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Plant condition and plant growth

Planting experiments with spruce (*Picea abies* (L.) Karst.) on *Calluna* heath land

Plantkondition och tillväxt

Planteringsförsök med gran på ljunghedar

by

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ABSTRACT

A study has been made of the effects of different methods of fertilizing spruce plants (*Picea abies* (L.) Karst.) in the nursery before planting them on *Calluna* heath land in S.W. Sweden. It was found that the use of superphosphate led to strongly stimulated development of the plants after planting. The same was also the case after fertilizing with NPK, while the use of only a similar amount of nitrogen or potassium as is contained in NPK did not have a positive effect. The growth of spruce was often further promoted if a dose of lime (5,000 kg/ha) was added in the nursery. Fertilization after planting was effective only if carried out after the plants had overcome the stunt period of juvenile development. The development of mycorrhiza kept pace with the growth of the plants. It was not possible to establish whether the plants grew better once the development of mycorrhiza (which is clearly stimulated by the addition of phosphate) had increased or whether the development of mycorrhiza was stimulated in conjunction with the improved plant growth. Combined cultures using pine, larch, birch and alder led to an improvement in the growth of the spruce plants on condition that the auxiliary trees were cleaned at an early stage.

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CONTENTS

1. Introduction

The problem concerning the often slow growth of spruce at the juvenile stage, the spruce's so-called stunt period, has been the subject of many scientific and practical experiments in a number of countries. The stunt period of spruce after planting on heath land has in particular been studied in England and Scotland in conjunction with the extensive planting programme which has been carried out by the Forestry Commission since 1918 (cf. e.g. Leyton, 1954, 1958). This problem had been observed much earlier chiefly in Denmark where P. E. Müller (1910 *et al.*), the founder of the forest biology soil science, interpreted the old method of using auxiliary trees when planting mountain pine (*Pinus mugo* L.) in such a way that it was here a question of indirect assistance to the spruce plants. Thus according to Müller its mycorrhiza fungi were capable of fixing atmospheric nitrogen, which also benefited other tree species.

Other explanations have also been given for the slow growth of spruce at the juvenile stage or the failure of plantings. The nature of the site can naturally be of fundamental importance. A site which is too dry or exposed to frost can thus constitute the direct reason for the failure of a planting. According to others, toxic substances given off by *Calluna* affect the spruce's mycorrhiza fungi thereby retarding the growth of spruce (see Handley, 1963 and literature cited there). On the other hand, experience has shown that plants which differ physiologically have different prospects of developing under unfavourable ecological conditions. It has been noticed that this concerns not only plants of different genetical constitution selected for a certain habitat, but also plants of similar origin which have been exposed to various kinds of treatment in the nursery, such as transplantation, root pruning or fertilization. However, remarkably few experiments have so far been made in this field.

At the end of the 1940's, when serious attention was given to establishing nurseries in the north of Sweden, there was a lively discussion regarding the significance of the type of nurseries to be constructed, suitable fertilization, the use of compost, etc. As a reaction to the old nurseries on agricultural land, and the frequent occurrence of English-based "humusmysticism" which had been developed concerning a suitable compost to be used (cf. Rayner, 1939; Rayner & Levisohn, 1941; Growther, 1951), nurseries were instead established on "natural forest ground", preference being given to sites with poor soil. The first nurseries of this type were those in Knäred, Halland, in southern Sweden, and in Sörgidsjö, Ångermanland, in the north (Björkman, 1954).

The object of using nurseries on poor soil was to take the opportunity they offered to fertilize them in different ways and so produce plants of different physiological types. This gave more importance than ever before to the question of the most suitable method of fertilization in nurseries. To judge from preliminary observations, it appeared possible that certain methods of fertilization could produce plants of a certain favourable condition and with better prospects of continuing to develop quickly after planting.

So as to be able to study this question in greater depth a large number of fertilization experiments were started in six different nurseries and, after 2 and 3 years respectively, non-transplanted plants of spruce, *Picea abies* (L.) Karst. and pine, *Pinus silvestris* L., were planted in various types of forest ground. Short accounts of these experiments have already been published (Björkman, 1953, 1954). The following is a brief account of the longest observed and catalogued experiments carried out on *Calluna* heath land in the province of Halland in southern Sweden (cf. Malmström, 1939; Romell, 1952; Malmer, 1968) using spruce plants treated in different ways in the nursery. A comparison is made at the same time with plantings on a practical scale made in the same area.

2. Planting experiments with 2+0- and 3+0-spruce plants fertilized in different ways in the nursery

2.1. Material and methods

The plants which were later planted on *Calluna* heath land were raised in two different nurseries, some in the nursery established in 1946 by the County Forestry Board in Knäred on ground that had borne 50-year-old pine, but which had previously been heath land, and some in a newly-established experimental nursery on open heath land close to the prospective planting site in Mörkhult near Mästocka in the province of Halland and in a few other nurseries. The following account refers mainly to the plants from the nursery in Mörkhult.

A chemical analysis of the nursery soil gave the following values:

NH_4-N	3.8 mg/kg soil
NO_3-N	1.4 "
P_2O_5-tot.	0.06 g/l soil
K_2O-tot.	0.09 "
CaO	0.02 %
pH	4.5

This table shows that the soil in the Mörkhult nursery was extremely poor.

Sowing in the nursery was carried out in May 1947 one week after fertilization. The seed material originated from the Mästocka region near to the planting area. Four hundred seeds were used per metre in 4 rows in each parcel. There were 4 parcels of the same type in the nursery distributed according to the block method. Each parcel measured 140×70 cm.

The plant nutrient used was applied by extremely careful manual methods in dry, calm weather, and consisted of threee different nitrogen fertilizers (ammonium nitrate, ammonium sulphate and lime nitrogen, i.e. calcium cyanamide), phosphorus in the form of superphosphate and Thomas phosphate, potassium in the form of 40 % potash and potassium sulphate and calcium in the form of ordinary agricultural lime, $CaCO_3$. The experiments were carried out with three different quantities (ratio 1:3:9) of fertilizer. The planting experiments were made with plants which in the nursery had been given different amounts of these fertilizers.

Altogether the experiment covered 180 different fertilizer combinations of pine and spruce. However, the present report deals only with spruce plants which obtained the highest dose of the following fertilizer:

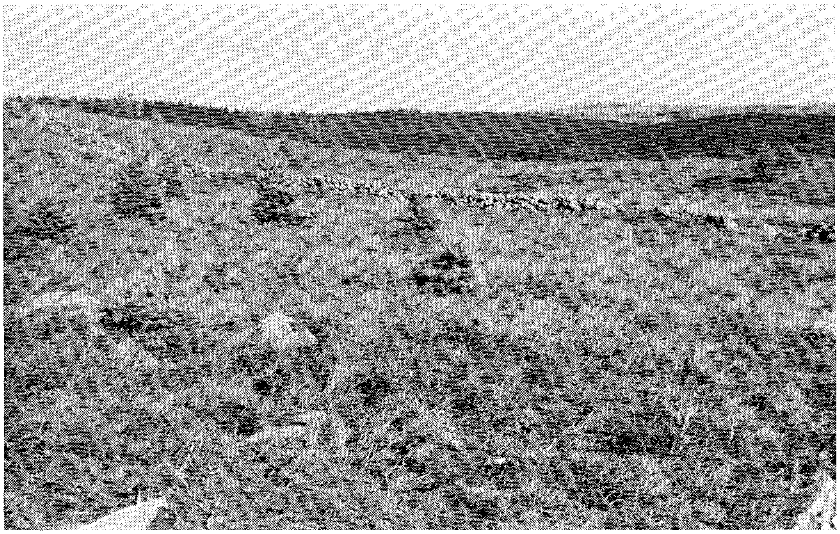

Fig. 1. Open *Calluna* heath landscape in Mörkhult at Mästocka in southern Halland, 1947. In the foreground grazing land, in the background the closed *Calluna* heath where the 1949 and 1950 test plantings were made.

lime ammonium nitrate	corresponding	to	about	400 kg N/ha
superphosphate	”	”	”	400 kg P/ha
potassium sulphate	”	”	”	500 kg K/ha

In a parallel series the same fertilizer was used in the same quantities together with an admixture of lime corresponding to 5,000 kg/ha.

Planting was performed partly in May 1949 with 2+0-plants, and partly with equivalent plants as 3+0 in May the following year. Certain plantings with other types of plants (1+0, 1+1 and 2+2) from other nurseries took place in 1950.

At the start of the experiment the planting site consisted of open *Calluna* heath land with occasional small pines and juniper bushes protruding through the closed covering of *Calluna* (Fig. 1). The central part of the experimental area consisted of a bare plateau completely covered by *Calluna* and of a very uniform appearance. The perimeter areas and the part beneath this plateau consisted partly of swampland with *Eriophorum vaginatum* L. Other species typical of the area were *Narthecium ossifragum* (L.) Huds., *Galium hercynicum*, Weig., *Potentilla erecta* (L.) Räusch., *Vaccinium vitis idaea* L., *Deschampsia flexuosa* (L.) Trin., *Pteridium aquilinum* (L.) Kuhn. Interspersed with the ordinary heather (*Calluna vulgaris* (L.) Hull.) there were patches of bell heather (*Erica tetralix* L.)

On closer examination it was discovered that the heath land in the selected experimental area was nowhere nearly so uniform as the evenly closed covering of *Calluna* suggested. The ground was very stony. Orientating chemical analyses also showed local variations.

The experimental plots were made quite small (8.4×8.4 m), as the original object was to study the growth of the plants during the actual establishment phase and for a few years after that. The parcels were laid out in four replications in blocks at a certain distance from each other in the experimental area. The planting was made in open grooves after a 0.5×0.5 m patch had been opened in the *Calluna* turf. Care was taken to avoid errors by ensuring that the planting was carried out uniformly. The plant material itself was sorted so that plants of equal size and average quality were selected at the time of planting.

Following the planting the experiments were catalogued on a number of occasions, namely in 1951, 1954, 1957, 1963, and 1965, at which time the length of the plants and the length of the terminal leaders were measured in the first place. On a few occasions the length of needles was also measured and an assessment made of the plants' "habitus", colour of needles, etc. The plant height was taken as being the most important indication of the growth of the plants. Needless to say, the calculation of the mean height of a spruce population affected by a more or less delayed juvenile development is fraught with considerable difficulties. Oh the other hand it can be assumed that variations caused by faults in planting, the quality of the root system, genetic constitution, etc. and also errors in measuring are fairly equally distributed between the four parallel plots in the same set of experiments and for that matter also in the entire test material.

During the measuring, plants with double tops or broken tops were removed, as also individual plants displaying insect damage. Such cleaning of the experimental material is questionable but would appear to be justified firstly because of the fairly small number of damaged plants, secondly because the height growth of the removed plants was influenced by secondary factors which had nothing to do with the problem under investigation. Moreover, it was found that the damage referred to was fairly equally distributed in the entire experimental area.

2.2. Results

2.2.1. The 1949 planting

In Fig. 2 the result of plant height measurements made in 1965 has been collated in the form of a staple diagram, where also the averages calculated are given. As a total of 147 plants shared between 3 parcels is given (one

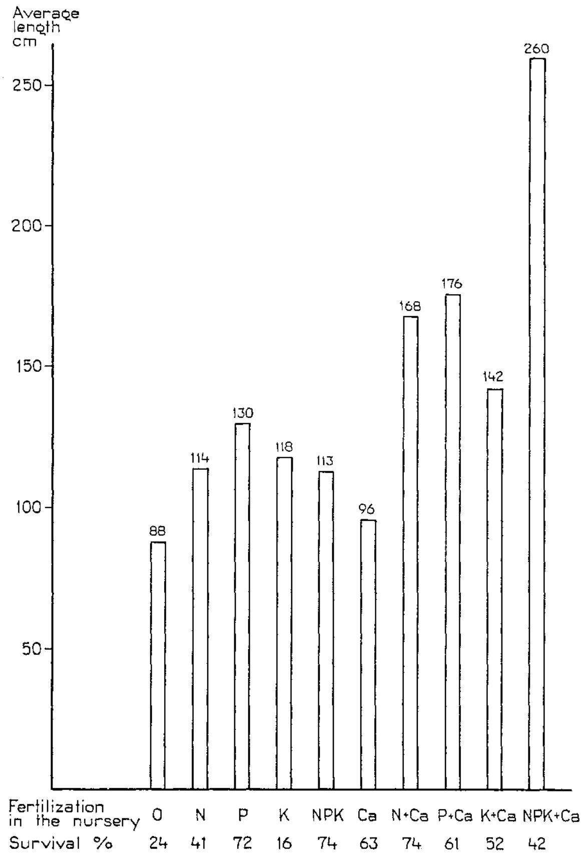

Fig. 2. Mean length of unfertilized and fertilized (in the nursery 1947) spruce plants from Mörkhult. Planting on *Calluna* heath in June 1949 (plants 2+0). No fertilization after planting. Measured August 1965.

repetition with 49 plants being consistently ignored because of the situation of this test block in the swampy section), Fig. 2 shows the extent of the loss of plants during the experiment. Even though it was necessary to reduce the original number of plants—an average of 5 %—because of double tops, broken tops or other damage, the figures show the extent of the plant loss which was apparantly caused by the "condition" of the plants when they were planted. The stimulating influence of the lime is particularly remarkable.

As regards the growth of the plants, it was noticed that the plants which had been given full fertilizer plus lime in the nursery (NPK+lime) were in every way superior. Even other fertilized plants which had received lime in

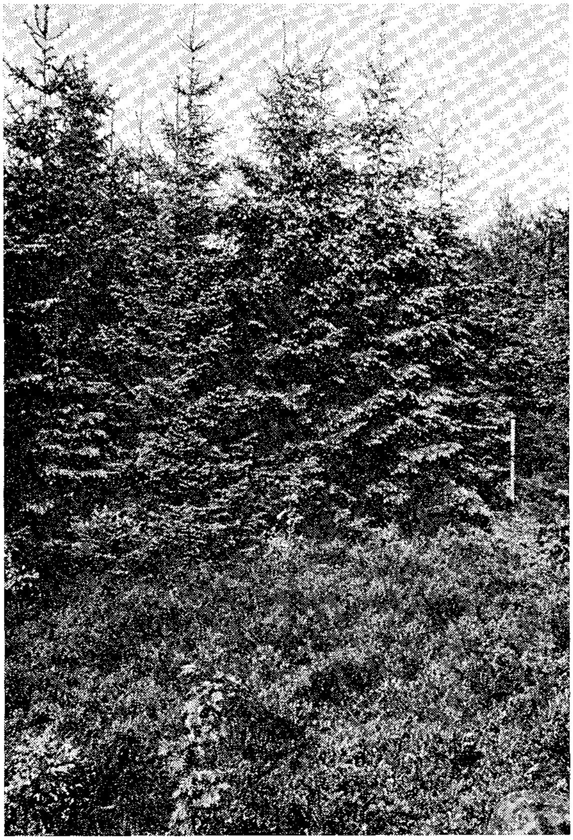

Fig. 3. Test parcel on *Calluna* heath with spruce which at the plant stage in the nursery received superphosphate and lime but was not fertilized after planting. The pole, right, approx. 1 m. In the foreground a parcel with unfertilized stagnated plants of similar age and planted at the same time. Photograph 1969.

the nursery showed a better height growth than those plants which had been given only N, P or K. This development was recorded already at the first cataloguing in 1951 and up to 1956. The plants which had received phosphorus and lime overcame the stunt period quickest and attained the best height growth (Fig. 3). The plants which had been given NPK plus lime started their real development somewhat later but gradually took the lead in height growth. Of the plants which did not receive lime in the nursery, those fertilized with phosphorus developed best from the start and retained this lead 15 years later. A statistical analysis was made on the basis of the 1951 and 1954 measurement values. This showed significant differences between the unfertilized plants and those which had been fertilized with phosphorus, as also such plants as had received NPK plus lime, but not between unfertilized plants and those which had been treated with N, K and only NPK or lime in the nursery. A statistical analysis based on material obtained from height measurements as late as 1965 or after can hardly be regarded as giving a reliable result, as fast growing plants gradually begin to suppress plants which from the outset have lagged behind, and more rapid height growth was no longer an expression of the causal connection which the experiment intended to study.

The experiment therefore shows that the addition of plant nutrients in a poor nursery is of the utmost significance to the later growth of spruce plants after planting in an environment where there is competition for available nutrients. If lime is added together with nitrogen or potassium or full fertilizer the plants grow better than plants which were not given lime. As regards phosphorus, this plant nutrient was in a class of its own. Thus fertilization with phosphorus in the nursery had a strongly stimulating effect in the experiments on the height growth of 2+0-plants after planting. (Proof of the fertilized plants' different inner physiological character was seen in the fact that such plants were preferred by wood-grouse which on one occasion entered the nursery in Knäred. Thus the parcels which had been treated with both NPK and lime had been more or less completely nipped off by the grouse on all parcels containing this combination, while plants in adjacent unfertilized or "weaker" fertilized parcels were left untouched.)

2.2.2. The 1950 planting

The planting was carried out with the same type of plants as were used in the 1949 planting. The plants were therefore 3+0 when planted in the experimental parcels. Unlike the pine plants which were planted at the same time and which had been raised in the Mörkhult and Knäred nurseries and fertilized in different ways, the spruce plants were very similar to each other as regards size with the exception of the plants which had been treated with phosphorus or full fertilizer and lime (cf. Table 1.).

The first cataloguings (1951 and 1954) showed that the development of the plants in the 4 blocks in each series of the experiment varied most considerably. A statistical analysis showed that one block in particular was entirely different from the others. This was in all probability due to the site class differences, which were revealed by chemical analyses. Depending on calamaties it appeared hazardous to use the mean values for all four parcels in the same series of experiments. The following deals only with that block in which the plants showed themselves to be the most uniform and, to judge

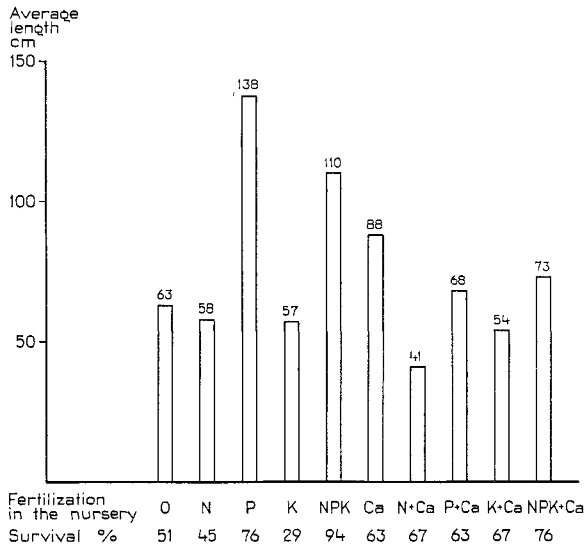

Fig. 4. Mean length of unfertilized and fertilized (in the nursery 1947) spruce plants from Mörkhult. Planting on *Calluna* heath in June 1950 (plants 3 + 0). No fertilization after planting. Measured August 1965.

from random analyses taken in a larger area, to have the most representative site conditions, where the survival for unfertilized plants was as high as 51 %.

Fig. 4 shows that the fully fertilized plants and those treated with phosphorus displayed the highest survival percentage. Fig. 4 also shows that in principle the general initial development was the same as for the 2+0-plants planted one year earlier, but that growth followed a somewhat flatter curve than for these. This can appear to be remarkable, as when planted the 3-year-old plants had considerably longer terminal leaders than as 2-year-old plants the previous year. A statistical analysis carried out by Forest Officer Harry Eriksson established that there was no correlation between the length of the terminal leader on planting and later rapid height growth. Earlier experiments have shown that 3+0-plants are less capable of forming long annual shoots after planting than 2+0-plants of the same type planted at the same time (cf. Björkman, 1953).

Considerable differences could still be established in plants that had once been fertilized in different ways in the nursery. Thus plants which had been fertilized with phosphorus were best developed (Fig. 5). The poorest development was displayed by those plants which had been treated either with nitrogen or potassium in the nursery (Fig. 6). As in the 1949 experiments

Fig. 5. Test parcel on *Calluna* heath with spruce which at the plant stage in the nursery received superphosphate but was not fertilized after planting. In the foreground a parcel with unfertilized stagnated plants of similar age and planted at the same time. Photograph 1969.

Fig. 6. In the foreground a test parcel on *Calluna* heath with spruce which at the plant stage in the nursery was given potassium but was not fertilized after planting. Photograph 1969.

it was seen that the addition of lime in the nursery was of importance to the future development of the plants after planting, this with the exception of the plants in the phosphorus series, which grew better if they did not receive lime in the nursery. A characteristic feature of the development of the plants in this experiment was that the height increment was considerably lower than in corresponding experiments with the same plants planted a year earlier.

The plants which overcame the stunt period fastest were, as in the case of the 1949 planting, those which had been treated with superphosphate in the nursery. Thus these plants were more than twice as tall as the control plants.

2.2.3. Investigation of the root systems of test plants

When the plants were lifted from the nursery the roots were examined for length and mycorrhiza formation. Whereas the pine plants showed ample mycorrhiza, it was generally poorly developed in the case of the spruce plants. The best mycorrhiza formation occurred on plants treated with phosphorus in the nursery. Table 1 is a collation of the mycorrhiza frequency at the time of planting the 2+0-spruce plants in 1949 and the 3+0-plants planted in 1950. Of the individual types of mycorrhiza (see Björkman, 1942) type *A* and type *B* represented the most common form with a thin hyphal mantle and a relatively insignificant Hartig network, while type *C*, constituted by *Boletus* species, did not occur at all in the spruce plants. Type *Da* representing ordinary mycorrhiza of *A*- or *B*-type covered with the black parasitical soil mycelium "*Mycelium radicis atrovirens*" (Melin, 1925) and type *Dn* formed by the similarly black soil fungus *Cenococcum graniforme* (Sow.) Fred. & Winge, the mycelium of which is called "*Mycelium radicis nigrostrigosum*", occurred only to a very limited extent. The major part of the short roots were transformed to so-called pseudomycorrhiza comprising the original short roots which had been attacked by parasitical soil fungi. This pseudomycorrhiza, which does not have the characteristics of the real ectotrophic mycorrhiza in the form of swollen cells in the primary cortex and the more or less well developed Hartig network and hyphal mantle, are regarded from the aspect of nutrient uptake as representing ineffective roots which have lost their root hairs as a result of attack by soil fungi.

Table 1 also shows the development of mycorrhiza on corresponding plants and trees from random samples of roots taken from the various test plots in the summer of 1969. The spruces which still remained at the stunt stage showed themselves to have considerably weaker developed mycorrhiza,

Table 1. Mycorrhiza development on spruce plants fertilized in the nursery in different ways before planting in 1949 and 1950 respectively on *Calluna* heath at Mörkhult in Halland.

Plant type	Fertilization in the nursery	Plant height cm		Root length 1949, cm	Mycorrhiza, per cent of all short roots											
					Type *A*		Type *B*		Type *C*		Type *Da*		Type *Dn*		Pseudo-mycorrhiza	
		1949	1965		1949	1969	1949	1969	1949	1969	1949	1969	1949	1969	1949	1969
2 +0 1949	O	24	88	192	0	21	5	11	0	0	0	2	0	0	95	86
	N	25	114	185	0	24	3	9	0	0	0	4	0	0	97	63
	P	30	130	200	13	28	12	12	2	0	3	6	0	5	70	49
	K	24	118	183	0	20	4	5	0	0	0	2	0	0	96	73
	NPK	48	113	229	0	27	5	6	0	0	0	4	0	2	95	61
	Lime	25	96	207	2	20	2	5	0	0	0	2	0	4	96	69
	N +lime	30	168	216	0	27	3	6	0	0	0	2	0	0	97	65
	P +lime	38	176	241	16	34	10	6	2	0	0	3	0	0	72	57
	K +lime	34	142	196	0	20	2	2	0	0	0	2	0	0	98	76
	NPK +lime	54	260	252	4	26	2	9	0	0	0	4	0	0	94	61
3 +0 1950	O	31	63	220	2	19	6	9	0	0	0	2	0	0	92	70
	N	33	58	217	0	16	4	3	0	0	0	0	0	0	96	81
	P	42	138	302	16	34	6	6	4	0	2	4	0	0	72	56
	K	28	57	209	4	14	5	4	0	0	0	0	0	0	91	82
	NPK	58	110	314	3	24	5	5	0	0	0	2	0	0	92	69
	Lime	35	88	235	3	20	3	5	1	0	1	2	0	0	92	73
	N +lime	39	41	275	1	4	4	6	0	0	0	0	0	0	95	90
	P +lime	48	68	340	19	24	6	6	2	0	2	2	0	0	71	68
	K +lime	39	54	268	2	10	2	5	0	0	0	0	0	0	96	85
	NPK +lime	58	73	355	6	16	4	10	1	0	4	2	0	0	85	72

while the mycorrhiza frequency in the case of the strong young trees which had long since overcome the competition with the *Calluna* was relatively high. However, no other differences which can be directly linked with the original treatment given in the nursery appear to exist any longer. Neither is it possible with the help of observations in the same direction to say with certainty anything about cause and effect, namely whether the stronger mycorrhiza formation is the cause of improved plant growth or whether mycorrhiza finds it easier to develop on plants which were in this particular case treated with phosphorus. However, since there are many examples from various parts of the world that the presence of a certain mycorrhiza fungus can result in strong forest tree plants (see e.g. Moser, 1958; Björkman, 1964; Vozzo, 1968; Mikola, 1969; Hacskaylo, 1970), there is reason to assume that mycorrhiza development can be, to the extent that it is stimulated to occur, the primary factor.

3. The effect of additional fertilization after planting

So far only the effect on the development of plants occasioned by fertilization in the nursery has been dealt with. It has been proved that the initial development of the plants can be influenced to a great extent by such fertilization, and that also the continued development of the plants can be affected by their ability from the start to develop in competition with the *Calluna*. As it appeared to be of interest to investigate whether the addition of nutrients to the plants after planting would be able to accelerate the development of those plants which had still not started to grow normally, a fertilization experiment was carried out on the test plot described above.

3.1. Material and methods

In May 1960 an addition was made partly of nitrogen in the form of granulated lime nitrogen (18 % N), partly full fertilizer NPK 7-7-14 at 10 g per plant and 25.6 g per plant respectively. This was regarded as a "normal" dose for fertilizing forest tree plants. The dose of full fertilizer was proportioned so that the admixture of N was the same in both cases. The nitrogen in the full fertilizer was in the form of ammonium nitrate. The cyanamide component of lime nitrogen must first be converted to ammonia before it can be taken up. The rate of conversion can vary in different climates and soil moisture. Lime nitrogen was chosen because of its relatively slow effect, which it was assumed would prevent too rapid leaching and allow the nitrogen to be used more effectively. However, lime nitrogen must be used with caution because of the strong toxic effect it has for a while after application and which makes it suitable for use as an agricultural weed killer. The fertilizer was applied and dibbled into a cleared patch round each plant measuring 40×40 cm.

In the 1949 planting experiments a number of parcels were chosen where the plants showed uneven development and where the majority were still at the stunt stage. These test plots consisted of parcels with plants which were entirely unfertilized in the nursery and a few parcels with plants under good development, namely parcels with plants which had previously been treated with phosphorus, full fertilizer or lime.

Cataloguing of the experiment took place in 1966 and 1969. To enable a comparison with other measured material the plant height up to and including the 1965 terminal leader is given here.

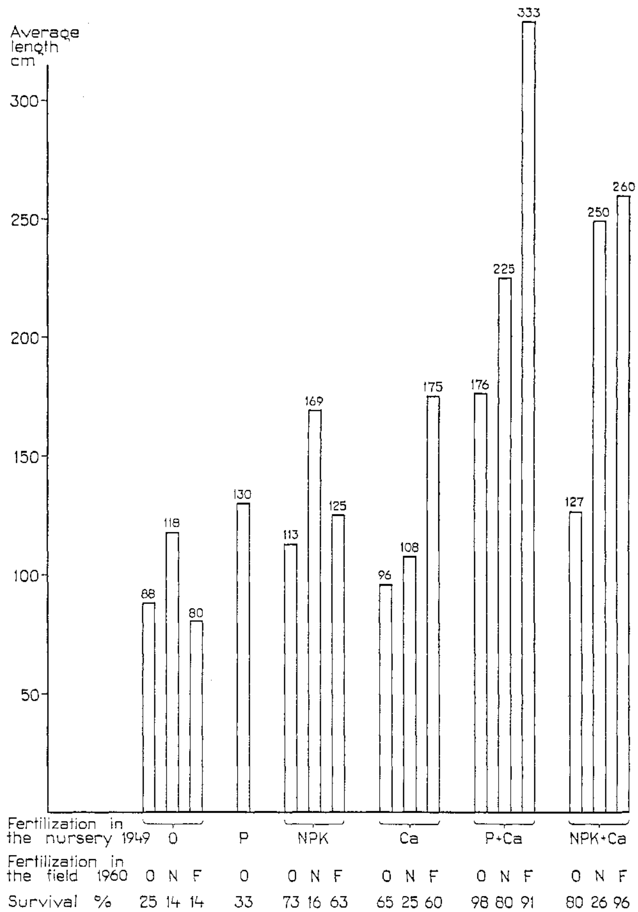

Fig. 7. Mean length of unfertilized and fertilized (in the nursery 1947 and in the field 1960 respectively) spruce plants from Mörkhult. Planting on *Calluna* heath in June 1949 (plants 2 + 0). Additional fertilization in June 1960 on certain parcels. Measured 1965. F = full fertilizer (NPK).

3.2. Results

It can be seen from Table 1 and Fig. 7 that the addition of nitrogen in the form of lime nitrogen had a favourable effect especially on those parcels where the plants were already under development, i.e. the plants which had been treated with full fertilizer. On the other hand, the addition of N or NPK had only an insignificant effect on plants that were still at the stunt stage and which had not received extra plant nutrients in the nursery. Fig. 7 shows that the number of plants was reduced on the addition of lime nitrogen in the dose used. Those plants which were given lime in the nursery but had otherwise not been fertilized reacted more positively to the additional fertilization in the field than plants which had not received any additional plant nutrients of any kind in the nursery. Those plants which had once been fertilized with full fertilizer or superphosphate and were moreover given lime in the nursery reacted very strongly to the additional fertilization in the field and to some extent attained about the same height as simultaneously planted transplanted spruce plants (2+2) from a nursery on arable land in Laholm.

A variance analysis made by Forest Officer Ingemar Eriksson concerning the length of terminal leaders in 1961 of unfertilized and fully fertilized spruce plants used in the experiment showed that in three groups there were differences between the parcels in the test series which could not be explained as being incidental. Between the test series reliable differences emerged in two groups. These plants which from the beginning were ahead in development normally had longer terminal leaders than plants which still remained at the stunt stage. Therefore, height growth observed is a result partly of fertilization and partly of natural increment. One possibility in such a case of studying the effect of fertilization therefore seemed to be to limit the investigation to making comparisons between parcels which showed the same mean plant height. Student's t-test in this respect gave great significance to the fertilization effect. A question of particular interest, however, is the problem of how the different "height levels", which occur among spruce at the stunt stage, are affected by strong fertilization. A regression analysis made by Forest Officer Eriksson showed that the fertilization did not affect the "height level" tendency in the test parcels. Relatively speaking, the weaker plants had thus increased their growth as much as the better developed plants. Needless to say, the absolute increase was greatest in the case of the strongest plants, both in the fertilized and unfertilized parcels. A further analysis of the material showed, however, that plants with a good "starting height" also displayed good growth without fertilization. If a comparison is made between the 1960 fully fertilized parcels with plants which did not receive any additional fertilization in the nursery and the test series which was given comprehensive fertilization or, as was later to be seen, the significant phosphorus fertilization in the nursery but no fertilization in the field, it will be seen that the plants which received no fertilization in the nursery at least did not overtake the plants which were well fertilized in the nursery in height, despite a strong reaction after fertilization in the field. It therefore seems to be difficult in a later stage of development to compensate for the lack of physiological balance and adaptability which can be traced to the unsatisfactory treatment of the plants in an early stage of development. Concerning the parcels fertilized with lime nitrogen, a corresponding analysis gave less reliable results on account of the toxic effect of this fertilizer which in a more or less uncontrollable way can have interfered with the progress of the experiment.

Thus the experiment shows that the additional fertilization had an effect on the continued development of the plants and trees only when growth had already commenced and the *Calluna* suppressed. In those cases where the plants were still more or less at the stunt stage and the *Calluna* dominated the place of growth everything suggests that the bulk of the additional nutrients was taken up by the *Calluna*. This substantiates the situation cited by Oksbjerg (1954) that in Danish experiments with nitrogen fertilization of spruce at the stunt stage a very brief effect was obtained and that after three years unfertilized spruce grew stronger than the fertilized (cf. Björkman, Lundeberg & Nömmik, 1967). An explanation of this can be that the plants which have access to plentiful nourishment preferably develop the parts above ground level (cf. Björkman, 1942, 1970). When the effect of fertilization declines or ceases the plants are forced to revert to building up their root systems, at which time temporary cessation of growth can occur.

4. Planting of selected 2+2 "plus" and "minus" plants of spruce on heath land

In 1950, 2+2-spruce plants raised in the Knäred nursery, where weak basic fertilization with NPK was carried out before planting and N in the form of ammonium sulphate was added once after transplantation, were planted in 8.4×8.4 m parcels with 3 replications. The 4 parcels were laid out in the same blocks in the Mörkhultsheden test plot as the parcels with the non-transplanted plants from the Mörkhult nursery in 1950.

Before the planting in May 1950 the plants were sorted into big, well-developed plants (plus variants) and smaller but in other respects equivalent plants from the same parcels in the nursery (minus variants),

When the plant height was measured in 1965 it was found that the plus variants continued to hold their lead in two blocks but that the minus plants in one of the blocks were practically as big as the original plus variants. This can probably be explained by the superior condition of the ground in this sector. Virtually all the plants developed without a stunt period.

Fig. 8 shows therefore, that less well-developed plants—whether this is due to genetic factors or competition in the nursery—can develop just as well after planting as plus variants, but that in a poor environment the well-developed trees can retain their lead for a long time.

It is also interesting to compare the growth of the transplanted spruce plants from the Knäred nursery with the development of non-transplanted plants of a generally similar age which had been fertilized with superphosphate and in addition received lime in the poor nursery in Mörkhult.

The non-transplanted (2+0) plants generally developed worse than the transplanted plants. The plants which were fertilized with superphosphate and lime in the nursery and planted as 2+0 and later given additional fertilizer in the field in the form of NPK after planting, developed for the most part almost as well (height on average 333 cm, Fig. 7) as the average of the transplanted plus variants (on average 375 cm) and minus variants (on average 284 cm), which moreover were a year older than the transplanted plants (cf. Fig. 8).

In general, however, it could be established that transplanted spruce plants were consistently superior to other types of plants, fertilized or unfertilized. (The experiments made also with 2+0-, 1+1-, 3+0- and 2+1-plants from different nurseries are not accounted for in this context.)

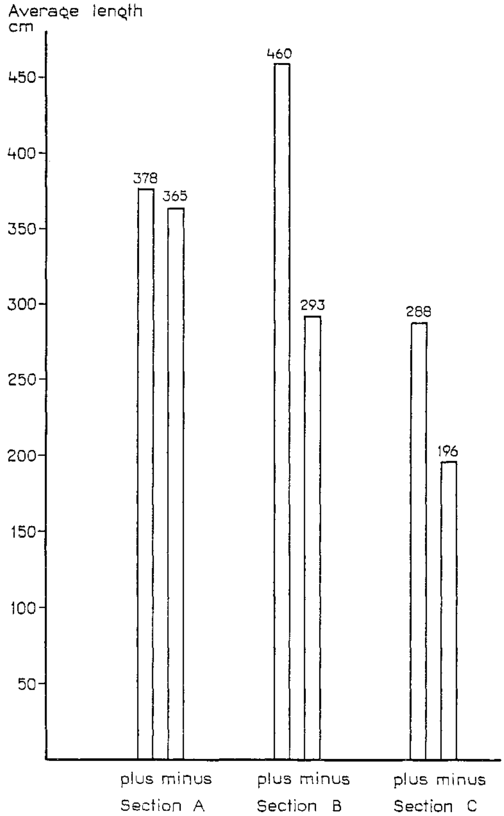

Fig. 8. Mean length of plus and minus plants (=well and poorly developed respectively) 2+2-spruce plants raised in the Knäred nursery after weak and comprehensive and uniform fertilization. Section A fertilized with superphosphate, sections B and C unfertilized. Measured 1965.

5. Combined cultures of transplanted spruce and pine, larch birch, alder and broom on heath land

5.1. Material and methods

With the intention of testing the old observation (cf. Løfting, 1945; Brantseg, 1948, 1954; Braathe, 1950; Oksbjerg, 1954 *et al.*) that combined cultures with other species can stimulate the juvenile growth of spruce so that the stunt period is considerably shortened, 2+2-spruce plants (*Picea abies*) raised in the Laholm field nursery were in May 1950 planted in 4 blocks in different parts of the test field in Mörkhult in the same hollow (double planting) as 2+0-pine (*Pinus silvestris*), 2+0-larch (*Larix decidua* L.), 2+0-birch (*Betula verrucosa* L.), 2+0-alder (*Alnus incana* L.) and 2+0-broom (*Sarothamnus scoparius* (L.) Wimm.). Each test plot measured 8.4×8.4 m. In another series of experiments were planted 4 blocks of the same 2+2-spruce in 4 rows alternating with 3 rows of pine, larch, birch, alder and broom of the same type as in the first series (row planting). The spacing was 1.2 m.

Plant height and length of terminal leaders were first measured by the County Forestry Board in the province of Halland in the autumn of 1951 and again in the spring of 1955 and the autumn of 1957. Clearing and pruning were carried out in 1959 and again in 1962 in three of the parcels, while one parcel was left untouched. Larch and pine which were obstructing the development of the spruce were removed during the cleaning. Only a few larches which it was thought would grow to pulpwood dimension were left. Birch and alder trees were topped so that the terminal leaders of the spruce were left free. The broom gradually disappeared spontaneously on account of frost damage. This test series has therefore been left out of the account of the test results in Fig. 10—11.

5.2. Results

The average height growth of the auxiliary trees in the two main parcels in 1957 can be seen in Fig. 9. The development of spruce partly in the untouched parcel, partly in the other three parcels where cleaning was carried out in 1959 can be seen in Fig. 10. In Fig. 11 the height of the spruce in 1965 after the second cleaning in 1962 is shown in the form of a staple diagram. The survival of spruce in all the test series was practically 100 %.

Fig. 9 shows that of the auxiliary trees larch, followed by alder, developed best. The birch did not thrive very well but had to be cleaned in 1959 so that it did not interfere with the development of the spruce.

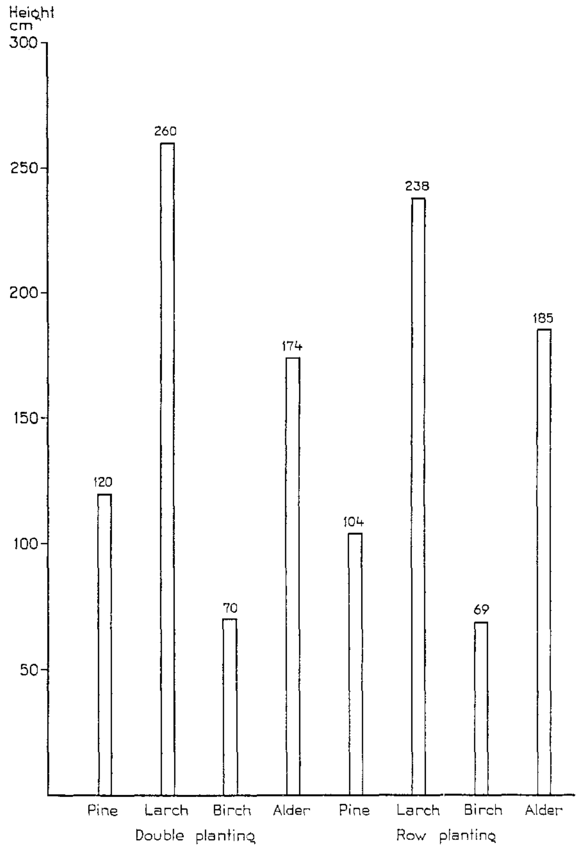

Fig. 9. Mean length of 2 + 0-pine, -larch, -birch and -alder in combined cultures with 2 + 2-spruce planted on *Calluna* heath in May 1950. Measured 1965.

Fig. 10 shows that the height growth of the spruce was strongly stimulated in the cleaned cultures. In addition there was a noticeable tendency for the spruce plants to be promoted in their development in combined cultures with the other species both in the cleaned and uncleaned parcels. A statistical analysis has been made by Forest Officer Ingemar Eriksson to test more carefully whether a general conclusion could be regarded as being justified on the basis of the admittedly extensive but, with regard to the height distribution of the spruce, heterogenic material. If the standard deviations between plants in parcels were taken into account (Table 2) it could also be established that none of the tested combined cultures was a reliable way of bringing about even height development of the spruce.

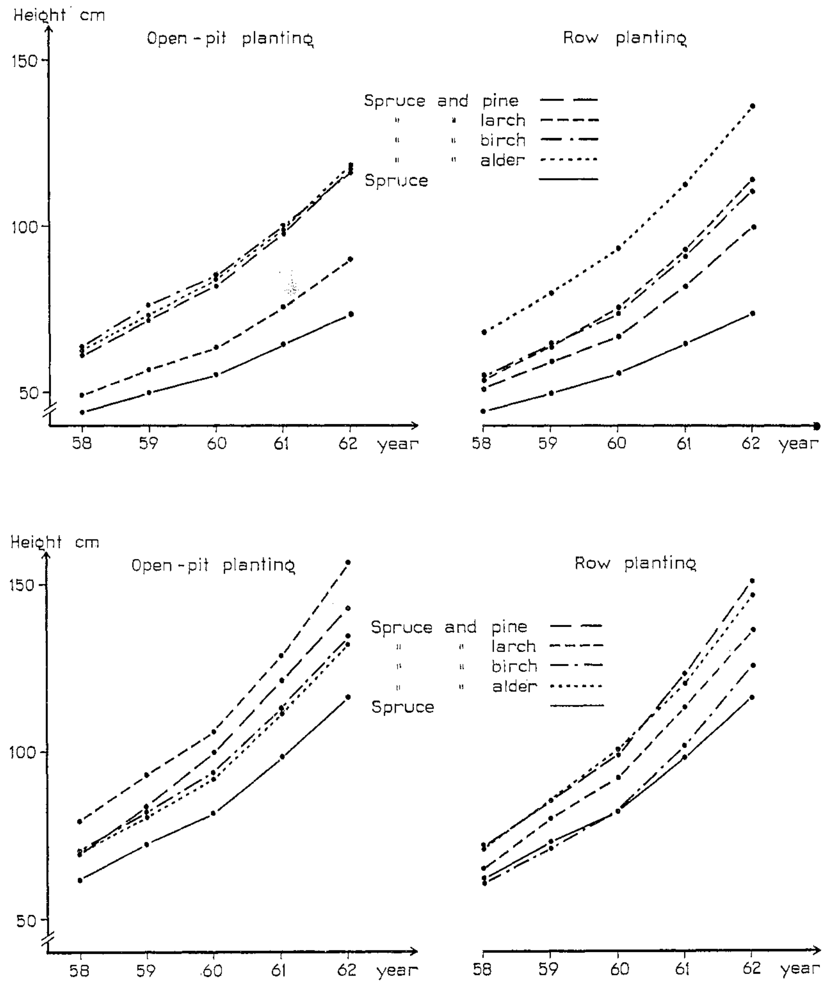

Fig. 10. Height growth of spruce plants planted as 2 + 2 in May 1950 on *Calluna* heath in combined cultures with pine, larch, birch and alder. *Above:* not cleaned cultures, *below:* cleaned cultures.

In order to analyse in more detail the difference indicated in the mean values (Table 2), and which even to the naked eye appear to exist between spruce which has grown alone and spruce with various auxiliary trees, a variance analysis with so-called hierarchical division (Bonnier & Tedin, 1957) was made. In this the test series with "pure spruce" and spruce in combined cultures represent the superior groups and the parcels the inferior groups. The variance analysis of height in 1962 for certain test combinations was performed as follows:

Table 2. Height development 1958 and 1962 of spruce in combined cultures with different tree species planted partly in the same spot as the spruce and partly in every other row as 2+2 1949. Measurements made by I. Eriksson.

$\bar{x}$ = mean of the heights within a parcel,
s = standard deviation of the heights within a parcel.

		Height, cm, in block								
		A		B		C		D		B—D
Planting	Year	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
Spruce	1958	44.5	17.6	51.5	14.6	58.4	17.1	72.4	25.3	61.0
	1962	73.7	28.5	95.0	32.7	111.4	38.7	138.3	60.6	115.4
Double planting										
Spruce +pine	1958	62.4	17.0	81.3	27.9	44.6	14.1	75.9	27.9	68.5
	1962	117.1	35.8	172.2	72.6	88.3	33.0	162.1	68.6	142.4
Spruce +larch	1958	63.8	22.6	67.5	26.4	58.9	22.4	110.7	33.0	79.1
	1962	116.4	44.6	142.6	60.3	118.2	60.0	205.4	60.2	156.6
Spruce +birch	1958	49.0	14.5	54.8	19.5	52.4	13.8	100.3	45.7	69.2
	1962	89.8	29.2	97.7	35.8	103.2	38.6	201.9	92.8	134.5
Spruce +alder	1958	63.1	18.2	58.1	14.2	60.1	23.9	84.9	48.6	68.1
	1962	117.5	36.7	117.9	59.3	117.4	59.3	157.3	94.1	131.3
Spruce +broom	1958	60.1	14.9	59.9	16.4	79.5	24.9	79.9	29.8	72.8
	1962	108.5	28.5	113.1	40.6	191.1	72.9	147.4	65.1	150.1
Row planting										
Spruce +pine	1958	51.7		68.4		69.8		76.4		71.4
	1962	99.6	31.1	143.7	56.1	147.7	51.4	157.3	73.4	149.3
Spruce +larch	1958	55.0		54.1		49.2		85.9		64.4
	1962	110.1	43.0	110.6	47.8	97.4	44.4	188.2	77.3	135.5
Spruce +birch	1958	54.6		62.8		49.2		69.7		60.8
	1962	113.7	43.5	118.6	39.2	106.3	40.7	148.7	57.2	125.1
Spruce +alder	1958	68.1		60.0		68.4		81.7		70.6
	1962	135.3	54.7	115.6	37.4	161.1	47.1	156.9	46.9	145.8
Spruce +broom	1958	63.1		50.0		55.1		64.2		56.5
	1962	117.2	53.8	94.0	35.6	127.2	53.5	113.6	29.6	111.5

1) test series spruce-spruce/pine (double planting)
2) ” ” spruce-spruce/larch (” ”)
3) ” ” spruce-spruce/pine (row planting)

A look through the analyses shows that in all combinations there was a considerable variation between the parcels in the same test series. A comparison between the mean values in the experiment with spruce alone with the help of the Students' t-test showed that there are differences between blocks B and C which cannot be described as a chance variation. The analysis also showed that the difference noticed between the test series did not give a reliable basis on which to assert with certainty that the combined cultures in the experiment had had a favourable influence on the height growth of spruce. Thus the conclusion to be drawn from the test up to and including the measurements taken in 1962 is that combined culture did not entail any advantage whatsoever. Moreover, a considerable disadvantage is always linked with this method on account of the increased cost of planting and above all, in connection with cleaning.

As mentioned above, when this conclusion had been drawn a further cleaning was carried out in 1962 of auxiliary trees on the test plot, where since the cleaning in 1959 the growth of the spruce had been strongly stimulated. The height development of the spruce three years after this latest cleaning has been collated in the staple diagram in Fig. 11. This shows that the spruce has now started to grow extremely strongly in those parcels where auxiliary trees were originally used, and about the same if the planting of auxiliary trees was made in the same hollow or in rows between the spruces. In some cases (planting together with larch and birch) the mean height in 1965 was approximately twice as big as in the control parcels with spruce only. It should hardly be necessary to carry out a statistical analysis of this material to conclude that combined culture with other species can have an extremely stimulating effect on the growth of spruce on *Calluna* heath land and presumably also on other ground where keen competition for available nourishment exists, this on condition that the auxiliary trees are cleaned so strongly that the spruce is never suppressed. It was remarkable that even pine when used as an auxiliary tree appeared to have a very stimulating effect on the development of spruce in combined culture. This, however, confirms the older findings of practical forestry, where preferably *Pinus mugo* was earlier used as an auxiliary tree.

But the explanation of the effect of auxiliary trees on the juvenile development of spruce on ground where *Calluna* competes vigorously for nourishment and water is not univocal on the basis of the experiments made. However, it would appear to be indisputable that the suppression of the competition by *Calluna* with the help of other more tolerant trees with which spruce can more easily live in symbiosis is a primary reason. The root systems of these trees are often to be found at a different ground level from that of spruce and are moreover associated with specific microorganisms. Thus *Pinus* species often have richly developed *Boletus* mycorrhiza ("*C*-type") to which Müller (1903) even ascribed the ability to fix aerial nitrogen. Even though this has not yet been confirmed the richly branched surface mycelium of *Boletus* mycorrhiza does constitute a great enlargement of the nutrient

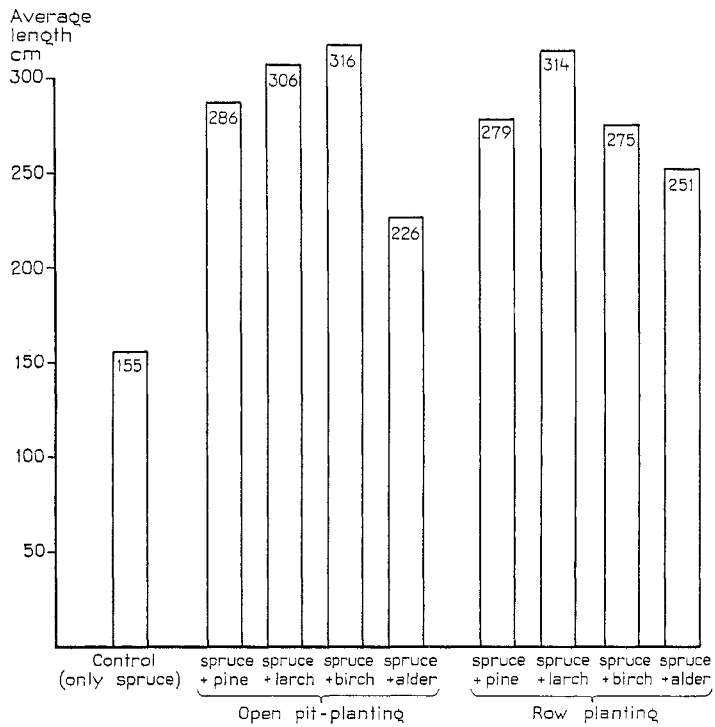

Fig. 11. Mean length of spruce plants planted as 2+2 in May 1950 on *Calluna* heath in combined cultures with pine, larch, birch and alder. The cultures were cleaned in 1959 and 1962. Measured 1965.

assimilating surface. The extensive growth area of in particular *Pinus mugo*, which suppresses the *Calluna*, has also been linked with the special ability of this species to have a stimulating effect on spruce in combined cultures. Neither does it seem improbable that the litter which auxiliary trees gradually leave in mixed stands can also contribute to the development of the spruce. This has been considered as important particularly concerning leguminous plants, such as *Sarothamnus*, and alder, whose root nodule organisms can fix aerial nitrogen and which indirectly benefits the host plant.

On the other hand there appears to be a certain risk that the auxiliary trees, because of their more rapid juvenile growth, can suppress the spruce and in this way do more harm than good. Failure at a sufficiently early stage to clean plantations where combined cultures are used would therefore appear to explain the bad results so often obtained from combined cultures.

A glance at the result of the 1949 experiment with spruce also shows that a more even development at no extra cost can be obtained only with the help of properly proportioned fertilization of the plants in the nursery.

6. Experiences from the planting activity by the Forestry Society at afforestation on heath land in the south of Sweden

In order to obtain a comparison between the results of the Mörkhult experiment and in particular those of the plantings carried out by the Forestry Society on a practical scale, a number of inventories were made of such plantings of similar age in the Mästocka area. The height growth of such spruces, which it was calculated would constitute the future stand, has therefore been measured in the plantings carried out in 1949 with 2+2-spruce plants.

The most important comparison material in the Mörkhult experiment was obtained from the 1949 planting series with 2+0-spruce plants fertilized in different ways in the nursery. To enable a full comparison to be made with regard to the planting sites a number of soil samples were taken with a drill from the humus layer of several test plots in the Mörkhult experiments and from adjacent planted stands of the same age. In this way 20 samples were taken at random from each locality and mixed before the analysis (cf. Gjems, Holstener-Jörgensen, Karlsson, Tamm & Troedsson, 1960). Analysis data from a few of these test plots and localities have been collated in Table 3.

Table 3 shows that the localities in question were fairly similar. The height measurements which were taken show that the regular plantings, in which 2+2-spruce plants from nurseries which had been fertilized in a standard way were used, resulted after 15 years in well-developed young trees which in the Mörkhult experiments are generally comparable with trees which were planted as 2+2-plants in combined cultures with other species (double planting with larch compared in particular). However, it is interesting to note that the plantings of the same year with 2+0-spruce plants, which received superphosphate and lime in the Mörkhult nursery (1947) and were then fertilized in the field with NPK (1960), reached about the same development as 2+2-plants in regular plantings.

The comparison, of which only a few examples are given here, therefore shows that the Forestry Society's plantings were carried out with physiologically well-balanced plants on the *Calluna* sites in question. Thus the doses of fertilizers used in the nursery were well proportioned. A certain stratification has admittedly nearly always occurred in the earlier development of spruce in all the plantings (cf. Fig. 12), but since very close spacing was used (1.2×1.2 m) this stratification has as a rule had little effect on the final result.

Table 3. Chemical analyses of the humus layer of the young stand of spruce planted in 1949 on *Calluna* heath at Mörkhult in Halland, partly in the Forestry Society's plantations with 2+2-plants, partly in the 1949 test series with 2+0-plants.

Test plot	Tree height 1965 cm	pH	P-Al	K-Al	Ca-HCl	P-HCl	K-HCl	Ntot % of air dry sample	NH_4-N mg/l air dry sample	NO_3-N mg/l air dry sample
Test plot south of the test field	342	4.5	0.9	7.7	40	39	83	0.14	3	0.2
Test plot north of the test field	320	4.5	1.2	10.2	40	45	154	0.10	4	0.3
Unfertilized test plot in the 1949 experiment with unfertilized plants in the nursery	88	4.9	0.7	7.1	60	49	184	0.14	5	0.3
Unfertilized test plot in the 1949 experiment with P-fertilized and lime-treated plants in the nursery	176	5.0	0.9	6.4	80	48	126	0.16	6	0.2
Unfertilized test plot in the 1949 experiment with P-fertilized and lime-treated plants in the nursery. Additional fertilization with NPK 1960	333	5.2	1.1	8.0	40	46	134	0.12	3	0.3
Unfertilized test plot with the 1949 double planted 2+2-spruce and 2+0-larch which were cleaned	260	5.1	1.3	11.0	70	52	176	0.18	7	0.4

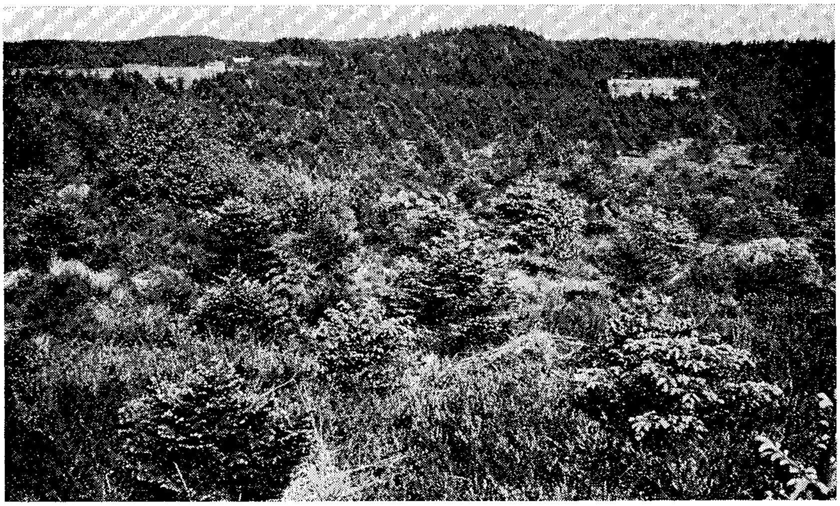

Fig. 12. Ten-year-old plantations of *Calluna* heath with 2+0-spruce at Mästocka. The spruce has developed quite uniformly but has not completely overcome the stunt period.

However, in certain older spruce plantations on *Calluna* heath land, and where combined cultures of 2+0-plants have been used, the planting result has been extremely bad. There are consequently large areas where such combined cultures occur in an uncleaned condition, and where bad-quality pine—often attacked by *Fomes annosus* (Fr.) Cke. or *Crumenula abietina* Lagerb.—represents the main tree species. The spruce is more or less suppressed and bears witness to the neglected cleaning of the culture. Provenances which are unsuitable for the district can also be a reason for the poor result, particularly where pine is concerned. As can be seen from the Mörkhult experiment the combined culture method is biologically sound and, properly used within the framework of economic reality, can lead to particularly fine stands. The risk involved in using this method lies in not cleaning the culture at an early stage. In a number of cases it is still not too late to clean successfully, but if stratification has occurred in the stand and the existing spruces are showing signs of extreme stagnation in their growth, total felling and reforestation is the only way to form a successful stand. In this connection transplanted plants (2+2) have shown themselves to have the best chance of developing quickly after planting.

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The Author is also deeply grateful to Forest Officers Harry Eriksson and Ingemar Eriksson, who in the form of examination work went through various parts of the experimental material, some of the results of which are cited in the text. Warm thanks go also to the Forestry Society in Gothenburg for supporting the experiments and making possible their conclusion. This vote of thanks goes in the first place to the Director of the Forestry Society, Forest Officer Tore Svensson.

REFERENCES

BJÖRKMAN, E. 1942. Über die Bedingungen der Mykorrhizabildung bei Kiefer und Fichte (On the conditions for the formation of mycorrhiza in pine and spruce). *Symb. Bot. Upsalienses, 6: 2,* 191 p.

— 1953. Om orsakerna till granens tillväxtsvårigheter efter plantering i nordsvensk skogsmark (Factors arresting early growth of the spruce after plantation in Northern Sweden). *Norrl. Skogsvårdsförb., Tidskr., 51,* 285—316.

— 1954. Betydelsen av gödsling i skogsträdsplantskolor för plantornas första utveckling i skogsmarken. *Norrl. Skogsvårdsförb. Tidskr., 52,* 35—58.

— 1964. Report and recommendations from IUFRO's Mycorrhiza Working Group (section 24) meeting in Puerto Rico, July 2—7, 1964. *Inst. Skogsbotanik, Skoghögskolan, Stockholm, Publ., 137,* 7 p.

— 1970. Mycorrhiza and tree nutrition in poor forest soils. *Stud. For. Suec.. 83,* 1—24.

BJÖRKMAN, E., LUNDEBERG, G. & NÖMMIK, H. 1967. Distribution and balance of N^{15} labelled fertilizer nitrogen applied to young pine trees (*Pinus silvestris* L.). *Stud. For. Suec., 48,* 1—23.

BONNIER, G. & TEDIN, O. 1957. *Biologisk variationsanalys,* 186 p. Svenska Bokförlaget, Stockholm.

BRAATHE, P. 1950. Granas veksthemning på lyngmark. *Tidsskrift for Skogbruk, 58,* 42—45.

BRANTSEG, A. 1948. Granas veksthemning. In: *Skogen og klimaet.* Bergens Museum.

— 1954. Planting av gran på lyngmark. *Skogbrukeren, 29,* 161—168.

CROWTHER, E. M. 1951. Sub-committee on nutrition problems in forest nurseries. Summary report on 1949 experiments. *Forestry Commission. Report on Forest Research for the year ending March 1950.*

GJEMS, O., HOLSTENER-JÖRGENSEN, H., KARLSSON, N., TAMM, C.-O. & TROEDSSON, T. 1960. Recommendations for forest soil sampling. *Kungl. Skogs- och Lantbruksakademiens Tidskr., 99,* 97—104.

HACSKAYLO, E. 1970. Biological amendments to improve forest soil. *J. For., 68,* 332—334.

HANDLEY, W. R. C. 1963. Mycorrhizal associations and *Calluna* heathland afforestation. *Forestry Commission Bull., 36,* 1—70.

LEYTON, L. 1954. The growth and mineral nutrition of spruce and pine in heathland plantations. *Imp. Forestry Inst., Univ. Oxford, 31*, 1—109.

— 1958. Some aspects of forestry research in Great Britain. *Univ. Toronto For. Bull., 5*, 1—19.

LØFTING, E. C. L. 1945. Laerkearternes Udvikling i Hedeplantagerne og Japansk Laerks Anvendelighed som Hjaelpetrae ved Opbygning af Hedeskov. *Det forstl. Fors.-vaesen i Danm., 14*, 323—364.

MALMER, N. 1968. Om ljunghedar och andra rishedar i Sydvästsverige. *Sveriges Natur, Årsbok 1968*, 177—188.

MALMSTRÖM, C. 1939. Hallands skogar under de senaste 300 åren. En översikt över deras utbredning och sammansättning enligt officiella dokuments vittnesbörd (Die Wälder Hallands während der letzten 300 Jahre. Eine Übersicht über deren Verbreitung und Zusammensetzung nach amtlichen Angaben). *Medd. Stat. skogsförsöksanst. 31*: *6*, 171—300.

MELIN, E. 1925. *Untersuchungen über die Bedeutung der Baummykorrhiza*, Jena.

MIKOLA, P. 1969. Comparative observations on the nursery technique in different parts of the world. *Acta For. Fenn., 98*, 24 p.

MOSER, M. 1958. Die künstliche Mykorrhizaimpfung von Forstpflanzen. 2. Die Torfstreukultur von Mykorrhizapilzen. *Forstwiss., Cbl., 77*, 273—278.

MÜLLER, P. E. 1903. Über das Verhältnis der Bergkiefer zur Fichte in den jütländischen Heidekulturen. *Naturwiss. Zeitschr. f. Land- u. Forstwirt., 1*, 289—306.

MÜLLER, P. E. *et al.* 1910. Bidrag till Kundskab om Rødgranens Vaekstforhold i midjydska Hedebund. *Forstl. Forsogsv. i Danmark, 3*, 1—270.

OKSBJERG, E. 1954. Nogle Foryngelseproblemer. 1. Om Rodkonkurrence og Røddernes Udvikling. *Dansk Skovfor. Tidsskr., 39*, 93—113.

RAYNER, M. C. 1939. The mycorrhizal habit in relation to forestry. 3. Organic composts and the growth of young trees. *Forestry, 13*, 19—35.

RAYNER, M. C. & LEVISOHN, I. 1941. The mycorrhizal habit in relation to forestry. Studies in mycorrhizal response in *Pinus* and other conifers. *Forestry, 15*, 1—36.

ROMELL, L. G. 1952. Heden. *Natur i Halland*, 331—347.

VOZZO, J. A. 1968. Inoculation of pine with mycorrhizal fungi in Puerto Rico. *Ph. D. Diss. The Geo. Wash. Univ. Washington, D. C.*, 85 p.

Sammanfattning

Plantkondition och tillväxt
Planteringsförsök med gran på ljunghedar

Orsakerna till granens kända stagnation i ungdomsutvecklingen särskilt på ljunghedar har varit föremål för stor uppmärksamhet av forskare och praktiker. Olika förklaringar har givits till detta fenomen. Enligt en uppfattning skulle ljungen avge för plantorna eller deras mykorrhizasvampar toxiska ämnen, och enligt en annan mening skulle den ojämna förekomsten av lämpliga mykorrhizasvampar vara anledningen till den ojämna tillväxten. Mest uppenbar är emellertid betydelsen av konkurrensen från ljungen om vatten och icke minst näring.

Det förefaller naturligt att plantor i dålig balans med sin nya miljö kommer att utvecklas dåligt. Då plantans fysiologiska kondition grundlägges i plantskolan, förefaller det naturligt att undersöka om olika behandling i plantskolan kan resultera i olika utveckling efter planteringen. Det mest näraliggande sättet att inverka på plantans fysiologiska status är gödsling. I de försök som behandlas i denna uppsats gödslades sålunda granplantor på flera olika sätt företrädesvis i en näringsfattig plantskola med samma slags mark, som den plantorna efter 2 resp. 3 år sedan utplanterades i, nämligen typisk ljunghed i södra Halland.

Försöken visade att en behandling av plantorna med fosforsyra resulterade i omedelbar och vida bättre tillväxt efter planteringen än efter tillsats av kväve eller kalium. En tillsats av fullgödsel (NPK) resulterade likaledes i bättre plantutveckling. Effekten förhöjdes i regel ytterligare om även kalk tillförts i plantskolan. Mykorrhizabildningen visade i stort sett en parallell utveckling till plantornas utveckling.

Gödsling av mer eller mindre stagnerade plantor i fält med kväve och fullgödsel visade att en stimulation av tillväxten endast inträdde om plantorna redan kommit igång, vilket var fallet speciellt med de i plantskolan P- eller NPK-gödslade plantorna. En gödsling i ett starkt skiktat bestånd av smågranar som dels börjat utvecklas, dels står kvar i ”stampen” förmådde icke utjämna denna skiktning. Det visade sig sålunda vara svårt att i ett senare utvecklingsskede kompensera den brist på fysiologisk balans och anpassningsförmåga, som kan härledas till en otillfredsställande behandling av plantorna på ett tidigt utvecklingsstadium.

Utplantering av s. k. plus- och minus- varianter (resp. förväxande och mindre väl utvecklade) 2+2 granplantor på ljunghed har visat att plusvarianterna fortfarande behöll sitt försprång inom block utlagda på näringsfattiga delar av försöksfältet, men att skillnaderna utjämnades på bättre mark.

Vid samkultur av gran med resp. tall, lärk, björk, al och *Sarothamnus scoparius* på ljunghed kunde visas, att denna planteringsform innebär en gynnsammare start och utveckling av granplantorna förutsatt att en röjning på relativt tidigt stadium utföres. Om röjning företages i etapper kan en avsevärd stimulans i granens utveckling erhållas, men metoden är så dyrbar att den knappast är motiverad i praktisk skala.

En jämförelse mellan de av Skogssällskapet utförda ljungplanteringarna i praktisk skala under 1940- och 1950-talen och de utförda modellförsöken med bl. a. olika gödsling i plantskolan visade att dessa planteringar utförts med fysiologiskt väl balanserade plantor som visserligen normalt stagnerat några år men så småningom kommit väl igång. Användningen av 2+2 granplantor, som blev allt vanligare från slutet av 1950-talet, har emellertid ofta medfört god tillväxt omedelbart efter planteringen.

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