SOME EXPERIENCES FROM FOREST FERTILIZATION TRIALS IN SWEDEN

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Introduction

Forest fertilization on a practical scale is just starting in Sweden, as in a number of other countries. However, scientific research on the effect of nutrient applications has been going on for many years. Simple field experiments were also laid out some 50 years ago. The first attempt to create a scientific foundation for forest fertilization in Sweden was made by H. V. TIBERG (1907, see TAMM and TAMM, 1963), the director of one of the many iron and steel works in middle Sweden. TIBERG was familiar with the German literature on forest nutrition, and made a number of soil and plant analyses, mostly from his factory's forests. Unfortunately, the correct observation that poor forest soils contained much less calcium than fertile soils, led him to the same conclusion as many German investigators, viz., that liming was the most necessary treatment. TIBERG's field experiments were not followed up after his death in 1913, and as far as is known there was never great growth promotion by his treatments.

TIBERG's line of thought was taken up and applied within a particular field, to a drained peatland, by W. ÅLUND, chief forester of Robertsfors Company (province of Västerbotten, North Sweden). Ålund applied wood ashes, produced in the company's sulphite mill, to plots on peatland, which had remained un-

Fig. 1. N. Hällmyren, Robertsfors, province of Västerbotten. Deep peat drained in 1910, still treeless except where fertilized (the self-sown stand in the background) and along ditches (to the left in the background). Dose of fertilizer: 12 500 kg of wood ash per hectare in 1926. Altitude 90 m. — Photo H. HOLMEN 21. 8. 1962.

productive for a long time after being drained. The result was a striking improvement (Fig. 1, cf. MALMSTRÖM 1934, 1952), which confirmed the idea of TIBERG and ÅLUND, that poor sites are unable to supply a forest stand with the mineral nutrients needed for good growth.

At the same time H. HESSELMAN worked intensively on the problems of forest growth and regeneration in northern Sweden. He showed conclusively (HESSELMAN 1917, 1926) that forest growth, and particularly the development of saplings, was closely related to the nitrogen turn-over in the soil. In the twenties he also started field experiments in which nitrogenous fertilizers were applied, mostly ammonium nitrate in very dilute solutions. The effects were almost as striking as those obtained by ÅLUND, both with old spruce forest (HESSELMAN 1937) and with young pines in so-called lichen pine forest. In the latter case, however, the test saplings soon died, probably owing to over-doses (ROMELL and MALMSTRÖM, 1945).

Subsequent research has for a long period concentrated on the causes of the growth-check studied by ÅLUND and HESSELMAN, on the problem of mineral nutrient deficiency in drained peatlands (MALMSTRÖM 1935, 1952), and on the problem of nitrogen deficiency in mineral soils (ROMELL 1938, TAMM and CARBONNIER 1961). During the last decade a number of new experiments have been laid out, and new methods have been worked out, for the study of forest nutrition problems, (e.g. foliar analysis), and it is now possible to present a more diversified picture than was the case some ten years ago. On the other hand, the main results of the old experiments have been confirmed repeatedly, and some of the old plots are still of great value, because they can tell us something about the duration of the effects of fertilization.

Examples of fertilizer effects in recent experiments on mineral soils

Well-drained to moderately well-drained sites

Fig. 3 and some following diagrams show the diameter growth after fertilization in relative figures. The relative growth-values were obtained in the following way: the average ring-width for a certain year and for a certain plot, (in some cases for a certain size group of trees within a plot), was expressed as a

percentage of the average ring-width of the same trees in the year before treatment. The values obtained by this method were then expressed as percentages

Fig. 2. Pine stand at Siljansfors Experimental Park, province of Dalarna. Altitude 280 m, soil stony till of low fertility. Fertilized to the right of the arrow with 250 kg of nitrochalk (25% N) per hectare in May, 1960 (and June, 1962). Note denser crowns. Stand age in 1959: 120 years. Photo C. O. TAMM 26. 5. 1962.

of the corresponding values for the control plot (or for the mean of the control plots). The volume-growth for the individual plots during the period after fertilization is also given in the figure.

The tree species discussed in this paper are Scots pine *(Pinus sylvestris)*, Norway spruce *(Picea abies)*, and birch (mainly *Betula verrucosa* on the upland plot No. 725, and mainly *Betula pubescens* on the peatland plots).

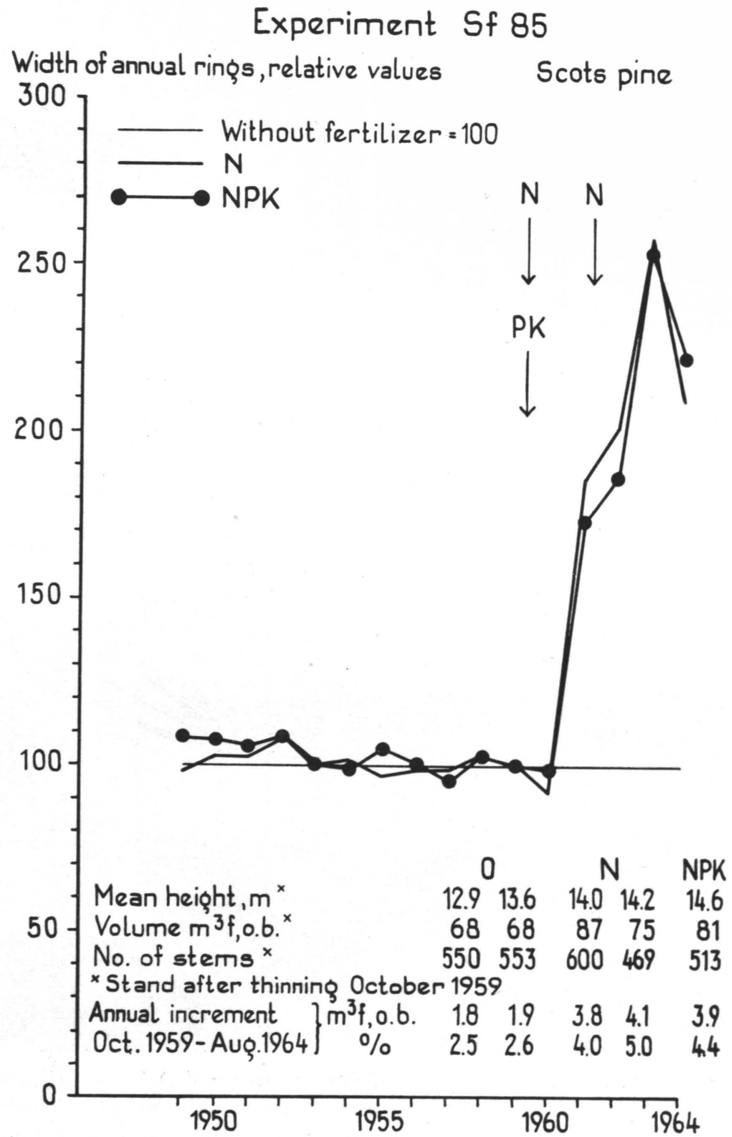

Fig. 3. Stand data and increment measurements for Experiment No. Sf 85, laid out 1960 in the stand shown in Fig. 2.

Fig. 3 shows the relative diameter-growth after fertilization of an old pine stand in middle Sweden, and fig. 2 shows the appearance of the stand concerned. The results are typical of our experiments on poor sites; a very great response is showed for nitrogen, but little or none for other nutrients. The downward trend in 1964 is probably not accidental, but may be an expression of the rapid decline after the end of the application. Figs. 4 and 5 show results from experiments

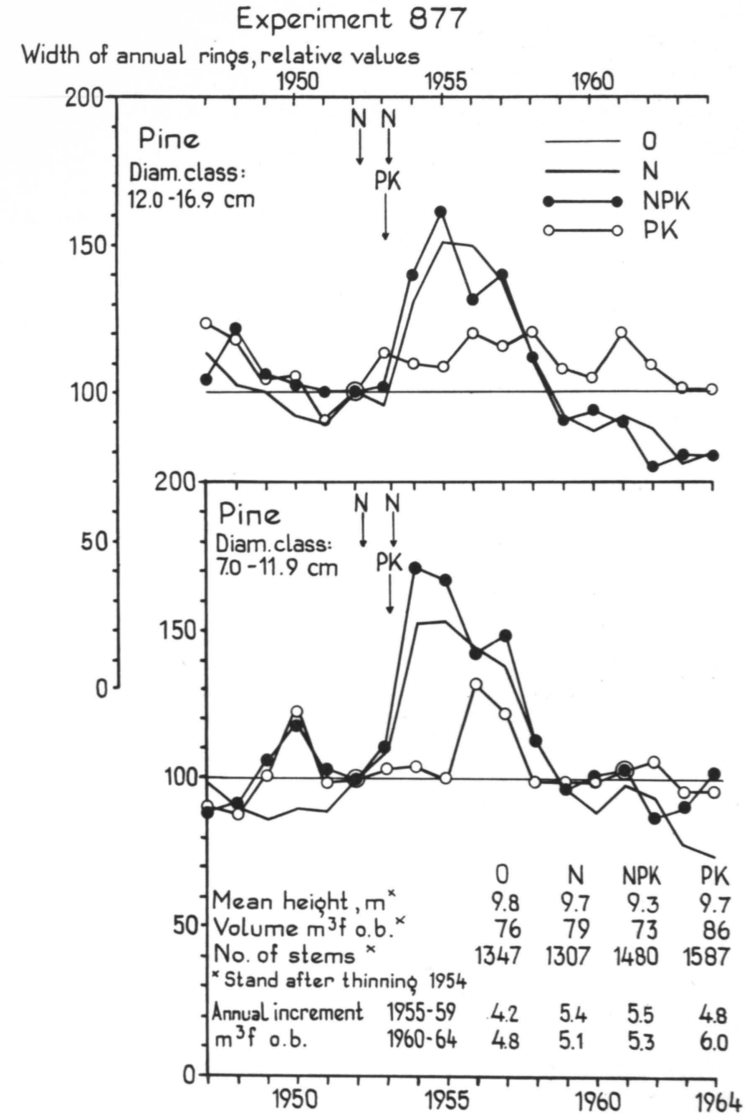

Fig. 4. Stand data and increment measurements for Experiment No. 877, laid out in 1953 on a dry sandy soil at Ölvingstorp near Kalmar, province of Småland. Stand age in 1953: 30 years. Altitude 40 m. Nitrogen (100 kg N/ha) given twice, in 1953 and 1954.

which have been pursued for longer periods, and which demonstrate this trend in time more clearly. Experiment No. 877 is situated on a dry site (a glacifluvial eskar) in southeastern Sweden, with rainfall below 500 mm. annually. Lack of water is probably as important as lack of nutrients in this case, and the growth increase after nitrogen application is much less than in Expt. No. Sf 85. No significant difference was obtained between nitrogen only, and nitrogen + minerals; the deviations of the PK curve from the control are not to be considered significant, and in this case it is doubtful whether the fall of the N and NPK curves below the control at the end of the experiment indicates any real difference, because trees of different sizes do not appear to behave similarly. In other pine stands, however, such a fall has been observed (TAMM & CARBONNIER 1961), and perhaps indicates a disturbance of the normal growth conditions, where tree growth is well adjusted to the prevailing nutrient supply.

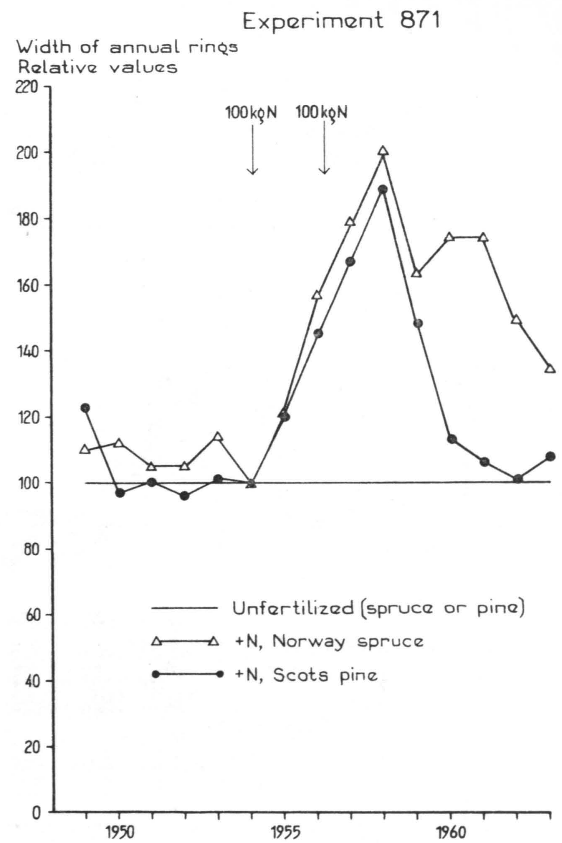

Fig. 5. Relative diameter growth of pine and spruce on a plot fertilized twice with nitrogen (ammonium sulphate in October, 1954, and nitrochalk in May, 1957). Experiment No. 870, on a good site at N. Forsnäs near Karlstad, province of Värmland. Altitude 65 m. Stand age in 1954: 54 years.

The course in time of the growth response for nitrogen application is further illustrated in Fig. 5. It is clear that the growth increase continues longer in spruce than in pine. During the first years, however, the reaction was very similar for both species in this mixed stand. The spruce minimum in 1959 is probably connected with the summer drought in that year.

Fig. 6. Mixed stand at Ljusbergskilen near Arbrå, province of Hälsingland. Altitude 280 m. Stand age in 1957: 80 years; annual increment of control plot 1958—1962 7.4 m^3 per hectare. Photo C. O. TAMM 3. 9. 1957.

A further example of the growth reactions in a mixed stand during the first five-year period after fertilization is given in Fig. 7. The treatments were nitrogen only (2 × 100 kg/ha), nitrogen with PK (700 kg/ha basic slag + 430 kg »kali-magnesia»), PK only, nitrogen with lime (10 000 kg $CaCO_3$ per hectare), lime only, and control. As the nitrogen effect alone appeared significant, the diameter growth of various diameter classes was computed only for treatments which included nitrogen and for treatments which were without nitrogen. Fig. 7 shows that spruce dominates the smaller size classes, while pine dominates the larger classes. Birch made up only a small part of the total of stems, and was mostly of intermediate size. Values for size classes with fewer than four individual trees represented, were discarded; in most cases the number of trees was 10—15.

Regarding the effect of sociological position, and tree species, on the growth response, it can be seen from Fig. 7 that small trees have a lower absolute response than larger trees, but that on a relative basis the response of small trees is larger than that of medium-diameter trees. The largest trees, in this case pine only, respond less than the somewhat smaller ones (cf. POPOVIĆ and BURGTORF 1964).

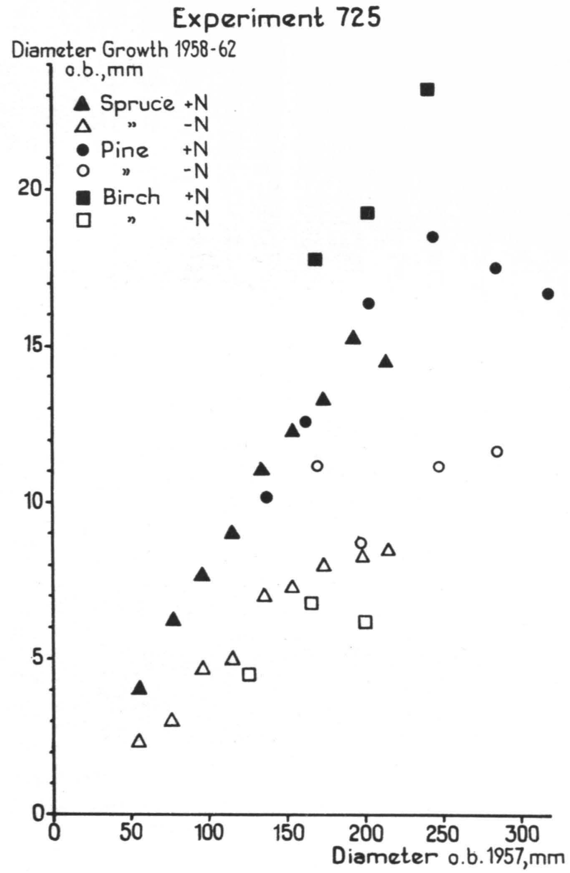

Fig. 7. Diameter growth of trees in the stand in Fig. 6 both fertilized twice with nitrogen (100 kg N per hectare in June, 1958, 100 kg in May, 1960) and without nitrogen. (Some of the plots had received PK or lime, both in the +N and the —N groups.)

The birches appear to grow less than pines and spruces of the same diameter on plots without nitrogen (as is often the case in stands of this age), but respond very strongly to nitrogen application, judging from Fig. 7.

A 45-year-old spruce stand of high annual increment, situated in south-western Sweden, was fertilized in October 1955 and May 1956 with the plant nutrients listed in Table 1. Nitrogen (as nitrochalk) was given again in July, 1958. The effects of the treatments have been small, but almost significant, in the case of nitrogen, which gave a positive effect during the period 1956—1959. Table 1 shows, however, that in the second measuring period, the response of the NPK plot was greater than that of the N plot. PK alone has given no positive effect, as in the first period. In the absence of duplicate plots, we cannot decide whether this result is accidental, or whether it is suggestive of a delayed effect

Table 1. Experiment 883, Halland. Spruce planted 1911 on old arable land.
Stand data after thinning in 1955 and growth data for the period 1955—1964. Sample plot area 0.2 ha.

Added element kg/ha			Mean diameter	Mean height	Number of stems	Basal area	Volume	Annual increment in			
								basal area, per cent		volume m³ f o.b.	
October 1955	May 1956	July 1958	cm	m		m² o.b. per hectare	m³ f o.b. per hectare	1956—59	1960—64	1956—59	1960—64
—	—	—	17.3	17.3	1 125	26.3	232	3.6	4.5	13.5	17.2
—	100 N	100 N	18.7	18.4	980	26.8	250	3.9	4.3	15.3	17.6
42 P + 95 K	100 N	100 N	18.1	17.5	1 030	26.4	233	4.0	4.8	14.3	19.3
10 000 $CaCO_3$	100 N	100 N	17.4	17.5	1 070	25.5	226	4.4	5.0	14.8	18.3
10 000 $CaCO_3$	—	—	18.1	18.2	1 055	27.2	251	3.5	4.7	13.1	18.6
42 P + 95 K	—	—	18.2	17.7	1 005	26.2	235	3.6	4.6	13.5	17.2

of lime and perhaps of phosphate. However, it may safely be said that the application of plant nutrients to this stand has not improved growth much, and that the main growth-limiting factors on this site are other than those directly connected with tree nutrition.

The last experiment to be described in this section concerns plots supplied with various amount of nitrogen, applied annually from 1957 onwards. One-half of the plots also received a PK application. The experimental area had been arable land until 1947, when it was planted with spruce (4-year-old transplants).

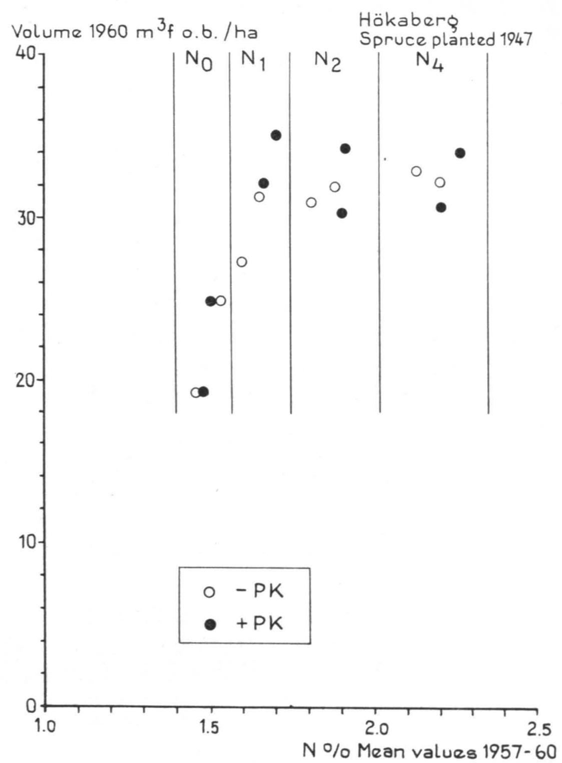

Fig. 8. Standing volume in 1960 in 16 plots in a young spruce stand (planted in 1947 on former arable land) against nitrogen concentration of exposed needles. Plots marked N 1, N 2 and N 4 were fertilized annually from 1957 onwards with, respectively, 50, 100 and 200 kg of N per hectare. Filled dots denote plots with additional applications of PK fertilizers. Remningstorp, province of Västergötland. Altitude 130 m. (For further details, see TAMM 1964 a)

Fig. 8 shows the total volume in 1960, of each of the 16 plots, expressed both as a function of the average foliar nitrogen concentration in exposed needles and in terms of nitrogen application (N_0 = no nitrogen, N_1 = 50 kg/ha annually, N_2 = twice as much as N_1, N_4 = four times N_1). P and K were given in 1957, 1959 and 1962. Fig. 9 shows the volume increment between 1960 and 1963 but is otherwise similar to Fig. 8. The volume data in both diagrams are adjusted

for the small differences in the initial mean height of the plots, in order to make them more comparable.

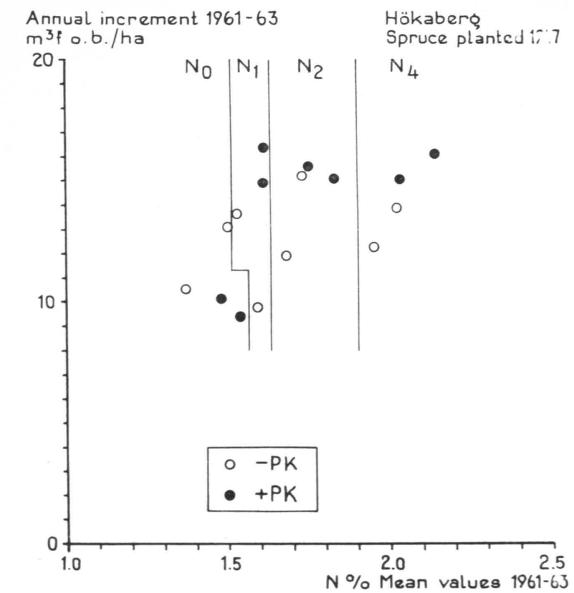

Fig. 9. Annual volume increment 1961—1963 in the same 16 plots as in Fig. 8 against needle nitrogen concentration.

Both diagrams show a clear response of the young spruce stand to nitrogen, but though the foliar analyses have indicated an increased uptake of P and K after fertilization with these elements, no effect on the standing volume in 1960 can be observed; (the stem volume on the plots at the start of the experiment was negligible in comparison with that formed from 1957 to 1960). In Fig. 9, however, the NPK points are highest, and indicate an effect of the PK treatment, in cases where nitrogen is supplied also. This seems quite natural, though perhaps it is the more remarkable that such an intensive nitrogen application is needed to demonstrate an effect of PK fertilizers. There is, however, little doubt that a PK effect can be demonstrated more easily on soils other than this, and particularly on sandy soils (cf. Table 1, TAMM 1962).

Experiments on poorly drained mineral soil

So far only two experiments of this kind have been revised, both cases concerning areas where not entirely successful attempts have been made to improve drainage and forest growth by ditching. One of these experiment is located in a very flat area in southern Sweden in a soil which has a layer of sand to fine sand over a heavy clay. It is described in some detail in a recent publication by HÖJER (1965); the main result is that NPK gave a much better effect

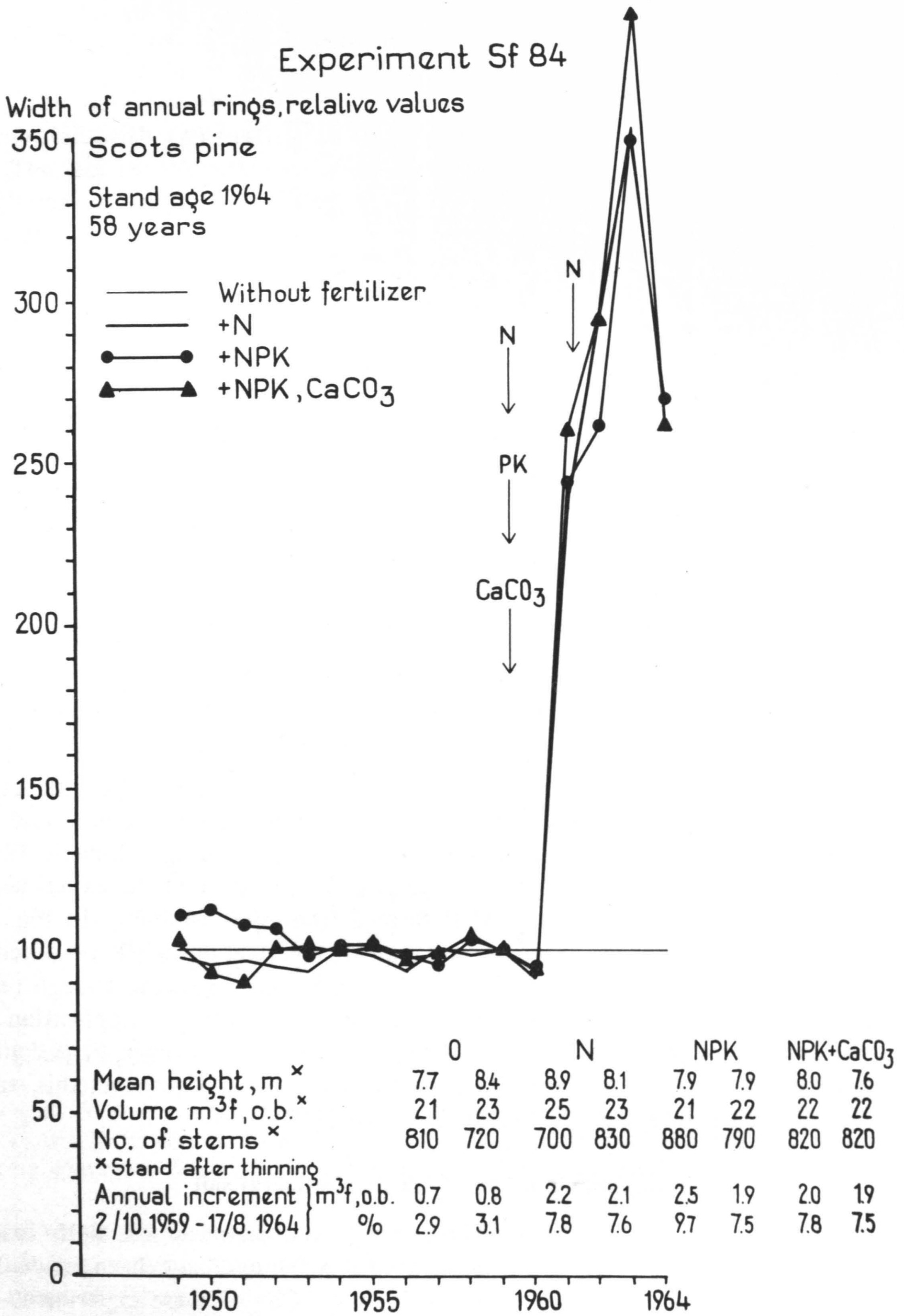

Fig. 10. Stand data and increment measurements for Experiment No. Sf 84 (Siljansfors Experimental Park, province of Dalarna). Altitude 240 m. Nitrogen given as in Experiment SF 85, other elements as in Experiment 725 (cf. Fig. 2 and text).

than N only, while the addition of lime to the NPK plots had no effect during the first four-year period after treatment.

The results from the other experiment of this type are illustrated in Fig. 10. This experiment was located on a gentle slope at Siljansfors experimental forest (cf. Fig. 2). The stand consisted of about 60-years old pines which had slender stems and thin crowns, probably as a result of the unsatisfactory site conditions, both of nutrition and of drainage. Of these, the latter was probably worse earlier, before the water supply from above was cut off by ditches. As is seen from Fig. 10, during the first experimental period there was no sign whatever that elements other than nitrogen would have improved growth. But nitrogen application almost trebles the growth over a five-year period, though in absolute terms the growth increase is only moderate. The next experimental period may show whether there are any delayed effects of phosphate or lime application.

More definite conclusions cannot be drawn until further experiments have been carried out on various other types of poorly drained site.

Some experiments on drained peatlands

As was said in the introduction, experiments with minerals on drained peatlands have been an important line in Swedish forest nutritional research, particularly since Malmström described the »Hällmyren» plots at Robertsfors in 1935. During the last decades an increasing number of experiments has been laid out, in some cases with more elaborate designs, including nitrogen and/or micro nutrient applications. Most of the latter experiments are quite recent, and therefore we know little about their effects. On the other hand, we have a fairly large number of plots where the effects of a composite mineral fertilizer, (wood ashes or basic slag + potassium sulphate) have been followed for a long time. These plots have showed that the response to this treatment is positively correlated with the percentage of nitrogen of the peat (Malmström 1952), and that the reactivity of a drained peatland follows similar rules as does reactivity of swamps which have been drained. A cold climate decreases the response and delays it, and poorer types of peat (e.g. *Sphagnum fuscum* peat or *Scirpus caespitosus* peat) also decrease the response. The low nitrogen content is one reason and another is the difficulty of draining such peatlands effectively.

A further valuable result from the old experiments concerns the duration of the growth improvement. Table 2 shows some data from the »classical» Hällmyren experiments (Fig. 1), where it is shown that a plot given a moderate amount of wood ashes in 1918 now grows relatively slowly. According to visual observations (Malmström 1952), growth was good for about 25 years. Another plot received a heavy application of wood ashes in 1926, and there the growth is

Table 2. Stand data after thinning in 1952, and growth increment, in different parts of the Hällmyren plots, Robertsfors, province of Västerbotten. Self-sown stand on peatland drained in 1910 and fertilized in 1918 (S. Hällmyren) and 1926 (N. Hällmyren).

Treatment	Sample plot area, ha	Mean diameter (birch) cm	Mean height (birch) m	Number of stems per hectare		Basal area m^2 o.b.	Volume m^3 f o.b.	Annual increment in		
								basal area, per cent (approximate figures)		volume m^3 f o.b. per hectare
				birch	pine and spruce	per hectare		1953—58	1959—63	1953—63
N. Hällmyren Wood ash in 1926 12 500 kg/ha										
No thinning	0.030	6.1	9.2	5 500	2 067	21.8	97.6	5.8	2.9	7.9
Thinned 1949, 1952, 1958 .	0.068	8.4	9.5	2 400	844	14.9	67.1	7.4	5.3	6.9
S. Hällmyren Wood ash in 1918 3 300 kg/ha										
No thinning	0.062	6.3	8.5	5 872	496	19.4	82.0	2.7	2.0	2.8
Thinned 1949, 1952, 1958 .	0.030	7.9	9.0	2 367	267	12.6	55.6	4.7	3.5	3.2
Thinned 1949, 1952, 1958, new application of wood ash in 1949 (4 000 kg/ha)	0.040	8.4	9.7	2 275	350	14.1	65.8	7.3	4.0	6.0

still excellent, better than on most surrounding areas of mineral soil. Yet symptoms of potassium deficiency are common on this plot, forecasting a future growth decrease. A part of the earliest treated plot was refertilized in 1949 and now forms the most healthy-looking part of the experimental area. The data for basal area increment in Table 2 may suggest a decrease in growth from the first period observed, to the second one. This is, however, probably only a temporary fluctuation in growth, owing to climatic causes, as it occurs on all plots, the healthy-looking refertilized plot as well as the potassium-deficient area on N. Hällmyren, and the slow-growing area on S. Hällmyren, where the stand is presumably adjusted to the low annual output of nutrients.

The Hällmyren plots are examples of peatlands with a peat relatively high in nitrogen, but lacking minerals, probably phosphorus in the first place and potassium in the second. Table 3 shows some data from an experiment sited on drained peat with a very low potassium status. The forest growth is extremely poor, and all the spruce are chlorotic. Fertilizers containing potassium rapidly remove these symptoms, but the best growth response is obtained, if both potassium and phosphorus are supplied. The fertilized plots still look healthy 11 years after the application, with the exception of a few scattered spruce within the PK treatment-area, whose weak symptoms of chlorosis may forecast a future growth decrease. On the other hand, the difference in growth between the two periods in Table 3 is probably due to climatic reasons rather than to the exhaustion of the nutrient supply, as the control also shows a decrease. It is still too early to estimate the duration of the effect of a single application of potassium, on a peatland of this type, but apparently there is a limitation of the period during which one potassium addition can maintain the forest yield at a high level, on peatlands as also on the sandy soils investigated by Brüning (1959).

Both the Hällmyren plots and Experiment No. 881 represent peatlands with a high content of nitrogen in the peat (well above 1.5 per cent D.W.). Very little is known about the effect of nitrogen application on such peatlands, but our limited results agree with the Norwegian experience, that addition of nitrogen to the PK treatment may enhance development, particularly on recently-drained peat. On peatlands with lower concentrations of nitrogen in the peat, it seems quite clear that the NPK treatment is superior to PK where the growth response is concerned. Fig. 11 presents one example. The economy of both types of treatment appears doubtful on the poorest types of peatland, but it may well be possible to use fertilizer containing a certain amount of nitrogen together with P and K, on peatlands with an existing tree stand and a moderately low nitrogen content of the peat.

Results from a further example of a fertilizer experiment on drained peatlands are presented in Fig. 12. This experiment is to be considered as a semi-practical fertilization, made on the initiative of the land-owner, Stora Kopparbergs

Table 3. Experiment 881, Uppland. Drained deep peat. Stand data after thinning in 1955 and growth data for the period 1955—1964. Sample plot area 0.1 ha

Added element (December 1953) kg/ha	Mean diameter cm	Mean height m	Number of stems per hectare: birch	Number of stems per hectare: pine and spruce	Basal area m^2 o.b. per hectare	Volume m^3 f o.b. per hectare	Annual increment in basal area, per cent 1955—59	Annual increment in basal area, per cent 1960—64	Annual increment in volume m^3 f o.b. per hectare 1955—59	Annual increment in volume m^3 f o.b. per hectare 1960—64
No fertilizers . .	10.6	10.1	1 601	346	17.1	81	1.3	1.7	1.8	1.3
100 P	10.6	9.8	1 379	245	14.3	66	1.1	1.6	1.4	1.1
100 K	10.5	9.4	1 394	381	15.5	68	2.9	3.9	3.6	3.4
100 P + 100 K	11.0	10.2	1 474	498	18.9	90	2.9	3.9	5.4	4.4

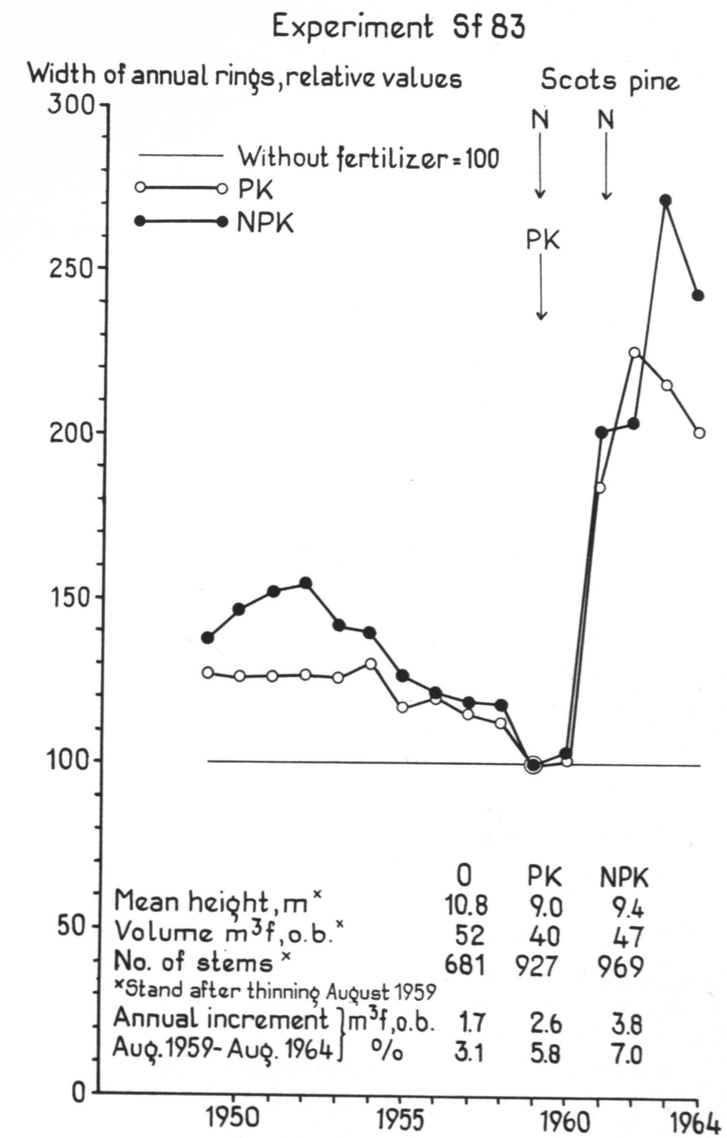

Fig. 11. Stand data and increment measurements for Experiment No. Sf 83 (Siljansfors Experimental Park, province of Dalarna). Stand age in 1959: 115—130 years. Altitude 220 m. Peatland drained in 1925. Total amounts of added nutrients per ha: 160 kg N, 120 kg P_2O_5, and 120 kg K_2O.

Bergslags AB. The total area of the nine fertilized plots was 20 hectares. The general conditions within the area were not very different from those on Experiment No. 881, although the stand contained less birch and more pine and spruce (the last usually as an understory). The application was made from an aeroplane in September, 1959. Three different dosages were used, viz. 300, 600, or 900 kgs/ha of a combined granulated potassium-phosphorus fertilizer (20 per cent P_2O_5, 20 per cent K_2O). The data in Fig. 12 are taken from a preliminary strip survey of the experiment, three years after treatment. Quantitative information (on increment cores) could be obtained only from pines with a diameter exceeding 10 cm at breast height, but both pines and spruces were classified

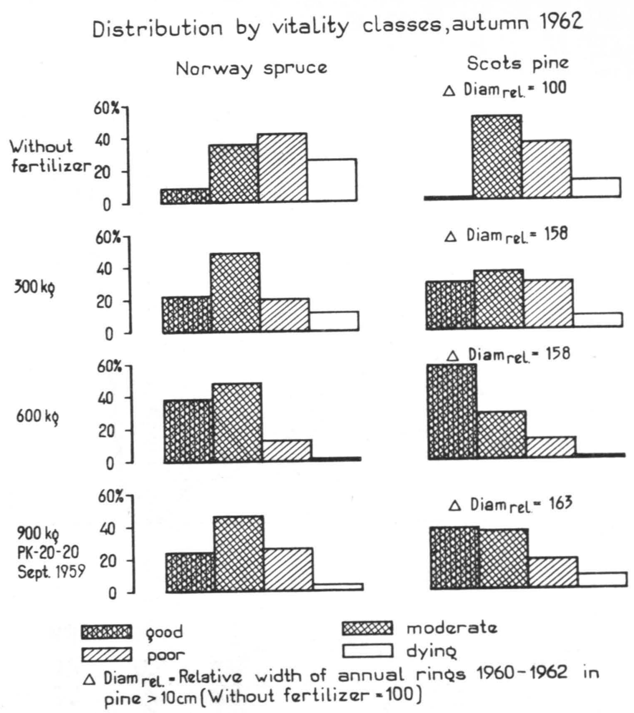

Fig. 12. Distribution by vitality classes of a self-sown mixed stand on drained and fertilized deep peat, Sjöängen, province of Uppland. Altitude 40 m. First ditches made about 70 years ago, drainage still not perfect. Fertilized September 1959 by aerial application of a PK fertilizer (20 per cent P_2O_5, 20 per cent K_2O) at three different rates.

according to their vigour. From Fig. 12 it can be concluded that in both tree species the reaction to fertilizer was best for the medium application, although the heavy one did not differ significantly. The lowest application did not improve the vigour to the same extent, but increased the diameter growth of the larger pines by 58 per cent, the same figure as for the medium application. It is premature to draw definite conclusions from this experiment at present, but it seems clear that a fertilizer application must not be too small, and that a well-balanced fertilization may rapidly transform an almost worthless stand into one which looks promising.

Experiments with fertilizers at the time of planting

Fertilization at the time of planting is often discussed as a means for helping the transplants over the first critical period. However, the most critical factor during the first years after plantation is usually not soil nutrient supply. When the planting is made on a properly prepared regeneration area, the break-down of litter and humus formed by the former stand provides a much better nutrient supply than ever existed in the closed stand (ROMELL's »assart effect», see TAMM 1964 b). Water supply and root development are more important during at least the first summer after plantation.

It may be possible to stimulate further the growth of the transplants by

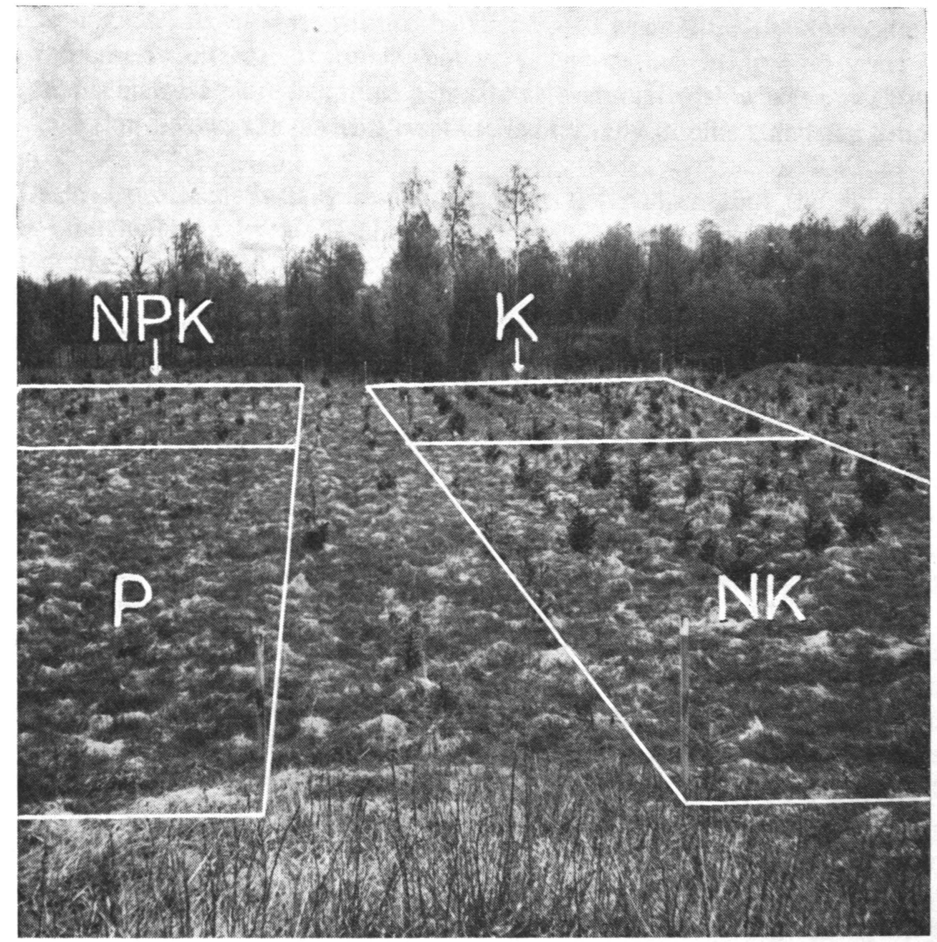

Fig. 13. View of a fertilizer experiment with spruces planted 1958 on abandoned fields on peatland. Survival and growth extremely poor, except on plots with potassium additions to the individual spruces (10 g K_2SO_4 in 1960, repeated in 1963). The effect of N and P additions is negative, particularly when no K is given. Remningstorp, province of Västergötland. — Photo C. O. TAMM 13. 5. 1964.

supplying nutrients, even when they come from a well-fertilized nursery, but unfortunately the ground vegetation also is stimulated by fertilizers, and by nitrogen in particular. It therefore seems dangerous to apply nitrogenous fertilizers wherever the competition from ground vegetation may impede development (Fig. 13). PK fertilizers do not as a rule have the same stimulating effect on ground vegetation, and may often have a striking positive effect on spruce planted on peatlands, e.g. abandoned fields As the cost is moderate, an application of a combined PK fertilizer around the transplants after planting seems to be worth recommending in all plantings on deep peat. If chlorosis or other deficiency symptoms occur in trees on similar sites in the neighbourhood, such a fertilization should be considered essential.

Summary

Experience obtained from earlier experiments in applying nutrients to forest land has encouraged Swedish foresters to begin forest fertilization on a practical scale. But there are many unsolved problems which make it difficult to forecast accurately the biological and economic consequences of the new system. Some of these problems are discussed in this paper, illustrated with representative examples from the experiments made at the Royal College of Forestry. The most common types of forest in Sweden, pine or spruce stands on well-drained mineral soil, with a ground vegetation of dwarf shrubs and feather mosses, respond strongly to nitrogenous fertilizers, but the effect of phosphate, potash or lime is small or nil, at least within the first 5—10 years after the application. The response to nitrogen is usually not very long-lasting, being 4—5 years in pine and somewhat more in spruce. Cases have been met with where a negative after-reaction follows the positive response (so far only in pine stands on sandy soils).

Drained peatlands usually respond to mineral fertilizers, but the improvement brought about by a PK application depends, *inter alia*, on the nitrogen content of the peat. Peatlands with a peat low in nitrogen need NPK fertilization; it is not yet known how often the nitrogen application has to be repeated. Information on this point is essential for all calculations regarding the economy of the fertilizer treatment. For deep peatlands, with a moderate or high nitrogen content, a single PK application (e.g. 500 kg/ha of »potassium-superphosphate 20—20») improves growth conditions for a very long time, although a new application will probably be necessary after some decades. In such cases the forester has to decide whether or not a peatland should be drained and fertilized, on the basis of the expected site quality (much dependent on climate) and the possibility of establishing a valuable stand. An existing tree stand, even if it is rather poor, is usually a good help in this respect.

Experience of fertilizing shallow peatlands and poorly-drained mineral soils is very limited, but it seems easy to get a growth response either with nitrogen alone, or with NPK. The possibility of getting a growth improvement even without draining should not, however, be taken as evidence that draining is innecessary; on the contrary, there is reason to believe that the fertilizer effect is much better on well-drained sites than on those which are temporarily waterlogged.

The results of fertilizer application at the time of planting have not, as a rule, been very good in Sweden. We are still waiting for a cheap nitrogenous fertilizer, the effect of which extends over at least three years. An exception is the afforestation of abandoned fields on drained deep peat. In this case, a moderate application of a PK fertilizer around the plants seems to be essential for both survival and growth.

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