Early Growth of Sitka Spruce on Gleyed Soils in Northern Ireland

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1. *Introduction*

UNTIL the late 1960s practically all forest nutrition research in Northern Ireland dealt with the problems of Sitka spruce planted on oligotrophic peats. There were few experiments on other soil types. The fact that gleys were neglected for so long indicates that nutritional problems were not so great on them as on deep peats. But, high elevation gleyed forest soils of basaltic or carboniferous origins amount to about 40 per cent of the forest area. They are therefore important. The aim of this paper is to discuss the results of the few existing experiments on gleyed soils.

2. *Classification of Gleyed Soils in Northern Ireland*

The classification of mineral soils used in the forest soil survey at present being carried out in Northern Ireland is similar to that used by the British Forestry Commission (Pyatt, 1970). Two major kinds of gleys are recognised: non-peaty and peaty gleys. Non pleaty gleys are mineral gleys with up to 5 cm of peat on the surface and peaty gleys have an upper horizon of peat between 5 and 50 cm in depth. In this paper no further sub-division of these soils has been recognised.

3. *Fertilizing Practice on Gleyed Soils in Northern Ireland*

Fertilizing practice on all upland gleyed soils has changed considerably over the past 20 years. During the 1950s and early 1960s it consisted of giving each plant a handful of basic slag at planting. Since then coarse rock phosphate (CRP) has been applied, broadcast, at the rate of 500 kg/ha at the time of planting on most sites and more recently as much as 750 kg/ha has been applied to the poorest sites.

Fertilizing practice on gleys unlike the situation on deep peat (Dickson and Savill 1974) was based upon only limited experi-

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mentation, and more recent work indicated that on some sites application rates were unnecessarily high. This was not too important when the cost of fertilizing at planting was only a small fraction of the total establishment cost, but the price of rock phosphate quadrupled between 1972 and 1975 and the elimination of any wasteful use is now economically highly desirable.

4. *Problems of Tree Growth on Gleyed Soils*

The forest soil survey has indicated that growth of Sitka spruce on gleys is far from uniform on areas of apparenly uniform soil. In a study carried out in Lisnaskea Forest, Adams *et al* (1970) found that yield classes on non-peaty gleys ranged from 10-24 with a mean value of 17.5 and on peaty gleys from 9-23 with a mean of 16.9. The present classification of gleyed soils is therefore of limited use to forest management since the two groups embrace a range of conditions so wide that the growth of Sitka spruce can vary from its best to almost its poorest. It was clearly desirable to determine which soil factors most influence the growth of the trees and to find a method of subdividing the categories of gleyed soils so that difference in growth potential can be predicted before planting in order that fertilizers and other treatments can be applied in the most beneficial and economical way.

Some indications as to which factors might be influencing tree growth were provided by Adams *et al* who studied the relationships between various physical and chemical soil properties, tree growth and foliar nutrient levels. No obvious subdivision of value for management purposes could be identified from the physical or chemical characteristics of the soil by the analytical methods used but it was shown that poor growth is associated with low foliar nutrient status, particularly of P and N, and an accumulation of organic matter. It was suggested that further approaches to the problem could either be through raising the nutrient status of crops by the additions of fertilizers, or by attempting to increase the rate of organic matter decomposition by drainage and/or liming.

All these approaches have been followed up but the one which appears to be the most promising, at least in the short term, is the improvement of the nutrient status by the addition of fertilizers.

5. *Lisnaskea Experiment 8/69—Effects of Fertilizers on Growth of 8-10 Year Old Sitka Spruce Crops*

The direct approach of increasing the nutrient status of the

TABLE 1
LISNASKEA 8/69 TREATMENTS APPLIED IN SPRING OF 1969

Symbol	Treatment
P0	No P applied
P1	625 kg/ha CRP (80 kg/ha P)
P2	1250 kg/ha CRP (160 kg/ha P)
N0	No N applied
N1	312 kg/ha urea (145 kg/ha N)
N2	624 kg/ha urea (290 kg/ha N)
K0	No K applied
K1	312 kg/ha KCl (155 kg/ha K)

Note: All trees received a handful of slag when planted.

crop by addition of fertilizers was tried at Lisnaskea in 1969. The aim of the experiment is to investigate the responses of crops to different fertilizer treatments with and without drainage. It is laid out as a complete factorial experiment over a representative range of soils and conditions of growth in Lisnaskea Forest, Co. Fermanagh.

Four applications of each of the fertilizer treatments shown in Table 1 were laid out in each of High YC and Low YC areas. Because of practical difficulties, heights of only the five trees of greatest diameter were measured in each of the High YC plots. In the Low YC's 24 trees per plot were measured.

5.1. *Results*

5.1.1. *Effect of applied phosphate on growth and foliar nutrient concentrations*

In the Low YC plots at Lisnaskea growth has been significantly better in the presence of applied CRP each year since 1968 (Table 2). Even the PO plots received a handful of basic slag at the time of planting, so differences between the P0 and P1 treatments might have been greater if this had not been done. As it is however the increase over the five-years in terms of total growth represents a difference of about one yield class when the PO anl P2 treatments are compared.

TABLE 2
LISNASKEA 8/69 EFFECT OF APPLIED PHOSPHATE ON GROWTH MEAN HEIGHT (cm) AND FOLIAR P CONCENTRATION—(% DRY MATTER)

	Low YC Plots					High YC Plots				
Year	P0	P1	P2	Mean	SEm	P0	P1	P2	Mean	SEm
Growth 1969	31	29	29	30	0.8 NS	51	51	49	50	0.9 NS
1970	37	39	41	39	0.8 **	65	65	66	65	1.5 NS
1971	39	44	49	44	2.5 ***	(44)	(35)	(39)	(39)	3.0 NS
1972	46	56	60	54	1.5 ***	80	78	77	78	1.8 NS
1973	41	49	53	48	1.3 ***	54	54	55	54	1.4 NS
Growth 69–73	185	222	234	213	5.5 ***	288	286	287	287	6.0 NS
Foliar P 1973	0.13	0.18	0.22	0.17	0.007**	0.18	0.23	0.23	0.21	0.007**
					Diameter 1973	8.8	8.9	8.8	8.9	0.19 NS

The effect of phosphate applied in 1969 on foliar P concentrations in 1973 in the Low YC plots is marked, as shown in Table 2. At the PO level it is just above the "critical" concentration of 0.12 per cent dry matter (Van Goor 1970) while at the two higher levels it is well above this concenration. By contrast, in the high yield classes. applied phosphate has had no significant effect upon growth at any time or on foliar P concentrations in 1973. Foliar P concentrations were much higher in the untreated plots in the High YC's than in the Low YC's.

The experiment occupies almost 12 ha of forest. In such a large area it was impossible to achieve the desired degree of crop uniformity within each block. In the Low YC series yield classes ranged from 8-18, with a mean value of 14. In the High YC plots they ranged from 14-24 with a mean of 18.

This variation provided an opportunity to study the relationships between the response of individual yield classes in terms of height

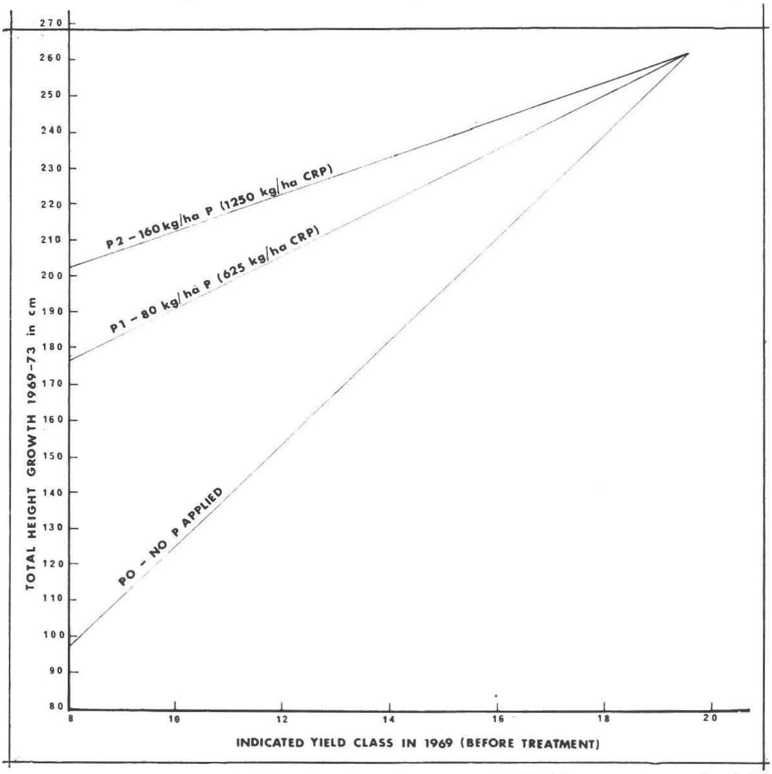

Fig. 1—Lisnaskea 8/69. Relationships between 1969-73 growth, and yield class, at each level of applied phosphate.

TABLE 3
LISNASKEA 8/69 EFFECT OF APPLIED NITROGEN ON GROWTH MEAN HEIGHT (cm) AND FOLIAR N CONCENTRATION (% DRY MATTER)

Year	Low YC Plots N0	N1	N2	Mean	SEm	High YC Plots N0	N1	N2	Mean	SEm
Growth 1969	30	30	29	30	0.8 NS	50	50	50	50	0.9 NS
1970	39	40	38	39	0.9 NS	62	66	68	65	1.5 *
1971	42	45	45	44	2.5 NS	(38)	(43)	(37)	(39)	3.0 NS
1972	51	55	56	54	1.5 *	74	81	80	78	1.8 *
1973	46	48	50	48	1.3 NS	56	54	53	54	1.4 NS
Growth 69–73	206	214	220	213	5.4 NS	283	292	285	287	6.0 NS
Foliar N 1973	1.49	1.51	1.48	1.50	0.035 NS	1.51	1.59	1.58	1.56	0.035 NS
					Diameter 1973	8.5	9.0	9.1	8.9	0.114 **

growth, 1969-1973, to different rates of applied phosphate. The results for the Low YC plots only are illustrated in Figure 1.

The three regression lines show that responses to applied CRP are greatest on the poorest sites and become less marked as the yield class increases. At YC 20 (which involved extrapolating one yield class), the three regression lines converge, indicating that there is no advantage in applying phosphate to crops growing at this rate or more. It should be noted however that none of correlation coefficients was very high though all were significant. (They were PO = 0.68***, P1 = 0.43***, P2 = 0.32*).

The calculated regressions for the High YC plots did not differ significantly from each other.

5.1.2. *Effect of applied nitrogen on growth and foliar nutrient concentrations*

Applied nitrogen slightly, but not significantly, increased overall height growth in crops of both yield classes (Table 3). In both cases the effect of nitrogen was significant in 1972 (and in 1970 as well in the High YC plots). In the High YC plots mean breast height diameter in 1973 was significantly increased by applied nitrogen.

The fact that responses to nitrogen were small is not surprising since, as indicated by foliar N levels in 1973, nitrogen was not limiting growth. It was well above the "critical" concentration of 1 per cent dry matter in all nitrogen treatments shown in Table 3 and was well above 1 per cent in every individual plot.

5.1.3. *Effect of applied potash on growth and foliar nutrient concentrations*

Applied potash had no effect at all upon growth (Table 4). As in the case of nitrogen, this is not surprising since average foliar K levels were well above the "critical" 0.4 per cent dry matter. Out of all the plots sampled, only seven had concentrations below 0.5 per cent and of these only one was as low as 0.4 per cent.

In both the High and the Low YC plots it was found that applied phosphate significantly increased the uptake of K by the trees. Where no phosphate had been applied, the mean foliar K concentration was 0.59 per cent; at the P1 level it was 0.62 per cent and at the highest level of applied phosphate it was 0.66 per cent.

TABLE 4
LISNASKEA 8/69 EFFECT OF APPLIED POTASSIUM ON GROWTH MEAN HEIGHT (cm) AND FOLIAR K CONCENTRATION (% DRY MATTER)

	Low YC Plots				High YC Plots			
	K0	K1	Mean	SEm	K0	K1	Mean	SEm
Growth 1969	30	29	30	0.6 NS	51	50	50	0.7 NS
1970	39	39	39	0.7 NS	66	65	65	1.2 NS
1971	43	45	44	2.0 NS	(40)	(39)	(39)	2.4 NS
1972	53	55	54	1.2 NS	79	77	78	1.4 NS
1973	48	48	48	1.0 NS	54	55	54	1.1 NS
Growth 69–73	210	216	213	4.4 NS	288	287	287	4.8 NS
Foliar K 1973	0.62	0.63	0.63	0.017 NS	0.61	0.64	0.63	0.017 NS
				Diameter 1973	8.9	8.8	8.9	0.09 NS

6. *Proposed classification of gleys*

The results of this experiment have shown that on some gleyed soils, where growth is relatively poor, substantial improvements can be obtained by the application of phosphate. On other soils, which are apparently similar in terms of soil chemical and physical properties, but on which growth is good, no improvement can be obtained from applied phosphate. Within the relatively small area of Lisnaskea forest climatic differences are obviously small and are not the main cause of growth differences.

The experiment did not show the rate of phosphate which should be applied to achieve optimum growth on the poorer sites, nor has it been possible to show whether as good growth could have been obtained on the better yield class sites in the absence of any applied phosphate since all plots at Lisnaskea received a handful of basic slag at the time of planting. However it is clear that on these better sites additional applied phosphate is wasted

There is therefore a need to find a way of predicting tree performance on gleys. Although the methods used by Adams *et al* (1970) proved unsuitable for this, tree growth is obviously being influenced by soil conditions and some other index of soil potential for tree growth must be found.

In practical terms it is more common to assess the potential of a site in terms of the native vegetation that grows on it rather than by describing the characteristics of the soil (Anderson 1950). This method is used successfully for deep peats in Northern Ireland (Dickson and Savill 1974) and a similar approach was tried for the gleyed soils.

Several areas in Lisnaskea Forest were visited including all the block involved in experiment 8/69 and as far as possible the vegetation growing on open ground adjoining them was described and related to the yield class of the crops. It was found that both peaty and non peaty gleys of similar yield classes had essentially the same ground vegetation. For the purposes of a classification based on vegetation the two soil types are not distinguishable. However the distinction is worth maintaining since other factors, such as stability, may vary with basic soil type.

The survey showed that changes in growth rates of Sitka Spruce were related to changes in the proportions of the most common constituents of the vegetation. On practically all sites almost all the following plants could be found:-

Calluna vulgaris
Molinia caerulea

Descampsia flexuosa	
Juncus effusus	
Deschampsia caespitosa	
Holcus lanatus)	
Anthoxanthum odoratum)	Soft grasses
Agrostis spp)	
Poa spp)	

However the fertility of the site in relation to the growth of Sitka spruce could be recognised by the proportion of each of these species in the vegetation. Thus at the poorest extreme *Calluna* predominates but as conditions improve slightly *Molinia, Deschampsia flexuosa* and *Juncus articulatus* become relatively more common. At the other extreme the site is dominated by *Juncus effusus,* soft grasses and *Deschampsia caespitosa.* There is a continuous variation between the two extremes. The previous history of the area also has a marked effect on the vegetation of any one site. For example, it is commonly observed that the vegetation in old fields, particularly those which are near houses or ruins, tends to be of a more eutrophic kind than on unenclosed land.

All the high yield class sites were on enclosed land of this kind, although some of the poorer sites were enclosed too. The greater fertility of old fields is probably caused by the fact that they were cultivated and manured by farmers and, over many years, the P status has been built up. Abrupt changes in vegetation can frequently be seen along boundaries from one field to the next or from a field to open ground.

Preliminary surveys in many forests in Northern Ireland have indicated that the relationship between the growth of Sitka spruce and vegetation on gleyed soils is likely to be similar to that at Lisnaskea.

For practical purposes it is necessary to provide some fairly arbitrary classification of vegetation as a basis for fertilizer prescriptions and the one shown in Table 5 is proposed as being suitable for most gleyed soils.

7. *Belmore Experiment 1/56—Effect o fFertilizers on growth of Sitka Spruce from time of Planting*

If the classification shown in Table 5 is to be of practical use, one would expect crops on eutrophic sites scarcely to respond at all to applied phosphate. Those on mesotrophic sites should give a maximum response to moderate rates of phosphate and those on

TABLE 5
CLASSIFICATION OF GLEYED SOILS

Nutrient class	Characteristic species of vegetation*		Other features
	Botanical name	Local name	
Oligotrophic	Calluna vulgaris Molinia caerulea Deschampsia flexuosa Juncus articulatus	Heather Purple moor grass Wavy hair grass Sprit or jointed rush	Normally unenclosed land. Poorer parts on typical marginal farms.
Mesotrophic	Deschampsia flexuosa Juncus articulatus Juncus effusus Calluna vulgaris Polytrichum spp	Wavy hair grass Sprit or jointed rush Soft rush Heather Mosses generally abundant	Occasionally enclosed land. Usually poorer fields adjoining unenclosed area. Unlikely ever to have received farmyard manure.
Eutrophic	Juncus effusus** Holcus lanatus Agrostis spp Anthoxanthum odoratum Deschampsia caespitosa	Soft rush Yorkshire fog Bent grasses Sweet vernal grass Tufted hair grass Mosses not abundant	Normally enclosed land. Usually best fields convenient to farm buildings. Frequently given farmyard manure in past.

*Species are listed according to their relative abundance in the native vegetation.
**Rushes may be absent from locally well drained areas.

oligotrophic sites to high rates. Only one (unreplicated) experiment is old enough to give any indication as to the medium-term responses of Sitka spruce on gleys from the time of planting. It is used here to confirm the validity of the classification proposed in Table 5.

The experiment is at Belmore Forest, Co. Fermanagh, at an elevation of about 300m. The soil is a non-peaty gley. At the time of planting in 1956 the ground vegetation consisted largely of *Juncus articulatus, Juncus effusus, Eriophorum angustifolium,* and *Molinia caerulea.* According to the classification in Table 5 this is a mesotrophic site.

Earlier experience had shown that Sitka spruce growth on similar sites was disappointing.

As a result, the range of fertilizer treatments shown in Table 6 was applied to see if any would improve growth.

7.1. *Effect of treatment on growth and foliar nutrient concentrations*

Table 6 shows clearly that growth in all the plots which received some phosphorous was better than in the untreated plot. Growth in the plots which received basic slag only was best, and on average it was 50 per cent better than in the untreated plot.

At the other extreme, applied calcium and possibly nitrogen depress growth. The depressing effect of lime is consistent with the early results of liming experiments on peats (Dickson 1972). Fertilizer nitrogen applied at the time of planting on peats often depresses growth too, though it becomes essential in later years (McConaghy 1962, Dickson and Savill 1974).

The annual mean heights since 1957 of the two plots which were treated with slag only are shown in Figure 2 and compared with the untreated conrol plot. It will be seen that there has been very little difference in growth between the two treated plots at any time since planting, indicating that on this site 250 kg/ha basic slag is as good as 500 kg/ha. The increase in height as a result of applying slag indicates an improvement in predicted yield class, which has been consistent since planting from YC12 to YC20.

Determinations of foliar N, P and K levels at intervals since planting (Table 7) have shown that in the slagged plots N and K levels were normally above the "critical" concentrations of 1 and 0.4 per cent dry matter respectively (Leyton, 1958, Van Goor, 1970). By contrast foliar P concentrations in the untreated plot have always been below the "critical" level of about 0.12 per cent; in the slagged plots P levels have always been higher than in the

TABLE 6
BELMORE 1/56 TREATMENTS APPLIED IN SPRING OF 1956

kg/ha element				Applied as (fertiliser)	kg/ha fertiliser	Mean height at end of 1971 (cm)
N	P	K	Ca			
	22.5			Basic slag	250	670
	45			Basic slag	500	663
	22.5		 2000	Basic slag Ground limestone	250 5000	574
26 7.5	 22.5 45	 62.5		Ammonium sulphate Bone meal Basic slag Muriate of potash	125 250 500 125	 554
	22.5		 1785	Basic slag Burned lime	250 2500	529
10 26	14	17		Special potato manure Ammonium sulphate	250 125	516
				Nil		442
			1785	Burned lime	2500	359
			2000	Ground limestone	5000	343
26 52		 62.5	 38	Ammonium sulphate Nitrochalk Muriate of potash	125 250 125	 228

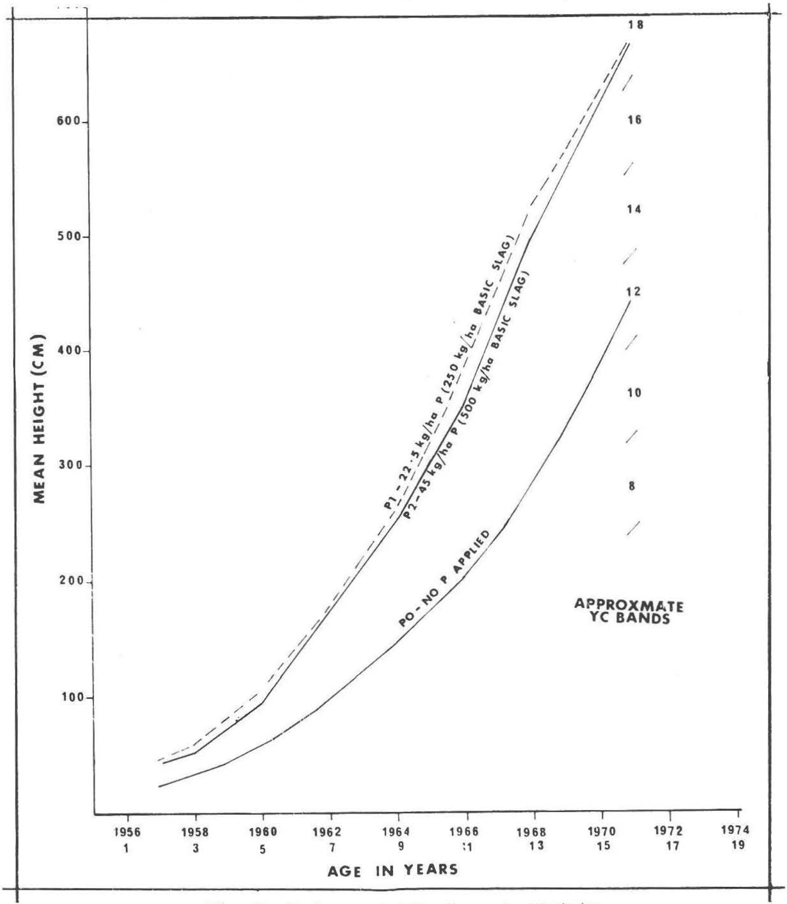

Fig. 2—Belmore 1/56. Growth 1957-71.

untreated plot though in two seasons concentrations were just below the "critical" level.

It seems therefore that on this site growth is limited by a deficiency of available phosphorus which can be corrected by applying a moderate rate of basic slag.

8. *Discussion*

The Belmore experiment has confirmed that the classification in Table 5 is valid, at least as far as this mesotrophic site is concerned, since no advantage to growth is indicated by applying basic slag at rates exceeding 250 kg/ha (about 22 kg/ha P) at this stage in the rotation. However, in an attempt to make general recommendations for management purposes, there must at this stage inevitably be some uncertainties, for example the Lisnaskea experi-

TABLE 7
BELMORE 1/56 FOLIAR N P AND K CONCENTRATIONS EXPRESSED AS PERCENTAGE DRY MATTER

	Foliar N P and K concentrations in winters of								
	1963			1964			1965		
Treatment	N	P	K	N	P	K	N	P	K
P0 Nil	1.24	0.08	0.54	–	0.10	0.53	1.32	0.12	0.50
P1 250 kg/ha slag	1.33	0.10	0.64	–	0.14	0.49	1.47	0.14	0.53
P2 500 kg/ha slag	1.45	0.11	0.43	–	0.13	0.53	1.44	0.13	0.54
	1966			1967			1973		
Treatment	N	P	K	N	P	K	N	P	K
P0 Nil	1.24	0.09	0.48	1.29	0.08	0.42	1.46	0.12	0.50
P1 250 kg/ha slag	1.40	0.11	0.48	1.57	0.14	0.50	1.89	0.21	0.63
P2 500 kg/ha slag	1.33	0.11	0.54	1.61	0.12	0.48	1.89	0.19	0.69

ment indicated increasing responses to increasing rates of applied CRP, but in this case the phosphate was not applied until about 9 years after planting and at the time of writing they had only been growing for five seasons since treatment. It seems likely though that the current application rate of CRP at 500 kg/ha (65 kg/ha P) will be adequate for the poorest, oligotrophic gleys, from the time of planting. On the more fertile mesotrophic gleys like the Belmore site, 250 kg/ha CRP (32 kg/ha P) should be adequate. On the best eutrophic sites, it is probable that growth will be perfectly satisfactory in the absence of any applied phosphate but this is also uncertain. An experiment on a eutrophic gley a Kesh Forest indicates that growth immediately after planting, in plots which received no phosphate at planting is as good as that in the plots which received rates up to 105 kg/ha P.

The results of the Belmore and Lisnaskea experiments have given no indication that it is worth applying potash or nitrogen at an early stage though it is worth noting that at Lisnaskea small but significant responses to applied nitrogen were found. It is not suggested that nitrogenous fertilizers should be used so early in the crop rotation but later results of this trial may indicate that later applications could have beneficial effects.

9. *Acknowledgements*

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10. REFERENCES

Adams, S. N., Jack, W. H. and Dickson, D. A. (1970). The growth of Sitka spruce on poorly drained soils in Northern Ireland. Forestry 43, 125-33.

Anderson, M. L. (1950). The selection of tree species. London. pp. 154.

Dickson, D. A. (1972). Effect of limestone, phosphate and potash on the early growth and nutrient uptake of Sitka Spruce planted on deep peat in Northern Ireland. Proc. 4th Int. Peat Congress, Finland 1972. Volume 4, 479-488.

Dickson, D. A. and Savill, P. S. (1974). Early growth of *Picea sitchensis* on deep oligotrophic peat in Northern Ireland. Forestry 47, 57-88

Leyton, L. (1958). The mineral requirements of forest plants. Encyclopaedia of plant phys., 4, 1026-39, Springer, Berlin.

McConaghy, S. (1962). The effects of fertilizer treatments on growth and composition of Sitka spruce. Irish Forestry, 19, 56-59.

Pyatt, D. G. (1970). Soil groups of upland forests. Forestry Commission. For. Rec. 71 pp 51. HMSO.

Van Goor, C. P. (1970). Fertilization of conifer plantations. Irish Forestry 27, 68-80.