Long-term study of Sitka spruce

(Picea sitchensis (Bong.) Carr.)

on blanket peat

2. WATER-TABLE DEPTH, PEAT DEPTH AND NUTRIENT MINERALISATION STUDIES

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ABSTRACT

Depth to water table was monitored during two growing seasons, peat depth changes over a 15 year period measured and nitrogen and phosphorus mineralisation studies conducted in a fertiliser and lime experiment on a pole stage crop of Sitka Spruce (*Picea sitchensis* (Bong.) Carr) on oligotrophic blanket peat. The original fertiliser experiment, a nitrogen and phosphorus factorial was established in 1967 and in 1977 it was subdivided, one part receiving no further treatment (Experiment 1) with lime and further applications of nitrogenous and phosphatic fertilisers being made to the other (Experiment 2). When the two experiments were treated as one, mean depth to water table was linearly related to growth parameters. The best relationship was obtained with basal area. However, there were marked differences between experiments and significant differences in water table depth were recorded between treatments in Experiment 2, where fertiliser induced growth differences were also measured, but not in Experiment 1 where the 1967 treatments were no longer producing growth increment differences.

Peat subsidence has occured in the experimental plots at an average rate of 1.2cm per year. In shallow peat situations experimentation on peat-soil mixing should be initiated to test long-term effects.

Levels of mineral nitrogen were depressed in forest floor samples from limed, fertilised plots. Neither total nitrogen concentrations nor mineral nitrogen levels showed any evidence of a residual effect of fertilisation. Plots treated with phosphate in 1977, by contrast had markedly higher extractable phosphorus concentrations than material from Experiment 1.

INTRODUCTION

Depth to water-table was monitored, peat depth changes measured and nitrogen and phosphorus mineralisation studies conducted in a long-term Sitka spruce (*Picea sitchensis* (Bong.) Carr.) fertiliser and lime experiment on oligotrophic low level

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blanket bog. There is an annual water surplus (rainfall minus evapotranspiration plus deep seepage) of 660 to 760mm in the region. The ability of tree crops to increase depth to water table has been established on this site type under a mixed species forest tree shelterbelt (O'Hare 1972) and under plantation conditions in the present experiment (Farrell and O'Hare 1974). In the latter study, measurements were made in 1969-1970 when the crop was 8-9 years old. In this paper results of measurements made in the period 1981 to 1982 are reported. The purpose of this investigation was to review the results of the earlier study in the context of increased crop growth and under the influence of additional experimental treatments applied in 1977 to 1979. Most of the experimental plots were thinned about midway through the measurement period and the influence of thinning on depth to water-table was examined.

The peat depth measurements were made at the initiation of the experiment in 1967. The measurements were repeated in 1981 and the differences are reported here.

Forest floor and peat samples were taken from four of the experimental plots and mineralisation rates of nitrogen and phosphorus were measured in an incubation study over a 189 day period.

EXPERIMENTAL

The experiment was located in a Sitka spruce crop, on oligotrophic, low level blanket bog at Glenamoy State Forest in north-west Co. Mayo. The climate of the area is extreme maritime, annual rainfall averages 1,400mm distributed over 270 days. The wind climate is very severe with gales in almost every month. Details of the natural flora and afforestation procedures when the crop was established in 1962 have been reported (Farrell 1985).

The original fertiliser experiment, established in 1967, was divided in two in Spring 1977. In two of the original four blocks no further treatments were applied (Experiment 1). In the other two blocks (Experiment 2), all plots received an application of 8 tonnes of ground limestone per ha in addition to further applications of nitrogen and phosphorus. Treatment details are summarised in Table 1.

In August 1969 one slotted PVC drainage pipe, 7.0cm diameter 1.6m long, was installed in a bore hole at the centre of each plot. The method of installation has been previously described (O'Hare 1972). Depth to water-table was monitored in these bore holes in the 1969-1970 period as previously reported (Farrell and O'Hare 1974). They were examined, missing caps replaced etc. in 1981 and

Table 1. Summary of Treatments Applied in Experiment 1 and Experiment 2 (kg nutrient ha^{-1}). All treatments applied in springtime.

Year	N_0	N_1	N_2	P_0	P_1	P_2	P_3
1967[1,2]	0	132	264	0	55	110	220
1969	0	132	0	0	0	0	0
			Experiment 1				
1977/ 1979			No further treatments applied.				
			Experiment 2				
1977[3,4]	0	75	75	0	35	70	105
1978	0	0	75	0	0	0	0
1979	0	0	75	0	0	0	0

1 N applied as sulphate of ammonia; P as ground rock phosphate.
2 Sulphate of potash (42% K) was applied to all plots at 125kg per ha and copper sulphate (25% Cu) at 11kg per ha.
3 N applied as calcium ammonium nitrate; P as superphosphate.
4 All plots limed at 8t ground limestone per ha.

measurements were conducted at approximately biweekly intervals between May 1981 and June 1983. A probe was used to measure peat depth at one point at the centre of each plot in spring 1967. The same procedure and measurement point were used in winter 1981. On the latter occasion, forest floor thickness at each measurement point, which was negligible in 1967, was deducted from the measured depth.

Samples were collected from forest floor (01 and 02 horizons) and peat to 10cm depth for nitrogen and phosphorus mineralisation studies in April 1981. Samples were taken at 30 points in each of the plots of the N_0P_2 and N_2P_2 treatments in both Experiment 1 and Experiment 2. On returning to the laboratory, samples were deep frozen (–18°C) until required. In order to prepare material for study, samples were allowed to thaw and dry until suitable for sieving through a builders screen. They were then dried further until moisture content was estimated to be slightly below that at 60% of field capacity. Moisture content was determined on samples taken immediately before bagging. Samples for field capacity determination were also taken at this time. Field capacity was determined on the sand box under 100cm suction. These samples were analysed in duplicate for total N by distillation procedure following micro Kjeldahl digestion and for total P, K, Ca, Mg, Na, S, A1, Si, Mn, Fe, Cu, Zn and Cl by X-ray fluorescence spectrophotometry.

The incubation experiment ran for 189 days with four replicate samples removed for pH and extractable nitrogen and phosphorus at 0, 7, 21, 63, 126 and 189 days. pH was determined on fresh material in a 1:1 peat-water slurry. Extractable nitrogen fractions (NH_4^+ and $N0_3^-$) were determined by distillation of a M KCl extract of fresh material (equivalent dry weight 2.5g, 100ml M KCl, shaken for 1 hour followed by centrifugation at 2000rpm and filtered through a Whatman No. 42 filter paper). Extract solutions were frozen until the time was suitable for determination. Extractable phosphorus was determined by the ascorbic acid procedure after shaking 1g dried ground peat with 50ml 1.5 M H_2S0_4 in a 100ml centrifuge tube followed by centrifuging and filtering.

RESULTS AND DISCUSSION

When both experiments were analysed together, the linear regressions of mean depth to water table on top height at the end of the 1979 growing season, on basal area at the end of the 1981 season and on basal area increment in the 1980-1981 season were all significant. Depth to water table was calculated for the whole measurement period and separately for each year and growing season. The best relationship was obtained between mean depth to water table during the second (1982) growing season and basal area at the end of the 1981 season and the results of this analysis only are presented (Figure 1).

There were marked differences in water table variation between Experiment 1 and Experiment 2. Values for the growing seasons only are presented here. Calculations based on the full calendar year showed very similar trends, but treatment differences, although having generally the same level of significance, were less pronounced, in absolute terms, than in the growing seasons. Within Experiment 1, which was untreated in 1977, no significant difference in depth to water table was observed between plots grouped according to the original treatments (Table 2). This corresponds with the absence of treatment effects on growth increment during the period of water table measurements (Farrell 1985). In Experiment 2, the phosphate treatments significantly increased depth to water table ($p < 0.01$) over both growing seasons (Table 2). In addition, an effect of nitrogen was observed during the first (1981) growing season.

Mean depth to water table over the whole measurement period was 46.7cm in Experiment 1 and 45.4cm in Experiment 2,

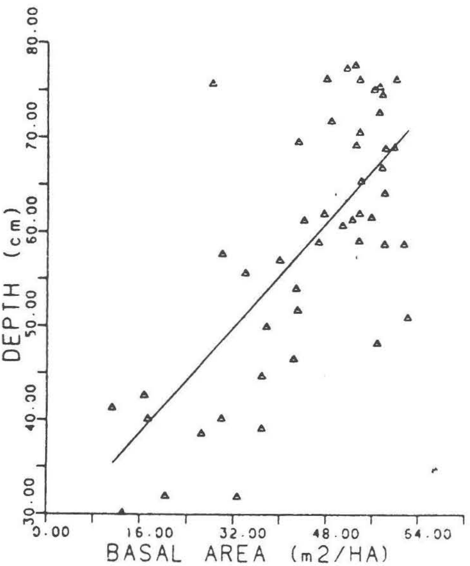

Fig 1 Regression of Depth to Water Table (cm), mean of 1982 Growing Season, on Plot Basal Area (m^2 per ha), 1981.
$Y=27.50+0.6992X$. $F=45.96$ ($p<0.01$).

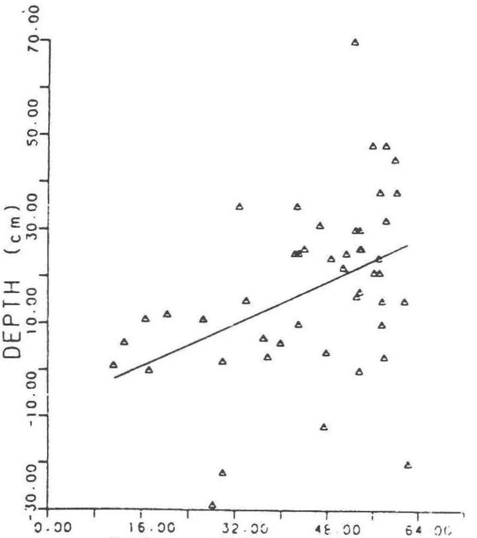

Fig 2 Regression of Decrease in Peat Depth (cm), 1967-1981, on Plot Basal Area (m^2 per ha), 1981.
$Y=-8.249+0.5689X$. $F=9.87$ ($p<0.01$).

Table 2 Mean depth to water table during 1981 and 1982 growing seasons.

Main Effect	Main effect means. Depth to water table (cm) 19-5 to 24-9 1981 Expt. 1	 19-5 to 24-9 1981 Expt. 2	 8-4 to 23-9 1982 Expt. 1	 8-4 to 23-9 1982 Expt. 2	 2-4 to 24-9 1970* Expts. 1 and 2 Combined
N_0	47.3	42.1	60.7	54.8	40.8
N_1	51.0	47.7	63.0	60.2	40.3
N_2	44.3	50.4	55.0	60.2	37.8
SE trt mean	4.44	1.99	4.64	2.43	1.62
		a			
P_0	35.6	27.2	46.9	37.6	36.6
P_1	54.2	51.1	65.5	64.0	42.6
P_2	49.8	53.6	62.3	65.1	39.8
P_3	50.5	55.0	63.4	66.9	39.6
SE trt mean	5.13	2.3	5.35	2.80	1.88
		b		b	c
Overall Mean	47.5	46.7	59.4	58.4	39.5
Mean Weekly Rainfall (mm)	26.3		18.3		24.4

a $N_0 < N_2$ $p < 0.05$
b $P_0 < P_1, P_2, P_3$ $p < 0.01$
c $P_0 < P_1$ $p < 0.05$

*Taken from Farrell and O'Hare (1974).

considerably greater than in 1970. Water table depth during the 1981 growing season averaged 7.6cm more than in the 1970 season (Table 2). In 1982, water table depth was, on average, deeper than in 1981, 19.4cm deeper than in 1970. This was despite the fact that thinning was carried out in the early summer of 1982. A decrease in water table depth in peatland forests has been measured, in other studies, following thinning (Heikurainen and Päivänen 1970). However, rainfall was less in 1982, a mean of 18.3mm per week in the growing season. This compares with 26.3mm per week in 1981 (Table 2). In addition, the line thinning procedure adopted left an almost inact cover of cut trees and fresh slash on the felled lines which probably intercepted a significant proportion of the incoming precipitation.

Before establishment of the original experiment in spring 1967, mean peat depth in the experimental plots was 2.93+0.85m. In the winter of 1981 it was 2.75+0.77m. The mean difference of 18cm was significant ($p < 0.01$) and represents an average subsidence of 1.2cm per year. This subsidence can be attributed in part, to drying of the peat brought about by increased evapotranspiration of the vegetation and in part, to peat decomposition. There was no difference in subsidence between Experiment 1 and Experiment 2. Regression of decrease in peat depth on crop basal area (1981) over all 48 plots was significant (Figure 2) although the degree of association was low (17.7%).

In the mineralisation study, the data represent the net production of mineral nitrogen and phosphorus, that is the quantities released from organic matter which are surplus to the requirements of the microbial population. In the forest floor, where large quantities of nitrogen are stored in organic compounds unavailable to plants, net nitrogen mineralisation was greater in material from Experiment 1 than from Experiment 2 (Figure 3). This was despite the fact that no fertilisers had been added to the Experiment 1 plots since 1969, whereas the plots in Experiment 2 had received lime and phosphorus in 1977 and in the case of the N_2 plots, nitrogen in 1977-1979. It is safe to assume that lime, which increased forest floor pH to 6.9-7.0 (Table 3), stimulated microbial activity. The immobilisation either of nitrogen in forest floor or of added nitrogen, as a consequence of increased microbial activity has been frequently reported (Zöttl 1960, Viro 1963, Nömmik 1968, Adams and Cornforth 1973, Carey and Farrell 1981). In the limed plots, a greater proportion of the mineral nitrogen was recovered as nitrate (Table 4), which is more mobile and easily leached from the soil, than as ammonium, which dominated in the samples from Experiment 1. This too accords with previous experience (Carey and Farrell 1981).

In the peat, the effect of lime is less obvious. The pH of the surface peat (0-5cm) and total calcium at both depths have been increased by liming (Table 3). Nitrate makes up a larger proportion of total mineral nitrogen than in Experiment 1 (Table 4). Nevertheless, net mineral nitrogen levels, while exhibiting a definite upward trend with time, showed no clear treatment differences, except towards the end of the incubation period, when the N_0 plots yielded greater quantities of nitrogen than the N_2 plots across both experiments (Figure 3). At 5-10cm, the upward trend was again obvious, but differences between treatments were even more obscure than in the surface peat (Figure 3).

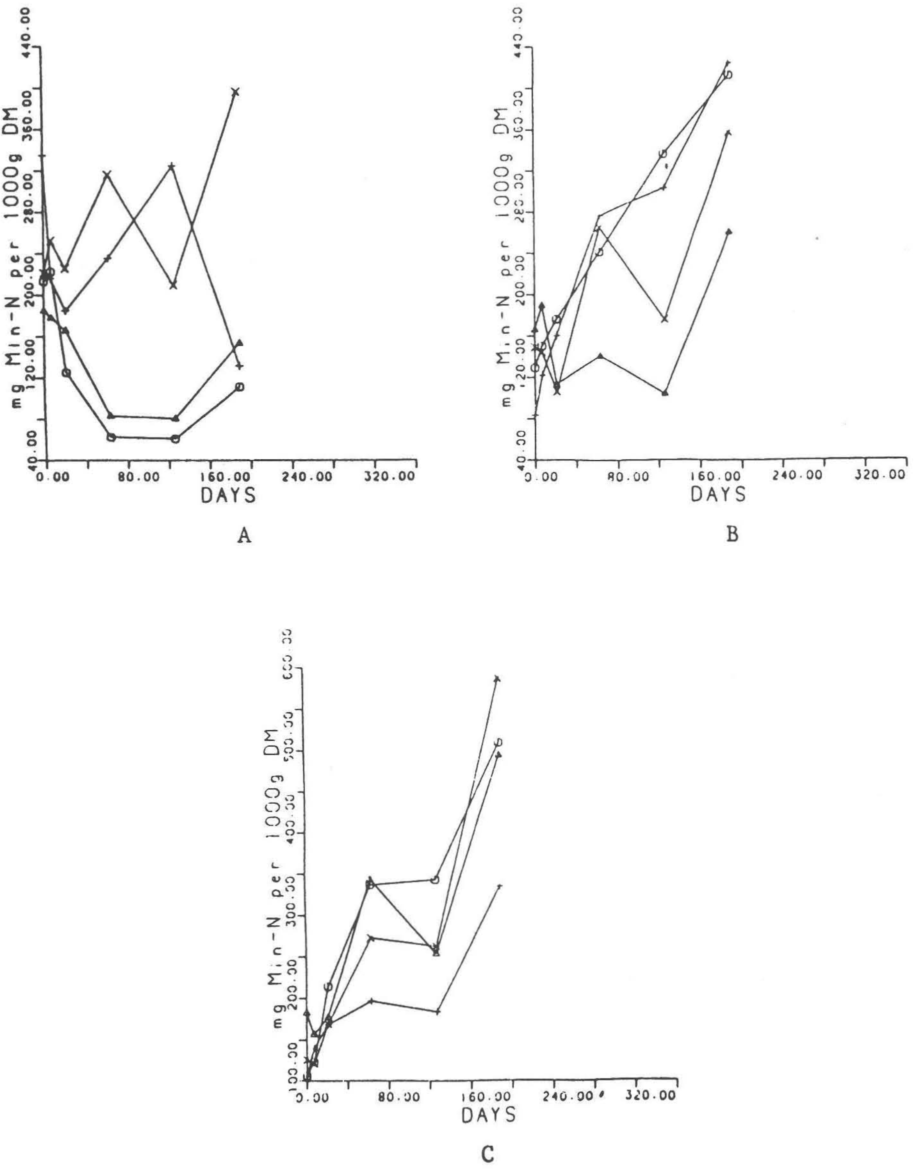

Fig 3 Net Nitrogen Mineralisation in (a) Forest Floor (b) Peat 0-5cm and (c) Peat 5-10cm. Treatments: Experiment 1, N_0P_2+, N_2P_2 X; Experiment 2, N_0P_2 0, N_2P_2 △

Table 3 Chemical composition of peats used in N-P mineralisation studies.

EXPERIMENT 1					% D.M.								Mg. g^{-1} peat		
Treatment N_0P_2	pH	N	P	K	Ca	Mg	Na	S	Cl	Si	Al	Mn	Fe	Cu	Zn
Forest Floor	4.5	1.46	.098	.085	.51	.16	.046	.16	.14	.20	.027	12	152	3	8
Peat 0-5cm	4.0	1.48	.050	.050	.18	.14	.041	.21	.17	.33	.045	3	256	11	4
Peat 5-10cm	3.9	1.53	.031	.037	.10	.16	.046	.28	.17	.34	.048	4	585	3	5
Treatment N_2P_2															
Forest Floor	4.6	1.70	.094	.072	.53	.17	.036	.18	.13	.19	.029	15	188	3	7
Peat 0-5cm	4.1	1.60	.042	.045	.16	.13	.034	.24	.14	.42	.044	3	560	14	5
Peat 5-10cm	4.0	1.80	.033	.037	.07	.14	.042	.30	.15	.41	.052	2	844	3	4
EXPERIMENT 2															
Treatment N_0P_2															
Forest Floor	6.9	1.17	.140	.070	3.61	.23	.039	.16	.08	.17	.036	68	322	5	10
Peat 0-5cm	4.9	1.75	.074	.059	.99	.13	.050	.26	.16	.63	.090	12	2617	13	5
Peat 5-10cm	4.0	1.92	.046	.041	.21	.12	.041	.34	.17	.45	.092	3	1563	3	4
Treatment N_2P_2															
Forest Floor	7.0	1.31	.140	.066	3.64	.24	.029	.18	.07	.14	.035	56	295	5	13
Peat 0-5cm	5.7	1.67	.070	.091	1.75	.14	.042	.25	.15	.48	.086	13	1376	13	7
Peat 5-10cm	4.0	2.15	.050	.080	.33	.11	.050	.34	.18	.57	.100	4	2279	4	4

Table 4 Nitrate content of forest floor and peat as % of total mineral nitrogen over 189 days incubation.

		Experiment 1		Experiment 2	
Forest Floor	Incubation Period (days)	N_0P_2	N_2P_2	N_0P_2	N_2P_2
	0	9.6	1.9	24.8	32.4
	7	14.4	15.0	35.6	79.9
	21	6.7	6.3	23.3	44.7
	63	10.3	9.8	7.5	38.3
	126	25.1	10.2	41.4	41.9
	189	18.6	32.2	27.5	53.7
Peat 0-5cm					
	0	57.3	5.6	22.8	14.9
	7	14.3	20.0	14.8	34.1
	21	29.0	9.9	8.2	39.9
	63	7.0	24.7	42.4	49.6
	126	8.8	0	53.1	80.8
	189	10.0	25.8	70.1	58.5
Peat 5-10cm					
	0	40.7	2.9	4.0	20.0
	7	8.1	27.1	6.4	11.3
	21	28.8	14.4	14.7	7.3
	63	8.8	2.4	6.8	19.1
	126	9.4	5.3	12.6	7.0
	189	7.1	32.9	11.8	14.5

There was no consistent pattern of phosphorus mineralisation and despite some exceptions, levels remained fairly constant through the course of the incubation. However, the effect of the 1977 application is clear in the increased levels of total phosphorus (Table 3) and extractable phosphorus, in both forest floor and peat (Figure 4).

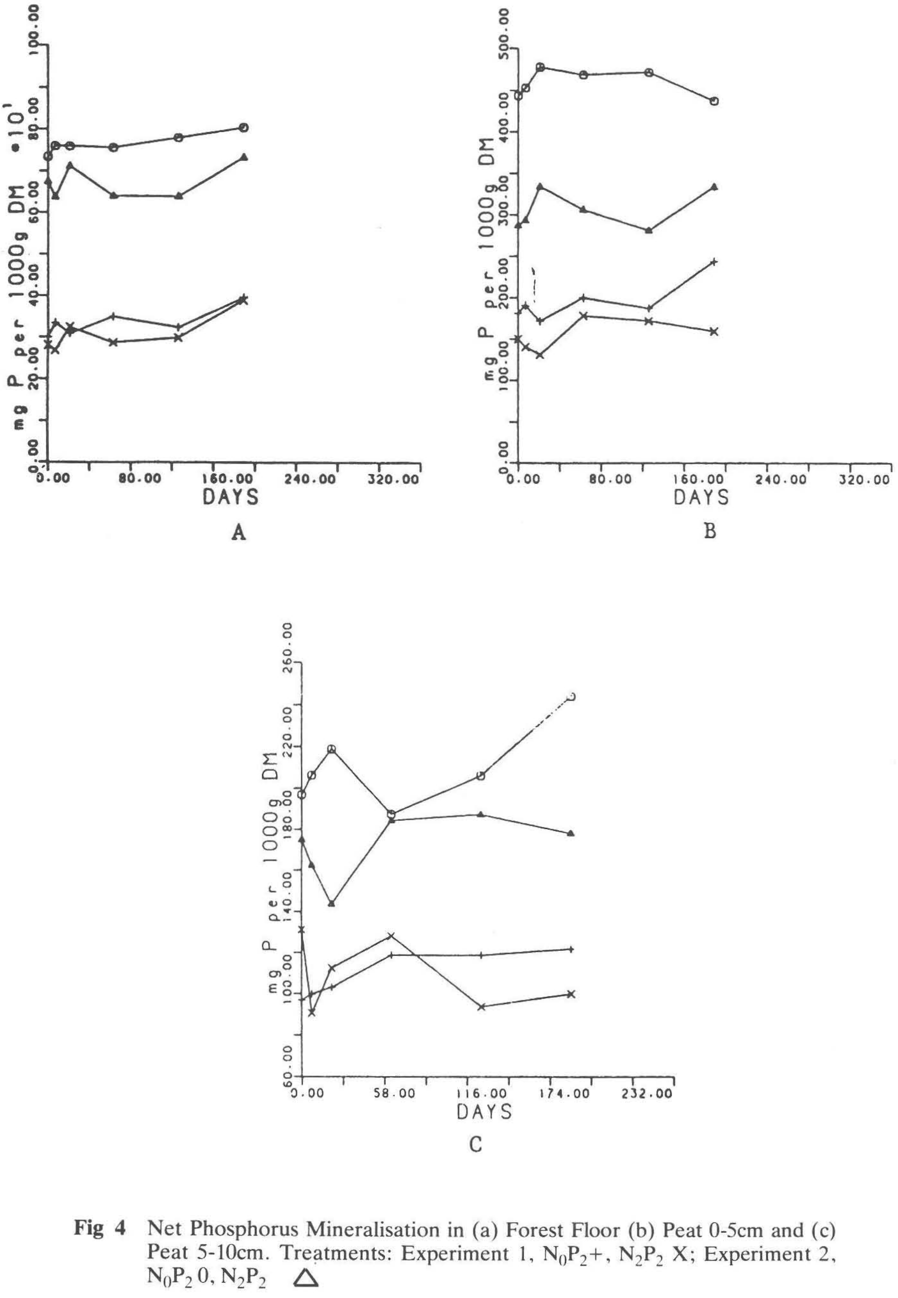

Fig 4 Net Phosphorus Mineralisation in (a) Forest Floor (b) Peat 0-5cm and (c) Peat 5-10cm. Treatments: Experiment 1, N_0P_2+, N_2P_2 X; Experiment 2, N_0P_2 0, N_2P_2 △

CONCLUSIONS

The close correspondence between growth response to fertiliser and depth to water table, recorded both in the present study and in the previous one (Farrell and O'Hare 1974), is remarkable. The relationship is probably indirect, resulting from increases in needle biomass induced by the fertiliser (Albrektson et al. 1977) with consequently increased evapotranspiration.

It is to be expected that rates of evapotranspiration from forest canopies will be high in the west of Ireland. This is because evaporation is high in areas of frequent rainfall where the canopy is almost continually wet (Jarvis and Stewart 1979). Growing season mean depth to water table of 50 to 67cm, as was reached in the phosphate treated plots in these experiments, is very satisfactory for a low level blanket peat site although it would be presumptuous to expect any significant rooting at or even close to this depth range (Farrell and Mullen 1979). Also, allowance must be made for the experimental conditions, as height differences between adjacent plots will lead to increases in aerodynamic roughness of the forest canopy surface and this will result in increased evaporation (Jarvis and Stewart 1979).

Water table depth has probably reached its maximum, as with thinning, the stand is being opened up and the point of maximum current annual increment is already past. While water table depth did not rise rapidly following thinning, as had been anticipated, there is no doubt that it is sensitive to canopy cover. As there is little reason to believe that the stand can have an influence on depth to water table which will persist after clearfelling, it may well prove difficult and costly to provide adequate drainage for the second rotation crop on low level blanket bog sites, which, characteristically have low-angle slopes and peat of inherently poor permeability. Limiting the size of clearfells may reduce the problem, but the possibility of installing widely spaced, deep drains excavated to permeable material should be explored where peat depth, drainage outfalls and the nature of the subpeat mineral soil permit.

The rate of peat subsidence presents no threat to the long-term prospects of forestry on most blanket peat sites. It may be anticipated that on shallower peats the rate of subsidence will be less. In shallow peat situations where less than 50cm of surface organic matter remains, experimentation on peat-soil mixing techniques would be desirable to test the long-term effects of such treatment on crop production and organic matter stability.

The purpose of applying nitrogen in Experiment 2 in 1977 to 1979 was to alleviate potential nitrogen deficiency which might occur, in the short-term, following a lime induced flush of microbial activity. Although a response in basal area increment to nitrogen was measured, the indications are that growth was retarded by the lime (Farrell 1985). However, it would appear that deficiency of nitrogen was not the cause of the reduction in growth. Foliar nitrogen levels increased during the period in both experiments (Farrell 1985). Measureable immobilisation of nitrogen was detected only in the forest floor. However, samples for incubation were taken four years after fertiliser application, by which time an immobilisation effect might be expected to be on the wane.

It is clear that neither in mineral nitrogen levels, (Figure 3), nor in total nitrogen concentration (Table 3), is there real evidence of a residual effect of the 1977-1979 nitrogen applications on the peat. This may not be of great significance, however, if, as has been suggested, trees fertilised with nitrogen make no demands on soil nitrogen after fertilisation has ceased, over and above those made by unfertilised trees (Miller 1981).

By contrast, the residual effect of the 1977 application of phosphate is marked and despite the decline in foliar phosphorus concentrations between 1975 and 1979 (Farrell 1985), provide some reassurance on the persistence of the phosphate response in this experiment.

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