, that a quantity of phosphoric acid corresponding to 25 kg P/ha, when administered alone, would have promoted the height growth. It is possible that this quantity of P may only have effect when administered simultaneously with nitrogen. Such an interaction between N and P has been observed by Holstener-Jørgensen in the Klosterheden Plantation, where the effect of NP-fertilizing (N and P supplied simultaneously) exceeds the total effect of N and P administered separately.

A similar phenomenon is apparent in the present investigation. From Table 5 it appears that the height growth in the N-fertilized plots in site-class group 4—7 is 9 % greater, on an average, than in the control plots. The P-fertilizing and the K-fertilizing have had no influence on the height growth, whereas the combined NKP-fertilizing has resulted in an increase in the height growth of 33 %. Accordingly, the addition of K or P has an effect only when administered together with nitrogen. The present investigation affords no possibility of deciding whether it is the addition of K or of P, or of both, which interacts with nitrogen.

In Klosterheden Plantation, Holstener-Jørgensen found interaction only between N and P but not between N and K or P and K. Nor was any effect found of fertilizing with potash in a quantity corresponding to 120 kg K/ha, i.e. 3 times as large a dose as in the present investigation.

In the above it has been assumed that a lack of effect from P-fertilizing may be due to too small a dose of P. The results shown in Tables 5 and 6 seem to contradict this assumption, as in site-class group 4—7 there is a significantly positive effect of the P/2 fertilizing, but not of the P-fertilizing. A contributory cause may be that one of the control plots (O_4) of the P-plot, which borders upon the NKP plot, is neighbour-influenced — at any rate as far as the height growth is concerned (cfr Table 3). Although the neighbour effect is slight, and inconsequential in other respects, it is enough to mask any small effect of the P-fertilizing. The P/2 plot is not subject to such disturbances (cfr Fig. 2).

Knowledge of the reactions of the diameter growth to fertilization is at least just as necessary as knowledge of the reactions of the height growth — not least for evaluating the influence of the fertilization on the volume yield of the trees. The fertilizing treatments in the present investigation have, largely, had the same effect on the diameter growth as on the height growth. The nitrogen fertilizers seem, however, to have had a somewhat greater influence on the diameter growth than on the height growth (cf. p. 152 above).

In the site-class group 4—7, the diameter in the greater proportion of the sub-experiments has, as previously mentioned, been measured at 0.5 m height. The measurements available afford no possibility of distinguishing between the effect of the fertilizing treatments on the diameter growth at 0.5 m height and at 1.3 m height. There are, however, no signs of different reaction at the two measuring heights. In site-class group 4—7 of the NKP sub-experiments the relative diameter effects, measured at 0.5 m height, thus vary from 3 to 82 per cent, while the two effects measured at 1.3 m height are 34 and 42 per cent, respectively.

In order to assess the influence of the fertilization on the volume yield of the trees it is necessary to know the dependence, if any, of the form factor on the fertilization. This dependence has not been investigated in the present work. However, in the fertilized plots the height/diameter ratio is only about 3 % smaller than in the unfertilized plots (Table 11). In an estimation of the volume yield in fertilized vs. unfertilized plots, it is therefore reasonable to disregard any influence on the form factor. In this connection, no distinction has been made between the diameter effects at 0.5 and 1.3 m height either.

Table 11. A-experiment. Spruce. Site-class group 4—7. Relative volume of the stems in the N-, N/2-, and NKP-plots. The volume of the stems in the control plots is 100. Besides, the height/diameter ratio in the fertilized plots is compared with that of the control plots.

Fertilizer	Height/diameter ratio		Relative fertilizing effect		
	Fertilized plot $\frac{H_B}{D_B}$	Control plots $\frac{H_K}{D_K}$	Height $\frac{H_B}{H_K}100$	Diameter $\frac{D_B}{D_K}100$	Volume $\frac{H_B D_B^2}{H_K D_K^2}100$
N/2	63	65	104	108	120
N	63	64	109	111	134
NKP	63	65	133	138	256

In Table 11 the influence of the nitrogen fertilization on the volume yield of the trees has been made up for site-class group 4—7. The relative effects have been calculated in analogy to the height and diameter effects in Tables 5 and 6, the volume in the control plots, M_K, having been put equal to 100, after which the relative volume in fertilized plots is calculated

$$100 \frac{M_B}{M_K} = 100 \frac{H_B\left(\frac{\pi}{4} D_B{}^2\right) f_B}{H_K\left(\frac{\pi}{4} D_K{}^2\right) f_K} = 100 \frac{H_B D_B{}^2}{H_K D_K{}^2}$$

where M_B is the volume in the fertilized plot, and the form factor in the fertilized plot, f_B, is put equal to the form factor in the control plot, f_K.

It will be seen that even if the nitrogen fertilization may have reduced the form factors a little, there is a considerable increase in the volume of the trees, especially for the NKP-fertilizing.

Beech Experiments.

The growth reactions of the beech experiments are much smaller and more localized than those of the spruce experiments. A contributory cause of the smaller effects is undoubtedly that, in general, the beech experiments stand on better soil than do the spruce experiments, especially as far as the lowest site-class groups are concerned (compare, e.g. the soil's content of potash in Tables 1 and 2). The local results, among which the positive reaction to N and K in the Rold Forest experiments (No. 13, 17 and 19) should be emphasized, as well as the positive reaction to nitrogen (incl. NKP) in experiment No. 06 cannot, apparently, be explained by means of the prevailing soil conditions. With regard to K-content in the soil, experiments No. 13 and 17 have low values, but so have experiments 20 and 22, which did not respond to K-fertilizing (Table 2).

In a beech culture in Jægersborg Dyrehave with a relatively high K-content in the soil, *Holstener-Jørgensen* (1964) found increased height growth after K-fertilizing. Here twice the quantity of K per hectare was used as in the present investigation.

On the whole the reactions in beech are inconsiderable from a technical and economic point of view.

IX TABULAR WORK A

(Tables A1—A36)

Table A1. A-experiment. Spruce. Neighbour effect. Height. Experiments with 7 rows per plot. L.S.D. (5 %) is the least significant difference between the central row-group and the outer row-groups. × indicates neighbour effect demonstrated, — neighbour effect not demonstrated. + indicates significant effect or difference, and 0 no significant effect or difference.

Experiment		NKP-plot					
Designation	No.	Row-group No.			L.S.D. (5 %)	Neighbour effect in	
		1 Central rows m	2 Next-outermost rows m	3 Outermost rows m	m	Next-outermost rows	Outermost rows
Frederiksborg	7	6.75	6.48	6.20	0.66	—	—
Nødebo	9	7.71	7.62	7.74	0.47	—	—
Silkeborg	11	5.74	5.72	5.82	0.48	—	—
Løndal	27	5.05	5.04	5.17	0.63	—	—
Kompedal 404	12	5.41	5.33	5.20	0.35	—	—
Randbøl	14	3.07	2.82	3.35	0.43	—	—
Kompedal 197	15	2.60	2.71	2.39			
Liebe	18	4.41	4.85	4.93	0.65	—	—
Skygge	19	4.20	4.56	4.21	0.32	—	—
Agerskov	20	3.97	3.28	3.22	0.48	×	×
Haraldslund	21	2.64	2.93	2.76	0.40	—	—
Harreskov	22	3.04	3.16	2.62	0.52	—	—
Dose, with harrowing	31	1.87	2.05	1.90	0.22	—	—
Dose, without harrowing	32	1.80	1.73	1.66	0.17	—	—
Number of experiments with neighbour effect						1	1
Number of experiments with effect of NKP							

Table A1 (continued).

Effect of NKP. Significance	Difference between control plots O_4 and O_5. Significance	Control plots (O_4 and O_5)						Number of observations	
		Row-group No.			L.S.D. (5 %)	Neighbour effect in		Fertilized row-groups	Non-fertilized row-groups
		4 Outermost rows m	5 Next-outermost rows m	6 Central rows m	m	Next-outermost rows	Outermost rows		
0	0	6.52	5.97	5.90	0.60	—	×	148	165
+	0	7.38	7.10	6.65	0.43	×	×	170	202
0	0	5.52	5.63	5.40	0.44	—	—	163	182
0	0	4.67	4.94	4.54	0.56	—	—	171	213
+	0	5.08	4.58	4.43	0.33	—	×	166	180
+	0	2.88	2.68	2.40	0.37	—	×	147	176
	+	1.81	1.60	1.43				165	193
0	0	4.97	5.11	4.62	0.57	—	—	128	151
+	0	4.08	3.84	3.45	0.30	×	×	152	164
+	0	3.21	2.65	2.27	0.42	—	×	117	144
+	0	2.70	2.30	2.17	0.37	—	×	132	135
+	0	2.11	2.51	2.24	0.49	—	—	74	85
+	0	1.68	1.62	1.65	0.20	—	—	117	127
+	0	1.35	1.26	1.24	0.15	—	—	142	159
						2	7		
9									

Table A2. A-experiment. Spruce. Neighbour effect. Diameter. Further explanation in table A1.

Experiment		NKP-plot					
Designation	No.	Row-group No.			L.S.D. (5 %)	Neighbour effect in	
		1 Central rows	2 Next-outermost rows	3 Outermost rows		Next-outermost rows	Outermost rows
		cm	cm	cm	cm		
Frederiksborg	7	8.92	8.44	7.86	1.39	—	—
Nødebo	9	9.53	9.13	9.80	0.84	—	—
Silkeborg	11	7.38	7.51	7.40	0.85	—	—
Løndal	27	6.46	6.56	6.88	1.09	—	—
Kompedal 404	12	7.32	7.09	6.93	0.66	—	—
Randbøl	14	4.88	4.01	5.27	0.94	—	—
Kompedal 197	15	5.16	5.21	4.61			
Liebe	18	6.25	6.71	6.63	1.07	—	—
Skygge	19	6.70	7.61	6.73	0.70	—	—
Agerskov	20	6.69	5.29	5.15	0.96	×	×
Haraldslund	21	4.12	4.54	4.42	0.75	—	—
Harreskov	22	4.57	4.84	3.46	0.91	—	×
Dose, with soil-working	31	3.58	3.95	3.65	0.47	—	—
Dose, without soil-working	32	3.31	3.27	3.06	0.35	—	—
Number of experiments with neighbour effect						1	2
Number of experiments with effect of NKP							

Table A2 (continued).

Effect of NKP. Significance	Difference between control plots O_4 and O_5. Significance	Control plots (O_4 and O_5) Row-group No. 4 Outermost rows cm	5 Next-outermost rows cm	6 Central rows cm	L.S.D. (5 %) cm	Neighbour effect in Next-outermost rows	Neighbour effect in Outermost rows	Number of observations Fertilized row-groups	Non-fertilized row-groups
0	0	8.77	7.63	7.63	1.26	—	—	148	165
+	0	9.00	8.60	7.95	0.77	—	×	170	202
0	0	6.71	6.88	6.52	0.78	—	—	163	182
0	0	5.69	6.13	5.63	0.98	—	—	171	213
+	0	6.49	5.63	5.70	0.63	—	×	166	180
+	0	4.15	3.67	3.07	0.81	—	×	147	176
	+	3.53	3.14	2.74				165	193
0	0	6.80	7.22	6.12	0.93	—	—	128	151
+	0	6.48	6.05	5.51	0.65	—	×	152	164
+	0	5.15	4.14	3.63	0.84	—	×	117	144
0	0	4.33	3.81	3.67	0.69	—	—	132	135
+	0	2.93	3.27	2.98	0.86	—	—	74	85
+	0	2.94	2.71	2.79	0.44	—	—	117	127
+	0	2.36	2.18	2.19	0.30	—	—	142	159
						0	5		
8									

Table A3. A-experiment. Spruce. Neighbour effect. Height. Experiments with 9 rows per plot. Further explanation in table A1.

Experiment		NKP-plot							
Designation	No.	Row-group No.				L.S.D. (5 %)	Neighbour effect in		
		1 Central rows m	2 3rd outermost rows m	3 Next-outermost rows m	4 Outermost rows m	m	3rd outermost rows	Next-outermost rows	Outermost rows
Lindet	13	4.19	3.79	3.79	3.52	0.30	×	×	×
Hesselvig	16	4.39	4.50	4.12	4.54	0.66	—	—	—
Birkebæk	17	4.50	4.02	4.39	3.55	0.60	—	—	×
Gludsted 52	23	5.02	4.98	5.18	5.06	0.32	—	—	—
Gludsted 142	24	5.62	5.41	5.25	5.03	0.29	—	×	×
Number of experiments with neighbour effect							1	2	3
Number of experiments with effect of NKP									

Table A4. A-experiment. Spruce. Neighbour effect. Diameter. Further explanation in table A1.

Experiment		NKP-plot							
Designation	No.	Row-group No.				L.S.D. (5 %)	Neighbour effect in		
		1 Central rows cm	2 3rd outermost rows cm	3 Next-outermost rows cm	4 Outermost rows cm	cm	3rd outermost rows	Next-outermost rows	Outermost rows
Lindet	13	6.71	5.98	6.21	5.69	0.58	—	—	×
Hesselvig	16	8.32	9.56	7.62	8.88	1.36	—	—	—
Birkebæk	17	7.03	6.31	6.98	5.61	0.96	—	—	×
Gludsted 52	23	7.36	7.46	7.72	7.30	0.68	—	—	—
Gludsted 142	24	8.08	7.27	7.01	6.59	0.60	×	×	×
Number of experiments with neighbour effect							1	1	3
Number of experiments with effect of NKP									

Table A3 (continued).

Effect of NKP. Significance	Difference between control plots O_4 and O_5. Significance	Control plots (O_4 and O_5) Row-group No. 5 Outermost rows m	6 Next-outermost rows m	7 3rd outermost rows m	8 Central rows m	L.S.D. (5 %) m	Neighbour effect in 3rd outermost rows	Next-outermost rows	Outermost rows	Number of observations Fertilized row-groups	Non-fertilized row-groups
+	0	2.88	2.11	2.13	1.98	0.29	—	—	×	253	265
+	0	3.78	3.64	3.44	3.25	0.58	—	—	—	141	192
+	0	4.16	3.50	2.77	3.10	0.53	—	—	×	149	192
+	0	4.96	4.88	4.65	4.23	0.29	×	×	×	212	231
+	0	4.65	4.51	4.40	4.25	0.28	—	—	×	226	230
							1	1	4		
5											

Table A4 (continued).

Effect of NKP. Significance	Difference between control plots O_4 and O_5. Significance	Control plots (O_4 and O_5) Row-group No. 5 Outermost rows cm	6 Next-outermost rows cm	7 3rd outermost rows cm	8 Central rows cm	L.S.D. (5 %) cm	Neighbour effect in 3rd outermost rows	Next-outermost rows	Outermost rows	Number of observations Fertilized row-groups	Non-fertilized row-groups
+	0	4.71	3.68	3.74	3.33	0.55	—	—	×	253	265
+	0	7.10	6.63	6.32	6.02	1.18	—	—	—	141	192
+	0	6.70	5.74	4.18	4.81	0.85	—	×	×	149	192
+	0	6.74	6.61	6.58	6.18	0.63	—	—	—	212	231
+	0	5.95	5.67	5.62	5.61	0.58	—	—	—	226	230
							0	1	2		
5											

T a b l e A5. A-experiment. Spruce. N-sub-experiment. Height. Mean of the heights in the fertilized plot and in the two control plots. L.S.D. (5 %) is the least significant difference between the fertilized plot and the mean of the two control plots. L.S.D. is only calculated in the sub-experiments in which the two mean values of the control plots are not significantly different (the 5 % level). + indicates significant, positive effect, 0 no significant effect and — significant, negative effect, according to the analyses of variance (cf. section 3c). The horizontal lines divide the results into the site-class groups (cf. table 1).

Experiment		Fertilized plot H_B	Control plots H_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.			Effect H_B - H_K	L.S.D. (5 %)	Significance	$\frac{H_B}{H_K}$ 100	
		m	m	m	m			
Bidstrup	01	8.92	8.52	0.40	0.75	0	105	117
Brahetrolleborg	02	8.35	8.31	0.04	0.57	0	101	95
Bregentved	03	9.85	10.17	—0.32	0.55	0	97	102
Gjorslev	04	7.68	8.39	—0.71	0.68	—	92	74
Sorø I. Højb.	05	6.01	5.85	0.17			103	111
Sorø I. Blødb.	05	3.64	3.58	0.06	0.45	0	102	114
Valdemar Slot	06	5.53	5.22	0.31			106	96
Frederiksborg	07	5.24	5.03	0.21			104	104
Hvidkilde	08	6.49	6.32	0.17	0.48	0	103	90
Nødebo	09	7.70	7.14	0.56			108	
Lindenborg	10	6.32	6.50	—0.18	0.53	0	97	108
Silkeborg	11	4.51	4.26	0.25			106	102
Kompedal 404	12	4.16	4.28	—0.12	0.29	0	97	103
Løndal	27	4.63	4.69	—0.06	0.63	0	99	87
Lindet	13	2.67	2.58	0.09	0.35	0	104	99
Randbøl	14	3.18	2.98	0.20	0.31	0	107	97
Kompedal 197	15	1.82	1.49	0.33			122	77
Hesselvig	16	3.24	2.72	0.52	0.58	0	119	93
Birkebæk	17	3.19	2.77	0.42	0.47	0	115	106
Liebe	18	4.65	4.17	0.48	0.47	+	111	99
Skygge	19	3.86	4.11	—0.25	0.33	0	94	103
Agerskov	20	2.61	2.61	0.00			100	87
Haraldslund	21	2.74	1.84	0.90	0.39	+	149	92
Harreskov	22	1.01	1.64	—0.63			62	105
Gludsted 52	23	4.43	3.90	0.53	0.33	+	114	109
Gludsted 142	24	5.29	4.59	0.70	0.28	+	115	104

Table A6. A-experiment. Spruce N-sub-experiment. Diameter. Mean of the diameters in the fertilized plot and in the two control plots. Further explanation in table A5.

Experiment		Fertilized plot D_B	Control plots D_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.	cm	cm	Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	
Bidstrup	01	8.56	7.85	0.71	0.94	0	109	117
Brahetrolleborg	02	8.90	8.42	0.48	0.91	0	106	95
Bregentved	03	9.54	9.86	—0.32	0.84	0	97	102
Gjorslev	04	8.74	9.58	—0.84	1.15	0	91	74
Sorø I. Højb.	05	6.81	6.55	0.26			104	111
Sorø I. Blødb.	05	4.41	4.16	0.25	0.81	0	106	114
Valdemar Slot	06	6.64	6.01	0.63	0.67	0	111	96
Frederiksborg	07	7.30	6.62	0.68			110	104
Hvidkilde	08	8.99	8.41	0.58	0.99	0	107	90
Nødebo	09	9.05	8.96	0.09	1.14	0	101	
Lindenborg	10	7.23	7.18	0.05	0.84	0	101	108
Silkeborg	11	5.71	5.20	0.51			110	102
Kompedal 404	12	5.84	5.54	0.30	0.56	0	106	103
Løndal	27	6.61	6.30	0.31	1.18	0	105	87
Lindet	13	4.55	4.25	0.30	0.64	0	107	99
Randbøl	14	4.50	4.25	0.25	0.65	0	106	97
Kompedal 197	15	3.99	3.08	0.91	0.45	+	130	77
Hesselvig	16	5.92	4.85	1.07	1.03	+	122	93
Birkebæk	17	5.57	4.89	0.68	0.87	0	114	106
Liebe	18	6.58	5.69	0.89	0.73	+	116	99
Skygge	19	6.38	6.75	—0.37	0.61	0	95	103
Agerskov	20	4.26	4.26	0.00			100	87
Haraldslund	21	4.74	3.19	1.55	0.73	+	149	92
Harreskov	22	1.29	2.27	—0.98			57	105
Gludsted 52	23	6.30	5.62	0.68	0.59	+	112	109
Gludsted 142	24	7.24	6.06	1.18	0.54	+	119	104

Table A7. A-experiment. Spruce. N/2-sub-experiment. Height. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	8.34	8.76	—0.42	0.76	0	95	118
Brahetrolleborg	02	8.90	8.78	0.12	0.50	0	101	106
Bregentved	03	10.13	9.79	0.34	0.58	0	104	117
Gjorslev	04	8.28	7.70	0.58	0.61	0	108	87
Sorø I. Blødb.	05	3.68	3.46	0.22	0.44	0	106	110
Valdemar Slot	06	5.44	5.84	—0.40	0.33	—	93	85
Frederiksborg	07	5.96	6.10	—0.14	0.49	0	98	100
Hvidkilde	08	7.12	6.69	0.43	0.47	0	107	102
Nødebo	09	7.08	7.16	—0.08	0.60	0	99	
Lindenborg	10	5.07	5.40	—0.33	0.58	0	94	98
Silkeborg	11	6.20	5.62	0.58	0.59	0	110	83
Kompedal 404	12	4.20	4.08	0.12			103	97
Løndal	27	4.27	4.54	—0.27			94	103
Lindet	13	2.20	2.16	0.04	0.28	0	102	104
Randbøl	14	2.79	2.66	0.13	0.43	0	105	105
Kompedal 197	15	1.85	1.68	0.17	0.21	0	110	78
Hesselvig	16	3.43	2.93	0.50	0.58	+	117	96
Birkebæk	17	2.43	2.77	—0.34			88	111
Liebe	18	4.24	4.14	0.10	0.55	0	102	105
Skygge	19	3.42	3.54	—0.12	0.33	0	97	92
Agerskov	20	1.90	1.60	0.30			119	75
Haraldslund	21	2.60	2.14	0.46	0.32	+	121	106
Harreskov	22	1.35	1.89	—0.54	0.34	—	71	60
Gludsted 52	23	4.46	4.23	0.23	0.30	0	105	94
Gludsted 142	24	4.21	3.90	0.31			108	101

Table A8. A-experiment. Spruce. N/2-sub-experiment. Diameter. Further explanation in table A5.

Experiment		Fertilized plot D_B	Control plots D_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.			Effect $D_B - D_K$	L.S.D. (5 %)	Significance	$\frac{D_B}{D_K}$ 100	
		cm	cm	cm	cm			
Bidstrup	01	8.19	8.46	—0.27	1.04	0	97	118
Brahetrolleborg	02	9.09	8.96	0.13	0.96	0	102	106
Bregentved	03	10.42	9.99	0.43	1.00	0	104	117
Gjorslev	04	9.83	8.48	1.35	0.99	+	116	87
Sorø I. Blødb.	05	4.23	3.86	0.37	0.68	0	110	110
Valdemar Slot	06	6.39	6.61	—0.22	0.63	0	97	85
Frederiksborg	07	7.48	8.11	—0.63	0.82	0	92	100
Hvidkilde	08	9.45	8.35	1.10	1.02	+	113	102
Nødebo	09	8.39	8.06	0.33	0.90	0	104	
Lindenborg	10	6.01	6.02	—0.01	0.90	0	100	98
Silkeborg	11	7.80	6.60	1.20	0.88	+	118	83
Kompedal 404	12	5.67	5.05	0.62			112	97
Løndal	27	5.34	5.64	—0.30			95	103
Lindet	13	3.94	3.70	0.24	0.51	0	106	104
Randbøl	14	3.80	3.54	0.26	0.91	0	107	105
Kompedal 197	15	3.64	3.35	0.29	0.45	0	108	78
Hesselvig	16	6.34	5.26	1.08	1.09	+	121	96
Birkebæk	17	4.24	4.33	—0.09			98	111
Liebe	18	5.97	5.76	0.21	0.87	0	104	105
Skygge	19	5.63	5.74	—0.11	0.68	0	98	92
Agerskov	20	3.56	2.79	0.77			128	75
Haraldslund	21	4.26	3.39	0.87	0.63	+	126	106
Harreskov	22	1.88	2.56	—0.68	0.50	—	73	60
Gludsted 52	23	6.73	6.24	0.49	0.53	0	108	94
Gludsted 142	24	5.74	5.13	0.61	0.47	+	112	101

Table A9. A-experiment. Spruce. K-sub-experiment. Height. Further explanation in table A5.

Experiment		Fertilized plot H_B	Control plots H_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.			Effect $H_B - H_K$	L.S.D. (5 %)	Significance	$\frac{H_B}{H_K} 100$	
		m	m	m	m			
Bidstrup	01	9.22	8.36	0.86	0.89	+	110	96
Brahetrolleborg	02	8.12	8.31	—0.19	0.45	0	98	98
Bregentved	03	10.14	10.29	—0.15	0.53	0	99	107
Gjorslev	04	7.82	7.59	0.23			103	95
Sorø I. Højb.	05	6.57	5.87	0.70	0.61	+	112	100
Sorø I. Blødb.	05	4.10	3.93	0.17	0.47	0	105	102
Valdemar Slot	06	5.72	5.43	0.29	0.39	0	105	101
Frederiksborg	07	5.63	5.75	—0.12	0.67	0	98	114
Hvidkilde	08	6.27	6.21	0.06	0.53	0	101	97
Nødebo	09	7.17	7.01	0.16			102	
Lindenborg	10	6.20	6.50	—0.30	0.42	0	95	103
Silkeborg	11	4.88	4.85	0.03	0.58	0	101	102
Kompedal 404	12	4.15	4.18	—0.03			99	108
Løndal	27	4.77	4.58	0.19	0.60	0	104	100
Lindet	13	2.13	2.43	—0.30	0.36	0	88	98
Randbøl	14	3.02	2.68	0.34			113	100
Kompedal 197	15	1.20	1.36	—0.16	0.17	0	88	110
Hesselvig	16	2.80	2.85	—0.05	0.70	0	98	105
Birkebæk	17	2.61	2.50	0.11	0.38	0	104	101
Liebe	18	3.70	3.74	—0.04			99	99
Skygge	19	4.36	3.91	0.45			112	102
Agerskov	20	2.34	2.27	0.07	0.35	0	103	101
Haraldslund	21	1.72	1.96	—0.24	0.31	0	88	87
Harreskov	22	2.70	2.28	0.42	0.50	0	118	60
Gludsted 52	23	3.98	3.84	0.14	0.36	0	104	96
Gludsted 142	24	4.66	4.41	0.25			106	104

Table A10. A-experiment. Spruce. K-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	8.27	7.74	0.53	0.97	0	107	96
Brahetrolleborg	02	8.29	8.32	—0.03	0.80	0	100	98
Bregentved	03	10.03	10.17	—0.14	0.87	0	99	107
Gjorslev	04	9.60	8.77	0.83			110	95
Sorø I. Højb.	05	6.98	6.47	0.51	0.89	0	108	100
Sorø I. Blødb.	05	4.87	4.59	0.28	0.79	0	106	102
Valdemar Slot	06	6.47	6.20	0.27	0.62	0	104	101
Frederiksborg	07	7.26	7.52	—0.26	0.99	0	97	114
Hvidkilde	08	8.10	8.19	—0.09	1.05	0	99	97
Nødebo	09	8.56	8.47	0.09			101	
Lindenborg	10	6.58	7.16	—0.58	0.68	0	92	103
Silkeborg	11	5.74	5.87	—0.13	0.87	0	98	102
Kompedal 404	12	5.04	5.39	—0.35	0.60	0	94	108
Løndal	27	6.14	5.88	0.26	1.02	0	104	100
Lindet	13	3.67	4.24	—0.57	0.67	0	87	98
Randbøl	14	4.30	3.48	0.82			123	100
Kompedal 197	15	2.34	2.86	—0.52	0.42	—	82	110
Hesselvig	16	4.98	5.02	—0.04	1.22	0	99	105
Birkebæk	17	4.90	4.56	0.34	0.71	0	107	101
Liebe	18	5.38	5.24	0.14			103	99
Skygge	19	6.86	6.38	0.48			108	102
Agerskov	20	3.65	3.76	—0.11	0.56	0	97	101
Haraldslund	21	3.08	3.40	—0.32	0.58	0	91	87
Harreskov	22	4.03	3.26	0.77	0.87	0	124	60
Gludsted 52	23	5.70	5.62	0.08	0.59	0	102	96
Gludsted 142	24	5.74	5.90	—0.16	0.51	0	97	104

Table A11. A-experiment. Spruce. K/2-sub-experiment. Height. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect H_B - H_K m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	8.96	9.13	—0.17	0.82	0	98	113
Brahetrolleborg	02	8.67	8.71	—0.04	0.55	0	100	105
Bregentved	03	9.91	9.46	0.45	0.62	0	105	86
Gjorslev	04	8.71	8.31	0.40	0.64	0	105	104
Sorø I. Blødb.	05	3.35	3.45	—0.10	0.39	0	97	128
Valdemar Slot	06	5.88	6.30	—0.42			93	99
Frederiksborg	07	6.18	5.73	0.45	0.56	0	108	98
Hvidkilde	08	6.13	6.30	—0.17	0.55	0	97	100
Nødebo	09	6.88	7.25	—0.37	0.83	0	95	
Lindenborg	10	5.63	5.57	0.06	0.57	0	101	100
Silkeborg	11	5.67	5.36	0.31	0.62	0	106	105
Kompedal 404	12	3.69	3.43	0.26	0.33	0	108	95
Løndal	27	4.52	4.06	0.46	0.56	0	112	100
Lindet	13	1.96	2.09	—0.13	0.32	0	94	98
Randbøl	14	2.96	2.70	0.26	0.41	0	109	106
Kompedal 197	15	1.88	1.83	0.05			103	104
Hesselvig	16	2.39	3.03	—0.64			79	84
Birkebæk	17	1.98	2.55	—0.57			78	96
Liebe	18	3.56	4.10	—0.54	0.47	—	87	103
Skygge	19	4.22	3.42	0.80	0.31	+	123	93
Agerskov	20	2.96	2.03	0.93	0.34	+	146	109
Haraldslund	21	1.62	2.15	—0.53	0.28	—	75	99
Harreskov	22	1.49	1.65	—0.16	0.29	0	90	89
Gludsted 52	23	4.73	4.14	0.59	0.27	+	114	101
Gludsted 142	24	3.96	3.60	0.36	0.26	+	110	96

Table A12. A-experiment. Spruce. K/2-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	8.39	8.54	—0.15	1.04	0	98	113
Brahetrolleborg	02	8.77	8.90	—0.13	0.91	0	99	105
Bregentved	03	9.74	9.60	0.14	0.97	0	102	86
Gjorslev	04	9.82	9.34	0.48			105	104
Sorø I. Blødb.	05	3.65	3.85	—0.20	0.61	0	95	128
Valdemar Slot	06	6.54	7.19	—0.65	0.67	0	91	99
Frederiksborg	07	7.98	7.70	0.28	0.92	0	104	98
Hvidkilde	08	8.20	7.82	0.38	0.95	0	105	100
Nødebo	09	8.08	8.22	—0.14	1.07	0	98	
Lindenborg	10	6.31	6.05	0.26	0.79	0	104	100
Silkeborg	11	6.31	6.25	0.06	0.92	0	101	105
Kompedal 404	12	4.54	4.15	0.39	0.52	0	109	95
Løndal	27	5.40	5.01	0.39	0.87	0	108	100
Lindet	13	3.37	3.59	—0.22	0.56	0	94	98
Randbøl	14	4.02	3.52	0.50	0.83	0	114	106
Kompedal 197	15	3.71	3.55	0.16	0.48	0	104	104
Hesselcig	16	4.39	5.56	—1.17			79	84
Birkebæk	17	3.10	4.29	—1.19			72	96
Liebe	18	5.10	5.90	—0.80	0.72	—	86	103
Skygge	19	6.81	5.69	1.12	0.63	+	120	93
Agerskov	20	4.67	3.41	1.26	0.62	+	137	109
Haraldslund	21	2.45	3.50	—1.05	0.55	—	70	99
Harreskov	22	2.00	2.33	—0.33	0.47	0	86	89
Gludsted 52	23	6.53	6.09	0.44	0.47	0	107	101
Gludsted 142	24	5.12	4.71	0.41	0.45	0	109	96

Table A13. A-experiment. Spruce. P-sub-experiment. Height. Further explanation in table A5.

Experiment		Fertilized plot H_B	Control plots H_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.			Effect $H_B - H_K$	L.S.D. (5 %)	Significance	$\frac{H_B}{H_K}$ 100	
		m	m	m	m			
Bidstrup	01	8.87	9.28	—0.41			96	100
Brahetrolleborg	02	8.36	8.91	—0.55			94	83
Bregentved	03	9.63	9.99	—0.36	0.52	0	96	93
Gjorslev	04	7.73	7.13	0.60	0.61	+	109	167
Sorø I. Højb.	05	5.94	6.23	—0.29			95	93
Sorø I. Blødb.	05	3.25	3.69	—0.44			88	105
Valdemar Slot	06	5.83	5.85	—0.02			100	99
Frederiksborg	07	6.01	5.85	0.16	0.65	0	103	111
Hvidkilde	08	5.53	6.11	—0.58	0.49	—	91	102
Nødebo	09	6.60	6.40	0.20	0.57	0	103	
Lindenborg	10	5.82	5.89	—0.07			99	99
Silkeborg	11	5.13	5.18	—0.05	0.52	0	99	98
Kompedal 404	12	4.14	4.17	—0.03			99	117
Løndal	27	4.39	4.65	—0.26	0.59	0	94	99
Lindet	13	2.19	2.15	0.04	0.30	0	102	98
Randbøl	14	2.61	2.48	0.13	0.34	0	105	103
Kompedal 197	15	1.47	1.36	0.11	0.16	0	108	96
Hesselvig	16	2.52	3.19	—0.67	0.58	—	79	83
Birkebæk	17	3.53	2.77	0.76	0.44	+	128	98
Liebe	18	4.26	4.07	0.19			105	96
Skygge	19	3.50	3.55	—0.05	0.31	0	99	103
Agerskov	20	2.19	2.25	—0.06	0.43	0	97	96
Haraldslund	21	1.99	2.01	—0.02	0.39	0	99	95
Harreskov	22	2.38	2.11	0.27	0.35	0	113	102
Gludsted 52	23	4.06	3.89	0.17			104	100
Gludsted 142	24	4.28	4.17	0.11	0.27	0	103	101

Table A14. A-experiment. Spruce. P-sub-experiment. Diameter. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	8.12	8.65	—0.53	1.03	0	94	100
Brahetrolleborg	02	9.18	9.51	—0.33			96	83
Bregentved	03	9.25	9.62	—0.37	0.78	0	96	93
Gjorslev	04	9.15	7.99	1.16	1.03	+	115	167
Sorø I. Højb.	05	6.83	6.86	—0.03			100	93
Sorø I. Blødb.	05	3.80	4.33	—0.53			88	105
Valdemar Slot	06	6.50	6.48	0.02			100	99
Frederiksborg	07	7.56	7.43	0.13	0.96	0	102	111
Hvidkilde	08	7.11	8.13	—1.02	0.93	—	88	102
Nødebo	09	8.92	7.83	1.09	0.92	+	114	
Lindenborg	10	6.21	6.63	—0.42			94	99
Silkeborg	11	6.05	6.28	—0.23	0.82	0	96	98
Kompedal 404	12	5.26	5.35	—0.09	0.58	0	98	117
Løndal	27	5.48	5.80	—0.32	1.00	0	95	99
Lindet	13	3.72	3.78	—0.06	0.51	0	98	98
Randbøl	14	3.29	3.18	0.11	0.71	0	104	103
Kompedal 197	15	2.80	2.75	0.05	0.39	0	102	96
Hesselvig	16	4.45	5.66	—1.21	1.05	—	79	83
Birkebæk	17	5.67	4.65	1.02	0.80	+	122	98
Liebe	18	5.68	5.55	0.13			102	96
Skygge	19	5.84	5.74	0.10	0.59	0	102	103
Agerskov	20	3.36	3.67	—0.31	0.73	0	92	96
Haraldslund	21	3.46	3.51	—0.05	0.73	0	98	95
Harreskov	22	3.40	2.86	0.54	0.60	0	119	102
Gludsted 52	23	5.94	5.73	0.21	0.53	0	104	100
Gludsted 142	24	5.55	5.45	0.10	0.50	0	102	101

Table A15. A-experiment. Spruce. P/2-sub-experiment. Height. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	8.72	9.28	—0.56	0.87	0	94	114
Brahetrolleborg	02	8.78	8.58	0.20	0.57	0	102	109
Bregentved	03	9.75	9.45	0.30	0.56	0	103	94
Gjorslev	04	8.55	8.34	0.21	0.64	0	103	76
Sorø I. Blødb.	05	3.31	3.75	—0.44	0.37	—	88	105
Valdemar Slot	06	5.82	5.91	—0.09			99	99
Frederiksborg	07	6.14	5.86	0.28	0.62	0	105	107
Hvidkilde	08	6.46	6.30	0.16	0.50	0	103	95
Nødebo	09	7.12	6.90	0.22	0.69	0	103	
Lindenborg	10	6.58	6.09	0.49	0.46	+	108	98
Silkeborg	11	4.95	4.92	0.03	0.51	0	101	107
Kompedal 404	12	3.83	3.59	0.24			107	101
Løndal	27	4.10	4.17	—0.07	0.49	0	98	97
Lindet	13	2.71	2.40	0.31			113	103
Randbøl	14	3.00	2.80	0.20	0.34	0	107	101
Kompedal 197	15	2.33	2.12	0.21	0.27	0	110	102
Hesselvig	16	3.47	3.19	0.28	0.62	0	109	88
Birkebæk	17	3.54	3.13	0.41	0.40	+	113	95
Liebe	18	4.18	4.32	—0.14	0.56	0	97	92
Skygge	19	3.18	3.11	0.07	0.39	0	102	101
Agerskov	20	2.18	2.16	0.02	0.34	0	101	100
Haraldslund	21	2.13	2.26	—0.13	0.29	0	94	115
Harreskov	22	1.62	1.40	0.22	0.35	0	116	98
Gludsted 52	23	4.27	4.21	0.06	0.24	0	101	97
Gludsted 142	24	3.89	3.63	0.26	0.24	+	107	103

Table A16. A-experiment. Spruce. P/2-sub-experiment. Diameter. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	7.89	8.73	—0.84	1.09	0	90	114
Brahetrolleborg	02	8.85	8.92	—0.07	0.97	0	99	109
Bregentved	03	9.78	9.56	0.22	0.89	0	102	94
Gjorslev	04	9.53	9.82	—0.29	1.15	0	97	76
Sorø I. Blødb.	05	3.60	4.20	—0.60	0.56	—	86	105
Valdemar Slot	06	6.67	6.85	—0.18			97	99
Frederiksborg	07	8.35	7.67	0.68	0.97	0	109	107
Hvidkilde	08	8.77	8.24	0.53	1.01	0	106	95
Nødebo	09	8.23	8.10	0.13	0.99	0	102	
Lindenborg	10	7.29	6.73	0.56	0.76	0	108	98
Silkeborg	11	5.70	5.80	—0.10	0.77	0	98	107
Kompedal 404	12	4.81	4.46	0.35			108	101
Løndal	27	5.22	5.18	0.04	0.81	0	101	97
Lindet	13	4.48	4.00	0.48			112	103
Randbøl	14	4.03	3.83	0.20			105	101
Kompedal 197	15	4.22	3.98	0.24	0.40	0	106	102
Hesselvig	16	6.03	5.82	0.21	1.02	0	104	88
Birkebæk	17	5.90	5.33	0.57	0.75	0	111	95
Liebe	18	6.01	6.07	—0.06	0.81	0	99	92
Skygge	19	5.63	5.58	0.05	0.77	0	101	101
Agerskov	20	3.57	3.58	—0.01	0.63	0	100	100
Haraldslund	21	3.51	3.85	—0.34	0.57	0	91	115
Harreskov	22	2.46	1.98	0.48	0.65	0	124	98
Gludsted 52	23	6.22	6.20	0.02	0.43	0	100	97
Gludsted 142	24	5.20	4.73	0.47	0.44	+	110	103

Table A17. A-experiment. Spruce. NKP-sub-experiment. Height. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	9.12	9.31	—0.19			98	86
Brahetrolleborg	02	9.01	9.22	—0.21	0.53	0	98	107
Bregentved	03	9.92	9.85	0.07	0.54	0	101	89
Gjorslev	04	7.47	7.79	—0.32			96	58
Sorø I. Blødb.	05	2.79	3.35	—0.56	0.47	—	83	68
Valdemar Slot	06	6.00	5.99	0.01			100	98
Frederiksborg	07	6.54	6.20	0.34	0.63	0	105	99
Hvidkilde	08	6.54	6.43	0.11	0.51	0	102	96
Nødebo	09	7.65	6.85	0.80	0.48	+	112	
Silkeborg	11	5.67	5.43	0.24	0.44	0	104	83
Kompedal 404	12	5.13	4.51	0.62	0.37	+	114	111
Løndal	27	5.20	4.89	0.31	0.66	0	106	76
Lindet	13	3.95	2.06	1.89	0.30	+	192	106
Randbøl	14	3.02	2.54	0.48	0.37	+	119	56
Kompedal 197	15	2.68	1.50	1.18			179	65
Hesselvig	16	4.29	3.28	1.01	0.69	+	117	72
Birkebæk	17	4.57	3.17	1.40	0.48	+	144	84
Liebe	18	4.38	4.56	—0.18	0.52	0	94	91
Skygge	19	4.36	3.48	0.88	0.31	+	125	98
Agerskov	20	3.73	2.45	1.28	0.47	+	152	91
Haraldslund	21	2.77	2.14	0.63	0.39	+	129	105
Harreskov	22	3.06	1.98	1.08	0.39	+	154	93
Gludsted 52	23	5.15	4.22	0.93	0.32	+	122	95
Gludsted 142	24	5.49	4.14	1.35	0.27	+	133	97

Table A18. A-experiment. Spruce. NKP-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect D_B - D_K cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Bidstrup	01	9.28	9.02	0.26	1.10	0	103	86
Brahetrolleborg	02	9.86	9.91	—0.05	1.11	0	100	107
Bregentved	03	10.28	9.61	0.67	0.90	0	107	89
Gjorslev	04	9.00	8.86	0.14	1.18	0	102	58
Sorø I. Blødb.	05	2.98	3.79	—0.81	0.75	—	79	68
Valdemar Slot	06	7.06	6.66	0.40	0.70	0	106	98
Frederiksborg	07	8.73	7.90	0.83	1.04	0	111	99
Hvidkilde	08	8.90	8.48	0.42	1.03	0	105	96
Nødebo	09	9.70	8.12	1.58	0.88	+	120	
Silkeborg	11	7.21	6.48	0.73	0.82	0	111	83
Kompedal 404	12	6.77	5.68	1.09	0.67	+	119	111
Løndal	27	6.99	6.08	0.91	1.10	0	115	76
Lindet	13	6.30	3.59	2.71	0.59	+	176	106
Randbøl	14	4.58	3.43	1.15	0.82	+	134	56
Kompedal 197	15	5.20	3.01	2.19			173	65
Hesselvig	16	8.36	5.83	2.53	1.29	+	143	72
Birkebæk	17	7.09	5.02	2.07	0.86	+	141	84
Liebe	18	6.24	6.06	0.18	0.92	0	103	91
Skygge	19	7.14	5.63	1.51	0.67	+	127	98
Agerskov	20	6.15	3.92	2.23	0.87	+	157	91
Haraldslund	21	4.33	3.59	0.74	0.74	0	121	105
Harreskov	22	4.74	2.60	2.14	0.69	+	182	93
Gludsted 52	23	7.48	6.28	1.20	0.64	+	119	95
Gludsted 142	24	7.51	5.30	2.21	0.53	+	142	97

Table A19. A-experiment. Spruce. Different sub-experiments. Height. Further explanation in table A5.

Experiment		Fertilizer	Fertilized plot H_B	Control plots H_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.				Effect $H_B - H_K$	L.S.D. (5 %)	Significance	$\frac{H_B}{H_K} 100$	
			m	m	m	m			
Gjorslev	04	1/2 NKP	8.42	7.59	0.83	0.62	+	111	77
Lindenborg	10	K	6.29	6.62	—0.33	0.47	0	95	
Lindenborg	10	K/2	5.51	5.89	—0.38	0.57	0	94	
Lindenborg	10	NKP	6.27	5.73	0.54			109	
Lindenborg	10	K_2SO_4	6.09	6.29	—0.20	0.47	0	97	
Lindenborg	10	1/2 K_2SO_4	5.64	5.18	0.46	0.58	0	109	
Kompedal 404'	12	$(NH_4)_2SO_4$	3.64	3.78	—0.14		0	96	108
Lindet	13	Nitrophoska	4.45	2.45	2.00	0.38	+	182	102
Kompedal 197	15	$(NH_4)_2SO_4$	2.34	2:28	0.06	0.27	0	103	100
Liebe	18	$CaHPO_4$	4.87	4.67	0.20	0.55	0	104	100
Skygge	19	$CaHPO_4$	3.92	3.57	0.35			110	93
Agerskov	20	3 P	2.52	2.16	0.36	0.34	+	117	123

Fertilizer:

1/2 NKP:	150 kg 15.5 % $Ca(NO_3)_2$, 50 kg 50 % KCl, 100 kg 18 % superphosphate, per ha/year (23 kg N + 21 kg K + 7.5 kg P)
K:	100 kg 50 % KCl per ha/year (42 kg K)
K/2:	50 kg 50 % KCl per ha/year (21 kg K)
NKP:	300 kg 15.5 % $Ca(NO_3)_2$ + 100 kg 50 % KCl + 200 kg 18 % superphosphate per ha/year (46 kg N + 42 kg K + 15 kg P)
K_2SO_4:	kg K_2SO_4 per ha/year (42 kg K)
1/2 K_2SO_4:	kg K_2SO_4 per ha/year (21 kg K)
$(NH_4)_2SO_4$:	65 kg $(NH_4)_2SO_4$ per ha/year (14 kg N)
Nitrophoska:	350 kg nitrophoska per ha/year (56 kg N + 58 kg K + 24 kg P)
$CaHPO_4$:	88 kg $CaHPO_4$ per ha/year (16 kg P)
3 P:	600 kg 18 % superphosphate per ha/year (45 kg P)

Table A20. A-experiment. Spruce. Different sub-experiments. Diameter. Further explanation in table A5. Fertilizers as in table A19.

Experiment		Fertilizer	Fertilized plot D_B	Control plots D_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.				Effect $D_B - D_K$	L.S.D. (5 %)	Significance	$\frac{D_B}{D_K} 100$	
			cm	cm	cm	cm			
Gjorslev	04	1/2 NKP	10.20	8.91	1.29	1.25	+	114	77
Lindenborg	10	K	6.29	7.33	—1.04	0.63	—	86	
Lindenborg	10	K/2	6.16	6.38	—0.22	0.82	0	97	
Lindenborg	10	NKP	6.52	6.52	0.00	0.86	0	100	
Lindenborg	10	K_2SO_4	6.65	6.78	—0.13	0.77	0	98	
Lindenborg	10	1/2 K_2SO_4	6.40	5.65	0.75	0.82	0	113	
Kompedal 404	12	$(NH_4)_2SO_4$	4.39	4.83	—0.44		0	91	108
Lindet	13	Nitrophoska	6.91	4.00	2.91	0.69	+	173	102
Kompedal 197	15	$(NH_4)_2SO_4$	4.22	4.21	0.01	0.43	0	100	100
Liebe	18	$CaHPO_4$	6.54	6.43	0.11	0.84	0	102	100
Skygge	19	$CaHPO_4$	6.46	6.15	0.31			105	93
Agerskov	20	3 P	4.08	3.65	0.43	0.63	0	112	123

Table A21. A-experiment. Beech. N-sub-experiment. Height. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	5.22	5.22	0.00			100	
Sønderborg, Nygård	03	5.87	6.59	—0.72	0.44	—	89	
Sønderborg, Øvelgunde	04	7.80	6.86	0.94			114	76
Valdemar Slot	05	7.28	6.99	0.29			104	107
Brahetrolleborg	06	5.84	5.35	0.49	0.35	+	109	
Bregentved, Ganneskov	07	4.69	5.05	—0.36	0.48	0	93	98
Bregentved, Boelskov	08	5.78	5.81	—0.03	0.37	0	100	107
Frederiksborg	09	4.78	4.97	—0.19	0.48	0	96	65
Hvidkilde	10	6.53	6.45	0.08	0.33	0	101	114
Nødebo	11	4.80	5.48	—0.68	0.39	—	88	101
Buderupholm	13	5.60	4.92	0.68	0.36	+	114	88
Viborg, Vindum	14	7.30	7.04	0.26	0.27	0	104	87
Frijsenborg, Tårup	15	4.98	5.29	—0.31	0.45	0	94	94
Frijsenborg, Sønderskov	16	5.43	5.65	—0.22	0.41	0	96	90
Lindenborg	17	3.23	3.14	0.09	0.23	0	103	
Lindet	18	6.96	7.66	—0.70			91	91
Nørlund	19	5.34	5.15	0.19	0.44	0	104	84
Palsgård, Velling	20	16.78	17.58	—0.80	2.26	0	96	86
Randbøl	21	5.74	5.77	—0.03	0.39	0	100	
Silkeborg	22	3.93	3.74	0.19	0.44	0	105	93
Løvenholm	23	2.49	2.67	—0.18			93	

Table A22. A-experiment. Beech. N-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	3.39	3.15	0.24	0.37	0	108	
Sønderborg, Nygård	03	4.32	4.74	—0.42	0.82	0	91	
Sønderborg, Øvelgunde	04	5.62	4.95	0.67			114	76
Valdemar Slot	05	4.73	4.91	—0.18	0.66	0	96	107
Brahetrolleborg	06	3.80	2.99	0.81	0.50	+	127	
Bregentved, Ganneskov	07	4.63	4.97	—0.34	0.81	0	93	98
Bregentved, Boelskov	08	4.88	4.69	0.19	0.59	0	104	107
Frederiksborg	09	3.53	3.88	—0.35	0.72	0	91	65
Hvidkilde	10	5.35	5.24	0.11	0.65	0	102	114
Nødebo	11	3.53	3.86	—0.33	0.59	0	91	101
Buderupholm	13	4.21	3.38	0.83	0.59	+	125	88
Viborg, Vindum	14	7.80	7.03	0.77	0.75	+	111	87
Frijsenborg, Tårup	15	4.05	4.23	—0.18	0.70	0	96	94
Frijsenborg, Sønderskov	16	4.95	4.67	0.28	0.74	0	106	90
Lindenborg	17	1.74	1.65	0.09	0.30	0	106	
Lindet	18	6.59	6.78	—0.19	0.97	0	97	91
Nørlund	19	3.67	3.35	0.32	0.62	0	109	84
Palsgård, Velling	20	22.59	20.24	2.35	3.32	0	112	86
Randbøl	21	4.32	4.59	—0.27			94	
Silkeborg	22	2.85	2.51	0.34	0.59	0	113	93
Løvenholm	23	1.58	1.63	—0.05			97	

Table A23. A-experiment. Beech. N/2-sub-experiment. Height. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	5.40	5.48	—0.08	0.36	0	99	
Sønderborg, Nygård	03	7.15	6.35	0.80			113	
Sønderborg, Øvelgunde	04	8.13	8.03	0.10	0.48	0	101	93
Valdemar Slot	05	7.58	7.39	0.19	0.51	0	103	89
Brahetrolleborg	06	6.74	6.14	0.60	0.24	+	110	
Bregentved, Ganneskov	07	4.14	4.33	—0.19	0.42	0	96	109
Bregentved, Boelskov	08	5.07	5.53	—0.46	0.36	—	92	104
Hvidkilde	10	6.41	6.40	0.01			100	109
Nødebo	11	5.38	5.81	—0.43	0.34	—	93	103
Wedellsborg	12	6.38	6.79	—0.41			94	108
Buderupholm	13	4.84	4.53	0.31	0.40	0	107	94
Viborg, Vindum	14	4.96	5.53	—0.57			90	106
Frijsenborg, Tårup	15	5.58	5.43	0.15	0.56	0	103	113
Frijsenborg, Sønderskov	16	5.62	5.70	—0.08	0.35	0	99	101
Lindenborg	17	3.75	3.37	0.38			111	
Lindet	18	6.88	6.22	0.66	0.62	+	111	86
Nørlund	19	5.11	4.95	0.16	0.47	0	103	107
Palsgård, Velling	20	14.83	14.76	0.07	0.92	0	100	150
Randbøl	21	5.34	5.34	0.00	0.35	0	100	
Silkeborg	22	4.69	4.44	0.25	0.50	0	106	103
Løvenholm	23	2.46	2.19	0.27	0.27	0	112	

Table A24. A-experiment. Beech. N/2-sub-experiment. Diameter. Further explanation in table A5.

Experiment		Fertilized plot D_B	Control plots D_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.			Effect $D_B - D_K$	L.S.D. (5 %)	Significance	$\frac{D_B}{D_K} 100$	
		cm	cm	cm	cm			
Sorø I	02	3.11	3.44	—0.33	0.47	0	90	
Sønderborg, Nygård	03	5.51	4.67	0.84	0.79	+	118	
Sønderborg, Øvelgunde	04	6.43	6.08	0.35	0.93	0	106	93
Valdemar Slot	05	5.73	5.56	0.17	0.72	0	103	89
Brahetrolleborg	06	4.69	3.64	1.05	0.52	+	129	
Bregentved, Ganneskov	07	4.39	4.40	—0.01	0.73	0	100	109
Bregentved, Boelskov	08	3.87	4.66	—0.79	0.55	—	82	104
Hvidkilde	10	4.81	4.71	0.10	0.59	0	102	109
Nødebo	11	4.26	4.49	—0.23	0.63	0	95	103
Wedellsborg	12	5.74	6.17	—0.43	0.70	0	93	108
Buderupholm	13	3.63	3.28	0.35	0.64	0	111	94
Viborg, Vindum	14	5.41	5.58	—0.17			97	106
Frijsenborg, Tårup	15	4.46	4.25	0.21	0.83	0	105	113
Frijsenborg, Sønderskov	16	4.80	4.58	0.22	0.67	0	105	101
Lindenborg	17	2.28	1.85	0.43	0.34	+	124	
Lindet	18	6.55	5.09	1.46	0.97	+	129	86
Nørlund	19	4.00	3.76	0.24	0.68	0	106	107
Palsgård, Velling	20	15.68	16.65	—0.97	2.49	0	94	150
Randbøl	21	3.70	3.93	—0.23	0.52	0	94	
Silkeborg	22	3.02	3.02	0.00	0.63	0	100	103
Løvenholm	23	1.28	1.05	0.23	0.27	0	122	

Table A25. A-experiment. Beech. K-sub-experiment. Height. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	5.33	5.61	—0.28	0.32	0	95	
Sønderborg, Nygård	03	6.29	6.68	—0.39	0.46	0	94	
Sønderborg, Øvelgunde	04	6.74	6.40	0.34	0.40	0	105	80
Valdemar Slot	05	7.37	7.60	—0.23			97	85
Brahetrolleborg	06	5.21	5.41	—0.20	0.29	0	96	
Bregentved, Ganneskov	07	4.67	4.84	—0.17	0.52	0	97	104
Bregentved, Boelskov	08	5.69	5.91	—0.22	0.38	0	96	101
Frederiksborg	09	4.96	4.98	—0.02	0.58	0	100	116
Hvidkilde	10	6.20	6.32	—0.12	0.33	0	98	98
Nødebo	11	5.64	5.61	0.03	0.36	0	101	102
Wedellsborg	12	6.34	6.62	—0.28	0.37	0	96	97
Buderupholm	13	5.08	4.91	0.17	0.44	0	104	105
Viborg, Vindum	14	6.34	6.33	0.01			100	115
Frijsenborg, Tårup	15	5.31	4.82	0.49	0.44	+	110	112
Frijsenborg, Sønderskov	16	5.62	5.62	0.00	0.43	0	100	102
Lindenborg	17	3.41	3.31	0.10			103	
Lindet	18	7.09	7.53	—0.44			94	105
Nørlund	19	5.33	5.19	0.14	0.47	0	103	95
Palsgård, Velling	20	16.77	16.55	0.22			101	112
Randbøl	21	5.67	5.90	—0.23	0.37	0	96	
Silkeborg	22	2.94	3.45	—0.51			85	54
Løvenholm	23	2.51	2.78	—0.27	0.24	—	90	

Table A26. A-experiment. Beech. K-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect D_B - D_K cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	3.75	3.45	0.30	0.48	0	109	
Sønderborg, Nygård	03	4.64	5.10	—0.46	0.83	0	91	
Sønderborg, Øvelgunde	04	4.62	4.24	0.38	0.59	0	109	80
Valdemar Slot	05	4.93	5.07	—0.14	0.64	0	97	85
Brahetrolleborg	06	2.85	2.96	—0.11	0.39	0	97	
Bregentved, Ganneskov	07	4.58	5.26	—0.68	0.87	0	87	104
Bregentved, Boelskov	08	4.41	4.99	—0.58	0.60	0	88	101
Frederiksborg	09	3.97	4.00	—0.03	0.88	0	99	116
Hvidkilde	10	4.98	5.46	—0.48	0.70	0	91	98
Nødebo	11	3.81	4.16	—0.35	0.60	0	91	102
Wedellsborg	12	5.09	5.24	—0.15	0.62	0	97	97
Buderupholm	13	3.88	3.46	0.42	0.56	0	112	105
Viborg, Vindum	14	5.75	5.95	—0.20			97	115
Frijsenborg, Tårup	15	4.86	3.86	1.00	0.78	+	126	112
Frijsenborg, Sønderskov	16	4.74	4.63	0.11	0.74	0	102	102
Lindenborg	17	2.32	1.66	0.66	0.29	+	140	
Lindet	18	6.09	6.77	—0.68	1.03	0	90	105
Nørlund	19	4.10	3.66	0.44	0.70	0	112	95
Palsgård, Velling	20	19.75	18.41	1.34	2.73	0	107	112
Randbøl	21	4.33	4.63	—0.30			94	
Silkeborg	22	1.93	2.26	—0.33			85	54
Løvenholm	23	1.34	1.71	—0.37			78	

Table A27. A-experiment. Beech. K/2-sub-experiment. Height. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	5.45	5.15	0.30			106	
Sønderborg, Nygård	03	5.87	5.70	0.17	0.44	0	103	
Sønderborg, Øvelgunde	04	7.50	7.32	0.18			103	93
Valdemar Slot	05	7.40	7.59	—0.19	0.46	0	98	109
Brahetrolleborg	06	5.37	5.97	—0.60	0.28	—	90	
Bregentved, Ganneskov	07	4.59	4.50	0.09	0.48	0	102	105
Bregentved, Boelskov	08	5.29	5.59	—0.30	0.35	0	95	100
Hvidkilde	10	6.02	6.20	—0.18			97	111
Nødebo	11	4.38	4.68	—0.30			94	105
Buderupholm	13	4.38	4.09	0.29	0.39	0	107	101
Viborg, Vindum	14	4.62	4.57	0.05	0.59	0	101	107
Frijsenborg, Tårup	15	5.72	5.55	0.17	0.53	0	103	88
Frijsenborg, Sønderskov	16	5.58	5.63	—0.05	0.42	0	99	104
Lindenborg	17	3.99	3.89	0.10	0.35	0	103	
Lindet	18	5.81	6.69	—0.88	0.46	—	87	112
Nørlund	19	5.03	4.70	0.33			107	70
Palsgård, Velling	20	14.53	14.66	—0.13	0.90	0	99	126
Randbøl	21	5.78	5.60	0.18			103	
Silkeborg	22	4.19	4.15	0.04	0.51	0	101	76

Table A28. A-experiment. Beech. K/2-sub-experiment. Diameter. Further explanation in table A5.

Experiment Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	3.46	3.46	0.00	0.51	0	100	
Sønderborg, Nygård	03	4.26	4.35	—0.09	0.59	0	98	
Sønderborg, Øvelgunde	04	5.80	5.42	0.38			107	93
Valdemar Slot	05	5.07	5.47	—0.40	0.69	0	93	109
Brahetrolleborg	06	3.35	3.56	—0.21	0.42	0	94	
Bregentved, Ganneskov	07	4.38	4.40	—0.02	0.72	0	100	105
Bregentved, Boelskov	08	4.29	4.52	—0.23	0.54	0	95	100
Hvidkilde	10	4.24	4.62	—0.38	0.52	0	92	111
Nødebo	11	3.07	3.38	—0.31	0.40	0	91	105
Buderupholm	13	3.78	3.08	0.70	0.58	+	123	101
Viborg, Vindum	14	4.51	4.54	—0.03	0.88	0	99	107
Frijsenborg, Tårup	15	4.88	4.43	0.45	0.88	0	110	88
Frijsenborg, Sønderskov	16	4.54	4.71	—0.17	0.68	0	96	104
Lindenborg	17	2.48	2.04	0.44	0.33	+	121	
Lindet	18	4.59	5.65	—1.06			81	112
Nørlund	19	4.52	3.38	1.14	0.74	+	134	70
Palsgård, Velling	20	14.75	16.67	—1.92	2.27	0	89	126
Randbøl	21	4.42	4.26	0.16	0.60	0	104	
Silkeborg	22	2.82	2.83	—0.01	0.64	0	100	76

Table A29. A-experiment. Beech. P-sub-experiment. Height. Further explanation in table A5.

Experiment		Fertilized plot H_B	Control plots H_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.	m	m	Effect H_B - H_K m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}$ 100	
Sorø I	02	5.77	5.60	0.17	0.34	0	103	
Sønderborg, Nygård	03	6.52	6.46	0.06	0.43	0	101	
Sønderborg, Øvelgunde	04	7.16	6.81	0.35			105	112
Valdemar Slot	05	8.09	8.01	0.08	0.47	0	101	112
Brahetrolleborg	06	6.10	5.59	0.51	0.35	+	109	
Bregentved, Ganneskov	07	4.59	4.47	0.12			103	108
Bregentved, Boelskov	08	5.74	5.60	0.14			103	99
Frederiksborg	09	4.61	4.70	—0.09	0.49	0	98	71
Hvidkilde	10	6.27	6.25	0.02	0.35	0	100	93
Nødebo	11	5.34	5.58	—0.24	0.44	0	96	110
Wedellsborg	12	6.42	6.62	—0.20	0.37	0	97	86
Buderupholm	13	4.63	4.90	—0.27	0.51	0	94	91
Viborg, Vindum	14	4.95	5.87	—0.92	0.55	—	84	122
Frijsenborg, Tårup	15	4.67	5.27	—0.60			89	138
Frijsenborg, Sønderskov	16	5.83	5.56	0.27	0.44	0	105	103
Lindenborg	17	3.44	3.63	—0.19	0.31	0	95	
Lindet	18	7.02	7.12	—0.10	0.61	0	99	101
Nørlund	19	5.03	5.10	—0.07	0.47	0	99	105
Palsgård, Velling	20	16.33	16.01	0.32	0.84	0	102	116
Randbøl	21	5.62	5.61	0.01	0.46	0	100	
Silkeborg	22	3.80	3.74	0.06			102	137
Løvenholm	23	2.41	2.47	—0.06	0.23	0	97	

Table A30. A-experiment. Beech. P-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	3.67	3.78	—0.11	0.48	0	97	
Sønderborg, Nygård	03	4.35	5.07	—0.72	0.77	0	86	
Sønderborg, Øvelgunde	04	4.58	4.41	0.17	0.62	0	104	112
Valdemar Slot	05	5.93	5.50	0.43	0.81	0	108	112
Brahetrolleborg	06	3.75	3.34	0.41	0.55	0	112	
Bregentved, Ganneskov	07	4.84	4.66	0.18			104	108
Bregentved, Boelskov	08	4.56	4.47	0.09			102	99
Frederiksborg	09	4.20	4.08	0.12	0.74	0	103	71
Hvidkilde	10	5.14	5.24	—0.10	0.74	0	98	93
Nødebo	11	3.73	4.12	—0.39	0.59	0	91	110
Wedellsborg	12	5.42	5.50	—0.08	0.74	0	99	86
Buderupholm	13	3.51	3.52	—0.01	0.57	0	100	91
Viborg, Vindum	14	4.52	5.57	—1.05			81	122
Frijsenborg, Tårup	15	3.83	4.69	—0.86			82	138
Frijsenborg, Sønderskov	16	4.78	4.66	0.12	0.73	0	103	103
Lindenborg	17	2.04	1.79	0.25	0.29	0	114	
Lindet	18	6.37	6.18	0.19	0.93	0	103	101
Nørlund	19	3.36	3.89	—0.53	0.63	0	86	105
Palsgård, Velling	20	19.11	18.25	0.86	1.81	0	105	116
Randbøl	21	4.32	4.06	0.26	0.63	0	106	
Silkeborg	22	2.34	2.18	0.16			108	137
Løvenholm	23	1.36	1.38	—0.02	0.24	0	99	

Table A31. A-experiment. Beech. P/2-sub-experiment. Height. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}$ 100	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	5.49	5.12	0.37	0.43	+	107	
Sønderborg, Nygård	03	6.11	5.73	0.38	0.41	+	107	
Sønderborg, Øvelgunde	04	8.62	8.14	0.48	0.38	+	106	86
Valdemar Slot	05	7.58	7.52	0.06	0.43	0	101	83
Brahetrolleborg	06	5.81	6.28	—0.47			93	
Bregentved, Ganneskov	07	4.65	4.91	—0.26	0.42	0	95	97
Bregentved, Boelskov	08	5.54	5.49	0.05	0.39	0	101	88
Hvidkilde	10	5.78	5.90	—0.12	0.28	0	98	119
Nødebo	11	4.51	4.66	—0.15	0.31	0	97	97
Buderupholm	13	3.82	3.67	0.15	0.40	0	104	120
Frijsenborg, Tårup	15	6.06	5.75	0.31	0.55	0	105	82
Frijsenborg, Sønderskov	16	5.65	5.47	0.18	0.42	0	103	106
Lindenborg	17	2.92	3.21	—0.29			91	
Lindet	18	6.26	6.86	—0.60	0.55	—	91	94
Nørlund	19	4.59	4.62	—0.03			100	105
Palsgård, Velling	20	15.54	15.17	0.37			103	73
Randbøl	21	5.44	5.51	—0.07			99	
Silkeborg	22	3.50	3.74	—0.24	0.46	0	93	92

Table A32. A-experiment. Beech. P/2-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K} 100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	3.77	3.56	0.21	0.58	0	106	
Sønderborg, Nygård	03	4.22	4.12	0.10			102	
Sønderborg, Øvelgunde	04	5.49	4.98	0.51	0.72	0	110	86
Valdemar Slot	05	5.37	5.41	—0.04	0.72	0	99	83
Brahetrolleborg	06	3.56	3.82	—0.26			93	
Bregentved, Ganneskov	07	4.27	4.72	—0.45	0.68	0	91	97
Bregentved, Boelskov	08	4.34	4.51	—0.17	0.62	0	96	88
Hvidkilde	10	4.13	4.20	—0.07	0.45	0	98	119
Nødebo	11	3.16	3.29	—0.13	0.46	0	96	97
Buderupholm	13	2.90	3.01	—0.11	0.58	0	96	120
Frijsenborg, Tårup	15	5.07	4.39	0.68	0.87	0	115	82
Frijsenborg, Sønderskov	16	4.62	4.56	0.06	0.66	0	101	106
Lindenborg	17	1.58	1.70	—0.12			93	
Lindet	18	5.43	6.05	—0.62	0.92	0	90	94
Nørlund	19	3.53	3.32	0.21	0.62	0	107	105
Palsgård, Velling	20	17.81	16.53	1.28	3.59	0	108	73
Randbøl	21	3.87	4.51	—0.64	0.63	—	86	
Silkeborg	22	2.03	2.29	—0.26	0.48	0	89	92

Table A33. A-experiment. Beech. NKP-sub-experiment. Height.
Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot H_B m	Control plots H_K m	Fertilizing effect: Effect $H_B - H_K$ m	L.S.D. (5 %) m	Significance	$\frac{H_B}{H_K}100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	5.40	5.47	—0.07	0.37	0	99	
Sønderborg, Nygård	03	6.56	6.55	0.01	0.41	0	100	
Sønderborg, Øvelgunde	04	7.29	7.12	0.17	0.42	0	102	108
Valdemar Slot	05	8.06	7.70	0.36			105	103
Brahetrolleborg	06	6.18	5.95	0.23	0.30	0	104	
Bregentved, Ganneskov	07	4.21	4.16	0.05	0.37	0	101	84
Bregentved, Boelskov	08	5.47	5.33	0.14	0.37	0	103	101
Frederiksborg	09	5.24	4.72	0.52	0.47	+	111	93
Hvidkilde	10	6.10	6.10	0.00	0.37	0	100	79
Nødebo	11	5.15	5.69	—0.54	0.33	—	91	92
Wedellsborg	12	6.76	6.78	—0.02			100	103
Buderupholm	13	5.07	4.60	0.47	0.51	0	110	96
Viborg, Vindum	14	5.79	6.36	—0.57	0.47	—	91	93
Frijsenborg, Tårup	15	6.12	5.79	0.33	0.53	0	106	90
Frijsenborg, Sønderskov	16	5.71	5.68	0.03	0.35	0	101	98
Lindenborg	17	3.57	3.16	0.41			113	
Lindet	18	5.30	6.67	—1.37			79	92
Palsgård, Velling	20	15.02	15.25	—0.23	1.00	0	99	154
Randbøl	21	4.87	5.36	—0.49	0.41	—	91	
Silkeborg	22	4.59	4.35	0.24	0.50	0	105	97
Løvenholm	23	2.00	2.21	—0.21			91	

Table A34. A-experiment. Beech. NKP-sub-experiment. Diameter. Further explanation in table A5.

Experiment: Designation	No.	Fertilized plot D_B cm	Control plots D_K cm	Fertilizing effect: Effect $D_B - D_K$ cm	L.S.D. (5 %) cm	Significance	$\frac{D_B}{D_K}100$	Relative number of stems in fertilized plots. Control plots = 100
Sorø I	02	3.39	3.66	—0.27			93	
Sønderborg, Nygård	03	5.25	5.12	0.13	0.84	0	103	
Sønderborg, Øvelgunde	04	5.13	4.72	0.41	0.65	0	109	108
Valdemar Slot	05	6.08	5.74	0.34	0.71	0	106	103
Brahetrolleborg	06	4.41	3.56	0.85	0.61	+	124	
Bregentved, Ganneskov	07	4.86	4.19	0.67	0.68	0	116	84
Bregentved, Boelskov	08	4.38	4.14	0.24	0.58	0	106	101
Frederiksborg	09	4.49	3.87	0.62			116	93
Hvidkilde	10	5.64	5.08	0.56	0.80	0	111	79
Nødebo	11	4.39	4.35	0.04	0.64	0	101	92
Wedellsborg	12	6.00	6.05	—0.05	0.76	0	99	103
Buderupholm	13	4.10	3.42	0.68	0.65	+	120	96
Viborg, Vindum	14	6.62	6.48	0.14	1.08	0	102	93
Frijsenborg, Tårup	15	5.77	4.87	0.90			118	90
Frijsenborg, Sønderskov	16	5.15	4.56	0.59	0.71	0	113	98
Lindenborg	17	2.17	1.76	0.41	0.32	+	123	
Lindet	18	5.26	5.56	—0.30	0.95	0	95	92
Palsgård, Velling	20	15.90	18.05	—2.15	2.96	0	88	154
Randbøl	21	4.48	4.36	0.12	0.67	0	103	
Silkeborg	22	3.02	2.73	0.29	0.56	0	111	97
Løvenholm	23	0.83	1.06	—0.23			78	

Table A35. A-experiment. Beech. Different sub-experiments. Height. Further explanation in table A5.

Experiment		Fertilizer	Fertilized plot H_B	Control plots H_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.				Effect $H_B - H_K$	L.S.D. (5 %)	Significance	$\frac{H_B}{H_K} 100$	
			m	m	m	m			
Lindet	18	Nitrophoska	7.50	7.09	0.41	0.57	0	106	95
Nørlund	19	3 P	4.95	4.92	0.03	0.56	0	101	117
Nørlund	19	3/2 P	4.85	4.95	—0.10	0.43	0	98	112
Løvenholm	23	Urea	2.18	2.14	0.04			102	

Fertilizer:

Nitrophoska:	350 kg nitrophoska per ha/year (56 kg N + 58 kg K + 24 kg P)
3 P:	600 kg superphosphate per ha/year (45 kg P)
Urea:	100 kg urea per ha/year (47 kg N)

Table A36. A-experiment. Beech. Different sub-experiments. Diameter. Further explanation in table A5. Fertilizers as in table A35.

Experiment		Fertilizer	Fertilized plot D_B	Control plots D_K	Fertilizing effect				Relative number of stems in fertilized plots. Control plots = 100
Designation	No.				Effect $D_B - D_K$	L.S.D. (5 %)	Significance	$\frac{D_B}{D_K} 100$	
			cm	cm	cm	cm			
Lindet	18	Nitrophoska	6.42	5.80	0.62	0.91	0	111	95
Nørlund	19	3 P	3.10	3.43	—0.33	0.64	0	90	117
Nørlund	19	3/2 P	3.77	3.74	0.03	0.66	0	101	112
Løvenholm	23	Urea	1.01	0.98	0.03			104	

B. TESTING OF THE SAME FERTILIZERS AS USED IN THE A-EXPERIMENTS, ON MIDDLE-AGED STANDS OF BEECH, SPRUCE AND ASH — THE SOIL NOT BEING WORKED

I. SURVEY OF MATERIAL.

Localities, site classes, ages, treatment and soil analyses of the material will appear from Table 12.

Each B-Experiment comprises two sample plots, the sizes of which, as will be seen, vary from 0·05 to 0·36 hectare (Table 12). One plot has been treated with fertilizer as follows:

750 kg 15·5 % calcium nitrate	per ha. each year in
250 kg 50·0 % potassium muriate	April, or as an excep-
500 kg 18·0 % superphosphate	tion, a little later.

This is 2½ times the quantities given in the A-experiments but they are not exceeding what has been used with good results in wheat-growing.

The treatment was repeated 10 times from and including 1953 and until the spring of 1962. The fertilizer was spread on the ground in one application in April (or May). Surrounding the treated and measured plots is an 8 to 25 m wide belt (according to tree height), which has likewise been NKP-fertilized.*)

The other plot is unfertilized, serving as control. The distance between the plots varies from 12 to 70 metres. The B-experiments were thinned 2 or 3 times during the experimental period according to the practice of the district.

As regards index figures for the soil, see Table 12.

The effect of the treatment should appear as the difference between the increments of the two plots during the experimental period. It is necessary, however, to correct for differences in natural growth site class, which can only be done approximately.

*) In the spruce experiment in Gedhus plt. by a mistake a more than double dose of NKP was given the first year, the NKP destined for the isolation belt also being thrown on the plot proper. This had a very marked effect (see later).

Table 12. B-experiments.

Forest district	Forest	Compartment	Age from seed, spring 1964	Site class	Treatment	Plot ha.	Laboratory of the Danish Heath Society pH	Laboratory of the Danish Heath Society Ft	Laboratory of the Danish Heath Society Kt	Laboratory of the Danish Heath Society Fot	Nitrate fig.	State Laboratory of Plant Culture pH	State Laboratory of Plant Culture Ft	State Laboratory of Plant Culture Kt
BEECH														
Bidstrup	Avnstrup Overdrev	149	41	1.3	fertilized	0.22	4.2	1.4	8.0	0.2	0	4.1	1.2	10.8
					0	0.22	4.3	2.1	8.4	0.2	0	4.2	1.7	8.4
—	Hejede Overdrev	196	72	1.9	fertilized	0.36	4.5	1.2	6.7	0.5	0	4.4	0.6	7.0
					0	0.27	4.5	0.8	7.6	0.7	0	4.2	0.6	11.1
Bregentved	Boholte skov	V9	54	—	fertilized	0.17		—	—	—	—	4.7	1.3	7.3
					0	0.17								
Visborggaard	Nordskoven	94	41	1.5	fertilized	0.09	4.9	1.6	4.7	0.5	0			
					0	0.09								
NORWAY SPRUCE														
The Heath Society	Dalgas Plantation	20	57	6	fertilized	0.13	5.9	4.1	8.1	0.8				
					0	0.10								
—	Gedhus Plantation	16	59	5—6	fertilized*)	0.14	4.9	0.7	4.5	0.2				
					0	0.14								
ASH														
Havnø Lounkær		14	36	3	fertilized	0.05	3.9	0.5	2.5	0.2				
					0	0.05								

*) Double dose first year.

treatment 0 = not fertilized

Details about system of index figures Ft a. s. o., see tables 1 and 2 with text, p. 95.

The height and growth of the two equally old plots at the start of the experiments will be the best indication.

To be able to decide whether the treatment has had any effect it is necessary to coordinate the results from the four beech experiments, and likewise those from the two spruce experiments. This possibility does not exist in the small ash experiment.

II. DETAILED DESCRIPTION OF B-EXPERIMENTS.

BEECH

Bidstrup Forest District. Avnstrup Overdrev, Compt 149. (Zealand).

Culture planted in rows around 1925 after old Norway spruce.

The difference between the mean elevations of the two plots is insignificant. The northern plot (fertilized) has a slight slope to the east, the difference in levels between the western and eastern sides being 5 m. The southern plot is situated on a North-South ridge; the greater part of the area, however, is made up of the eastern slope. There is a difference in levels of about 2·5 m between the highest point and the lowest, which is situated at the eastern border. Thus, the difference in type between the two plots is not very great.

The distance between the centres of the plots is a little less than 100 m.

Soil. The rate of decomposition of the litter is 2—3 years. 5—7 cm light mor in good decomposition; 30—40 cm brown topsoil, slightly degraded, on a subsoil of very sandy loam.

The flora in 1953 on both plots was sparse and dominated by Oxalis, but comprising also Anemone, Asperula, Galium and Melica.

There are no ditches on the area, and the ground water table is at a rather great depth.

Bidstrup Forest District. Hejede Overdrev, Compt 196.

Artificial culture (method unknown), around 1890 after old spruce.

Difference in levels. The difference between the mean elevations of the two plots is 2 m, the western one being situated at the higher level.

The western plot (fertilized) has a fairly even slope with a southern aspect, the difference in levels between north and south being 5·5 m.

The eastern plot is comparatively level, though the south-easterly corner slopes evenly to the south-west to 2 metres below the level of the sample plot.

Also here the differences may be called small.

The distance between the centres of the plots is less than 100 m.

The soil. Rate of decomposition of the litter, 2—3 years. 4—5 cm light mor in good decomposition. About 35 cm topsoil, slightly degraded, on a topsoil of sandy loam. Scattered occurrence of 5—10 cm light, clayey hardpan.

The flora in 1963 was sparse and dominated by Oxalis on both plots, but comprised also Anemone, Asperula, Melampyrum and Stellaria hol. From the north a vigorous intrusion of Melica uniflora.

The ground water table is at a very great depth.

Bregentved Forest District. Boholte, Compt V 9. (Zealand).

Strip-sowing from 1910 after old beech.

The ground slopes slightly and evenly to the north-west. The greatest difference in levels within each plot is about 0.5 m. The distance between the centres of the plots is a little less than 100 m, and the difference in mean levels is significant.

There are no ditches on the area, and the ground water table is at a great depth.

The soil. Rate of decomposition of litter, 12—18 months. 3—5 cm granular mull on 20—40 cm rather light topsoil. Subsoil usually sandy loam, in places slightly loamy sand, the topsoil then being darker. The underground contains no lime.

The ground flora (1963) was abundant, dominated by Anemone, Asperula, Galeobdolon and Oxalis. Scattered occurrence of Geranium, Urtica dioeca, Mercurialis, Milium, Melica, Deschampsia caesp. and Juncus eff.

Visborggaard Forest District. Nordskoven, Compt 94. (East Jutland).

Densely planted culture (1924) in rows after old beech with ash intermingled.

The ground slopes evenly to the north. Greatest difference in levels within each sample plot is 1.5 m, and between the means of the two plots 2 m. Distance between centres of sample plots is about 100 m.

The fertilized plot is situated at the higher level.

Condition of mull: Excellent. Some small moist areas, where ash prevails. 40—60 cm dark topsoil rich in mull on a yellow, red-flamed subsoil ranging from loamy sand to sandy loam. No lime particles to be found.

Ground flora 1963: Abundant, dominated by Anemone, Asperula and Oxalis, with scattered occurrence of Mercurialis, Deschampsia caesp. and Geranium. On the fertilized plot Geranium and Urtica dioeca are also prominent, though not dominating.

On both plots plenty of self-sown ash, sycamore and a little beech, all heavily deer-bitten and seldom more than 0.5 m high.

NORWAY SPRUCE.

Dalgas Plantation, Compt 20, under The Danish Heath Society. (Central Jutland).

Norway spruce and Mountain pine planted in 1911—12 on heathland soil, which had been ploughed with an ordinary agricultural plow in 1904 and 1908, and trench-ploughed in 1910. At the start of the experiment (1953) the Mountain pine had long ago been felled.

The ground is flat, with variations in level of less than 0.5 m. Distance between the centres of the sample plots about 80 m.

The soil consists, at top, of an about 5 cm thick needle mor layer covered by moss. Under this layer a 35—40 cm thick layer made up of a mixture of bleached sand, hardpan, old heather mor and, in places, ploughed-up subsoil. Beneath these layers there is a dark brown precipitate layer — not cemented — with an undefined transition to the subsoil, which consists of yellow/yellowish-red, rather coarse pure sand, in places with some pebbles. The precipitate layer is thought partly to be older than the spruces and partly to have been formed under these.

Flora. At the start of the experiment, the flora was completely dominated by mosses (Hylocomium, Dicranum, Polytricum, Ptilium, a. o.), and there was a sparse occurrence of slightly developed Deschampsia flex. and some lichen species. The same flora was to be found on the non-fertilized plot in 1964.

On the fertilized plot the moss vegetation was completely scorched during the first summer. At the conclusion of the experiment the plot was very light after the dead trees had been cut, and, largely, free from mosses, while now various herbs were found. (See, further, the text on page 213).

Gedhus Plantation, Compt 32, under The Danish Heath Society. (Central Jutland).

Norway spruce and Mountain pine planted in 1909 on heathland soil which previously had been used for some years for agricultural purposes. No deep-ploughing. Planting in ordinary furrows. By 1953 the Mountain pines had long ago been felled.

The ground is quite flat. Distance between centres of sample plots 70 m.

Soil. About 5 cm needle mor; about 20 cm mixture of humus and bleached sand; 5 cm rather firm humus hardpan; about 20 cm dark, rust-coloured sand on a yellow subsoil of rather coarse sand.

Flora. At the start of the experiment, the flora was similar to that in Dalgas Plantation, and also here, on the fertilized plot, the moss vegetation was completely scorched in the first summer.

At the conclusion of the experiment in the spring of 1964 the stand in the (northerly) fertilized plot was in a greater state of decay than was the case in Dalgas Plantation, and the intruded vegetation was still more vigorous — greatly dominated by Chamaenerium angustifolium.

Many of the remaining trees showed distinct signs of nitrogen-overfeeding — with bent, bushy tops, etc. (Cf. figures on p. 214).

Neither here, nor in Dalgas Plantation, were the roots able to reach groundwater table.

ASH.

Lounkær Forest District. Lounkær Forest, Compt 14 b. (East Jutland).

Natural reproduction of ash after a mixed stand of alder and ash, dominated by alder.

The ground: Quite flat. Ground water table never deeper than 1 m, in wintertime near the surface, though the area has ditches. Distance between centres of the two plots about 40 m.

The soil: About 20 cm black topsoil very rich in humus, changing abruptly to a light grey subsoil of loamy fine sand. The litter is decomposed in less than 12 months.

In 1963 the bottom flora was dominated (mentioned after frequense) by Spirea ulm., Baldingera arund., Rubus idaeus and R. caesius, Archangelica, Deschampsia caesp., Dryopteris thel. and Urtica dioeca.

On the fertilized plot the same flora was found, though greatly dominated by Urtica, so that the border between fertilized and unfertilized areas was conspicuously defined by a sudden increase in the height and density of the vegetation.

III. METHODS.

a. Determination of Basal Area, Diameter and Number of Stems.

The basal areas of the plots were measured the first time in the spring of 1953, when the experiments were started, and have since been measured in connection with the thinnings. The basal areas were last measured in the spring of 1964. The basal area of a plot has been measured by crosswise calipering of all trees at a height of 1.3 metres. With the exception of Visborggaard and Lounkær, the measuring height was everywhere indicated in 1953 with yellow paint on the southern side of all the trees. The diameters have been measured in centimetres with a steel caliper. The "diameter" of the plot is the diameter of the mean basal area (basal area/stem number).

The basal area increment in the experimental period is found from the following formula:

Basal area increment = basal area 1964 — basal area 1953 + the sum of thinned basal areas.

The basal areas are given in square metres per hectare.

The diameter increment is calculated from the mean diameter in 1964 minus the mean diameter in 1953, the difference being converted into annual increment in the experimental period.

The reduction in the number of stems is determined by the difference between the stem numbers of 1953 and 1964, the stem numbers being converted into number per hectare.

b. Measuring of Height Increment.

It is true that the stand height was measured at the start of the experiment, but only from the ground, and this measurement was not considered sufficiently accurate. Therefore, in the spring of 1964 the heights were measured on representatively selected sample trees which were felled. In the two spruce experiments and one beech experiment 20 sample trees were selected in each plot, in the rest of the beech experiments 12 sample trees per plot, and in the ash experiment 6 trees per plot. The selection of n sample trees was carried out by plotting a square grid with n nodal centres on each plot. The tree being nearest a nodal centre then became a sample tree. The degrees of representation vary from 10 to 16 per cent in the spruce experiments, and from 6 to 20 per cent in the beech experiments.

The sample trees were felled before measurement, the height being measured on the felled trees with a steel tape measure. Readings were in decimetres. Height is defined as the vertical distance between top and ground.

The average, annual height increment in the experimental period was likewise determined on the felled sample trees. In the spruce experiments this was done by measuring the eleven year-shoots (1953—1963). In the beech experiments, where year-shoots cannot be recognised, transversal stem discs were cut out at distances of 2.7 and 3.0 metres from the top of the sample trees, measured along a vertical line through the stem indicated before felling. The number of annual rings in the stem discs were counted under a microscope. From the stem discs of n sample trees it is now possible to determine the average number of years (the average age of stem discs) that have passed, until 2.7 and 3.0 metres' height increment, respectively, have been reached. Whether the 2.7-metre discs of the 3.0-metre discs are used, depends on which comes nearest to the 11 years. By dividing the average age of the stem discs into 2.7 or 3.0 metres, the average annual height increment is obtained.

c. Determination of Effect of Treatment.

The results of the treatment are determined — for heights, diameters and basal areas — by:

Treatment effect = increment of NKP plot — increment of control plot.

A definite, positive treatment effect must be supposed to mean, that the NKP fertilizing has promoted the growth.

It should be observed that, as far as the basal area is concerned, the effects of the treatment are directly dependent on the effects for stem numbers and diameters (basal area = $\frac{\pi}{4}$ (diameter)^2 $\times$ stem number).

The effects of the treatment have not been analysed by mathematical-statistical methods, because there are so few B-experiments.

As previously mentioned it is of importance whether the two plots of the individual experiments had the same growth site class at the start of the experiment. Such information can be gained from the tables which indicate the height in the spring of 1953 and the consequential site class, as the age is the same in the two plots of an experiment. (Ash experiment excepted).

It will be seen that the material does not hold out any one-sidedness in this respect.

Certainly, the two plots of an experiment may deviate in site class, but at times the better site class may be found in the fertilized plot and at other times in the unfertilized plot. In beech, the mean site class for the two groups is almost equal, while in spruce there is a tendency for the fertilized plots to have the lower site class, so that the positive effect of fertilization may perhaps be a little greater.

IV. RESULTS OF B-EXPERIMENTS

BEECH

The stem number column in Table 13 — when compared with the other columns — shows that while the thinnings in the two Bidstrup experiments are of the same grade in the NKP and the 0 plots, the NKP plot at Bregentved has been much more heavily thinned than the 0 plot, whereas at Visborggaard the 0 plot has been more heavily thinned than the NKP plot. However the deviations almost outweigh each other, and none of the thinning grades exceed the limit where, according to our thinning experiments, the grade of thinning has little or no influence on the increment (Cfr Carl Mar: Møller 1965, p. 469).

Table 13 and 14 show that neither the basal area increment nor the diameter increment in the experiment has been influenced appreciably by the fertilizing. The small average effects are amply outweighed by the measuring inaccuracy.

On the other hand, the vigorous NKP fertilization seems to have affected the height increment negatively (about 15 %), and as this effect is repeated in all 4 experiments by almost the same value, the result may be taken to be factual.

The observations leave no possibility of an explanation. Increased salt concentration in the soil in the early summer may be assumed to have made the absorption of water more difficult, or the fertilization may have affected the position of the uppermost branches giving them a stronger outward curving — cfr. the tops of the spruce in Gedhus Plantation (p. 213). Comparative measuring of the shoots of the last 3 or 4 years, recognisable on the bark in the two experiments, might have shed light on the question, but the problem had not yet arisen at that time.

The only effect of the fertilizing on the ground flora was that the number of nitratophilous herbs rose conspicuously.

NORWAY SPRUCE

The vigorous fertilization had in the first years the effect that many trees died, while, on the other hand, others displayed an exuberant growth, with dark-green rich crowns, while others again represented a middle stage.

The effect was apparent by the great stem number reduction in fertilized plots, particularly in Gedhus Plantation cfr. Table

T a b l e 1 3. B-Experiment — Beech. Stem number and basal area in treated plot (NKP) and in control plot (0). (For further details, see text).

B experiment	Treatment	Age, spring 1964, Years	Area, ha	Number of stems: Spring 1953, No./ha	Number of stems: Spring 1964, No./ha	Reduction 1953-64: Absolute, No./ha	Reduction 1953-64: Relative	Basal area: Spring 1953, m²/ha	Basal area: Thinning 53-64 m²/ha	Basal area: Spring 1964, m²/ha	Increment 1953-64: Absolute, m²/ha	Increment 1953-64: Relative
Bidstrup, 149	NKP	41	0.2224	2.603	1.533	1.070	93	14.00	7.04	25.65	17.63	101
	0		0.2197	2.581	1.425	1.156	100	12.18	7.04	23.61	17.47	100
Bidstrup, 196	NKP	72	0.3601	225	169	56	100	18.87	4.25	23.62	9.00	95
	0		0.2695	260	204	56	100	18.10	4.30	23.31	9.51	100
Bregentved	NKP	54	0.1686	534	427	107	149	16.38	3.78	26.00	13.40	93
	0		0.1674	532	460	72	100	16.49	4.07	26.77	14.35	100
Visborggård	NKP	41	0.0900	1.244	833	411	71	15.47	8.14	24.24	16.91	118
	0		0.0900	1.178	600	578	100	14.67	8.38	20.62	14.33	100
					Mean for NKP		103			Mean for NKP		102

Table 14. B-Experiments. Beech. Height and Diameter. Mean of height increments has been calculated on the basis of sample trees. (See text).

B-experiments	Treat-ment	Age, spring 1964	Height							Diameter			
			No. of sample trees	Spring 1953 m	Spring 1964 m	Site class 1953	Increment			Spring 1953, cm	Spring 1964, cm	Increment 1953-64	
							period, years	Absolute, cm/year	Rela-tive			Absolute, cm/year	Rela-tive
Bidstrup, 149	NKP	41	20	8.6	12.5	2.7	11.3	35.4	84	8.3	14.6	0.573	93
	0		20	9.1	13.7	2.5	9.5	42.1	100	7.7	14.5	0.618	100
Bidstrup, 196	NKP	72	12	24.8	27.1	0.8	12.9	20.9	77	32.7	42.1	0.854	113
	0		11	23.7	26.7	1.2	11.0	27.3	100	29.8	38.1	0.754	100
Bregentved	NKP	54	12	17.1	20.6	1.3	8.6	31.4	83	19.8	27.8	0.727	110
	0		12	17.6	21.8	1.2	7.9	38.0	100	19.9	27.2	0.663	100
Visborggård	NKP	41	12	13.9	17.7	0.6	7.8	34.6	88	12.6	19.2	0.600	80
	0		12	13.8	18.1	0.7	7.6	39.5	100	12.6	20.9	0.754	100
							Mean for NKP		83		Mean for NKP		100

The mean site class for the 4 experiments is 1.35 for NKP and 1.40 for the 0-plots.

Table 15. B-Experiment. Spruce. Stem number and basal area in treated plot (NKP) and in control plot (0). (See also text).

B experiment	Treatment	Age, spring 1964, Years	Area, ha	Number of stems: Spring 1953, No./ha	Spring 1964, No./ha	Reduction 1953-64: Absolute, No./ha	Relative	Basal area: Spring 1953 m²/ha	Thinning 53-64 m²/ha	Spring 1964 m²/ha	Increment 1953-64: Absolute, m²/ha	Relative
Dalgas, 20	NKP	57	0.1290	2.256	984	1.272	168	17.74	11.91	19.57	13.74	139
	0		0.1033	2.197	1.442	755	100	18.10	6.03	21.96	9.89	100
Gedhus, 32	NKP	59	0.1431	1.670	985	685	253	17.57	11.67	16.16	10.26	92
	0		0.1399	1.651	1.380	271	100	17.90	2.76	26.33	11.19	100

Table 16. B-Experiment. Spruce. Height and Diameter. (See also text).

B experiment	Treatment	Age spring 1964, years	No. of sample trees	Height: Spring 1953, m	Spring 1964, m	Increment 1953-64: Absolute, cm/year	Relative	Diameter: Spring 1953, cm	Spring 1964, cm	Increment 1953-64: Absolute, cm/year	Relative
Dalgas, 20	NKP	57	20	8.8	12.5	33.6	130	10.0	16.4	0.582	123
	0		20	9.3	12.1	25.8	100	10.2	15.4	0.472	100
Gedhus, 32	NKP	59	20	10.5	13.1	23.3	74	11.6	19.8	0.745	210
	0		20	10.6	14.1	31.5	100	11.7	15.6	0.354	100

The height 1953 = H_{1964} — height increment measured.

In Gedhus double dose of NKP was given in the first year.

15. Here, the reduction was so great that the basal area increment dropped by 8 %, while in Dalgas Plantation it rose by 39 %, and that also the height increment dropped (by 26 %), while in Dalgas Plantation it rose by 30 % (cfr. Table 16).

The height increment measured in Gedhus Plantation is, however, largely influenced by the great number of bent tops (cfr. Figs. 11 and 12), which, presumably, was a result of the vigorous nitrogen fertilizing. The height increment was measured, not as the total length of the year-shoots of the period, but as the difference in levels between the highest points at the beginning and the end of the period.

Whereas diameter, basal area and basal area increment were determined by calipering of the whole stand, heights and height increments were determined on 20 objectively selected sample trees in each plot (cfr. p. 207). Both basal area increments per hectare and height increments were thus determined on a solid basis, whereas the diameter increments may have been statistically affected by the deaths, e.g. because these may primarily have befallen smaller trees, as was actually the case in Gedhus Plantation. It is therefore not possible to attach full importance to the exceptionally large diameter increment in Gedhus Plantation.

Especially in the dry summer of 1955 there were many deaths.

Altogether, the experiment shows that the fertilizing has augmented the growth where the basal area per hectare was not reduced too much by deaths. It also shows that too vigorous fertilizing may kill many trees, probably due to too heavy a salt concentration. The experiment the first year demonstrates two different degrees of overfertilizing.

On the other hand, the experiment offers no indication of what can be obtained by a more moderate NKP fertilizing.

On the soil, the NKP fertilizing had the effect that the moss flora almost died out in the first year, and later redevelopment was slight.

In 1964 Chamaenerium was very abundant, though of weak development. In addition, various herbs, such as Senecio silv., Stellaria media, Circium arvensa, Dryopteris spec., as well as a few Taraxacum off. occurred — and in Dalgas Plantation two specimens of Sambucus racemosa taller than a man were found, surrounded by progeny. Also Deschampsia flexuosa is spreading;

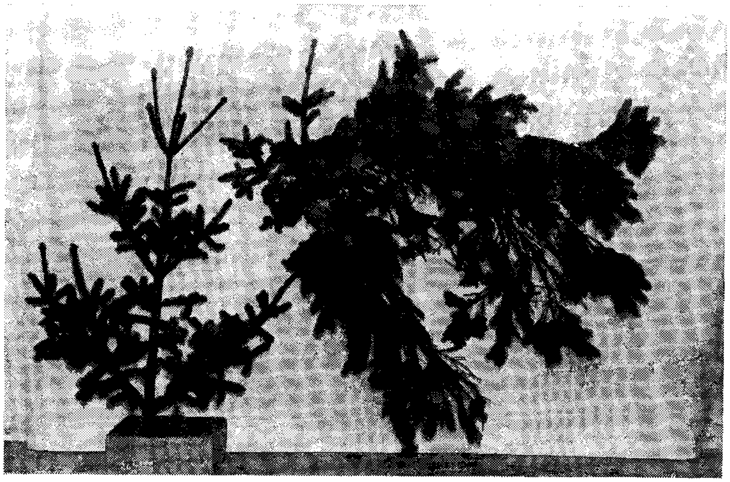


Fig. 11 & 12. Tops of overfed spruces in Gedhus Plantation, compt. 16, compared with normal tops to the left.
(Photo: J. Lundberg, 1965)

Fig. 11 & 12. Toppe af overernærede graner i Gedhus plantage afd. 16, sammenlignet med normale toppe til venstre.
(Foto: J. Lundberg 1965)

Table 17. B Experiment in Ash at Lounkær.

Treatment	Area ha	Age spring 1964, years	Basal area Spring 1953, m²/ha	Basal area Thinning 1953-64, m²/ha	Basal area Spring 1964, m²/ha	Increment 1953-64 m²/ha
NKP	0.0459	49	7.77	4.69	13.29	10.21
0	0.0459	42	8.17	6.21	10.02	8.06

	Height spring 1964 m	Height increment 1954-64 m	Height spring 1954 m
NKP plot	16.2	4.09	12.11
0 plot	13.8	3.25	10.55
Difference	2.4	0.84	1.56

and in Gedhus Plantation, where a track passed through the treated isolation belt of the fertilized plot, the NKP fertilization resulted in a conspicuously vigorous development of the cover of Deschampsia flex. on the track already in the first year.

The raw humus layer in the NKP-fertilized plots was remarkably thin, dark and slimy, apparently as a result of increased decomposition.

ASH

With regard to Table 17, it should be observed that the age of the two plots differs somewhat. According to a count on the stumps of the six sample trees, the unfertilized plot was 42 years, whereas the fertilized plot was 49 years.

This difference of seven years tallies very well with the height difference in 1953 and with the general impression of the stand at that time, the stand being a natural reproduction under old common alder intermingled with ash, felled in 1942.

As the basal area increment per hectare is normally falling with age, and as the grade of thinning in the two plots is the same, the greater basal area increment in the NKP plot must be regarded as a reality.

It is true that the height increment determination is based only on 6 objectively picked sample trees, but its result points in the same direction as the basal area increment determination.

We know that height increment is normally falling at that age, but in the experiment the oldest (and fertilized) plot has obviously had the greatest height increment.

It should be emphasized that the ground is completely flat and uniform.

The height increment in the NKP plot is, however, not significantly different from that of the 0 plot.

Altogether, there is a great probability that the fertilization has had a positive effect on increment.

But the effect is not considered great enough for the fertilizing to have been renumerative.

The effect on the ground flora was most striking, as the fertilized plot was very quickly filled with an extremely exuberant flora, dominated by Urtica dioeca.

A nearby control experiment, which had been going on for 6 years, with the same fertilization minus K and P, showed that the nettle growth was probably not brought about by the nitrogen fertilization, but by K or P or NKP.

C. EXPERIMENT ON FERTILIZATION OF SPRUCE CULTURES ON A MID-JUTLAND HEATH WITH AND WITHOUT SIMULTANEOUS HARROWING

With a view to elucidating the effect of harrowing on fertilized, respectively unfertilized spruce cultures on heath, a double strip experiment was established in 1955 in Dose Plantation under The Danish Heath Society, the result of which will appear from the following figures 13 and 14, demonstrating simultaneously the lay out in the field and the results obtained.

Each plot is 100 m long, each sub-plot being then 50 m. Each plot is 12 m wide and contains 7 longitudinal rows of Norway spruce. The plots are separated by a row of Japanese larch of the same age. In order to save space, the layout sketches have been compressed in the longitudinal direction of the plots.

It will be seen that the layout of the experiment is principally the same as that of the A-Experiments, cfr. p. 93, fig. 2.

The ground is a flat, meagre heath with a deep-lying ground water table, deep-ploughed in the summer of 1951. The hardpan had not been removed everywhere, but by a later drill-ploughing before planting, the soil was grubbed to a depth of 45 cm.

In 1951 a first and final application of 5.4 ts powdered lime, 1400 kg superphosphate and a little more than 600 kg 50 % potassic fertilizer were applied per hectare.

In 1952, 1953 and 1954 crops of rye were harvested, 450 kg/ha of ammonium sulphate being applied the first year and 360 kg/ha of calcium nitrate the 2nd and 3rd years, respectively.

In the spring of 1955 the area was planted with 2/2 Norway spruce in Bovlund-ploughed furrows, the rows and plants being spaced 1.5 m apart. All plots have 7 rows of Norway spruce separated by a row of Japanese larch. The rows follow the longitudinal direction of the plots.

The culture succeeded perfectly, and no beating up worth mentioning was necessary.

Fig. 13. Layout and Result of Experiment. Heights in metres in May 1963. (Figures in sub-plots).

Fig. 13. Plan af forsøget i Dose plantage. Tallene i del-parcellerne angiver højder i m i maj 1963.

Plot No.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Mean figures
Group A		1.39		1.52		1.64		1.91		1.88		1.73		1.80		1.70
(harrowed)	1.31		1.45		1.41		1.54		1.68		1.81		1.94		1.69	1.60
Track																
Group B		1.07		1.17		1.33		1.76		1.32		1.16		1.74		1.36
(not harrowed)	1.10		1.16		1.18		1.22		1.23		1.21		1.20		1.23	1.19
Fertilizer	0	P/2	0	K/2	0	N/2	0	N P K	0	P	0	K	0	N	0	

Fig. 14. Layout and Result of Experiment. Diameters in cm at 30 cm height in May 1963. (Figures in plot parts).

Fig. 14. Plan af forsøget i Dose plantage. Tallene i del-parcellerne angiver diametre i cm 30 cm over jorden i maj 1963.

Plot No.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Mean figures
Group A		2.33		2.54		2.81		3.60		3.22		3.17		3.43		3.01
(harrowed)	2.15		2.53		2.23		2.52		2.89		3.30		3.36		2.91	2.74
Track																
Group B		1.81		2.02		2.44		3.25		2.39		1.96		3.26		2.44
(not harrowed	1.85		1.98		1.96		2.01		2.23		2.15		2.17		2.16	2.06
Fertilizer	0	P/2	0	K/2	0	N/2	0	N P K	0	P	0	K	0	N	0	

All plots with even numbers have been fertilized, those with uneven numbers have not.

The plots of groups A and B have been equally fertilized, but Group A plots have been harrowed since the start of the experiment in 1955. Group B plots have not been harrowed.

The layouts have a northern aspect.

An access track separates Groups A and B.

Gruppe A harvet, Gruppe B ikke harvet. Gødskning som i A-forsøg, jvf. s. 92, ens i harvet og ikke harvet gruppe. 0 angiver ugødet kontrolparcel.

The fertilizing was done with the same quantities as in the A-Experiments (cfr p. 92) and took place each year in April, the first time in April of 1955, and has been continued after 1962. Also the annual harrowing started in 1955.

Before the fertilizing, samples for soil analysis were taken all over the area, by the method normally applied in agriculture (20 samples were mixed in a bucket and stirred thoroughly, after which a 1-kg sample was taken). The result of the analysis, calculated on new table values, was: $R_t = p_H = 5.1$; phosphoric acid number $F_t = 1.2$; phosphorus number $F_{ot} = 0.7$; potassium hydroxide number $K_t = 2.6$; nitrate number = 7. p_H was measured in distilled water. The unit for F_t and F_{ot} is 3 mg/P/100 g soil; that for K_t = mg K/100 g soil — all dry weight.

It will be seen that all the figures are rather high for heath conditions (cfr p. 97), as might be expected after the fertilizing.

In the 1963-measurement the heights and diameters of all the trees in the 5 middle rows of the plots were measured, with readings in decimetres and millimetres. The outermost two rows of each plot were left out to avoid any side effect from the rows of Japanese larch.

From the figures in the subplots of Figures 13 and 14 and their arithmetical means it appears that the harrowing has had a considerable effect, for harrowing alone of about the same magnitude as for the applied N-containing fertilizers alone.

The arithmetical means for the 0-plots are the following:
H = 1.19 m and D = 2.06 cm in Group B (not harrowed), and
H = 1.60 m and D = 2.74 cm in Group A (harrowed).

The average result of harrowing alone is thus an increase in height and diameter of 35 %. For the fertilized plots, the increase by harrowing is a little lower (25 % and 23 %, respectively), as a natural consequence of the increase in growth brought about by the fertilizing, especially the N-containing fertilizers. This increase has raised the average increment level, so that a certain increase in growth as a result of the harrowing must be related to a higher figure, which must give a lower percentage.

Also, the absolute increment increase due to the harrowing is smaller for the average of the fertilized plots than for that of the 0-plots.

The best explanation is, that where it has had a positive

Table 18. Effect on Height.

Experiment	Fertilizer	Fertilized plot H_B m	Mean of two adjacent 0-plots H_K m	Fertilizing effect: Absolute: Difference $H_B - H_K$ m	L.S.D. 5 % m	Significance	Relative $\frac{100 \cdot H_B}{H_K}$
Group A	N	1.80	1.81	—0.01	0.26	0	99
(with	K	1.73	1.87	—0.14	0.22	0	93
harrowing)	P	1.88	1.74	0.14	0.21	0	108
	NKP	1.91	1.61	0.30	0.24	+	119
	N/2	1.64	1.47	0.17	0.21	0	112
	K/2	1.52	1.43	0.09	0.17	0	106
	P/2	1.39	1.38	0.01	0.17	0	101
Group B	N	1.74	1.21	0.53	0.18	+	144
(without	K	1.16	1.21	—0.05	0.14	0	96
harrowing)	P	1.32	1.22	0.10	0.14	0	108
	NKP	1.76	1.23	0.53	0.16	+	143
	N/2	1.33	1.20	0.13	0.16	0	111
	K/2	1.17	1.17	0.00	0.13	0	100
	P/2	1.07	1.13	—0.06	0.13	0	95

Table 19. Effect on the Diameter at 30 cm Height.

Experiment	Fertilizer	Fertilized plot D_B cm	Mean of two adjacent 0-plots D_K cm	Fertilizing effect: Absolute: Difference $D_B - D_K$ cm	L.S.D. 5 % cm	Significance	Relative $\frac{100 \cdot D_B}{D_K}$
Group A	N	3.43	3.13	0.30	0.57	0	110
(with	K	3.17	3.33	—0.16	0.54	0	95
harrowing)	P	3.22	3.09	0.13	0.45	0	104
	NKP	3.60	2.71	0.89	0.52	+	133
	N/2	2.81	2.38	0.43	0.43	+	118
	K/2	2.54	2.38	0.16	0.37	0	107
	P/2	2.33	2.34	—0.01	0.33	0	100
Group B	N	3.26	2.17	1.09	0.41	+	150
(without	K	1.96	2.16	—0.20	0.34	0	91
harrowing)	P	2.39	2.19	0.20	0.36	0	109
	NKP	3.25	2.12	1.13	0.34	+	153
	N/2	2.44	1.99	0.45	0.37	+	123
	K/2	2.02	1.97	0.05	0.28	0	103
	P/2	1.81	1.91	—0.10	0.30	0	95

influence, the fertilizing has remedied the first immediate deficiency, and so the harrowing has acted virtually as an additional fertilizer, and it is a well-known fact that the effect of the fertilizer unit supplied last diminishes relatively.

The primary effect of the harrowing is a reduction of the competition from other vegetation, but at the same time it furthers the decomposition of the mor and other vegetable litter.

To illustrate the effect of the different types of fertilization, the material has been subjected to a mathematical-statistical analysis, the result of which will appear from Tables 18 and 19.

"L.S.D. 5 %" means the least significant difference at the 5 % level between the fertilized plot and the arithmetical means of the two control plots; + means a significant, positive effect; 0 means no significant effect; and — means a significant, negative effect.

It will be seen that only fertilizers containing nitrate have had any significant effect.

The following table contains a comparison of the relative figures of Tables 18 and 19, arranged according to the type and quantity of fertilizer with and without harrowing. Relative height is defined as height in fertilized plot in per cent of the mean height of the two adjacent controls.

Relative Height 1963.

	K	K/2	P	P/2	N	N/2	NKP
Harrowed	93	106	108	101	99	112	119
Not harrowed	96	100	108	95	144	111	143

Relative Diameter 1963.

	K	K/2	P	P/2	N	N/2	NKP
Harrowed	95	107	104	100	110	118	133
Not harrowed	96	100	108	95	144	111	143

It will be seen that the considerable percentage effect of NKP as well as N and N/2 has clearly been greatest in the plots which were not harrowed. For K and P, there is no such tendency — for K and K/2 rather the opposite tendency. The same holds good of the tendency which may be implied, of P having greater effect than P/2, and K having greater effect than K/2 — though negatively.

The Importance of the time of commencing harrowing.

When the Dose experiment was inspected in the summer of 1958, i.e. the 4th year of growth after the planting and the 3rd year after the start of the experiment, there was no conspicuous difference in the growth of the experimental groups harrowed since 1955 and the ones not harrowed.

After the planting of the area, only a scattered vegetation of Agropyrum repens occurred gradually — as is common in agricultural cultivations — which, in 1959 and later, on the untreated soil was being superseded by other grasses, sporadically occurring Chamaenerium and a little heather. In 1966 the heather was completely dominating the unharrowed plots.*)

As the soil of the experimental area consists of coarse heath sand with little capillary conduction of water, the idea suggested itself in 1958 that the loosening of the soil brought about by the harrowing might not have had any great value as a preventive measure against loss of water from the soil by evaporation. Another explanation might be the slight spread of the root systems of the plants in the first few years, the harrowing having been carried out only on the ridges and not on the sides and in the bottoms of the furrows.

In any case, the harrowing did not seem to have had any visible effect in the 3 first growth years after planting, but the question is: from what time would it have sufficient effect to be regarded as necessary?

In order to clarify this point, it was in 1958 decided to harrow one half of the 8 row interspaces of some of the 0-plots of Group B, beginning in different years, viz. as follows:

Plot 1, 1st time in the summer of 1959
— 3, - — - - — - 1960
— 5, - — - - — - 1961
— 7, - — - - — - 1962
and so on.

*) After deep-ploughing, the soil will normally be clean for 3 or 4 years, but in 1959 8 years had passed after deep-ploughing, three of which with rye crops.

In May 1963 in these 0-plots the heights and diameters of all trees in two rows farthest away from the larch rows were measured on the harrowed and the unharrowed half, respectively, with the following result, expressed in mean heights and mean diameters. A small steel caliper with millimetre readings was used for measuring the diameters, and a stick with centimetre divisions for measuring the heights.

	Height, metres				Diameter, centimetres			
Plot No.	With soil working (rows 2—3)	Since the summer of	Without soil working (rows 5—6)	Difference, %	With soil working (rows 2—3)	Since the summer of	Without soil working (rows 5—6)	Difference, %
1	1.49	1959	1.23	+0.26	2.70	1959	2.16	+0.54
3	1.44	1960	1.20	+0.24	2.53	1960	2.17	+0.36
5	1.17	1961	1.21	—0.04	1.92	1961	2.15	—0.23
7	1.04	1962	1.23	—0.19	1.60	1962	2.23	—0.63

These few figures do not provide any safe basis for a mathematical evaluation, but the even cadence of the differences seems more than accidental.

The following explanation seems natural:

Immediately following the first harrowing, the increment is reduced because a large number of roots in the superficial root system of the spruces have now been torn.

In the course of the first two summers a deeper root system is developed on the portion of the area which is harrowed once a year.

After that, the harrowing has an increment-promoting effect as compared with no harrowing, the unharrowed strips gradually becoming overgrown with grass and heather, as will appear from a description dated August 3, 1961.

As the average difference in height in 1963 between the 0-plots harrowed since 1955 and those not harrowed was 0.4 m and the difference in height between the plot parts harrowed from 1959 and 1960 and their neighbouring plot parts which had never been harrowed was only 0.25 m, there can hardly be any doubt that, in a purely physiological respect, the best procedure has been to harrow right from the planting — and not to put off harrowing until the 3rd or 4th year.

The economics of the matter are as follows:

Generally, the annual cost of harrowing of 1st cultures in heath plantations could be reckoned to be 50—100 kr per hectare in 1966 — in the most favourable cases, such as immediately after a deep-ploughing, as low as 25 kr.

In the main experiment in Dose Plantation, 9 years' harrowing has brought about an average height increment ranging from 1.19 m on the 0-plots not harrowed to 1.60 m on the harrowed 0-plots.

This additional increment may be estimated to have cost about 500 kr, assessed by the 1966-standard, which it is probably not worth. The 0.4 m may perhaps be regained after the closing of the stand, and in any case the advantage is uncertain.

On the other hand, it is of decisive importance to have the stand closed without the typical — and often lengthy — check period. But in the autumn of 1966 it was the impression that — under the special conditions of the experiment, amongst others the climate of the period — this might well be obtained also in the 0-plots not harrowed. At any rate, it is hardly economically justified to start harrowing until the heather threatens to conquer the area.

The Danish Heath Society will follow up the Dose experiment with observations.

D. EXPERIMENT WITH UREA IN MIDDLE-AGED HEATH SPRUCE

Extract of a report by Carl Mar: Møller and Jørgen Lundberg in the Journal of the Danish Heath Society 1966. (Hedeselskabets Tidsskrift 1966).

In connection with the B-experiment in Dalgas Plantation (see p. 212) an experiment with annual supplies of different

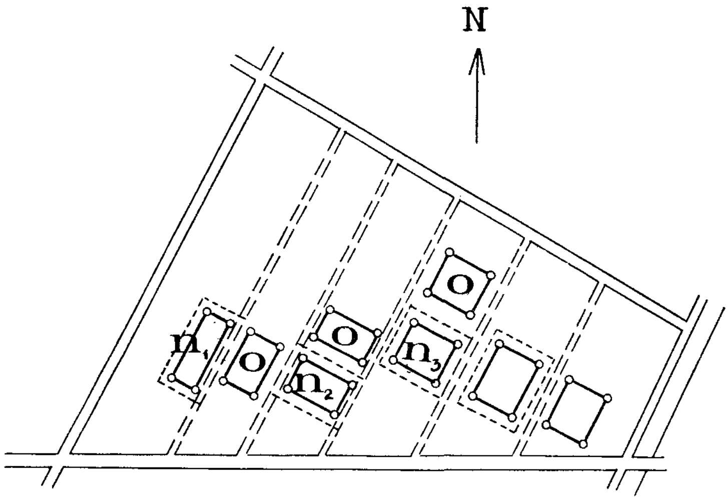


Fig. 15. Experiment Layout. The average size of the plots is about 1.000 m². The fertilized plots are surrounded by an 8 m wide isolating belt, which is fertilized in the same way as the plot, but tree-measuring is done only in the plot proper. The two plots without designation belong to the B-experiments, cfr. p. 212. The westerly one has been NKP fertilized very heavily, calcium nitrate being the N-source; the easterly one is unfertilized.

Fig. 15. Forsøgsskitse. Parcelstørrelsen er gennemsnitlig ca. 1000 m². De gødede parceller er omgivet af et 8 m bredt isolationsbælte, der gødes ligesom parcellen, men kun parcellens kerne er genstand for træmåling. De to ubenævnte parceller hører under B-forsøgene jfr. s. 212. Den vestlige har fået kraftig fuldgødning med kalksalpeter som N-kilde, den østlige er ugødet.

quantities of urea was established in 1957 in the same stand, in co-operation with the Danish Heath Society.

Here are given the results for the growth years 1957—63, inclusively. The experiment is being continued.

Figure 15 shows the location of the plots.

For ground conditions soil and stand, see section B p. 205.

The average index values for the soil of the 6 plots were (without any essential variation): pH = 4.8, $F_t = 1.4$, and $K_t = 0.8$. (As to units cfr. p. 101 below.)

The monthly average precipitation recorded by the "Søvang" weather station, situated 7 km NW of the experiment, corresponds very well to that of Denmark as a whole, whereas the mean temperature at the station is 6.8°C against that of the country, which is 7.5°C.

Table 20 contains the precipitation figures of recent years for the "Søvang" station, as well as average figures for the station and for Denmark without Bornholm.

Table 20. Søvang Weather Station. Precipitation, mm.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	May-Sep.	Annual Total
1955	55	18	40	28	49	22	29	57	69	77	63	102	226	609
1956	57	14	38	18	25	59	44	96	41	54	45	63	265	554
1957	60	46	55	15	14	52	87	105	82	82	37	45	340	680
1958	67	74	8	16	45	46	142	104	56	46	24	53	393	681
1959	83	4	40	70	13	41	97	136	27	77	63	58	314	709
1960	49	19	10	29	23	20	150	69	29	61	118	68	291	645
1961	42	36	45	38	37	51	121	55	98	75	78	58	362	734
1962	64	51	34	29	63	78	41	145	66	32	28	40	393	671
1963	5	5	24	44	94	27	50	132	34	90	153	14	337	672
1964	45	12	2	31	23	103	98	54	77	50	45	89	355	629
Aver. 1957/63	53	34	31	34	41	45	98	107	56	66	72	48	347	685
Average Precipitation at Søvang, mm														
	47	34	37	42	46	46	64	84	57	76	53	57	297	641
Denmark's Average Precipitation, mm														
	45	35	41	40	42	47	63	83	59	68	56	60	294	639

In the experimental period of 1957—63 the following quantities of urea were administered:

	1957-58	1959-63	Total	Aver. Yearly
n_1 plot 8	200 kg	67 kg	735 kg	105 kg
n_2 plot 6	400 kg	133 kg	1465 kg	209 kg
n_3 plot 4	600 kg	200 kg	2200 kg	314 kg

The fertilizer was spread evenly by hand in April.

The object of the large doses supplied in the two first years was to quickly satisfy the immediate nitrogen starvation of the trees, but it was clear that continued yearly doses would have to be much smaller, not more than the largest N-doses generally supplied in agriculture.

Measuring Results and the Direct Financial Result of the Fertilizing

will appear from the Table 21 and Fig. 16.

It can be seen from the heights in 1957 that the n_3-plot was of a somewhat lower site-class than the n_2- and n_1-plots, just as the site-class also varied a little in the 3 unfertilized plots.*) In the calculation of the average annual increment, correction has been made for this variation, so that the figures for all 6 plots now apply to the same site-class.

It will be seen that for the seven years, the following annual stemwood increment augmentations were obtained, calculated in m^3:

Kg urea, aver. per year/ha	m^3	Per cent
105	0.9	11
209	2.6	33
314	3.4	43

The stump (net-on-root) value of one m^3 has been taken from a price curve based on a large material and valid for November 1, 1964, with the value as ordinate and the diameter as abscissa.

*) The average site-class was practically the same for the 3 unfertilized plots as for the 3 fertilized plots, and also it was ascertained that in the period 1951—56 the two groups had had practically the same height increment and diameter increment.

Table 21. Measuring Results and Calculation of the additional value increment obtained by fertilizing. 1 hectare.

Plot No.	3	5	7	8	6	4
Fertilization		0		n_1	n_2	n_3
Spring 1957 — Age 50 Years						
No. of stems	1981	1790	1743	1630	1823	1932
Height, m	10.3	11.4	10.9	11.1	11.2	10.4
Diameter, cm	11.1	12.6	12.1	12.2	12.0	11.3
Basal area, m^2	19.31	22.23	19.87	19.05	20.62	19.47
Stemwood, m^3	111.6	140.1	120.2	117.3	127.8	113.4
Thinning, Spring 1961 — Age 54 Years						
No. of stems	392	504	297	328	433	435
Height, m	10.6	11.6	10.7	10.0	10.7	10.4
Diameter, cm	10.8	11.9	11.0	10.2	11.0	10.3
Basal area, m^2	3.57	5.62	2.86	2.66	4.10	3.59
Stemwood, m^3	21.3	36.3	17.2	15.1	24.7	21.2
Basal area after thinning, m^2	19.04	20.40	20.48	20.15	21.03	20.76
Before Thinning, Spring 1964 — Age 57 Years						
No. of stems	1589	1286	1446	1302	1390	1497
Height, m	12.1	13.3	12.7	13.5	13.5	12.8
Diameter, cm	13.1	15.0	14.2	14.9	15.0	14.3
Basal area, m^2	21.52	22.66	22.98	22.73	24.63	24.17
Stemwood, m^3	143.3	162.6	158.9	165.8	179.2	168.7
Average Annual Increment 1957—63, Inclusive						
Actual height increment, cm	24	24	24	30	29	32
Basal area increment, m^2	0.83	0.86	0.85	0.91	1.16	1.18
Relatively		100		107	137	139
Stemwood increment, m^3	5.57	8.40	7.99	9.09	10.87	10.93
Relatively		100		114	136	137
Corr. stemw. increm., m^3*)	7.99	8.01	7.97	8.90	10.61	11.41
Relatively		100		111	133	143
Augmentation of Increment 1957—63						
Total increment augmentation (corr.), m^3				6.37	18.34	23.94
Average annual increment (corr.), m^3				0.91	2.62	3.42
Average annual increment (corr.), m^3 per 100 kg urea				0.87	1.25	1.09
Additional Value Increment 1957—63						
Total additional value increment, kroner				568	1318	1429
Average annual addit. value increment, kroner				81	188	204
Annual cost of fertilizers and spreading, kroner				81	161	242
Annual net proceeds without interest, kroner				0	27	—38

*) "Corr" means: Corrected for differences in initial site-class.

The value increment for each individual plot has been calculated as the stump value of the stand in 1964 plus the net value of the thinning minus the stump value of the stand in 1957. The values have been corrected for differences in site-classes, as was the case with the stemwood increment, and an average of the three O-plots has been calculated. The additional value increment of the fertilized plots has finally been made up.

From this value the annual cost of fertilizers and spreading should be deducted, leaving the annual net proceeds without interest. The cost of the spreading has been put at 10 øre per kg, which it has actually cost done by hand.

When spreading is done mechanically from a truck, the costs of spreading are estimated to be less than half.

Aerial spreading, as is done in some Norwegian, Swedish and Finnish forest districts is considerably more expensive. This type of spreading has in Denmark been offered at 20 øre per kg.

In Scandinavia the spreading is reckoned to take place every fifth year only, but by five times the normal annual quantity.

The general (though not fully authenticated) opinion is that by this procedure no essential quantities of N are wasted, because urea is rather quickly hydrolysed to ammonium carbonate, which is easily fixed by the soil. It is true that urea may gradually be converted into leachable nitrate, but in heath forests this process takes place slowly and under keen competition from the great number of nitrogen-starving trees and other living beings. It is generally held that *all* assimilable nitrogen is quickly appropriated, including the greater part of the ammonium compounds first produced.

If it is possible to carry out fertilization every fifth year without loss, and the fertilizer is spread mechanically, the average yearly net proceeds in Table 21 will rise to 35—40 kroner for the n_2-dose.

The most advantageous average yearly supply is in this case estimated to be somewhere around 175 kg/hectare. One must then try by continued experiments to get closer to the most economic figures, which of course will vary with natural conditions and prices.

It should be observed that experiments made in 1963 and 1964 by the Danish State Plant-Culture Laboratory have shown

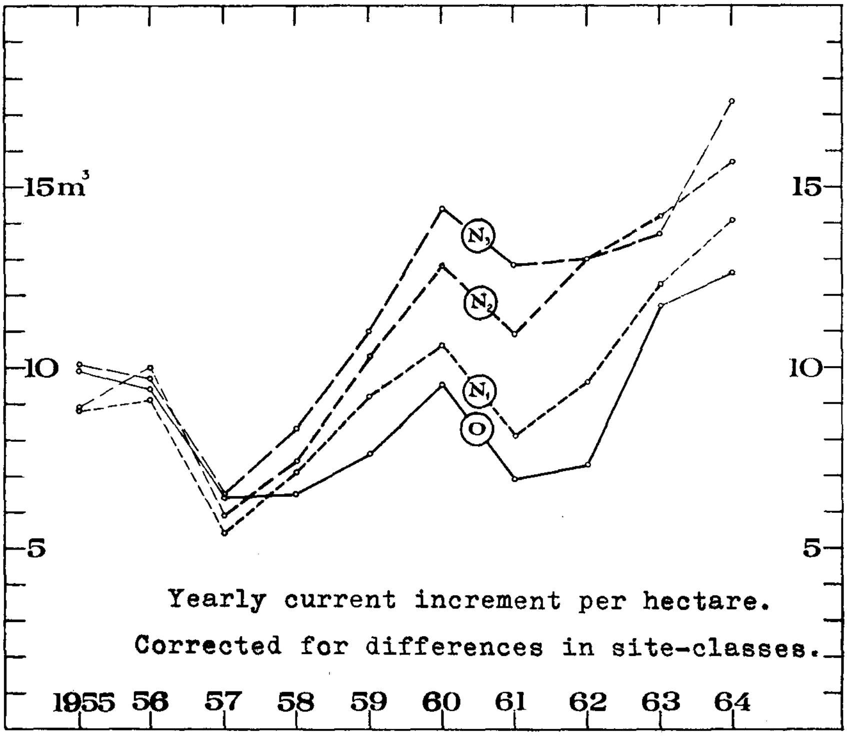


Fig. 16. Yearly current increment of experimental plots (O = average of plots 3, 5 and 7). For the years 1955—56 and 1964, the increment has been calculated on the basis of measurements of annual rings and year-shoots, and has been shown by a thinner line.

Fig. 16. Forsøgsparcellernes årlig løbende tilvækst (O er gennemsnit af parcel 3, 5 og 7). For årene 1955—56 og 1964 er tilvæksten beregnet på grundlag af årrings- og årsskudsmålinger og vist med tyndere streg.

that urea harrowed into agricultural soil had only 4—5 % additional effect as compared with urea spread without harrowing.

In forests, with the inferior evaporating conditions and the sour floor, the loss by evaporation may be assumed to be small.

The Course of the Increment.

Fig. 16, which shows the annual current stemwood increment, has been produced on the basis of the measuring results listed in Table 21.

In the first place, it will be seen that all 6 sample plots (O-fertilizing being represented by 3 sample plots) start with practically the same increment in 1957, i.e. the first summer after fertilization. The three O-plots are even a little better than the average of the three fertilized plots.

This uniformity agrees with the experience gained from other fertilizing experiments. The fertilization does not essentially influence the growth of the tree plants in the first summer, which is in agreement with the fact that a particularly favourable summer usually only results in long shoots the following summer.

Both things are connected with the phenomenon that in the new buds which they form in the course of the summer for use next spring, the tree plants "budget" the following year's growth under heavy influence of the "proceeds" of the present summer.

In a top bud of Norway spruce it is possible by means of a microscope to count the number of needles which next year's top shoot will get. Normally, a great number of primordial needles will give a long shoot. If the next year is unfavourable, e.g. extremely dry, the shoot will become short, however, and the number of needles will then be correspondingly small.

By 1958 the picture is getting clearer, and even more so in 1959 and 1960. The fertilized plots are far superior to the unfertilized ones.

It is true that the same is the case in 1961, but in relation to 1960 the whole increment level has suddenly dropped by about 20 %.

This is probably due to climatic conditions, and especially the abnormally slight precipitation in the period February-June of 1960, cfr. Table 20. It will be seen that at "Søvang" the total precipitation of these five months amounted to only 101 mm against the normal 205 mm, and that in no other year of the 10 years under review was it so low.

The unfertilized plots especially, seem to have suffered. But in 1963 the crisis is over, and the unfertilized plots are even gaining on the fertilized ones.

The After-Effect of Fertilization.

If, after having been continued for a number of years, the fertilizing is stopped, it is likely that the increment augmentation obtained does not cease immediately. The fact is that the quantities of N which are removed by thinning in a plantation are extremely small in relation to the supplies which have been given in this experiment.

By thinning, about 5 kg N, on an average, are removed annually, or less than the quantity that is supplied by precipitation, while 200 kg urea correspond to 92 kg N. If fertilizing has been going on for 10 years, the N store of the stand (contained in soil and trees) should thus have been increased by about 850 kg/hectare, or something like 20 %, if it may be taken for granted that only negligible amounts are lost by leaching.

We do not know as yet, however, how easily this additional store can be mobilised. It is a fact that there exists heather-grown heathland with just as large an N-store per hectare as a good beech forest, but whereas the nitrogen of the beech forest is under continuous conversion and is partially available in easily assimilable forms, the nitrogen of a heath mor is firmly fixed.

It is found in the hyphae of fungi and other organic complexes which can only be decomposed with difficulty, and extremely small quantities are liberated in an assimilable form before working of the soil, liming, etc., are commenced.

There is, however, indication that the nitrogen from the fertilizers will not be fixed so hard in a spruce stand.

The vegetation proper, the spruces, has proved to have a considerably greater power of decomposition than the heather. As the Jutland heath plantations grow older, they gain in site-class (cfr Fig. 72, Møller and Nielsen, 1953). Their height increment for a given potential site-class, (determined by height in relation to age) is greater than would be expected according to the tables, because the stands are getting into a better state.

There is much probability that our supply of nitrogen will stimulate this development, because the C/N ratio of the needles decreases with the more abundant N/supply, as will appear from Table 22 on p. 234, and experience shows that decreasing C/N ratio facilitates the decomposition.

If this should be the case, we shall obtain an indirect, long-lasting, financial gain, in addition to the direct one (table 21).

With regard to this question, factual information will soon be available, as in the Dalgas Plantation the fertilizing was stopped in two of the urea plots in 1966, while the rest of the experiment is being continued.*)

The Effect of Fertilization on Decomposition.

The effect visible to the naked eye will appear from the following summary of observation results of the six plots in the urea experiment, as well as from the fully fertilized plot in the same compartment, cfr Fig. 15 p. 225.

The description was made in the latter part of July, 1964. In the O-plots, which display uniform characters, the floor is completely dominated by mosses (Hylocomium, Dicranum, Polytricum, Ptilium, etc.), and there is only sporadic occurrence of slightly developed Deschampsia flexuosa. In addition, there are a few varieties of lichens.

In the urea-fertilized plots the layer of moss is clearly reduced, almost proportionally to the amount of fertilizer. In the most heavily fertilized plot, No. 4, there is scattered occurrence of D. flexuosa, Chamaenerium angustifolium and Senecio vulgaris. The humus seemed to become darker and more amorphous with increasing quantity of urea.

The strong effect on the fully fertilized NKP plot is described p. 213 under section B.

In order to get some idea about the chemical conditions underlying all the signs mentioned, raw humus samples were taken from all six plots of the urea experiment, as well as from the aforementioned NKP-plot, on each of the following dates: Sept. 28, 1959, March 23, 1960, May 2, 1960, June 9, 1960, July 15, 1960, and August 22, 1960.

Each sample was composed of ten sub-samples taken at random all over the plot and then mixed together.

Immediately on being taken, all samples were sent to the laboratory of the Danish Heath Society at Viborg, where a portion of each sample was immediately analysed, while another portion was stored for three months at about 20°C and at almost a con-

*) No after-effect of urea was hitherto found, but in the NKP experiment in the same stand (cf. p. 212) where fertilizing was stopped in 1963, an after-effect has actually been found, the volume increments of the NKP plot being the following percentages bigger than those of the O-plot: 1964 — 16 %, 1965 — 27 %, 1966 — 18 % and 1967 — 20 %. Possibly the after-effect is in this case also dependant on P & K.

Table 22. Average of humus samples taken on Sept. 28, 1959; March 23, 1960; May 2, 1960; June 9, 1960; July 15, 1960; August 22, 1960.

Fertilization	pH	mg per 100 g raw humus (dry matter) NH₄-N	NO₃-N	P (H_2SO_4)	P (zeolite)	K
	At the time of sampling					
0	3.7	6.8	0.7	8.6	9.3	49.3
n_1	3.7	6.8	0.8	7.4	8.9	51.9
n_2	3.7	9.8	2.0	6.9	8.5	45.0
n_3	3.8	12.7	2.1	6.7	8.0	45.7
	After 3 months' storage					
0	3.9	38.5	1.1	13.6	12.5	54.5
n_1	3.8	39.7	1.7	11.7	12.4	57.7
n_2	3.8	35.0	3.5	11.8	12.3	49.3
n_3	3.8	35.7	5.0	10.8	10.6	47.4
NKP at sampl. time	4.2	4.7	8.6	16.0	13.2	85.2
After 3 months	4.1	12.1	18.8	20.2	15.3	84.1

0 applies to plots 3, 5 and 7 collectively.

stant relative humidity, after which they were subjected to the same analyses as the portion analysed immediately on arrival.

The average results will appear from Table 22.

The phosphorus content accessible to plants was determined, partly by extraction with diluted sulphuric acid on the same method as used by the Danish State Plant Laboratory, and, partly, on the zeolitic method applied by the Danish Heat Society Laboratory (cfr p. 100).

The following seems proved by the experiment:

(1) In four years the urea-fertilizing has not affected the pH of the humus.

(2) At the time when they were taken out, the samples from the O-plots had a rather considerable content of ammonium-nitrogen and a very slight, though demonstrable, content of nitrate-nitrogen.

(3) At the time of sampling, the urea-fertilized plots had a clearly higher content of both types of nitrogen — the higher, the more vigorous the fertilizing. That the ammonium content increases, is a matter of course, but it is

interesting that the nitrate content also increases, although relatively more slowly.

(4) At the time of sampling, the content in the humus of both phosphorus and potash was percentually smallest in the most heavily urea-fertilized plots. Especially for P, the drop takes a very even course.
The most natural explanation is that by the more rapid decomposition of the humus in the fertilized plots, more P and K has been liberated in an assimilable form, and that these substances have been assimilated by the tree vegetation, which has been in need of more of these substances for its increased growth.

(5) After three months' storage, large quantities of ammonium-nitrogen have been formed in the samples from all six plots of the urea-experiment. In the O-plots and the n_1-plots the increase amounts to 32—33 mg, and in the n_3-plots to 23 mg. On the other hand, the amount of nitrate-nitrogen in the n_3-plots has risen by 140 % and in the O-plots only by 60 %.
In the NKP-plot the total amount of N in $NH_4 + NO_3$ is smaller after three months' storage than that of the O-plots. Obviously, the vigorous and comprehensive fertilizing has greatly promoted the decomposition and the assimilation.

(6) With regard to P and K, all values have risen considerably after storage. The explanation may be that the vigorous decomposition, of which the N-liberation is proof, has also liberated considerable quantities of plant-accessible P and, to a certain extent, K. As the figures are percentages, the rise may, however, in some degree be ascribed to loss of dry matter during the storage.

The main conclusion to be drawn from the table is that also the unfertilized spruce humus has a considerable capacity for forming ammonia, and also a little nitrate, and that fertilizing with urea promotes the formation of nitrate.

With regard to the course of the processes throughout the year, the analyses made immediately on taking the samples show — as might be expected — increasing formation of ammonia and nitrate in the period March 23—July 15.

E. ANALYSES OF NEEDLES

Needle and leaf analyses are being used to an ever increasing degree as a means of providing information about the nutrition of forest trees and, especially, for determining in advance whether fertilization may be expected to give positive results.

Several researchers have laid down approximate optimum and minimum values for the content of nutritious substances in various tree species, and there is rather good agreement between these indications. However, for Norway spruce, only a few investigations have been made. The following values for N, P and K were found in Norway spruce as percentages of needle dry matter by T. *Ingestad* (1962—63) from cultivation of seedlings in nutrient fluid for 160 days:

	Optimum	*Minimum*
N	1.8— 2.4 %	1.0 —1.7 %
P	0.1—> 0.3 %	0.05—0.11 %
K	0.7— 1.1 %	0.3 %*)

The minimum values represent the level of nutrition where symptoms of deficiencies are becoming apparent, but the extent to which these results will be valid for old plants has not yet been fully clarified. (See, however, footnote).

It is known that N-deficiency makes itself conspicuous by short needles of a yellowish colour; P-deficiency by short, very dark needles, often covered with black algae. In particularly serious cases the colour may vary between bronze-green and brownish-violet, with necroses on the outermost needles. K-defi-

*) *Heiberg and White* (1951) found a minimum value for K of 0.21 % in young needles of old plants. For N, *Süchting* (1939) found a minimum value of 1.2 % in young shoots of old plants, and *C. O. Tamm* (1956) an optimum value of more than 2 % in young needles of old plants.

ciency is apparent from the needles being green at the root and yellow towards the point, the shoot tips, however, being often yellow all over. All the deficiency conditions mentioned are accompanied by reduced growth.

In connection with the experiments reported above, the following needle analyses have been made:

In December 1955, i.e. after the third year of growth, samples of needles from the A-experiment in Haraldslund Plantation (Experiment No. 21, see p. 96) and the B-experiment in Gedhus Plantation (p. 205) were taken out for analyses.

For the sampling and analysing methods adopted, see *Møller and Schaffalitzky* 1957, p. 436.

In Haraldslund Plantation, where the growth in the unfertilized control plots was in a period of staying in check and the trees had yellowish needles, the samples were taken in the third whirl on ten medium-large trees in the central row. The three year-shoots were represented thus: 1953 15—20 %; 1954 and 1955 about 40 % each.

In the same way samples were taken in the middle-aged stand in Gedhus Plantation. In this case the colour of the needles was green, also in the unfertilized plot.

The analyses were made by the Plant-physiological Laboratory of the University of Copenhagen.

The results will appear from Table 23.

It should be noted that plots with uneven numbers are unfertilized plots, one on either side of a fertilized plot.

For Haraldslund it will be seen that fertilizing with N has brought about an obvious increase in the N-content and an obvious drop in the contents of K and P and, therefore, also of the content of ash, which is very natural, while the dry-matter percentage is not altered, the chlorophyll content is greatly increased, and naturally the C/N ratio has dropped.

The colour of the needles was a lush green.

At the same time, measurements in the field showed a considerable augmentation of the height increment and, consequently, the dry-matter production of the stand.

The drop in the percentual contents of K and P in the case of N-fertilizing, without any deficiency symptoms appearing, may be explained by the fact that the accessible quantities present in the soil, though small, were still so large that even with increased

Table 23. Survey of Analyses of Needles from Haraldslund and Gedhus Plantations. Contents of dry matter, ash, chlorophyll, N, K and P from fertilized plots compared with the average from neighbouring control plots. Dry matter is expressed in g per 100-g fresh weight; ash and N in g per 100 g dry matter; K, P and chlorophyll a + b in mg per 100-g dry matter.

Plantation. (Indices of available phosphoric acid and potassium)	Plot No.	Annual fertilization	Dry mat-ter	Ash	Chlo-ro-phyll	N	K	P	C/N*)
Haraldslund	1 & 3	0	41.2	4.42	160	0.99	641	204	54
	2	N 300 kg calcium nitr.	41.3	4.14	218	1.19	489	124	44
(F_t = 0.7,	3 & 5	0	40.5	4.39	173	0.96	688	180	55
T_k = 1.8)	4	K 100 kg muriate of pot.	41.2	4.65	150	0.95	806	180	56
	5 & 7	0	40.7	4.05	177	0.99	584	191	54
	6	P 200 kg superphosp.	41.2	4.49	194	0.93	591	255	57
	7 & 9	0	41.7	3.60	187	0.98	588	179	54
	8	N + K + P	40.0	3.86	225	1.14	715	191	46
Gedhus									
(F_t = 0.4,		0	40.0	3.48	360	1.34	652	186	40
T_k = 1.6)		2½ × NKP	40.7	3.91	413	1.91	753	196	28

*) In determining the C/N ratio, the C content has been put at 53 % of the dry-matter weight based on analyses submitted by *Wittich* (1939), according to which the per cent of C of the individual tree species varies only slightly and independently of the percentage of N.

dry-matter production the minimum values found by Ingestad have not yet been reached.

On the other hand, it will probably not be long before the values have dropped to that level, and it is therefore not to be wondered at if until 1963 continued pure N-fertilizing has resulted in deficiency values in the course of the experiment, such as it seemed to appear from a comparison of the first three years' experimental results from the A-series with the results of the final assesment of the results after 10 years fertilizing, cfr p. 154.

Fertilizing with K and P individually, the influence of which on the dry-matter production does not seem clearly demonstrable, has naturally increased the K and P percentages, respectively, and, consequently, the ash percentages. Also the dry-matter percentage has risen a trifle.

At the same time, the chlorophyll content has been influenced negatively by K and positively by P. Both of these effects are of the same considerable order of magnitude as the positive effect of N.

In the case of both K and P fertilizing, the C/N ratio has increased a little, corresponding to the slight drop in the N-percentage.

In both Haraldslund Plantation (an 11-year-old stand) and Gedhus Plantation (a 50-year-old stand) the NKP-fertilizing has brought about an increase in the percentual content of chlorophyll, N, K, P and ash.

The dry-matter content is a little greater, whereas the C/N ratio has, of course, fallen considerably.

In Gedhus Plantation the N-percentage is at a considerably higher level than in Haraldslund Plantation. The probable explanation will appear from Fig. 17 b, p. 243, which shows that on heathland soil the N-content of the needles generally reaches the minimum at the age when the stand closes, after which it gradually increases.

Above all, the analyses show that the amounts of fertilizer given have been partially assimilated by the spruces, and it is interesting to note that, percentually, the increase in the nutrient content of the needles has been of the same order of magnitude for the three types of fertilizer given, as will be seen from the following survey, applying to Haraldslund Plantation:

Proportional quantities by weight of the three elements administered per hectare		Percentual increase of content in needles resulting from fertilization	
N	100	N	20
K	91	K	15
P	33	P	25

As to the figures for the potash and phosphoric acid available before the experiment, see Table 1.

On the initiative of Jørgen Lundberg, of the Danish Heath Society, needle samples were taken again from the B-experiment in Gedhus Plantation on Jan. 16, 1967, using the same method as before. Analysing was done by the Laboratory of the Danish Heath Society, with the following results in per cent of dry matter. For comparison, the optimum and minimum values found by

Ingestad (1962—63) for Norway spruce have been stated, for copper (Cu) supplemented by a minimum figure found by *Oddvar Haveråen* (1964):

Table 24. Needle analyses in Gedhus plt., Jan. 1967.

	Unfertilized	Minimum	NKP plot	Optimum
Nitrogen, N	1.30	(1.0—1.7)	1.44	(1.8—2.4)
Potassium, K	0.52	(0.3)	0.63	(0.7—1.1)
Phosphorus, P	0.196	(0.05—0.11)	0.238	(0.1—>0.3)
Copper, Cu	0.00080	(0.00014—0.00025)	0.00055	
Magnesium, Mg	0.236	(0.02—0.07)	0.118	(0.09—0.16)
Calcium, Ca	0.260	(0.02)	0.376	(0.09—0.6)

It must be noted that the NKP-plot was last fertilized in 1962, so that 4 growth years have thus passed without fertilization. It is interesting that the N-content of the NKP-plot is already falling rapidly towards that of the unfertilized plot, whereas in 1953 it had reached 1.91 per cent after 3 years' fertilization, cfr Table 23. On the other hand, the proportion between the quantities of K and P in the NKP-plot and the O-plot, respectively, has been retained, and has even increased.

This is in harmony with general Danish experience, that in heath plantations the accessible content of N is particularly low, and this nutrient will therefore have a strong and early effect when fertilizers are supplied, while the need for other nutrients, especially P, may be satisfied later on.

While it appears that if fertilizing is stopped, the need for a further supply of nitrogen will rather soon make itself felt, this does not seem to be the case with K and P, where the reserves supplied in this case seem to suffice for some time.

With regard to Cu, Mg and Ca, with which no fertilization has been made, the figures of the analysis far exceed the minimum values — for Mg even the optimum range.

As far as these elements are concerned, no deficiency should occur in the B-experiment in Gedhus Plantation for the time being.

In connection with the urea-experiment in middle-aged Norway spruce in Dalgas Plantation, treated in Section D on p. 225, various needle analyses were also made. (For details, see *Møller and Lundberg*, 1966).

Samples of needles taken from the top whirls in all six plots of the urea-experiment in April before the fertilization and in December of the same year (1964), respectively, were first examined. The samples were taken from at least 10 representative sample trees.

The analyses were carried out by the Laboratory of the Danish Heath Society with the results given in Table 25.

Table 25. Analyses of Needle Samples from the plots in the experiment with urea in Dalgas plt., cfr section D. % of dry matter.

Treatment	Plot No.	April 1964 N	April 1964 P	April 1964 K	December 1964 N	December 1964 P	C/N
0	3	1.34	0.129	0.48	1.41	0.175	
	5	1.41	0.130	0.48	1.41	0.193	
	7	1.33	0.129	0.49	1.34	0.148	
Average		1.36	0.129	0.48	1.39	0.172	35
200 kg urea	8	1.49	0.123	0.54	1.51	0.157	
400 „ „	6	1.57	0.157	0.57	1.70	0.200	
600 „ „	4	1.60	0.122	0.61	1.66	0.168	
Average		1.55	0.134	0.57	1.62	0.175	29

It will be seen that both in April and December the N-content is clearly the highest in the fertilized plots, increasing with the quantity of urea.

Also for K, the content (in April) is significantly highest in the fertilized plots, while the P-content is almost unaltered, both these results being inconsistent with the results from Haraldslund Plantation.

We are unable to offer any explanation of the difference between the results for K and P.

It is well known that the decomposition rate of needles and leaves increases with a decreasing C/N ratio. (See, e.g., *Wittich* 1939, *Lindquist* 1941 and *Bornebusch* 1943).

As fertilization with N reduces the C/N ratio, it is probable that already for that reason alone, the mor formed by shed needles will have better properties, with a more active rate of decomposition, than the old mor.

As, on an average, spruce needles generally remain 5 years on the branches, and as it is probably chiefly the N-content of the newly formed needles that increases, the full effect will, however, hardly be obtained until five years after the initial fertilization, and as the needle mor found on the area of the urea-experiment is the result of almost 50 years' needle shedding, a complete change of the type of the mor brought about only by the needle shedding will take several decades.

But the needle-shedding is, of course, not the only factor to exert an influence. The direct effect of the fertilization on the mor, mentioned previously on p. 215, also contributes to the effect, and storage experiments made in connection with the urea-experiment render it possible that the effect is considerable, cfr Table 22. —

In conjunction with the Urea-experiment, endeavours were also made to elucidate the relation between the N-content of the needles and the growth, through two other channels, as will appear from figure 17.

On Fig. 17(b) the following comment may be offered: The 6-year-old culture, which is represented in the figure by the first point on the left, was established after deep-ploughing, so that at the time of sampling the floor was still relatively clean and the flora dominated by Chamaenerium angustifolium, which is known to be nitratophilous.

The 12-year-old culture, which is represented by the next

Fig. 17. Analyses of Needles.

(a) Average annual increment (without correction for site-class) of the measuring period in relation to the N-content of the needles in April 1964. Figures from the urea-experiment in Dalgas Plantation, section D.

(b) N-content in needles from Norway spruce stands, site class about 6½, of different ages. Samples taken in May, 1959.

(c) N-content in needles from Norway spruce stands of different site classes, but of almost the same age (about 30 years). Samples taken in the period December 1963—March 1964.

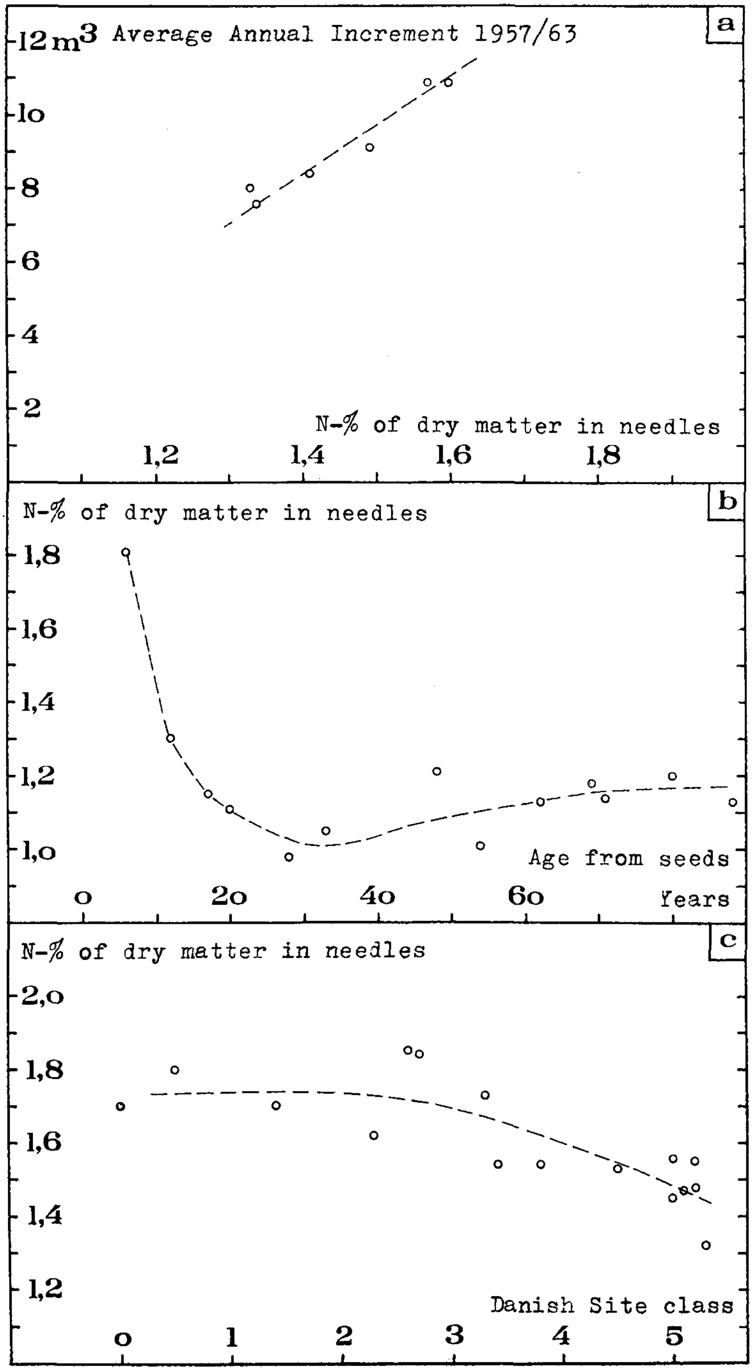
After Møller and Lundberg, Hedeselskabets Tidsskrift 1966, p. 98. The analyses were made by the Danish Heath Society Laboratory.

Fig. 17. Nåleanalyser.

a) Måleperiodens gennemsnitlige årlige tilvækst (i Urea-forsøget i Dalgas plt.) i forhold til nålenes N-indhold i april 1964.

b) N-indholdet i nåle fra rødgranbevoksninger bon. ca. 6.5 af forskellig alder. Prøverne er udtaget i maj 1959.

c) N-indholdet i nåle fra rødgranbevoksninger af forskellig bonitet. Prøverne er udtaget december 1963—marts 1964.


a
12 m3 Average Annual Increment 1957/63
10
8
6
4
2
N-% of dry matter in needles
1,2
1,4
1,6
1,8
b
N-% of dry matter in needles
1,8
1,6
1,4
1,2
1,0
Age from seeds
0
20
40
60
Years
c
N-% of dry matter in needles
2,0
1,8
1,6
1,4
1,2
Danish Site class
0
1
2
3
4
5

point, was established after topsoil-ploughing, and the heather had reappeared, though the colour of the needles was still green.

The 17-year-old and 20-year-old cultures were established after topsoil-ploughing, harrowing and subsoiling. The floor was again covered with heather rather soon, and the tree height was only about 1 m. The colour of the needles was partially yellowish.

The 28-year-old and 33-year-old cultures were established after deep-ploughing, but they had not been kept clean and therefore were soon overgrown with heather. The height varied between 2 and 5 m, and the needles were yellowish.

The height and appearance of the rest of the stands in fig. 17(b) then improves with increasing age. The needles are now green, and the N-content (site class 6.5) increases rather quickly to 1,2.

Fig. 17(c) provides a review of the N-content of the needles at different site classes. It will be seen that after a site class of about 3 has been reached, the N-content does not seem to rise with the site class, which is in good agreement with the results of our A-experiments in Norway spruce.

Fig. 17(c) may be supplemented with the N-content 1.2 % at site class 6.5 (see above), i.e. an increased drop with a continued fall in site class.

For comparison, *Strebel* (1960 and 1961) found the following figures: Site class lower than III 1.24; site-class II—III 1.33; site class better than II 1.40; site-class I 1.44.

The optimum figures of both investigations are at a lower level than those found by Ingestad in pot experiments (see p. 236).

The total result of the Danish needle investigations accounted for here agrees well with the results in Norway spruce of the A- and B-experiments.

Below a certain point, lying in the neighbourhood of site class 3 and 1.7 % in the needles, there is an obvious relation between N-content and dry-matter production.

On the other hand, it is evident that a prerequisite for the effect of the nitrogen-fertilizing must be that the growth is not inhibited by lack of other nutrients, which, as mentioned on p. 158 et al., may easily be imagined to be the case if the N-fertilizing is continued on meagre soil.

F. TOTAL SUMMARY AND DISCUSSION

For experimental plan, see page 88.

A-EXPERIMENTS

These comprise 25 experiments in Norway spruce cultures and 23 in beech cultures, with as wide a representation as possible of all site classes and different regions of the country (cf. Tables 1 and 2, and Fig. 1).

Annual fertilizing with 15.5 % calcium nitrate (N), 50 % muriate of potash (K), and 18 % superphosphate (P) in quantities similar to those used in agriculture, was initiated at the stage just before closing and continued for 10 years. (See, further, page 92).

A normal experiment, covering about 0.7 hectares (ha), comprises 15 plots, each about 50 m long, 9—14 m broad and containing 7, 9 or 11 rows of plants in the length of the plot. Every second plot is not fertilized, so that each fertilized plot may have two control neighbours (cf. Fig. 2).

Fertilizing was always made with N, K, P, NKP, and N/2, K/2, P/2 respectively. In some cases the normal experiment was supplemented by one or more different fertilizing methods.

Before the start of the fertilizing, pH, phosphoric acid figure Ft, phosphorus figure Fot, potassium hydroxide figure Kt, as well as colometrically measured nitrate figures, were determined for each experiment on the sampling methods normally adopted by agriculture (cfr tables 1 and 2).

The analytical accuracy has been checked by having analyses made by both the Danish State Plant Breeding Laboratory and the Danish Heath Society's Laboratory, whereby certain systematic differences were found, while the random variation was permissible, though not inconsiderable.

All index figures had a rising tendency with rising site classes.

Also the variation of the index figures within some typical experimental areas was determined and found rather considerable. (Cf. page 102).

At the end of 10 years' fertilizing (in a few cases less or more), all the experiments have been described, and measurements have been made of diameters (at 1.3 m or, in the case of small heights, 0.5 m above ground), and of heights of a large number of sample trees picked representatively, the following methods being applied:

Methods.

With its 7 different treatments, the typical A-experiment may be regarded as being composed of 7 sub-experiments, each consisting of a treated plot flanked by two untreated control plots. If the growth of the control plots agree, there is little probability of the intermediate, treated, plot (about 10 m wide and 50 m long) having a unilaterally deviating natural site class throughout its area.

Endeavours have been made to conduct each experiment in uniform soil. However, conditions in a forest area are so irregular, compared with conditions in agriculture, and moreover, the plots will have to be so much larger, that it has not been possible to avoid variations in conditions, particularly in the longitudinal direction of the plots.

With a view to eliminating this variation as far as possible, it was decided to divide the 3 plots of a sub-experiment into 3 groups by means of crosswise lines of demarcation, thereby establishing 9 equally large plot parts, i.e. 3 treated and 6 untreated ones.

In the selection of sample trees, endeavours have been made to measure a fairly constant number of trees per plot part. However, in fertilized plots a larger number of sample trees (about 15 per part) were measured than in unfertilized plots (about 10), a fertilized plot being compared to two unfertilized plots.

In the spruce experiments, the average degree of representation for fertilized plots is 17 % — for unfertilized plots 11 %. In the beech experiments the degree of representation is essentially smaller (about 5 % and 3 %) owing to the far greater number of stems.

The sample trees were selected by strictly objective methods.

The heights and diameters measured were entered on the spot into a table, from which these details, together with a numerical code representing tree species, experimental number, plot, and plot part, etc., were transferred to punched cards. The final calculations were then made on a digital computer (I/S Datacentralen, Copenhagen).

Two separate computing programmes for analysis of variance have been prepared, one for the main study and one for an investigation of side- or neighbour effects (cf. page 135), which has been based on separate measurements for the individual rows in some NKP sub-experiments, where the effect of the treatment has been greatest.

The layout of the A-experiments has had the effect that the boundaries between treated and untreated plots are very long in relation to the areas of the plots, and it is, therefore, important to know the extent of neighbour effects, if any, seeing that such effects might possibly be eliminated by interposing isolating belts.

The results of all the calculations will appear from Tables 3—4 and A1—A4.

With regard to *neighbour effects* the main impression gained from this separate investigation is that the extent of the neighbour effects is only from one to a few metres, showing that the concentration of fine roots declines rapidly with increasing distance from the tree, which is in agreement with more recent studies.

As a result of the investigation, an unmeasured isolating belt, comprising the outermost row of the untreated plot and the outermost row of the control plot, has been interposed between the plots.

The results of the fertilizing

are seen from the tables 5—9 and from Fig. 5—6 (spruce experiments) and Fig. 7 (beech experiments) and also the tabular work A page 163.

It should be noted that where the Tables indicate greater effects on diameter than on height (cf. p. 143), this may be partly due to the fact that the diameters in an experiment have been measured at a fixed height above ground, which means, that an acceleration of height growth by fertilizing will place the diameter measured at a relatively lower level compaired with the obtained height.

Experiments in Spruce.

In spruce only N, NKP and P/2 have had a significant, positive effect on the height increment in site classes 4 to 7, and K/2 in site classes 3 to 4. As regards the *diameters,* N, N/2, P/2 and NKP have all given a significant, positive effect in site classes 4 to 7, while in site classes 3 to 4 K/2 and NKP have given a significant, positive effect and P a significant, negative effect.

It should be observed that site classes 3 to 4 comprise only 4 experiments as against 9 in site classes 0 to 3 and 12 in site classes 4 to 7.

In site classes 0—3 no significant effect of any fertilizing, but perhaps a weak positive trend for N-containing fertilizers, and in site classes 3—4 a marked but not significant positive trend for NKP.

It is noteworthy that the NKP effects are much greater than the sum of the individual N, K and P treatments. Presumably the question here is one of an interaction.

Page 154 and the following pages contain a comparison with an earlier experimental survey on the height increment of Norway spruce after 3 years of fertilizing by a somewhat different method (*Møller and Schaffalitzky* DST 1957). The result is best seen by comparing Fig. 5 with Fig. 8—10.

It will be seen that for site classes 0 to 3 the two surveys are in good agreement, since no secure effects occur in either case.

For site classes 3 to 4, the positive trends of the NKP treatment are in agreement in the two surveys. But, whereas the 1955 survey showed a clearly positive effect of N and N/2 and no effect of P and K, the 1963 survey shows no effect of N and N/2, but a significant, positive effect of K/2.

In site classes 4 to 7 there is a fundamental agreement between the two graphical representations, as all treatments have a tendency towards positive effects, the effect of NKP being greatest, then follow the effects of N and, finally, the effects of K and P. In 1963, however, the effect of NKP is far more dominating than in 1955, while the isolated effect of N is essentially more moderate than in 1955.

The conclusion reached from the comparisons made must be that while the 1955 survey pointed to N as being most effective by far on meagre soils, the final survey appears to indicate that in the long run the effect of N depends on whether K and P are also added.

Experiments in Beech.

Generally, the beech experiments do not seem to have responded to the fertilizing, cf. Tables 7—8 and Fig. 7.

However, the three Rold Forest experiments (Table 9) show a tendency towards a positive effect of NKP, N, N/2, K and K/2. The order of magnitude of the trend is 5—10 % on the height, that of NKP being greatest with 11 %; next follow N and N/2 with 7 %, then K and K/2 with 4.5 %. The question is one of low site classes (3—4).

B-EXPERIMENTS

Each of these experiments comprises 2 sample plots in middle-aged forest, one of which has been fertilized for 10 years with NKP in 2½ times the quantities used in the A-experiments, while the other is an unfertilized control plot. Both have been observed by tabulation of measurements right from the start. The great quantities of fertilizers given do not exceed, what has been used with good results in wheat-growing, but in the spruce experiments in Gedhus and Dalgas plantations they had a marked effect on mortality.

The experiments were:

4 experiments in beech, varying between 30 and 61 years of age and between 1.3 and 1.9 in site classes (in 1953).

2 experiments in Norway spruce on heathland soil, 47 years of age, site classes 5—6 (in 1953).

1 experiment in ash, about 35 years of age, site class about 3 (in 1953).

Results (cfr tables 13—15 p. 210).

Beech. Neither basal area nor diameter increment has been affected noticeably by the fertilizing, while the height increment has been negatively affected (about 15 %), possibly because the increased salt concentration in early summer has made the absorption of water difficult (cf. the spruce experiments).

Norway spruce. The intense fertilizing had the effect that many trees died, while others displayed uncontrolled growth, especially in Gedhus plantation (cfr. figs. 11 and 12) where a double dose was given the first year (cfr. p. 201).

In the Dalgas Plantation, where the mortality rate was least, the basal area increment rose by 39 % and the height increment by 30 %. In the Gedhus Plantation both fell.

Altogether, the experiment shows that the fertilizing has augmented the growth where the basal area per hectare was not reduced too much by deaths.

On the soil the fertilizing had the effect that the moss flora almost died out the first year, and later only developed faintly, and the humus layer quickly became thin, dark and slimy.

At the same time, a herbal flora rich in species developed, and also Deschampsia flex., bracken, etc.

Ash. Judging from the results of the measurements, the fertilization has increased the basal area increment by about 25 % and the height increment by about 15 %.

The height increment rise is not significant, however.

The effect of the ground flora was remarkable, the fertilized plot being rapidly filled with an extremely exuberant flora dominated by Urtica dioeca.

A control experiment being run nearby for 6 years with the same fertilization minus K and P, showed that the growth of nettles was probably not brought about by the N-fertilization, but by K or P or NKP.

C-EXPERIMENTS

In order to ascertain the effect of harrowing on fertilized and unfertilized spruce cultures on heathland soil, a double strip experiment was established in 1955 in Dose Plantation under the Danish Heath Society. The method and results will appear from Fig. 13 and 14.

The experiment was laid out on exactly the same pattern as the A-experiments, but included a series which was harrowed and a parallel control series which was not harrowed.

The assessment in 1963 shows that on an average the harrowing in the O plots has resulted in an increment increase of about 34 %, or the same order of magnitude as obtained by means of N-containing fertilizers without harrowing.

In the fertilized plots the relative increase of increment resulting from the harrowing is a little smaller — about 24 % —, as a natural result of the increase in growth brought about by the fertilization, especially the one containing N, whereby a given increase of increment is put in relation to a higher numerical value. But also the absolute effect of the harrowing is, on an average, smaller for the fertilized plots than for the unfertilized plots, presumably because the nutrients made available by the harrowing in that case assume the character of an excess supplement, the effect of which decreases with the aggregate quantity.

The C-experiments also comprised a minor investigation aiming at establishing the most advantageous time for commencing the harrowing. Physiologically, harrowing is best started early, but, economically, it is hardly advisable to commence harrowing before the heather threatens to conquer the ground completely.

D-EXPERIMENTS

In connection with the B-experiment in Dalgas Plantation (page 212) an experiment with annual additions of different quantities of urea was established in 1957 in collaboration with the Danish Heath Society. In "Hedeselskabets Tidsskrift" No. 4, 1966, Carl Mar:Møller and Jørgen Lundberg have given an account of the results for the growth years 1957—63. The experiment is being continued. Since it has close relation to the experiment alseries mentioned here, a summary of the preliminary results is given on page 225.

The experiment comprises 6 plots, 3 of which are not fertilized, while the 3 others have received, on an average, 105 kg, 209 kg and 314 kg, respectively, of urea annually per ha, whereby *increment increases* of 11 %, 33 % and 43 %, respectively, were obtained.

A calculation of the financial result has been made, which presents the following picture for the period 1957—63, inclusive:

Yearly supply of urea per ha,	kg	105	209	314
Average yearly additional value increment,	kr.	81	188	204
Annual cost of fertilizer including cost of spreading,	kr.	81	161	242
Annual net proceed less interest,	kr.	0	27	—38

By mechanising the spreading, and limiting the delivery to every 5th year, it should be possible to improve the annual net proceeds by a figure of the order of 10—15 kr.

An investigation of the course of the increment year by year compared with meteorological data, shows that in heathland forest unfavourable precipitation conditions may have a negative effect on the increment of the same order of magnitude as the positive effect of the fertilization (Fig. 16). The negative effect was greatest on the unfertilized plots and the lightly fertilized plots.

To the eye, the effect of the fertilization on the *decomposing power of the soil* has been apparent. This fact was studied further by the taking of humus samples, which were stored for 3 months at 20°C and at an approximately constant relative humidity, analyses being made before and after the storage.

The main result of the analyses is that, at the time when the samples were taken, unfertilized spruce humus had a rather considerable content of ammonia and a small, though demonstrable, content of nitrate. Furthermore, unfertilized spruce humus, when stored, displayed a rather considerable ability to form ammonia plus small amounts of nitrate. Urea fertilizing had a promoting effect on the formation of nitrate, both during storage and in nature, while the greatly increased formation of ammonia during storage was equally great in the samples from fertilized plots and those from unfertilized plots.

Needle analyses were attached to the experiment and are mentioned in a later chapter, together with other such analyses.

It is pointed out in the text that N-fertilizing may be assumed to have a certain *after-effect,* partly through needle shedding and partly through the decomposing processes initiated in the soil.

NEEDLE ANALYSES

Needle analyses may be valuable for ascertaining whether the fertilizers administered have been assimilated and for determining in advance whether fertilizing may be expected to give a positive result.

In connection with the A and B experiments, needle samples were taken in December 1955 from the 3rd whirls in a culture in Haraldslund Plantation (experiment 21, see p. 96) on the plots fertilized with N, K, P and NKP as well as the adjoining and intermediate unfertilized control plots. In Gedhus Plantation the same was done on the NKP plot and the O plot in a ca. 50 years old stand (see p. 202).

From the needle samples the contents of ash, dry matter, chlorophyl, and of N, K and P, as well as the C/N ratio, were determined. For the fertilization with N at Haraldslund, tree measurements had shown a considerable increase in the height increment, and — at Gedhus — a considerable increase in the increment of healthy trees.

The needle analyses (see Table 23) showed that the fertilizers administered in both places had at least partly been assimilated by the spruces, seeing that the dry-matter percentage of a given fertilizer in the needles had always risen considerably in the plot where this fertilizer was given.

Additionally, for the plots treated with nitrogenous fertilizer alone, the analyses also showed a corresponding rise in the chlorophyll percentage, but a drop in K, P and dry-matter percentages — as well as, of course, the C/N ratio.

The drop in the K and P percentages points to the probability that continued fertilization with N alone will gradually reduce the K and P percentages to a detrimental minimum.

On the other hand, a drop in C/N will have a promoting effect on the decomposition of the litter — at any rate as long as K and P have not reached the detrimental minimum.

It is worth noting that in the middle-aged stand in Gedhus Plantation the percentage of N is at an essentially higher level than is the case in the Haraldslund culture.

In connection with the D-experiment with urea fertilization a number of needle analyses were also made. For details about methods, see Møller and Lundberg 1966.

From the needle analyses in Dalgas Plantation it appeared among other things (cf. Table 25), that the N percentage of the needles was substantially higher in the urea-fertilized plots than in the control plots, and that the percentage increased with the amount of urea, that is, the C/N ratio diminished — together with an increase of the increment (cf. Fig. 17 a).

Furthermore, two series of determinations of the N per cent of the needles were carried out: (b) in Norway spruce stands, all of site class approx. 6.5, but varying in age from 6 to 70 years, and (c) in Norway spruce stands, all of about 50 years, but varying in site class between 0 and 5.5. (Cf. Fig. 17).

It appeared that *in the former series* the N percentage is high (1.8 %) immediately on the establishment of the culture on a fully worked area; in the growth-check period it drops as low as 1.0 %, and rises again to almost 1.2 % at the middle age.

In the latter series, the content of N remains at about 1.7 % until we approach site class 3, when it drops to about 1.4 % in site class 5.5.

The relationship between the percentage of N and the increment seems well demonstrated by these investigations.

DYING OF PLANTS

There is reason to emphasize separately that an over-dose of fertilizers may result in the death of a number of plants or adult trees of Norway spruce.

This is specially mentioned under the B-experiments in middle-aged spruce in the Dalgas and Gedhus Plantations (see p. 201), where fertilization has been particularly intense.

Also in some A-experiments (see, particularly, table 1 p. 96 Nos 14, 15 and 27) deaths have occurred to a considerable extent in connection with fertilization.

It has not been possible to clarify the causal relation. Most probably, the cause is too great a salt concentration in the fine-root zone, which, in Norway spruce, is very superficially situated. The deaths have been particularly numerous during and immediately following the dry summer of 1955, and took place particularly in the NKP plots, though in some N plots too (experiment No. 15). In experiment No. 27 no fertilizing took place in 1954 due to an oversight, but, in return, a double application was administered in 1955, after which a great number of deaths occurred.

In experiment No. 14 (Frederikshaab Plantation, compt. 184), which is a culture on poor agricultural field, things were complicated by the presence of a vegetation of Agropyrum repens, which in the NKP plot was stimulated to such a violent growth that the competition became fatal to the spruce. In the NKP plot the mortality rate, as ascertained in January of 1966, was greatest in the centre row (out of 7), where it was 55 %, and diminished outwards until in rows Nos 1 and 7 it approached nil.

It is of interest to note that in the B experiments in beech, where fertilization was principally the same as in spruce, no mortality was observed, which may be explained partly by the more deeply situated and more vertically developed fine-root zone, and partly by the fact that the clay content of the soil, and consequently its water-retaining ability, was far greater.

On the other hand, measurements showed a reduction of the height increment for the heavily fertilized beech plots. (Cf. p. 209).

In the A-experiments with beech at the planting stage and 10 years afterwards the (weaker) NKP-fertilization had had no demonstrable negative effect whatever.

DISCUSSION

The main result of the experiments is that yearly fertilizing of forests in Denmark with quantities of NKP corresponding fairly well to those applied in agriculture, has produced no increment increase in beech — except perhaps to a moderate extent in the lowest site class. In Norway spruce it brought about increment increases, but principally only in site classes lower than 3 and then in a degree rising with a falling site class.

At first glance, the result may be wondered at, as fertilization in agriculture results in very considerable additional yields everywhere in Denmark.

It should be taken into account, however, that while a medium-sized grain crop of 36 hkg per ha removes about 50 kg nitrogen from the soil for the grain alone, only about 8 kg N are, on an average, removed from the forest annually by a good beech forest, where all age-classes are represented — a quantity which is covered alone by the amounts of nitrogen supplied by the precipitation, to which should be added the rather considerable amount of nitrogen bound by micro-organisms in the soil under good conditions.

Almost the same applies to potash and phosphoric acid, as in normal beech forestry the quantities removed from the forest are only about one-third of the amount which in good agricultural soil is assumed to be liberated by weather disintegration.

Therefore, it is not surprising that in Denmark we have not yet found any appreciable effect of fertilization of forest on good soil. Farmers, on the other hand, will have to apply considerable amounts of plant nutrients to maintain their yields.

Only in poor sands, where vigorous leaching took place during the Glacial Age and afterwards, is there such a small content of nutrients that forests and plantations suffer from deficiencies affecting the increment.

Whether it will pay to make up for these deficiencies is another question.

Per net weight unit of dry matter, forest products are cheaper than agricultural products. In the autumn of 1965 the price of one kilogram of kiln-dryed barley was about 55 øre, while the average price of one kilogram of merchantable beech wood with a corresponding water content was a little over 10 øre.

This might be taken to mean that fertilization of forests would then be less renumerative than fertilization in agriculture. It should be borne in mind, however, that it is the net return per kg produced which is decisive, and not the gross price per kg, and theoretically, the net return might will be imagined to be higher in forestry. — In fact 1960—65 it was almost the same as in agriculture. The annual dry-matter production per ha of these two trades does not differ much — nor did in 1960—65 their net proceeds per ha (compare the annual surveys of the Danish Bureau of Agricultural Economics of recent years and the economic surveys of the Danish Forest Association).

Even if the far greater removal of nutrients in agriculture is an adequate explanation why farmers have to fertilize substantially more than foresters, it does not, however, account for the fact that the dry-matter production of beech and spruce forests on better sites does not seem to be increased when the most important nutrients are made available in large quantities.

Even on first-class farmland soil it has been possible to force the annual dry-matter increment higher and higher by supplying the soil with ever larger quantities of fertilizer, though, of course, only up to a certain limit, which is in practice determined by profitability, but which may also be physiologically determined, as, in the case of cereals — by the occurrence of lodged crops.

The most probable explanation of this difference between agricultural and forestry cultures may be that in good forest soil the most important plant nutrients are present in quantities which, for the two abovenamed tree species, approach the optimum.

The theoretical possibility remains that quantities smaller than those typical in agriculture might have had a more favourable effect. The reduction in the height increment of middle-aged beeches found in the B-experiments for the plots fertilized with NKP seems to indicate this possibility as far as the biggest dosis are concerned.

In the main text of this paper, under section D p. 231, it is emphasized that, where fertilization has had a positive effect, there will probably be a continuing positive effect when fertilizing has ceased, as the store of nutrients of the stand has been increased (in the case of medium-heavy urea fertilization for 10 years by about 20 %, as far as N is concerned).

At any rate, the needles shed in the first five years after the cessation of fertilization will be richer in nutrients than those shed before fertilization commenced and will impart a continued stimulus to the decomposition of the litter. We know, for example, that the decomposition of leaves and needles is partially contingent on their content of nutrients. The best knowledge available concerns nitrogen, and several researches have demonstrated that, generally, decomposition takes place at a rate which is faster the lower the C/N ratio, i.e. the higher the nitrogen content. (*Wittich* 1939, *Lindquist* 1941, *Bornebusch* 1943).

It is probable that this stimulus will decrease when the last "fertilized" needles have been shed, but it is hardly likely to cease completely, as the initiated improvement of the decomposition will presumably continue for some time.

If we imagine fertilization continued so long and so abundantly that the soil, as far as nutrients and mull humus are concerned, will reach the level of the best site classes, it is very possible that also the increment will reach a corresponding level.

This is borne out very strongly by the German melioration experiments (refer, especially, *Wittich* 1952) which, it is true, also include soil working.

In addition the conditions prevalent in Danish heath plantations support the assumption of a residual effect of fertilization, for, after starting-difficulties on the old, generally uncultivated, heath soil, they constantly improve their site classes as measured by the current height increment. The most natural explanation is, that the "forest conditions" gradually dissolves the hard bond in which the nutrients were fixed in the heath mor, the deterioration of soil conditions by the burning of heather, sheep grazing, etc. having simultaneously stopped.

Newly applied plant nutrients must be expected to add naturally to the decomposing power of the heath forest soil.

Of the plant nutrients used in the experiment nitrogen has given the greatest effect, but it is pointed out that, in conformity with results of other Danish experiments presented by *Olsen, Rafn and Scheurer* 1960, *West-Nielsen and Oksbjerg* 1961 and *Holstener-Jørgensen* 1963, P (given simultaneously with N) has also frequently had great effect, which has been increasing with the duration of the experiment.

This fact may be explained as an exhaustion effect, as the increased growth brought about by the supply of N has also meant an increased consumption of other nutrients until these, and particularly P, have approached a detrimental minimum.

If the results of fertilization in heath forests continue in accordance with expectations, we may probably expect a repetition of what has taken place in agriculture: that in the long run an ever increasing number of nutrients will become detrimental minimum factors, primarily magnesium, copper and manganese.

However, an occount of the forest's low consumption of these substances, it will undoubtedly take far longer than has been the case in agriculture.

The experiments dealt with here were not set up to ascertain the effect of fertilization in old stands.

Many authors have pointed out that a particularly favourable effect may be expected here on the following grounds:

(1) The old forest may possibly have "exhausted" — or monopolised — such a large proportion of the nutrients of the locality that the increment has dropped more than otherwise necessary. The nutrients stored in the old stand are, for the greater part, liberated again by the final crop (cf. *Carl Mar: Møller* 1965 p. 354), and the quite young forest of the same species, which succeeds on the same area, will therefore have a smaller fertilization requirement, while the middle-aged forest will adopt an intermediate position.

(2) A given increase of increment will have a far greater direct value per m^3 in the old forest than in the young or middle-aged forest. It is true that the question may be one of comparing expectation values, but the calculation of expectation values is carried out on such an uncertain basis (rate of interest? — prices? — and so on), that such a comparison is of little value, even as a guide.

These points of view deserve a certain amount of attention, but it should be emphasized that acceleration of the growth of a culture may be of tangible value by increasing the safety and decreasing the costs, and that a given fertilization of middle-aged forest will possibly result in a greater number of cubic-metres of increment increase than the same fertilization of old forest, because the level of increment is higher, which may more than outweigh the smaller average price per m^3. It is a fact that in old forest the increment level is essentially lower (often ⅓ lower) than in middle-aged forest.

Finally, the exhaustion theory may not be so likely as imagined. Even on the very best soil the increment of the old forest will drop with age on purely physiological grounds (which are not to be discussed in this paper), and increment drops mean reduced consumption of nutrients, while the liberation of nutrients by disintegration probably continues as before, just as also the precipitation continues its supply of N as before, and the N-fixation of the micro-flora presumably continues as well. In any case, nothing has been demonstrated to prove the opposite.

Since several accounts of extremely good results of fertilization of old forests of conifers are available from abroad, it is, however, considered that we in Denmark should also initiate experiments in this sphere. Consequently, the Danish Forest Experiment Station has started 5 experiments on the fertilization of old Norway spruce on original heathland soil. Each experiment comprises 18 plots of a size varying between 0.09 ha and 0.15 ha, dependent on the ages and development stages of the stands. Experiments are being made with a one time application of

N_1 = 500 kg calcium nitrate per ha,
N_2 = 1000 kg — — - -,
P = 3000 kg superphosphate - -,
as well as combinations of these substances.

Two other experiments of the same type have been established under an agreement of cooperation between the Danish Heath Society and the Danish Forest Experiment Station.

Also, it should be mentioned that a Fertilization Committee set up by the Danish Forest Experiment Station has established fertilizing experiments with old Norway spruce also on good moraine soil.

As far as beech is concerned, the negative results of experiments on the fertilization of middle-aged forest presented here, do not make it likely that fertilizing of old beech forest will be remunerative. Moreover, owing to the occurrence of red heartwood, there is now a tendency towards a shorter rotation of beech.

It is more likely that the establishment of new fertilizing experiments with ash would attract interest, as we know that the increment of this tree species is affected by N-supply even on good soil. (Cf. *Fr. Weis* 1927 and *Treschow* 1934).

In conclusion, it should be pointed out that the results presented in this paper may be said to be a good average expression for the effect of fertilizers applied to Norway spruce and beech under the most important variations in growth conditions in Denmark, but that they do not permit of any generalisation, particularly as fas as conditions outside Denmark are concerned.

All the same, they may deserve some attention, also abroad, because they are based on an unusually comprehensive material, covering representatively a well elucidated sphere of Northern Europe's glacial formations.

ACKNOWLEDGEMENTS

The investigation accounted for in this paper is, to a considerable extent, the result of a cooperation between science and practice.

At the start of the investigation in 1953, a number of district foresters and rangers willingly undertook the rather troublesome task of carrying into effect — each within his own precinct — a common experimental plan, prepared on a scientifical basis. Following detailed arrangements in situ, the plots were marked out and surveyed, fertilizers were spread throughout a decade, etc., and, in the spring of 1953 and 1956, respectively, the heights of all the plants in the central row of each plot of the spruce experiments of the A-group were measured for use in a preliminary making-up of the results, which was published in Dansk Skovforenings Tidsskrift 1957 — and is mentioned in detail on page 154 of the present paper.

Also in the other experiments, a number of measurements were made in the period between 1953 and the final making-up of results in 1963—64, presented in this paper.

For each individual experiment, a field-book was kept right from the start, in which also special circumstances were recorded.

All was done freely.

We wish to express our gratitude to the many districts and practicians who carried out their share of the work with precision, and out of sheer interest in the cause.

Next, we thank The Danish National Technical-Scientifical Foundation for substantial support, without which the final making-up would not have seen the light of day, — the Rask-Ørsted Foundation for grant towards the translation of the paper into English and the Danish Forest Experiment Station for scientific contact and for publishing the report.

Finally, we wish to thank the Laboratory of the Danish Heath Society for the interest and willingness with which they participated in discussions and carried out — without charge — comprehensive analyses. Also, thanks are due to the Forest Department of the Royal Danish Veterinary and Agricultural College, which was the centre of the whole work.

SAMMENDRAG OG DISKUSSION

Hovedhensigten med de her forelagte forsøg har været at undersøge virkningen af sædvanlig landbrugsmæssig gødskning med kvælstof (N), kali (K) og fosforsyre (P) på skovkulturer og mellemaldrende bevoksninger af rødgran og bøg.

Gødningen har været tilført hvert år i sædvanlig 10 år i en mængde nogenlunde svarende til den i landbruget brugte.

Det fremskaffede materiale er behandlet i følgende afsnit:

A. Gødskning af kulturer af rødgran og bøg normalt på standpunktet lige før slutning, idet jorden normalt ikke har været bearbejdet siden anlæg (s. 90).

B. Gødskning af mellemaldrende bevoksninger af rødgran og bøg uden samtidig jordbearbejdning (s. 201).

C. Kombinerede gødsknings- og jordbearbejdningsforsøg i kulturer på hedebund med det formål at sammenligne virkningen af gødskning med og uden samtidig jordbearbejdning (s. 217).

D. Et gødskningsforsøg med urea i en typisk mellemaldrende rødgranbevoksning på hede uden samtidig jordbearbejdning (s. 225).

E. Nåleanalyser (s. 236).

F. Endeligt sammendrag og diskussion (hvilket afsnit gengives nedenfor på dansk).

A-FORSØGENE

omfatter 25 forsøg i kulturer af rødgran og 23 forsøg i kulturer af bøg, repræsenterende så vidt muligt alle vækstboniteter og landets forskellige egne (jfr. tab. 1 og 2 og fig. 1).

Den årlige gødskning med 300 kg 15,5 % kalksalpeter (N), 100 kg 50 % kaligødning (K) og 200 kg 18 % superfosfat (P), d. v. s. mængder svarende til hvad der anvendes i landbruget, blev principielt påbegyndt lige før bevoksningerne sluttede sig og fortsatte gennem 10 år.

Et normalforsøg, der omfatter ca. 0,7 ha, består af 15 parceller ca. 50 m lange og hver indeholdende 7, 9 eller 11 planterækker gående på langs af parcellen. Hver anden parcel er ugødet, for at enhver gødet parcel kan have to kontrolnaboer (jfr. figur 2).

Der er altid gødet med henholdsvis N, K, P, NKP, N/2, K/2, P/2. — I nogle tilfælde er normalforsøget suppleret med en eller flere andre gødningsbehandlinger.

Før gødskningens start er for hvert forsøg efter landbrugets sædvanlige prøveudtagnings-metoder bestemt pH, fosforsyretallet Ft, fosfattallet Fot, kalitallet Kt og kolorimetrisk målte nitrattal (smlgn. tab. 1 og 2).

Analysesikkerheden er belyst derved, at analyser i stor udstrækning er foretaget både af Statens Planteavlslaboratorium og af Hedeselskabets Laboratorium, hvorved små systematiske forskelle er fundet, medens den tilfældige variation var forholdsvis ringe.

Samtlige indextal havde en med boniteten stigende tendens.

Indextallenes variation inden for nogle enkelte typiske forsøg er også bestemt og fundet ret betydelig. — Jfr. s. 102.

Efter forløbet af 10 gødskningsår (i enkelte tilfælde dog færre eller flere) er alle forsøgene beskrevet, og der er foretaget målinger af højde og diameter (ved 1,3 m eller ved små højder 0,5 m over jorden) på et stort antal repræsentativt udtagne prøvetræer, idet der er anvendt følgende metoder:

Metoder.

Med sine 7 forskellige behandlinger kan det typiske A-forsøg opfattes som sammensat af 7 delforsøg, hvert bestående af en behandlet parcel flankeret af to ubehandlede kontrolparceller. Hvis disses vækst stemmer overens, er der ringe sandsynlighed for, at den mellemliggende ca. 10 m brede og ca. 50 m lange behandlingsparcel i hele sin udstrækning har en ensidigt afvigende naturlig vækstbonitet.

Selv om det er tilstræbt at placere hvert A-forsøg på ensartet jordbund, er forholdene i skov dog så uregelmæssige sammenlignet med landbrugets forhold, og parcellerne må desuden være så meget større, at betingelsesvariationer ikke har kunnet undgås og da især i parcellernes længderetning.

For så vidt muligt at eliminere denne variation har man valgt at dele de 3 parceller i et delforsøg i 3 grupper ved skillelinjer på tværs af længderetningen. Derved opstår 9 lige store parcelelementer, nemlig 3 behandlede og 6 ubehandlede.

Ved udtagning af prøvetræer er det tilstræbt at måle et nogenlunde konstant antal træer pr. parcelelement. Dog er i gødede parceller målt flere prøvetræer (ca. 15 pr. element) end i ugødede (ca. 10), idet de gødede parceller sammenlignes med to ugødede.

I granforsøgene er den gennemsnitlige repræsentationsgrad for gødede parceller 17 %, for ugødede 11 %. I bøgeforsøgene er repræsentationsgraden på grund af det langt større stamtal væsentlig mindre (ca. 5 % og ca. 3 %).

Prøvetræerne er udtaget efter strengt objektive metoder.

De målte højder og diametre er på stedet indført i et skema, hvorfra disse data sammen med talkode for træart, forsøgsnummer, parcel og parcelelement m. m. er overført på hulkort. Derefter er beregningerne udført på Digital Computer (I/S Datacentralen, København).

Der er udarbejdet to specielle beregningsprogrammer for variansanalyse, et for hovedundersøgelsen og et for en undersøgelse af nabovirkninger (jfr. s. 135), som er bygget på rækkevis adskilte målinger i nogle NKP-delforsøg, hvor behandlingsudslaget har været størst.

Opbygningen af A-forsøgene medfører nemlig, at grænserne mellem behandlede og ubehandlede parceller er meget lange i forhold til parcellernes arealer, hvorfor det er magtpåliggende at få størrelsen og udstrækningen af evt. nabovirkninger oplyst, idet man måske ved indskydelse af isolationsbælter kan få disse virkninger elimineret.

Med hensyn til *nabovirkninger* viser undersøgelsen klart, at parcellernes yderste rækker oftere er påvirket end de næstyderste. Hovedindtrykket af denne specialundersøgelse er, at nabovirkningernes udstrækning kun er én til få meter, hvilket indtryk er i overensstemmelse med nyere undersøgelser, der viser, at koncentrationen af finrødder aftager hurtigt med voksende afstand fra træet.

Som resultat af undersøgelsen er overalt mellem parcellerne indskudt et ikke målt isolationsbælte omfattende den behandlede parcels yderste række og kontrolparcellens yderste række.

Behandlingsresultaterne

fremgår af tabellerne 5—9 og af fig. 5—6 (granforsøg) og fig. 7 (bøgeforsøg), samt af tabelværk A s. 163.

Det må bemærkes, at når tabellerne viser større udslag på diametre end på højde, kan det til dels skyldes, at diameteren i samme forsøg er målt ved fast højde over jorden. Se nærmere s. 247 nederst.

G r a n f o r s ø g.

I gran er signifikante positive udslag på højdevæksten kun fremkommet for N, NKP og P/2 i bonitetsklasse 4—7 og for K/2 i bonitetsklasse 3—4, hvor dog NKP har en kraftig positiv tendens. For *diametrenes* vedkommende har N, N/2, P/2 og NKP alle givet signifikante positive udslag i bonitetsklasse 4—7, medens i bonitetsklasse 3—4 K/2 og NKP har givet signifikant positivt udslag og P signifikant negativt udslag.

Det må fremhæves, at bonitetsklasse 3—4 kun omfatter 4 forsøg mod 9 for bonitetsklasse 0—3 og 12 for bonitetsklasse 4—7.

I bonitetsklasse 0—3 fandtes ingen signifikante udslag, men nok en svag positiv tendens for N-holdige gødninger.

Man bemærker, at NKP-udslagene er meget større end summen af udslagene af N-, K- og P-behandlingerne enkeltvis. Der er formentlig her tale om en vekselvirkning.

S. 154 og flg. er foretaget en sammenligning med en tidligere forsøgsopgørelse for rødgrans højdevækst efter 3 års gødskning og efter en lidt anden metode (*Møller og Schaffalitzky* DST 1957). Resultatet fremgår bedst ved en jævnførelse af fig. 5 med fig. 8—10.

Det ses, at der for bonitetsgruppe 0—3 er god overensstemmelse mellem de to opgørelser, idet der i ingen af tilfældene kan konstateres udslag.

For bonitetsgruppe 3—4 stemmer NKP-behandlingens kraftige udslag overens ved de to opgørelser. Men medens opgørelsen for 1955 viste et klart positivt udslag for N og N/2 og ingen udslag for P og K, har opgørelsen pr. 1963 ingen udslag for N og N/2, men signifikant positivt udslag for K/2. (NKP udslaget i 1963 er vel kraftigt men ikke signifikant).

For bonitetsgruppe 4—7 er der principiel overensstemmelse mellem de to grafiske billeder, idet der er en tendens til positive udslag for alle behandlinger og således, at udslaget for NKP er størst, derefter kommer N og tilsidst K og P. Blot er i 1963 NKP's udslag langt mere dominerende end i 1955, medens N's selvstændige udslag er væsentlig mere beskedent end i 1955.

Den samlede konklusion af den foretagne sammenligning må være, at medens opgørelsen pr. 1955 pegede mod N som langt det virksomste stof på mager bund, indicerer den endelige opgørelse, at N's virkning i det lange løb er afhængig af, om der også gives K og P.

Bøgeforsøg.

I det store og hele synes bøgeforsøgene ikke at have reageret på gødskningen, jfr. fig. 7.

I de 3 Rold skov forsøg (tab. 9) ses dog en tendens til positiv virkning af NKP, N, N/2, K og K/2. Størrelsesordenen af tendensen er 5—10 % på højden, med NKP størst med 11 % og derefter N og N/2 med 7 % og K og K/2 med 4½ %. Det drejer sig om bonitet 3—4.

B-FORSØGENE

omfatter hvert 2 prøveflader i mellemaldrende skov, hvoraf den ene årlig gennem 10 år har fået NKP gødskning i 2½ gange så stor mængde som i A-forsøgene, medens den anden er en ugødet kontrol. Begge er fulgt med målinger fra starten. De store gødningsmængder overskrider ikke, hvad der er blevet brugt i hvededyrkning med godt resultat, men i Gedhus plt. blev der ved en fejltagelse givet dobbelt dosis det første år, hvilket medførte en extra stor dødelighed (se nedenfor).

Det drejer sig om

4 forsøg i bøg varierende i 1953 fra 30—61 års alder og i bonitet fra 1,3 til 1,9,

2 forsøg i rødgran på hedebund, i 1953 47 år, bonitet 5—6,

1 forsøg i ask i 1953 ca. 35 år, bonitet ca. 3.

Resultater (se tab. 13—15 s. 210).

Bøg. Hverken grundflade- eller diametertilvækst er påvirket mærkbart af gødskningen, hvorimod højdetilvæksten har været negativt påvirket (ca. 15 %), måske fordi den forøgede saltkoncentration i forsommertiden har besværliggjort vandoptagelsen (jfr. granforsøgene). Højdetilvækstbestemmelsen er udført ved overskæring og åringstælling på objektivt udtagne prøvetræer.

Rødgran. Den stærke gødskning bevirkede, at mange træer døde, medens andre viste en ubehersket vækst, ganske særlig i Gedhus plantage, jvf. fig. 11 og 12.

I Dalgas plantage, hvor dødeligheden var mindst, steg grundfladetilvæksten 39 % og højdetilvæksten 30 %. I Gedhus plantage faldt begge. Højdetilvæksten er bestemt direkte på objektivt udtagne prøvetræer.

Alt i alt viser forsøget, at gødskningen har forøget væksten, hvor stammegrundfladen pr. ha ikke ved dødsfald er bragt for langt ned.

På jordbunden havde gødskningen den virkning, at mosfloraen allerede første år næsten uddøde og siden kun udviklede sig svagt, samt at humuslaget hurtigt blev tyndt, mørkt og fedtet.

Samtidig bredte sig en artsrig urteflora.

Ask. Efter måletallene har gødskningen forøget grundfladetilvæksten med ca. 25 % og højden med ca. 15 %.

Højdetilvækstforøgelsen er dog ikke signifikant.

Virkningen på bundfloraen var slående, idet den gødede parcel hurtigt fyldtes af en overordentlig yppig flora domineret af Urtica dioeca.

Et i nærheden gennem 6 år løbende kontrolforsøg med samme gødskning ÷ K og P viste, at nældevæksten sandsynligvis ikke var fremkaldt af N-gødskningen, men af K eller P eller NKP.

C-FORSØG

For at belyse virkningen af renholdelse af respektive gødede og ikke gødede grankulturer i Heden anlagdes i 1955 i Dose plantage under Hedeselskabet et dobbelt stribeforsøg, hvis metode og resultater fremgår af fig. 13 og 14 s. 218.

Forsøget er anlagt efter ganske samme mønster som A-forsøgene, men med en serie, der renholdtes, og en parallelt løbende serie, der ikke renholdtes.

Opgørelsen i 1963 viser, at renholdelsen i 0-parcellerne i snit har givet en mertilvækst på ca. 34 %, hvilket er af omtrent samme størrelsesorden, som den mertilvækst, der opnåedes ved N-holdig gødskning uden renholdelse.

For de gødede parcellers vedkommende er den af renholdelsen forårsagede relative mertilvækst lidt mindre, ca. 24 %, som en naturlig følge af den vækstforøgelse, som gødskningen har bevirket, især for den N-holdige gødnings vedkommende, hvorved en given mertilvækst sættes i relation til en højere talværdi. Men også renholdelsens absolute effekt er i snit for de gødede parceller mindre end for de ugødede, vel som en virkning af, at de næringsstoffer som renholdelsen gør disponible, her har karakter af et mertilskud, hvis effekt jo falder med den samlede mængde.

C-forsøget omfatter også en mindre undersøgelse af, hvilket tidspunkt for rensningens påbegyndelse der er fordelagtigst. Fysiologisk er hurtig påbegyndt og fortsat rensning bedst. Men økonomisk er det næppe rigtigt at begynde rensning, før lyngen truer med helt at erobre bunden.

D-FORSØG

I forbindelse med B-forsøget i Dalgas plantage (s. 205) anstilledes i 1957 i samarbejde med Hedeselskabet et forsøg med årlig tilførsel af forskellige mængder urea. Carl Mar: Møller og Jørgen Lundberg har i Hedeselskabets Tidsskrift nr. 4 1966 afgivet en beretning omfattende resultaterne for vækstårene 1957—63. Forsøget fortsættes. Da det har nær tilknytning til de her omhandlede forsøgsserier, er der s. 225 givet en sammenfatning af de foreløbige resultater.

Forsøget omfatter 6 parceller, hvoraf 3 er ugødede, medens de andre 3 i gennemsnit har modtaget henholdsvis 105 kg, 209 kg og 314 kg urea årlig pr. ha, hvorved er opnået *mertilvækster* på henholdsvis 11 %, 33 % og 43 %.

Der er foretaget en *beregning af det økonomiske resultat, som giver følgende billede gældende for tiden 1957—63 inclusive:*

kg urea årlig pr. ha		105	209	314
gennemsnitl. årlig mer-værditilvækst	kr.	81	188	204
årlig udgift til gødning og udspredning	kr.	81	161	242
årlig nettoprovenu uden forrentning	kr.	0	27	÷38

Ved mekanisering af spredningen og udbringning kun hvert 5. år skønnes det årlige nettoprovenu at kunne forbedres med 10—15 kr., hvis samme gødningsvirkning opnås.

En undersøgelse af tilvækstens forløb år for år sammenholdt med meteorologiske data viser, at i hedeskov kan ugunstige nedbørsforhold have en negativ indflydelse på tilvæksten af samme størrelsesorden som den positive virkning af gødskningen (fig. 16). Den negative virkning var størst på den ugødede og den svagt gødede parcel.

Gødskningen har haft en for øjet tydelig virkning på *jordbundens omsætning.* Forholdet er nærmere belyst ved udtagning af humusprøver som lagredes i 3 måneder ved 20° og tilnærmelsesvis konstant fugtighedsgrad, idet der foretoges analyser før og efter lagringen.

Hovedresultatet af analysen er, at ugødet granhumus allerede ved prøveudtagelsen havde et ikke ubetydeligt indhold af ammoniak og et ringe, men konstaterbart nitratindhold. Ugødet granhumus viste endvidere en ret betydelig evne til under lagring at danne ammoniak + små mængder nitrat. Ureagødskningen fremmede nitratdannelsen betydeligt såvel under lagringen som i naturen, hvorimod den stærkt forhøjede ammoniakdannelse under lagringen var lige stor i prøverne fra ugødede og gødede parceller.

Til forsøget var knyttet *nåleanalyser*, som sammen med andre sådanne omtales i et følgende afsnit.

Det fremhæves i teksten, at N-gødskning må antages at have en vis *eftervirkning*, dels gennem nålefald, dels gennem de indledte omsætningsprocesser i jordbunden.

NÅLEANALYSER

Til konstatering af, at givne gødningsstoffer er optaget og til forlods afgørelse af, om gødskning kan ventes at give positivt resultat kan nåleanalyser være værdifulde.

I forbindelse med A- og B-forsøgene udtoges i december 1955 nåleprøver fra 3. grenkrans i A-forsøget i en kultur i Haraldslund i de med N, K, P og NKP gødede parceller samt i de tilgrænsende og mellemliggende ugødede kontrolparceller. I Gedhus tilsvarende i NKP-parcellen og i 0-parcellen i ca. 50årig gran.

Der bestemtes i nåleprøverne askeindhold, tørstofindhold, klorofylindhold, indhold af N, K og P samt C/N forholdet. Træmålinger havde for N-gødskningen i Haraldslund vist en betydelig forøgelse af højdetilvæksten og i Gedhus en betydelig forøgelse af sunde træers tilvækst.

Nåleanalyserne (se tab. 23) viste, at de begge steder givne gødningsmængder alle for en stor del er blevet optaget af granerne, siden nålenes tørstofprocent af et givet gødningsstof altid er steget betydeligt i den parcel, hvor dette stof er givet.

Analyserne viste dernæst for de med kvælstofgødning behandlede parceller tillige en tilsvarende stigning af klorofylprocent, men et fald af K-% og P-%, tørstofprocent — og naturligvis af C/N forholdet.

Faldet af K% og P% må pege på sandsynligheden af, at en fortsat gødskning med N alene med tiden vil bringe K og P i skadeligt minimum.

Derimod vil et fald i C/N virke fremmende på affaldets omsætning, i alt fald så længe K og P ikke er i skadeligt minimum.

Det er bemærkelsesværdigt, at N% i den mellemaldrende bevoksning i Gedhus ligger på et væsentlig højere niveau end i kulturen i Haraldslund. (Smlgn. med den nedenfor omtalte undersøgelse).

Også i forbindelse med D-forsøget med ureagødskning foretoges en række nåleanalyser. Angående detailler om fremgangsmåder se *Møller og Lundberg* 1966.

Af nåleanalyser i Dalgas plantage fremgik det bl. a. (jfr. tab. 25), at nålenes N% var væsentlig større i de urea-gødede parceller end i kontrolparcellerne, og at procenten steg med ureamængden, hvilket vil sige, at C/N faldt, begge dele sammen med at tilvæksten steg.

Yderligere foretoges to serier bestemmelser af nålenes N%, nemlig 1) i rødgranbevoksninger alle af bon. ca. 6½, men varierende i alder fra 6 til 70 år og 2) rødgranbevoksninger alle omkring 30 år, men varierende i bonitet mellem 0 og 5½ (jfr. fig. 17).

Det fremgik, at N% i *første serie* straks efter kultur på fuldbearbejdet flade er høj (1,8), i væksthæmningsperioden går helt ned på 1,0, for så igen at stige til næsten 1,2 i mellemalderen.

I *anden serie* holder N% sig på ca. 1,7, indtil vi nærmer os bon. 3, hvorefter den falder ned til ca. 1,4 ved bon. 5½ (og 1,2 ved bon. 6½). Sammenhængen mellem N% og tilvækst synes vel belyst ved disse undersøgelser.

PLANTEDØD

Der er grund til særskilt at fremhæve, at en overdosering med gødningsstoffer kan medføre, at en del planter eller voksne træer af rødgran dør.

Dette er specielt omtalt under B-forsøgene i Dalgas- og Gedhus plantager (se s. 212), hvor det drejer sig om mellemaldrende gran, og hvor gødskningen har været særlig kraftig.

Men også i en del A-forsøg (se især forsøg nr. 14, 15 og 27) er dødsfald indtruffet i betydeligt omfang i forbindelse med gødskning.

Den nærmere årsagssammenhæng har ikke med sikkerhed kunnet oplyses. Sandsynligheden taler for, at årsagen er en for stor saltkoncentration i den hos rødgran meget overfladisk beliggende finrodzone. Dødsfaldene har været særlig talrige i og lige efter den tørre sommer 1955 og har især fundet sted i NKP-parcellerne, men også i N-parceller (forsøg nr. 15). I forsøg nr. 27 blev der ved en forglemmelse ikke gødet i 1954, men til gengæld gav man dobbelt dosis i 1955, hvorefter stærke dødsfald indtrådte.

I forsøg nr. 14 (Frederikshåb plantage afd. 184), som er en agermarkskultur, kompliceredes forholdet ved tilstedeværelsen af en vegetation af Agropyrum repens, som i NKP-parcellen stimuleredes til en så voldsom vækst, at konkurrencen blev skæbnesvanger for granerne. Dødeligheden opgjort januar 1966 var i NKP-parcellen størst i midterrækken (af 7), hvor den var 55 %, og aftog udad så den i række 1 og 7 nærmede sig 0.

Det er interessant, at i B-forsøgene med mellemaldrende bøg, hvor gødskningen var af samme styrke som i rødgran, iagttoges ikke nogen dødelighed, hvilket kan forklares dels ved den dybere liggende og mere vertikalt udbredte finrod-zone, dels ved, at jordens lerindhold og dermed dens vandholdende evne var langt større.

Derimod viste målingerne en nedsættelse af højdevæksten for de stærkt gødede parcellers vedkommende. (Jvf. s. 265).

I A-forsøgene med bøg i kulturstadiet og 10 år frem, forårsagede gødskningen ingen påviselig negativ virkning af nogen art.

DISKUSSION

Forsøgets hovedresultat er, at gødskning af skov i Danmark med årlige mængder NKP, der nogenlunde svarer til landbrugets gødskning, ikke har frembragt tilvækstforøgelse i bøg undtagen måske i beskedent omfang på laveste bonitet, — og i rødgran kun på boniteter lavere end 3 og da ganske vist i stigende grad med faldende bonitet.

Overfladisk kan resultatet undre, da landbrugets gødskning overalt i Danmark bevirker meget betydelige merydelser.

Det må imidlertid tages i betragtning, at medens en middelstor kornhøst på 36 hkg pr. ha alene i kerne fjerner ca. 50 kg kvælstof fra jorden, drejer det sig i god bøgeskov kun om en gennemsnitlig fjernelse af gennemsnitlig ca. 8 kg N årlig, en mængde, der nogenlunde dækkes alene af de kvælstofmængder, der falder med nedbøren, hvortil kommer den ret betydelige kvælstofmængde, som der under gode forhold bindes af mikroorganismer i jordbunden.

Noget ganske lignende gælder kali og fosforsyre, hvor almindelig bøge-skovdrift kun fjerner ca. ⅛ af de mængder, man på god landbrugsjord regner med frigøres ved forvitring.

Det er derfor ikke overraskende, at vi ikke hidtil i Danmark har fundet nævneværdigt udslag for gødskning af skov på bedre jord, og at derimod landbruget for at opretholde sine afgrøder må give meget betydelige tilskud af næringsstoffer.

Først når vi kommer ud på meget mager jord, hvor der under og efter istiden er foregået en kraftig udvaskning, kan man regne med så ringe næringsstofindhold i jorden, at også skove og plantager lider af mangler, som påvirker tilvæksten i nedadgående retning.

Om det så betaler sig at afhjælpe disse mangler, er et andet spørgsmål.

Pr. tørvægtsenhed er skovprodukter jo billigere end landbrugsprodukter. Et kg tørvægt af byg lå i efteråret 1965 på ca. 55 øre, medens gennemsnitsprisen for 1 kg tørvægt af salgbart bøgetræ lå ved godt 10 øre.

Umiddelbart kunne dette opfattes sådan, at så må gødskning i skoven altid være mindre lønnende end i landbruget. Det må dog erindres, at det er driftsnettoen pr. kg produktion, som er afgørende og ikke bruttoprisen pr. kg, og teoretisk kunne det tænkes, at den var størst for skovbruget. I praksis var den dog 1960—65 omtrent den samme. De to brugsformers årlige tørstofproduktion pr. ha var ikke meget forskellig og deres nettoindtjening pr. ha heller ikke, jfr. Landøkonomisk Driftsbureaus årsoversigter for de senere år med Dansk Skovforenings økonomiske oversigter.

Selv om den langt større fjernelse af gødningsstoffer i landbruget er en fyldestgørende forklaring på, at landbruget må gødske væsentlig mere end skovbruget, forklarer den dog ikke, hvorfor bøge- og gran-skovs tørstofproduktion på bedre skovjord ikke synes at påvirkes, når de vigtigste gødningsstoffer stilles til disposition i større mængder.

Selv på prima landbrugsjord kan man dog i det enkelte år drive tørstoftilvæksten højere og højere op ved at give større og større gødningsmængder, men naturligvis kun til en vis grænse, der i praksis er bestemt af rentabiliteten, men også kan være fysiologisk bestemt, f. eks. for korns vedkommende ved optræden af lejesæd.

Forklaringen på denne forskel mellem landbrugs- og skovbrugskulturer må sandsynligvis ligge i, at de vigtigste plantenæringsstoffer i god skovjord er til stede i mængder, der for de to førnævnte træarters vedkommende er temmelig nær optimum.

Tilbage bliver den teoretiske mulighed, at mindre tilskudsmængder end de i landbruget anvendte kunne have virket gunstigere. Den i B-forsøgene fundne nedgang i mellemaldrende bøgs højdetilvækst for de NKP gødede parcellers vedkommende kunne tyde herpå for de største dosers vedkommende.

Det er i teksten til D-forsøgene fremhævet, at der, hvor gødskningen har haft positiv virkning, sandsynligvis vil blive tale om en positiv eftervirkning, når gødskningen er holdt op, idet bevoksningens forråd af næringsstoffer er blevet forøget (ved middelstærk urea-gødskning gennem 10 år med op til ca. 20 % for N's vedkommende).

De første 5 års nålefald efter gødskningens ophør vil i alt fald være rigere på næringsstoffer, end tilfældet var før gødskningen, og omsætningen af bundens affald vil derved fortsat få en stimulans, idet vi ved, at løvs og nåles omsætning for en del er betinget af nålenes indhold af næringsstoffer. Bedst oplyst er forholdet for kvælstofs vedkommende, hvor det af flere forskere er påvist, at omsætningen i almindelighed sker desto hurtigere, jo lavere C/N forholdet er, det vil sige jo større kvælstofindholdet er. (*Wittich* 1939, *Lindquist* 1941, *Bornebusch* 1943).

Det er sandsynligt, at denne stimulans vil aftage, når de sidste „gødede" nåle er faldet, men det er næppe sandsynligt, den helt vil ophøre, da den indledede forbedring af omsætningen nok vil køre videre, i alt fald en tid.

Tænker man sig en gødskning fortsat så længe og så rigeligt, at bunden i næringsrigdom og indhold af ægte humus kommer op på højde med de bedste boniteter, er der betydelig sandsynlighed for, at også vækstydelsen nogenlunde vil komme til at svare til disse.

Derpå tyder med stor styrke de tyske meliorationsforsøg (se særlig *Wittich* 1952), som ganske vist også indbefatter jordbearbejdning.

Også vore hedeplantagers almindelige forhold støtter antagelsen om en blivende virkning af gødskning, idet de efter begyndelsesvanskeligheder på den ofte kun svagt bearbejdede gamle hedebund stadig forbedrer deres bonitet målt med den løbende højdetilvækst. Dette må naturligt opfattes således, at skovtilstanden efterhånden løser den „hårdknude", hvori næringsstofferne var bundet i lynghedens mor, idet samtidig forringelse af tilstanden ved lyngbrænding, fåregræsning o. l. er ophørt.

Nytilførte næringsstoffer må ventes naturligt at gå ind i hedeskovens omsætning under stimulering af dens tempo.

Af de i forsøgene som tilskud anvendte plantenæringsstoffer har kvælstof givet de største udslag, men det er fremhævet, at også P i overensstemmelse med resultater af andre danske forsøg forelagt af *Olsen, Rafn og Scheurer* 1960, *West-Nielsen og Oksbjerg* 1961 og *Holstener-Jørgensen* 1963 ofte har haft betydelig virkning, når P gives samtidig med N, og i stigende grad jo længere forsøget har varet.

Dette forhold kan forklares som en udtømningsvirkning, idet den ved N-tilskuddet forstærkede vækst også har betydet et forstærket forbrug af andre næringsstoffer, indtil disse og måske især P er begyndt at komme i skadeligt minimum.

Hvis gødskningen i hedeskovene holder, hvad den lover, må vi nok forvente en gentagelse af, hvad der er sket i landbruget, nemlig at i det lange løb flere og flere næringsstoffer melder sig som farlige minimumsfaktorer, i første linie magnium, kobber og mangan.

På grund af skovens ringe forbrug vil det dog sandsynligvis vare meget længere end i landbruget.

Der er et forhold, som de her omhandlede forsøg ikke har forsøgt at belyse.

Det er virkningen af gødskning i gammel skov.

At der her kan blive tale om en særlig gunstig virkning, er fremhævet af mange forfattere med følgende som de vigtigste motiver:

1) *Den gamle skov kan muligvis have „opbrugt“ eller beslaglagt* en så stor del af lokalitetens næringsstoffer, at tilvæksten af den grund er sunket mere end ellers nødvendigt. Det i trævæksten accumulerede forråd bliver for den væsentligste del igen frigivet ved hovedbenyttelsen (jfr. *Carl Mar: Møller* 1965 s. 354), hvorfor den unge skov af samme træart, der følger efter på samme areal, vil have et mindre gødskningsbehov, medens mellemaldrende skov vil have en mellemstilling.

2) En given tilvækstforøgelse vil i den gamle skov have en langt større direkte værdi pr. m^3 end i den unge eller mellemaldrende skov.

Ganske vist kan der også blive tale om en sammenligning af venteværdier, men venteværdiers beregning sker på et så usikkert grundlag (rentefod? priser? o. s. v.), at en sådan sammenligning kun har vejledende værdi. —

Der må indrømmes disse synspunkter en vis vægt, men det må dog fremhæves, at en fremskyndelse af en kulturs vækst kan tænkes at have kontant og direkte værdi ved at forøge sikkerheden og mindske omkostningen, samt at en given gødskning af mellemaldrende skov muligvis frembringer flere m^3 mertilvækst end samme gødskning af gammel skov, fordi tilvækstniveauet ligger højere, og at dette kan mere end opveje den mindre middelpris pr. m³. Tilvækstniveauet ligger jo i gammel skov væsentlig lavere end i mellemaldrende, ofte på ca. ⅔.

Endelig er opbrugningsteorien måske ikke så sandsynlig. Selv på aller bedste jord falder den gamle skovs tilvækst med alderen af rent fysiologiske grunde, som her ikke skal diskuteres, og tilvækstfald betyder nedsat næringsstofforbrug, samtidig med at frigørelsen af næringsstoffer ved forvitring sandsynligvis fortsætter som før, ligesom nedbøren fortsætter sin tilførsel af N som før og mikrofloraens N-binding vel også fortsætter. Der er i alt fald intet oplyst om det modsatte.

Da der fra udlandet foreligger flere beretninger om overordentlig gode resultater af gødskning af gammel nåletræskov, er der dog ingen tvivl om, at vi også i Danmark bør anstille forsøg hermed.

Statens forstlige Forsøgsvæsen har derfor også igangsat 5 forsøg med gødskning af gammel rødgran på oprindelig hedebund. Hvert forsøg omfatter 18 parceller med en størrelse, der varierer mellem 0,09 ha og 0,15 ha efter bevoksningernes aldre og udvikling. Der forsøges med en engangstilførsel af

N_1 = 500 kg kalksalpeter pr. ha
N_2 = 1000 „ „ „ „
P = 3000 „ superfosfat „ „.
og kombinationer.

To forsøg af samme type er anlagt under en samarbejdsaftale mellem Hedeselskabet og Statens forstlige Forsøgsvæsen.

Endelig bør det nævnes, at det af Forsøgsvæsenet nedsatte Gødningsudvalg har anlagt gødningsforsøg i gammel rødgran på den gode moræneb und.

For bøgens vedkommende gør de her forelagte negative resultater af forsøg med gødskning af mellemaldrende skov det ikke sandsynligt, at gødskning af gammel bøgeskov normalt vil være lønnende. Desuden går tendensen på grund af rødkernedannelsen nu i retning af kortere omdrifter i bøg.

Det er mere sandsynligt, at det vil have interesse at anstille nye gødningsforsøg i ask, idet vi ved, at denne træarts tilvækst er påvirkelig i alt fald af N-tilskud, jfr. *Fr. Weis* 1927 og *Treschow* 1934.

Vi vil til slut fremhæve, at de her fremlagte resultater vel må siges at være et godt gennemsnitsudtryk for de anvendte gødningsstoffers virkning på rødgran og bøg under de væsentligste variationer i Danmarks vækstforhold, men at de dog ikke tillader nogen generalisation, især ikke gældende for forhold uden for Danmark.

Alligevel fortjener de vistnok påagtelse, også i udlandet, fordi de hviler på et usædvanligt omfattende materiale, der repræsentativt dækker et vel belyst område af nordeuropæiske istidsdannelser.

SLUTORD

De her forelagte forsøg er i betydelig udstrækning et resultat af samarbejde mellem videnskab og praksis.

Ved forsøgets start i 1953 påtog en række distriktsbestyrere og skovfogeder sig vederlagsfrit det ret krævende arbejde hver inden for sit område at realisere en på videnskabelig basis udarbejdet fælles forsøgsplan. Efter detaillerede aftaler på stedet gennemførtes afmærkning og opmåling af parceller, årlig udspredning af gødning gennem 10 år m. m. og i foråret henholdsvis 1953 og 1956 for A-gruppens granforsøgs vedkommende måling af samtlige planters højde i hver parcels midterrække til brug for en foreløbig opgørelse, der offentliggjordes i Dansk Skovforenings Tidsskrift 1957 og er nærmere omtalt s. 154 i nærværende tekst.

Også for de øvrige forsøgs vedkommende gennemførtes en række målinger i tiden fra 1953 til den her forelagte endelige opgørelse i 1963—64.

For hvert enkelt forsøg blev fra starten ført målebøger, hvori også noteredes særlige forhold.

Vi bringer en hjertelig tak til de mange skovdistrikter og praktikere, som alene i sagens interesse og med præcision har deltaget i samarbejdet.

Vi takker dernæst Statens Teknisk-Videnskabelige Fond for en betydelig støtte, som alene gjorde den endelige samlede opgørelse mulig, Rask-Ørsted Fonden for støtte til arbejdets oversættelse til engelsk og Statens forstlige Forsøgsvæsen for videnskabelig kontakt og publikationsmæssigt samarbejde.

Endelig retter vi en tak til Hedeselskabets Laboratorium for den interesse og beredvillighed, hvormed man deltog i drøftelser og uden vederlag udførte omfattende analyser, og til Landbohøjskolens skovbrugsafdeling, som har været moderstedet for hele arbejdet.

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