Nutrition of Sitka Spruce on Peat-Problems and Speculations

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Introduction

This paper deals with the problems of the mineral nutrition of Sitka spruce (*Picea sitchensis* Bong. Carr.) on peatland soils in Northern Ireland and speculates on the solutions to some of them. There are nutritional problems on the mineral soils in the country (Savill and Dickson, 1975) but on certain peat soils they are more acute and occur at an earlier stage than on any other major soil type. However not all peats are unproductive and it must be emphasised that there is as big a difference in potential productivity for Sitka spruce on low altitude valley or fen peat and upland blanket peat as there is between agricultural production on the best arable and poorest grazing soils in the country.

By far the most important group of peat soils devoted to forestry in Northern Ireland are the blanket peats; there are only relatively small areas of raised bog or fen peat and even less afforestation on them. About 80% of the blanket peat is over 1 m. deep and this type of peat has been classified into four "nutrient classes" ranging from the nutrient rich eutrophic class to the very impoverished dystrophic type. The classes are recognised by the characteristics of the natural vegetation. It is not claimed that the scheme is perfect; nor is it suggested that it necessarily has relevance outside a forestry context but it has the merits of simplicity and usefulness in practice.

There are very few nutritional problems with Sitka spruce on eutrophic peat. Only small areas of dystrophic peat have been planted in the past and this type is no longer planted with spruce. Deficiency of potassium (K) is the main nutritional problem on mesotrophic (semi-flushed peat, but this is fairly easily identified and overcome. Also it has been suggested (O'Carroll *et al.* 1973) that K deficiency may become less acute as the trees increase in size. The biggest problems both in extent and severity occur on oligotrophic peat (unflushed blanket bog) (Dickson and Savill, 1974) and the remainder of this paper deals with this topic.

Present situation regarding Sitka spruce on oligotrophic peat

The basic problem in the nutrition of Sitka spruce planted on oligotrophic peat is centred on nitrogen (N) availability. Although the total N content of the peat is relatively high, the amount which

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can be utilised by the trees at any one time is limited. Provided that sufficient phosphate is made available, Sitka spruce will grow quite satisfactorily on oligotrophic peat until the mean height of the crop reaches about 2.5. m. Thereafter growth under present management techniques becomes limited by N deficiency. The onset of N deficiency appears to be independent of age and occurs at about the critical height of 2.5 m. irrespective of whether the trees have spent some years in check through having insufficient fertilizer P at planting or whether they have reached the same height without interruption in from 6–8 years. It has been suggested that the reason for this N deficiency is that as the trees increase in size so also does the total N requirement. Unfortunately, the rate at which the N in the peat is made available to the trees by the activity of soil micro-organisms cannot keep pace with this increased demand by the trees and growth rate falls. This general pattern of reduced N uptake with time either from planting or after treatment of checked trees is typical of all spruce plantations on upland deep oligotrophic peat.

The future

There are two distinct situations facing the forest manager in dealing with oligotrophic peat:

A. The existing plantations of Sitka spruce which have had sufficient P for the foreseeable future but which are liable to N deficiency.

B. Afforestation of bare ground.

The options available are different in each situation and some are discussed below.

A. Existing plantations

Nearly all state-owned plantations in Northern Ireland have been adequately fertilized with P either from ground based machine or helicopter. Courses of action to overcome future N deficiency are limited by the physical presence of the trees but include:

1. Application of fertilizer N at intervals until the end of the rotation.
2. Improvement of existing drainage pattern in the hope that increased aeration will lead to greater activity of soil micro-organisms and hence an increased rate of N mineralisation.
3. Application of lime to decrease acidity of peat for same reasons as in 2.
4. Inter-planting of existing Sitka spruce with a "nurse" crop.
5. Removal of all or some of the spruce and replanting with a less nutrient demanding final crop species.

These options will be discussed in turn.

A1. Repeated application of fertiliser N

Before embarking on a committment to repeated application of fertilizer N the manager must know (1) what fertilizer to use, (2) how soon after planting to start application, (3) how frequently to apply it and (4) how much to apply at one time.

In Northern Ireland urea has been found to be as effective as any other commercially available N fertilizer. Its high N concentration (46 %) makes it particularly suitable for aerial application.

Application of N before the onset of acute deficiency, when the trees are about 2.5 m high, is wasteful. Prior to this any apparent N deficiency will probably be associated with P deficiency and both can be effectively overcome by P application.

The response of N deficient Sitka spruce to applied urea is relatively short-lived. Height growth generally reaches a maximum 2–3 years after application and falls to pre-treatment levels in a further 2–3 years. This patterns, of course, may change as crops get older. On present evidence the longest interval between applications consistent with an acceptable growth rate seems to be about 5 years.

The currently recommended rate of application is 250 kg urea/ha (115 kg N/ha). Higher rates have been tried to see if response time can be extended but excessively high rates can damage and actually kill the trees. Annual growth in a 10 year old crop of Sitka spruce in the first and second seasons after the application of a range of urea applications is shown in Table 1.

TABLE 1

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Height growth (cm) of Sitka spruce in first and second years after urea application

Season	Rate of Application (Kg N/ha as urea)			
	0	200	400	600
First	13	19	11	13
Second	32	49	36	29

Obviously rates of urea supplying more than 200 kg N/ha are detrimental to the growth of Sitka spruce at least in the years immediately following application.

A2. Improvement of existing drainage

The digging of a drain has two results—a ribbon of spoil above and a furrow below ground surface. Until recently it appeared that the volume of spoil above the ground had a bigger effect on the growth and N uptake of the trees than had the depth or spacing of the furrow (Savill *et al.* 1975). However some recent results suggest that the drainage effect *per se* becomes increasingly important as the crop gets older. This is illustrated in Fig. 1. By the end of the eleventh growing season the poorest growth and lowest foliar N concentration (0.93% DM) was in the plots drained at planting with only the DMB (double mould-board) plough and the best in the most intensively drained treatment—DMB ploughing with 0.9 m. deep drains superimposed at 7.5 m. intervals. The surprising fact is that growth and foliar N concentrations (1.20% DM) are so good in the SMB (single mould-board) only treatment. Have we been too cost-conscious in our attitudes to ploughing?

A3. Application of lime

The average pH of oligotrophic peat is about 3.2–3.5. In normally productive agricultural soils it is usually between 5.5 and 6. Many of the soil microorganisms active in breaking down organic matter and consequently releasing N are most active at between pH 5 and pH 6. It might be assumed that if the pH of the peat were adjusted to nearer this value then the N status and growth of planted Sitka spruce would be improved. Unfortunately, it is not quite as simple as this. It is relatively easy to raise the pH of the peat surface to the

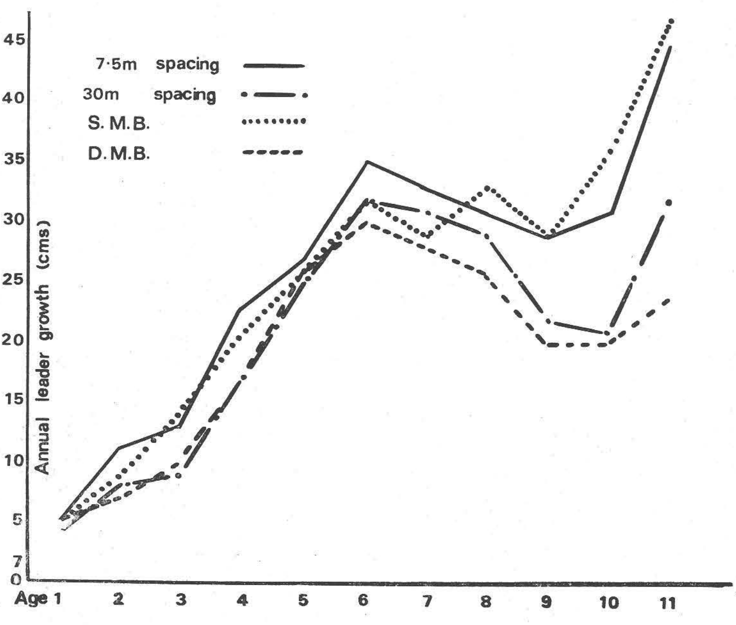

Figure 1. Effects of drain spacing and type of ploughing on growth of Sitka spruce.

required value by applying ground limestone at rates from 5–10 tonnes/ha (Dickson, 1972) but the trees take a long time to respond favourably to this treatment. A series of experiments has established that lime applied at planting reduces annual height growth of Sitka spruce on oligotrophic peat for about 6 years but there are indications that after this period, growth is increased by liming. The results of one such experiment are illustrated in Fig. 2.

A4. Inter-planting with "nurse" species

A traditional method of dealing with the establishment of a nutrient demanding species on a "difficult" site was to inter-plant a "nurse" species with the eventual maincrop species. This practice has largely died out because of practical management difficulties but there is evidence that admixture of N-fixing species such as broom, whin or alder and deciduous species such as Japanese larch leads to a considerable increase in N uptake and growth of Sitka spruce (see Carey, M. L., this issue). However attractive the idea of getting "free" N from a nurse crop may be it is unlikely to be a final solution because of management difficulties and the fact that the spruce crop will probably need supplementary N through to the end of the rotation by which time most nurse species will have been shaded out.

A5. Removal of the Spruce crop

The ultimate choice is to regard the Sitka as a total loss, write-off its establishment costs and replant in whole or part with the less nutrient demanding coastal lodgepole pine (*Pinus contorta* Dougl). Experiments testing various ways of doing this have been established in Northern Ireland but no results are yet available. Such a course of action could be contemplated only after very careful consideration of all the factors involved—economic, scenic and even psychological.

These then are the options open to the manager in dealing with established plantations of Sitka spruce on oligotrophic peat. All involve considerable capital outlay—some more than others—but each involves a conscious management decision which must be adhered to. The difficulties in making the right decision now are made greater by the fact that the final outcome is not even yet known. Most plantations of Sitka spruce correctly managed since planting on oligotrophic peat are still relatively young. Statements to the effect that N will have to be applied every five years until the end of the rotation or any reference to eventual Yield Class can with present knowledge be little more than intelligent guesses.

B. New Planting

The question as to the afforestation of virgin oligotrophic peat is simple—should we continue to plant Sitka spruce or should we plant a vigorous strain of coastal lodgepole pine which is known to be able to produce a worthwhile crop on this peat type with considerably less fertilizer input. From our experience in Northern Ireland we know that it will be expensive to grow Sitka spruce on these sites but how does a high input—high output enterprise using Sitka compare with a low input–low output system using lodgepole pine?

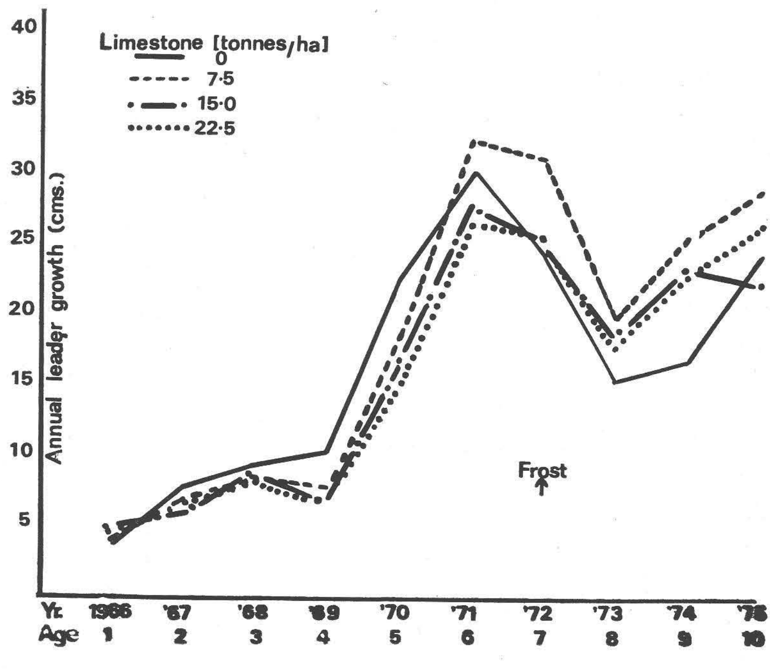

Figure 2. Effect of ground limestone on growth of Sitka spruce.

There is considerably more information on the growth of lodgepole pine on oligotrophic peat in the Republic than in Northern Ireland. However most of this information relates to low altitude bogs in the western counties. From the little information available it seems that lodgepole pine on most of the high altitude blanket peats in Northern Ireland is growing at a rate corrseponding to Y.C. 12 rather than Y.C. 16 or 18 which seems possible in Mayo or Galway. Such a difference has obvious economic implications.

If we make assumptions common to both species and use current fertilizer and applications costs the Net Discounted Revenue (N.D.R.) from plantations of Sitka spruce and lodgepole pine can be compared at different timber prices and Yield Classes.

From such calculations it can be shown that when the price per m^3 for the two species is the same, N.D.R. is higher with the pine at all Y.C.s from 10 to 18. However, given a price difference of £1 per m^3 in favour of its timber, N.D.R. is higher with spruce at Y.C. 16 and above. If the price difference reaches £2 per m^3 in favour of Sitka N.D.R. is bigger at Y.C. 12 and above. These conclusions of course are dependent on certain assumptions and on the fact that a rotation of 45 years can be achieved with both species on oligotrophic peat without serious windthrow damage.

So if Sitka spruce can be grown at least at Y.C. 16 and if the timber fetches at least £1 per m^3 more than lodgepole pine then it is cheaper to grow the former—even with a high input of fertilizer N. How much cheaper would it be if this input of fertilizer N could be avoided? Before this can be achieved a great deal more will have to be done to improve the physical and chemical conditions of the peat than has been done in the past or indeed is being done at present. In brief, the water-logged, acid and practically sterile virgin peat will have to be changed into a better aerated non-acid medium with an active population of soil microorganisms which can mineralise the native organically bound N in the peat and make it available to the trees. How best can such improvements be obtained?

The individual benefits of liming and deep intensive drainage on the growth of Sitka spruce on oligotrphic peat have already been outlined. Although both treatments increase growth, neither alone has brought about the dramatic changes required. The results of an experiment at Springwell forest suggest a technique which may just achieve the desired breakthrough.

The experiment was laid down in 1962 when hydrated and ground lime were applied at rates of from 0–25 tonnes/ha. Half of the area was rotovated just after lime application. All plots were ploughed with a S.M.B. plough at planting in 1968. In 1971 rock phosphate was applied at 500 kg/ha and after visual symptoms of severe K deficiency developed in 1973, 250 kg KCI/ha was applied.

Annual height growth in the non-limed and 5 tonnes/ha hydrated lime treatments over the first 8 years is shown in Fig. 3. In the ploughed only plots, liming had the effect previously described *i.e.* an initial reduction in growth over the first 6 years followed by a slight increase over the unlimed treatment. The exciting feature of the data in Fig. 3 is the very good growth of the trees in the lime plus rotovation treatment. Although rotovation without lime has improved growth over the standard treatment. in the combined treatment the annual height growth in the eighth season is over 75 cm. and foliar N concentrations are considerably higher (1.42% D.M.) than in the unrotovated control plot (0.88% D.M.).

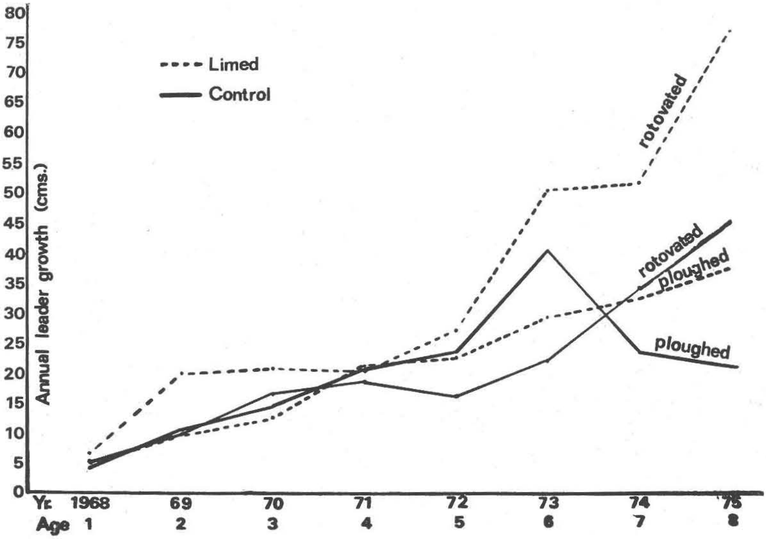

Figure 3. Effect of liming and rotovating on annual leader growth of Sitka spruce, Springwell Forest.

Admittedly this crop is still too young to speculate on the ultimate effect of the lime plus rotovation treatment but in conjunction with deep S.M.B. ploughing it is certainly a considerable improvement on previous establishment techniques. An interesting fact is that the vegetation in the lime plus rotovated plots is largely dominated by soft grasses and herbs whereas in the non-rotovated plots *Calluna* and associated species have largely re-colonised the ground, even where high rates of lime were applied. This suggests that a fairly profound change in the physical and chemical conditions of the peat has taken place. Hopefully the change is big enough and will last long enough to allow the crop to reach maturity without repeated inputs of fertilizer N.

Conclusions

1. On present evidence and using current techniques Sitka spruce will not form a merchantable crop on oligotrophic peat without repeated inputs of fertilizer N.

2. Given a price differential of at least £1 per m^3 of timber in favour of Sitka spruce compared with lodgepole pine the former species will give a higher N.D.R. if it can be grown at Y.C. 16 and above.

3. It *may* be possible to grow Sitka spruce on oligotrophic peat without repeated N fertilization to Y.C. 16 if enough ground preparation work is done before planting.

4. Tentative prescription for growing Sitka spruce on oligotrophic peat.
   (a) Apply lime+P (as Superphosphate)+KC1.
   (b) Plough deeply with S.M.B. plough (or tunnel plough if suitable).
   (c) Rotovate between plough ribbons.
   (d) Plant at no less than 2.4×2.4 m. or equivalent.

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