Sitka spruce or lodgepole pine?

A financial appraisal

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ABSTRACT

Problems arise in growing Sitka spruce on certain deep peat and Old Red Sandstone derived mineral soils due to lack of available soil nitrogen. Results from a number of experiments show that the species responds well in growth to nitrogen application in these situations. The object of this study was to make a financial comparison between growing Sitka spruce, using fertiliser nitrogen, and lodgepole pine which grows vigorously without any inputs of nitrogen. Japanese larch/Sitka spruce mixtures are also included in the appraisal.

The results suggest that the economics of growing pure crops of Sitka spruce on impoverished O.R.S. mineral soils using fertiliser nitrogen are questionable. Lodgepole pine or Sitka spruce/Japanese larch mixtures would appear more attractive options. However, the lower nitrogen inputs necessary to sustain production on some peat soils, and the lower production potential of the lodgepole pine, result in the spruce being the far more attractive option under certain circumstances, particularly if the price of nitrogen does not increase in real terms. The larch/spruce mixture appears an attractive proposition on O.R.S. mineral soils.

INTRODUCTION

The extension of afforestation in recent years in the Republic of Ireland on to increasingly difficult land has resulted in a sharp decline in the area being planted with Sitka spruce (*Picea sitchensis* (Bong.) Carr) and in a corresponding increase in area of coastal lodgepole pine (*Pinus contorta* var contorta loud). Whereas Sitka spruce comprised 66% of the total planting programme in 1973, the figure had dropped to just under 43% in 1980 (Fig 1).

This change in attitude is a reflection of the quality of the land concerned and its assumed problems in relation to the successful establishment and growth of Sitka spruce. Although the species can be successfully established on a wide range of site types, provided adequate phosphorus is applied at planting, both research and

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management experience showed in the nineteen sixties that growth fell off gradually after a period of years in many areas due to nitrogen deficiency.A condition known as "check" frequently developed. O Carroll (1962) commented: "Most of our Sitka spruce on peat seems to be living a life only bordering on the healthy".

The reason for this was partly because the initial quantity of phosphorus applied (usually about 30kg/ha) was inadequate to sustain growth and because it was spot rather than broadcast applied. As a result, most of the crops in this category were given a broadcast application of rock phosphate (92kg P/ha) in the late nineteen sixties and early nineteen seventies. This had a positive effect on growth in most situations except on the very impoverished sites where increment fell off again after a period of 3 to 5 years. This condition usually developed on soils derived from Old Red Sandstone (O.R.S.) where *Ulex gallii* was absent, certain unflushed (oligotrophic) blanket peat soils and on midland raised bogs. It was usually caused by nitrogen deficiency and was very often accentuated by the presence of heather which is known to adversely affect the uptake of this element (Handley, 1963).

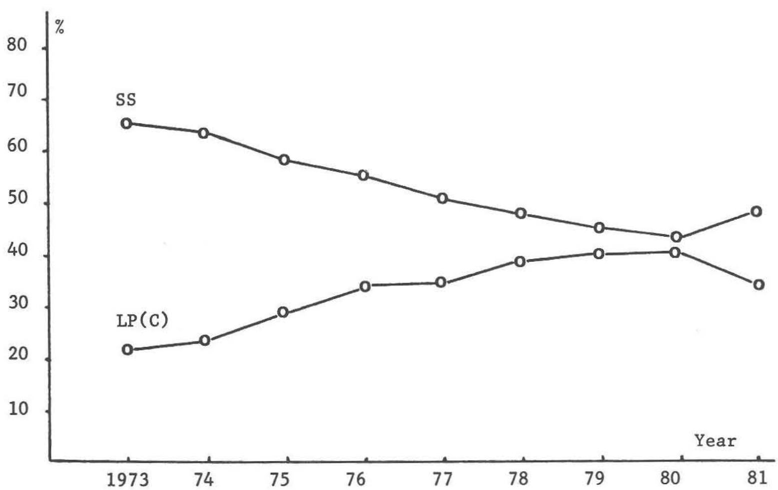


Fig. 1 Percentages of total area planted by the Forest and Wildlife Service with Sitka spruce (SS) and coastal lodgepole pine (LP(C)) 1973-1981.

Because of these experiences it is not surprising that attitudes changed and tended to favour the less demanding lodgepole pine. Despite the low availability of soil nitrogen, this species grows vigorously, provided adequate phosphorus is applied at planting time (Carey, 1981b). However, although the choice of lodgepole pine involves a lower input regime, providing what is now considered an excellent raw material at the end of the rotation, some concern has been expressed in recent years with regard to certain aspects of the species. This includes the problem of basal sweep, susceptibility to wind and snow damage, the Pine Shoot Moth and the recent outbreak of the Pine Beauty Moth in Scotland. These risks, together with the nutritional problems associated with growing Sitka spruce, result in the forest manager being faced with a dilemma in relation to the choice of species on the sites concerned.

In recent years a considerable amount of research has been carried out on the nutrition of Sitka spruce on both deep peat and O.R.S. derived soils. The basic problems of nitrogen availability have not yet been solved on a practical scale but research in progress would suggest that they can. However, enough knowledge has been gathered to enable a financial comparison to be made between the cost of growing Sitka spruce using fertiliser phosphorus and nitrogen and coastal lodgepole pine using phosphorus only. The aim of this paper is to present the results from such a study and in so doing to provide a more rational basis for choosing between the two species.

FERTILISER INPUTS

General

Phosphorus, applied as ground rock phosphate at a rate equivalent to about 500kg/ha (72.5kg P/ha), is essential in order to ensure good establishment and growth of both species on the sites concerned. Although further inputs of P may be necessary on some sites there is no reason at present to suspect that these will differ for either species.

Sitka spruce

The problem areas for Sitka spruce have, in general, been associated either with mineral soils derived from O.R.S. or raised or blanket bog peat soils. Although extreme variation occurs between and within these groups in relation to both soil chemical and physical characteristics, they all present the same basic problem in relation to the growth of Sitka spruce, lack of available nitrogen.

Research in recent years has shown that there are a number of broad site types which differ significantly in their requirements in this respect:

O.R.S. mineral soils: Results from experiments in a number of State forests have shown that nitrogen application is essential in the third year after planting in order to sustain vigorous growth unless a nitrogen fixing species such as *Ulex gallii* is a dominant feature in the vegetation. Large responses in growth are obtained in such instances to nitrogen application the magnitude of which is increased further where competing heather (if present) is eradicated through spraying. Although the optimum rate of application appears to be in the order of 200-220kg N/ha, the growth response appears to last only about 3 years after which the trees generally return to a checked condition unless nitrogen application is repeated.

Blanket peats: It is now established that Sitka spruce will grow vigorously after broadcast application of phosphate on a wide range of blanket peat sites for at least eight years, often up to ten or twelve years, before inputs of nitrogen are required. Some shallow peat areas, (say less than 1 metre deep), found in association with knolls or hillocks tend to show check symptoms somewhat earlier, probably because heather tends to be more vigorous in these drier situations compared with the deeper peat areas.

The response of slow growing or checked crops of Sitka spruce on high level blanket bog to fertiliser nitrogen is as striking as that found on O.R.S. derived mineral soils but the effect appears to last longer — up to five years, depending on the amount applied (Carey, 1980). In two experiments at Mullaghareirk and Newmarket State forests, the growth rates achieved correspond with those for yield class 18-20 of the Forest management Tables (Hamilton and Christie, 1971).

Although the quantity of nitrogen needed on peatland sites needs further refinement, the present recommendation would be similar to that for the O.R.S. mineral soils, 220kg N/ha. However, it would seem possible to extend the application cycle from three to five years.

Midland Raised Bogs: The situation on midland raised bogs would appear rather similar to that on high level blanket bogs. Heather control is desirable in about the fourth growing season after planting and, if carried out properly, is likely to delay the onset of nitrogen deficiency.

Cutaway Bogs: Substantial areas of peatland — particularly the raised bog type — have been cut over for fuel in Ireland over the last two centuries. In general these are highly productive forest soils, although problems may arise locally with Sitka spruce due to strong heather competition and/or copper deficiency. Because these are the exception, this site type is not considered further herein.

Application of fertiliser potassium to spruce plantations is a relatively common practice on certain peat soils in Britain (McIntosh, 1981) but significant and worthwhile responses to this element have so far only been found in the Republic of Ireland on either fen peats (O Carroll, 1966) or on flushed mesotrophic blanket peats carrying a dense sward of *Molinia.* Because it is most unlikely that either fen or mesotrophic peat will require inputs of nitrogen it is assumed for simplistic reasons that potassium application will not be needed on the sites discussed herein. Where it is needed, its cost will be more than offset by those included for nitrogen inputs.

In this study allowance is made for the basic differences that have emerged in recent years on the requirements of these broad site types. Because it is unclear at present whether nitrogen application will be necessary after canopy closure in order to sustain growth, separate calculations are presented for both possibilities i.e. nitrogen application at fixed intervals up to the end of the rotation and nitrogen application up to canopy closure. This question concerning fertiliser inputs following canopy closure is a key one and, although there is little hard information on it at present, evidence throughout the world suggests that most of the nutritional requirements may be satisfied through recycling at this stage of crop development. The poor response of polestage crops of Sitka spruce both in Britain and Ireland to fertiliser inputs in experiments over the last decade would support this hypothesis although few of these were in fact located on deep peat soils.

Lodgepole pine

No further fertiliser inputs other than P are envisaged at this point in time for lodgepole pine. Although potassium deficiency symptoms are a common feature on many young crops on peatland, the response to K application in general on the sites concerned does not justify the cost involved. This may be a function of both the extent of the maritime influence and the ability of the species to intercept K from the rainfall (Carey & O Carroll, 1981).

PRODUCTION

Sitka spruce:

The best guide to potential production for any given site must be existing healthy crops in the area concerned showing no nutrient deficiencies. The forest inventory books serve as an ideal data source in this respect. The average Yield Class for the species in the country as a whole is in the region of 16. Provided soil factors are not limiting (e.g. lack of N, P or K), Yield Classes of 18-20 plus seem attainable on a wide range of sites at elevations below about 250m. (This latter figure is by no means absolute and can be considerably affected by other site factors).

Lodgepole pine:

Evidence from many areas suggests that lodgepole pine can attain a Yield Class between 12-16 (occasionally 18) on the site types in question unless some factor such as elevation becomes a limitation. The mean Yield Class for the species in the Republic of Ireland is currently 12 and a survey of inventory records for 35 State forests known to be dominated by either O.R.S. mineral soils, blanket peat soils or raised bog soils gave mean Yield Classes of 12, 11 and 14 respectively for crops planted between 1958 and 1968. The calculations presented include data for a range of Yield Classes from 12 to 18 thereby enabling the manager on the ground to decide what option corresponds most closely to the average production in his area.

METHODS AND ASSUMPTIONS

Economic Methods: The usual method for comparing two or more silvicultural options is that known as net discounted revenue or N.D.R. In this approach all costs and revenues are discounted at a set rate of interest to year 0. Subtraction of one from the other gives the N.D.R. This can be negative or positive depending on the actual costs and revenue figures involved and the interest rates used. The N.D.R. figures can then be used as basis for comparison between the various options. It was decided to use a discount rate of 6% in these calculations. Lower interest rates are commonly used in forestry calculations of this kind. However a subsequent sensitivity test on the data using a 4% interest rate showed that the same conclusions emerged. The actual figures in each case were multiplied by the "infinite rotation adjustment factor" which allows for the N.D.R. for an infinite number of future rotation.

Assumptions: In order to calculate the N.D.R. for any treatment option certain assumptions must be made both with regard to the actual costs that are likely to accrue during the rotation and on the revenues that will arise from sales of timber. Data on costs were based on the most up to date available in January 1981 from F.W.S. Work Study Section. These are of necessity *average* data, the actual figures being very dependent on the nature of the site etc. Costs for fertiliser nitrogen represent the average retail prices pertaining in January 1981 for the country as a whole. Other assumptions made were as follows:

1. That a single application of 500kg of rock phosphate/ha at establishment is sufficient to ensure a production of 12-18m^3/ha/annum for lodgepole pine and that no further fertiliser additions will be necessary during the rotation.

2. That rotation lengths for Sitka spruce will be 20% less than the age of maximum mean annual increment for the yield class concerned. In the case of lodgepole pine final felling year will be equal to the age of maximum mean annual increment. This is in line with current policy on rotation lengths for both species and is influenced in the main by marketing considerations.

3. That all fertiliser materials will be applied from ground spreaders or by hand. Aerial application would very likely reduce costs in favour of the spruce options.

4. That stability or form is not affected by any of the treatment options.

5. That volumes produced correspond to those given in the British Forestry Commission Management Tables (Hamilton and Christie, 1971) for Sitka spruce and Forest and Wildlife Service Tables (Anon, 1975) for lodgepole pine. The Stand Assortment Tables (Hamilton and Christie, 1971) were used to quantify the amounts of timber in each category. It was also assumed that, because of basal sweep in the lodgepole pine, 20% of the sawlog category would be downgraded to boxwood and 5% of the latter to pulpwood. Finally, two variations on the current average price structure were tested in order to see what effect if any this would have on the end result:
   (i) a 10% reduction in sawlog and increase in pulpwood prices from £1.50 to £4.00/m^3
   (ii) a 20% reduction in sawlog and a 100% increase in pulpwood prices.

6. That timber prices are similar for both species and are as follows:
   Pulpwood, Top Diameter $<$ 14cm £1.50/m^3
   Boxwood, Top Diameter 14-20cm £10.50/m^3
   Sawlog, Top Diameter $>$ 20cm £24.50/m^3.
   These prices are based on January 1981 average data.

7. The cost of nitrogen: One of the major imponderables in a calculation of this kind rests in possible future trends in the price of nitrogenous fertilisers. This uncertainty, in association with a widespread belief that nitrogen prices were tied to oil prices, has contributed in no small way towards the decision to plant more lodgepole pine. In fact nitrogen prices have decreased significantly relative to the retail price index in the Republic of Ireland over the past 10 years (see Table 1) and it is highly unlikely that they will show a substantial increase in real terms in the foreseeable future. This is because energy costs account for only about 25 per cent of fertiliser costs and also because there is at present an excess of urea manufacture in particular, on the world market. Many countries besides Ireland have become committed to this industry in recent years and are unlikely to cease manufacture in the foreseeable future. In these calculations two

assumptions have been made in relation to the price of nitrogen fertiliser:

(a) That there will be no real increase in the prices of nitrogen over and above the rate of inflation.

(b) That the price of nitrogen will rise by 6% per annum in real terms.

8. Management costs common to the different options are excluded.

Options tested:

1. The yield classes tested for lodgepole pine were 12, 14, 16 and 18 and for Sitka spruce 16, 18, 20 and 22 except where stated using either SMB or DMB ploughing.

2. Sitka spruce. Phosphate at planting. SMB ploughing (or ripping). Nitrogen (N) application, 220kg N/ha (as urea[1]), and heather control year 4 and N application every 3 years thereafter (O.R.S. mineral soils and some shallow blanket bogs).

3. Sitka spruce. As in option 2 but N application only up to year 16.

4. Sitka spruce. Phosphate at planting. DMB ploughing. Heather control year 5. N application at year 10 and every 5 years thereafter. (Raised bog and high level blanket bog situations).

5. Sitka spruce. As in option 4 but N application only up to year 15.

6. Sitka spruce. Phosphate at planting. DMB ploughing. Nitrogen application at year 8 and every 5 years thereafter. Low level blanket bog.

7. Sitka spruce. As in option 6 but N application only up to year 13.

8. Sitka spruce/Japanese larch 50:50 mixture in lines.[2] Heather control year 4 and N application to the spruce only at year 4 and 8 (O.R.S. soils). Assume Yield Class 8 for JL and 16 or 18 for Sitka spruce.

9. Sitka spruce/Japanese larch 50:50 mixture. No treatment other than phosphate (peat soils). Assume Yield class 8 for JL and 18 for Sitka spruce.

Note: 1. Experiments to date show that urea and calcium ammonium nitrate are equally effective on the range of sites concerned. The former is preferred because of lower transport costs.

Note: 2. Treatments 8 and 9 were included because of the well established nursing ability of Japanese larch for Sitka spruce (see O Carroll, 1978). Recent observation suggests that N application and heather control may be essential in the earlier years for the spruce in O.R.S. situations.

Table 1: Retail price index in relation to the cost of fertiliser nitrogen 1970-1980 (Source: Nitrigin Eireann Teoranta).

Year	1970	1980
Retail Price Index	100	259
Cost of nitrogen	100	150

RESULTS

Data on net discounted revenues for the various options and assumptions in relation to production and the price of nitrogen are presented in Table 2. These are relative rather than absolute data because of the exclusion of management costs common to the various options. Because the type of ploughing varies with the nature of the ground. (O.R.S. v deep peat), data are included for both SMB and DMB in the lodgepole pine option. A flowchart guide to the use of the data in Table 2 in selecting between the species is shown in Figure 2.

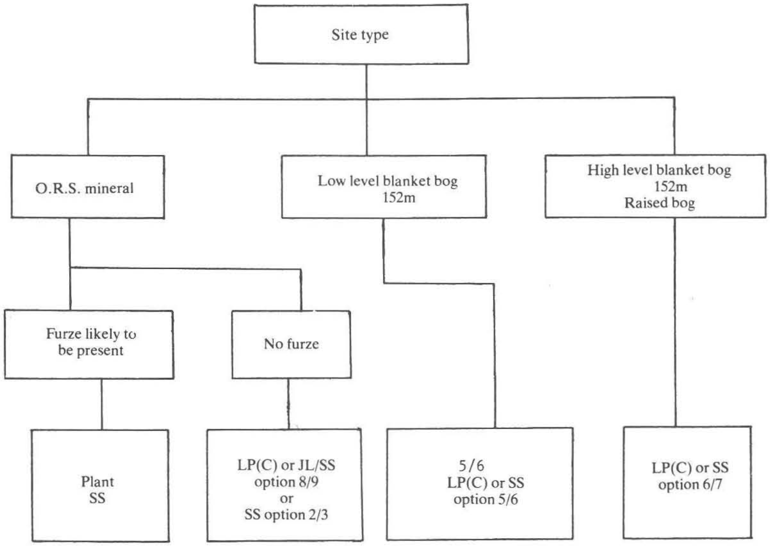
Net discounted revenues for the lodgepole pine options vary between £162 (Yield Class 12, SMB) and £815/ha (Yield Class 18, DMB). If it is assumed that there will be no *real* increase in the price of nitrogen it is apparent that a crop of lodgepole pine Yield Class 16 is more profitable than a crop of Sitka spruce Yield Class 18. Also a crop of lodgepole pine, Yield Class 18, is generally an economically better proposition than even Sitka spruce at Yield Class 20. However, the number of sites on which lodgepole pine production exceeds of Yield Class 16 seem to be the exception whereas Yield Classes of 18 to 20 are common in Sitka spruce. For this reason the data presented in Table 2 suggest very strongly that Sitka spruce, grown with the aid of fertiliser nitrogen, may be a far more profitable option than the pine with the exception perhaps of the O.R.S. sites. Spruce would still remain highly competitive and in many situations better than the lodgepole pine up to a 6% real increase in nitrogen prices.

Table 3 shows the effect of varying sawlog and pulpwood prices for the different options tested. When the price of sawlog falls by 20% and the price of pulpwood increases to £3/m^3, all the NDRs drop in value. However, this disimprovement is more acute in the higher yield classes for both species. If the price of sawlog only falls by 10% and the price of pulpwood increases to £4/m^3, then all the pine options become more economic than at the prices presently pertaining. Essentially speaking, however, the variations in NDRs

Table 2: Net Discounted Revenue for each option, Yield Class and N price assumption. (£/ha). Discount rate: 6%.

Option	YC m^3/ha		Cultivation		N price increase assumption % 0	6
			SMB	**DMB**		
1. LP	12		162	219		
	14		377	434		
	16		596	653		
	18		758	815		
2. SS	16		SMB/Ripper		–188	–718
N+2,4-D	18		SMB/Ripper		98	–433
yr. 4+N every 3 yrs.	20		SMB/Ripper		400	–132
	22		SMB/Ripper		710	177
3. SS. N+2,4-D	16		SMB/Ripper		–37	–186
Year 4+N every	18		SMB/Ripper		250	100
3 yrs up to yr 16	20		SMB/Ripper		550	400
	22		SMB/Ripper		860	710
4. SS. 2,4-D yr 5 and N	16		DMB		149	–145
at yr 10 and every	18		DMB		436	141
5 yrs	20		DMB		736	444
	22		DMB		1047	753
5. SS. 2,4-D yr 5 and	16		DMB		238	166
N at yrs 10 and 15	18		DMB		524	452
	20		DMB		825	753
	22		DMB		1135	1063
6. SS. N at yr	16		DMB		155	–185
8 and every 5 yrs	18		DMB		442	101
	20		DMB		742	401
	22		DMB		1053	712
7. SS. N at yrs 8	16		DMB		266	202
and 13	18		DMB		552	488
	20		DMB		853	789
	22		DMB		1163	1099
8. SS/JL	**SS**	**JL**				
	16	8	SMB/Ripper		176	156
	18	8	DMB		222	202
N+2,4-D yr 4 and	18	8	SMB/Ripper		296	276
N yr 8 to SS only	18	8	DMB		342	322
9. SS/JL	18	8	SMB/Ripper		398	ND
No N or 2,4-D			DMB		443	

N=Not determined.



* Option numbers refer to the data for N.D.R. presented in Table 2.

Examples:
1. Potential yield class 16 for LP and 18 for SS both species (based on inventory records for adjacent stands). Site type O.R.S. with no furze (*Ulex*).
   N.D.R. in Table 3 is £653/ha for LP and £98 or £250 for SS.
2. Potential yield class 20 for SS, 14 for LP (from inventory records). Site type low level blanket bog.
   N.D.R. in Table 3 is £434/ha for LP and £742 or £853 for SS.

Fig 2 Simplified flowchart guide to decision making in species selection between LP(C) and SS* caused by varying the prices for the different timber categories do not alter the previous conclusions in relation to the profitability of either species.

In general the NDR data for the Japanese larch/Sitka spruce mixture tend to be lower than those for most of the other treatment options. This is a result of the low yield class associated with the larch component in the mixture which essentially reduces the overall production to about 12m^3/ha/annum, depending on that achieved by the spruce. However, on O.R.S. mineral soils in particular, the mixture appears more profitable than Yield Class 18 Sitka spruce grown on its own using regular inputs of fertiliser nitrogen. On peat soils, the mixture is far less profitable than Yield Class 16 lodgepole pine. However, if the potential Yield Class of the site for the pine is less than 14 then the mixture deserves serious consideration.

The question of whether inputs of nitrogen will be essential after canopy closure has a major effect on the results for the various spruce options for obvious reasons. If nitrogen application can cease at between 13 and 15 years, without adversely affecting production, then Sitka spruce would in general appear a far more attractive species in money terms.

Discussion

Because of the many assumptions made herein, the results, must of necessity, be interpreted with caution. Nevertheless, they do provide a good indication of the relative profitability of both species for the broad site types described and, when used in combination with local production data from inventory books, their reliability should improve considerably. For instance, if the General Yield Class for the particular species in adjacent properties or compartments to that in question is 14 or 16 or 18, then it can be reasonably assumed that similar rates of production are achievable, provided the nutritional needs are satisfied.

On site types with a potential Yield Class of 16-18 for lodgepole pine, and where nitrogen inputs would be essential to grow Sitka spruce, the results in general endorse the increase in popularity of lodgepole pine in recent years. However, such sites are the exception and of the 35 forests referred to earlier in relation to inventory records only 3 had a mean Yield Class for this species of 16 or more. These were all on lowland sites probably dominated by raised bog soils. Twenty forests had a mean Yield Class for the

Table 3 The effect of varying sawlog and pulpwood prices on the NDR for a selected number of options (No nitrogen price increase and constant boxwood prices) £/ha.

Option	YC m^3/ha	Current Prices Sawlog £24.50 Pulp £1.50 /m^3	Sawlog (–20%)=£19.60 Pulp (+100%)=£3.00 /m^3	Sawlog (–10%)=£22.05 Pulp (+166.6%) =£4.00/m^3
1. LP	14 DMB	434	386	473
	SMB	377	329	416
	16 DMB	653	579	681
	SMB	596	521	524
	18 DMB	815	719	837
	SMB	758	661	780
2. SS Nitrogen+ heather control at yr. 4 & N every 3 yrs thereafter	18 SMB/R*	98	–8	121
	20 SMB/R	400	248	410
	22 SMB/R	710	510	700
3. SS Nitrogen + heather control at yr. 4 & N every 3 yrs up to yr 16	18 SMB/R	250	143	273
	20 SMB/R	550	400	562
	22 SMB/R	860	661	851
4. SS N at yr 10 and every 5 yrs thereafter	18 DMB	436	330	460
	20 DMB	736	578	738
	22 DMB	1047	832	1020
5. SS N at yr 10 and 15	18 DMB	524	418	548
	20 DMB	825	666	827
	22 DMB	1135	921	1108

R=Ripper

species equal to or less than 12. The data suggest that it is difficult to justify the planting of the pine in such situations, assuming the spruce attains Yield Class 18 or more although crops of LP(C) planted since 1968 may tend to have a somewhat higher Yield Class than those established in earlier years due to increased phosphorus fertilisation. However, on peat soils in particular, and in situations where higher levels of production can be attained, say Yield Class 20-22, Sitka spruce would appear to be a far more profitable option, regardless of whether nitrogen inputs are required. Although a figure of 22 may appear high, this figure is now being exceeded in the early years in a number of young (7 yr old) experiments on both blanket and raised bog sites which have so far only been given a broadcast application of rock phosphate. The Sitka spruce growing in the recently publicised tunnel plough experiment at Glenamoy forest (O Carroll, Carey, Hendrick and Dillon, 1981) has a Yield Class at age 19 of between 18 and 22. This is growing on typical low level Atlantic blanket bog and has not received any fertiliser nitrogen, nor is it likely to need any.

One of the major difficulties associated with species selection is to pinpoint those sites on which nitrogen deficiency will be a limiting factor. Although the problem may appear clearcut on O.R.S. mineral soils it is often confounded by the so far unpredictable invasion of certain sites by *Ulex gallii,* which, when it occurs, will more than likely satisfy the total nitrogen economy of the stand. On peat soils, the differences between those site types requiring and not requiring nitrogen are also difficult to identify and, until the present generation of fertiliser trials are more advanced, and relevant soil analytical methods are developed, local knowledge will remain the most reliable guide. However, when judging the performance of existing crops cognisance must be taken of their past history. Most of the checked areas of Sitka spruce visited for advisory purposes in recent years, for instance, were either spot treated with rock phosphate initially or were missed out entirely due to uneven application of the fertiliser material. This underlines the importance of evenness of fertiliser spread and similar arguments apply to the control of heather. *The treatment must be done properly if it is to be effective.*

Much of the experience with Sitka spruce on peatland sites was obtained during the era of spot application of fertiliser phosphate. The change over from spot to broadcast fertilising in the late nineteen sixties has had a profound effect on the development of the native vegetation and on the incidence of check on a wide range of site types. Whereas spot fertilising with rock phosphate and ploughing favoured the development of heather, where it was initially present, broadcast fertilising very often tilted the balance in favour of a *Molinia/Eriophorum* dominated sward. Because of the problems associated with heather, broadcast fertilising therefore resulted in a considerable improvement in many areas in site fertility for Sitka spruce.

The main argument put forward against planting more Sitka spruce instead of lodgepole pine centres around the extra cost that may be incurred as a result of having to purchase more chemicals and/or fertilisers. In small economies subject to tight constraints on cash flow at periodic intervals, lodgepole pine may be the safer option, provided that some of its associated diseases and pests do not get out of control. Others argue against the use of nitrogenous fertilisers on the grounds of an alleged pollution hazard. The quantities of nitrogen suggested herein are between 10 and 15 per cent of those used by grassland and tillage farmers, and recent indications are that the amounts concerned can probably be reduced. The energy equation in which a high energy product such as urea is applied to a low energy raw material, wood, has also been questioned. A simple calculation will show that the difference in total production at age 40 between Yield Class 16 and 20 Sitka spruce is about $180m^3$/ha. In energy terms this is equivalent to about 17 tonnes of urea/ha. Although not redeemable until the end of the rotation, this is of far greater magnitude than the amounts suggested here as being necessary for O.R.S. and peat soils to grow Sitka spruce, (5.0 and 1.3 tons/ha respectively).

The final controversial issue associated with the choice between the two species centres around the greater susceptibility of Sitka spruce to windblow because of its shallower rooting habit, particularly on deep peat soils where the watertable in the early years, following conventional ploughing, is seldom below 30cm. Although there is little evidence yet of windblow in spruce plantations in such situations, this may be a function of the small areas of deep peat that have been planted with the species and also because few if any crops have reached a top height greater than 12-14 metres. However, this extra risk must be seen in the context of the poor form in many plantations of coastal lodgepole pine. It can probably be reduced by tunnel ploughing as suggested by O Carroll *et al* (1981).

The final decision on species selection rests with the forest manager. This paper is nothing but a first attempt at putting more rationale into the decision making process. With time, and more research on the inputs required by both species, and on their production capabilities on different site types, it is hoped to put more refinement into the process.

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