Effects of Drainage Intensity and Planting Position on the Growth and Nutrition of Second Rotation Sitka Spruce on Shallow Peat

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Summary

Results are presented from a restocking experiment on shallow peat investigating the effects of intensity of drainage and planting position on growth and foliar nutrient levels of Sitka spruce *(Picea sitchensis (Bong.) Carr.)*. The previous crop of Sitka spruce had been felled prematurely after 36 years. Growth was significantly enhanced by drainage at 10m and 5m intervals, compared to an undrained control treatment, and by planting on mounds of spoil compared with planting directly into uncultivated soil. Foliar nitrogen concentration was significantly lower in undrained plots 16 years after planting. The physical or nutritional condition of the peat does not appear to have improved by the first rotation crop.

1. Introduction

Soils with an organic surface horizon comprise 64% of the total area (approximately 58,000 ha) afforested by the Northern Ireland Forest Service. Organic soils include peaty gleys, with 5-50cm of organic matter overlaying gleyed mineral material, shallow peats, with 50cm-1m of organic matter, and deep peats, with more than 1m of organic matter. Three-quarters of forests in this category are less than 30 years old. Consequently although the area of felling and replanting of these soil types is small at present, it will increase substantially in the coming decades (Savill and McEwen, 1978).

This paper presents results from an experiment which was laid down following clearfelling in Cam Forest, Co. Londonderry, in 1972. The object was to investigate the effects of drainage at different intensities, and mounding, before replanting on the growth of Sitka spruce on shallow peat. The previous crop of Sitka spruce, which was planted in 1936 on hand spaced turves, was growing more slowly in the experimental site than in other parts of the compartment where the peat layer was less deep; it was felled prematurely with the rest of the compartment.

2. **Site and Experimental Layout**

The experiment was laid down on a gently sloping site at an elevation of 250m. Mean annual rainfall (1941-1970) is 1200mm per annum. The experiment occupies a small area of shallow peat, overlying a gleyed soil derived from fine textured basaltic glacial till. The area was planted with Sitka spruce transplants of QCI origin.

The following experimental treatments were applied to plots of 0.16 ha in spring 1972:

1. Existing drains at 40m spacing cleaned out, with trees planted directly into uncultivated soil at 2.0m spacing.
2. Drains 1m deep installed by tracked excavator at 10m spacing, with spoil placed beside drains. Four rows of trees were directly planted between drains, avoiding the spoil taken from drains, resulting in an average spacing of 2.2m.
3. As above, but with trees planted on heaps of spoil placed in between drains (mound planting).
4. Drains installed at approximately 5m spacing, with 2 rows of trees planted between drains on heaps of spoil, resulting in an average spacing of 2.4m.

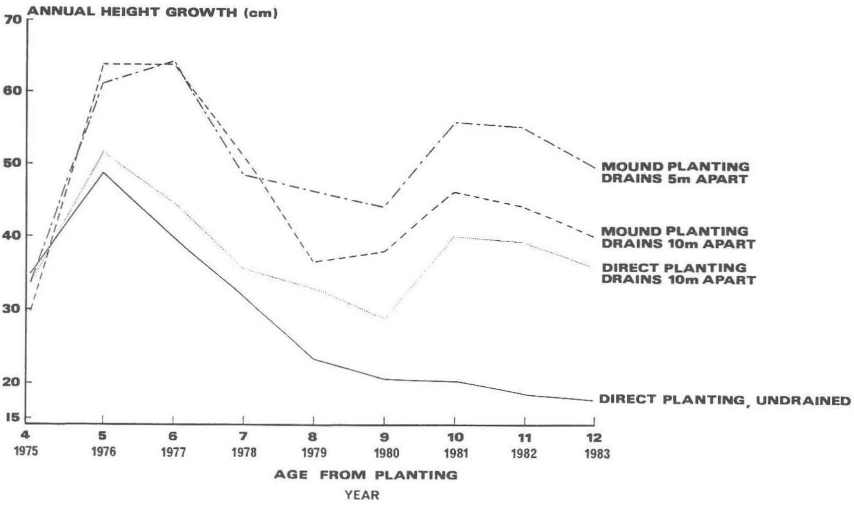

Figure 1: Effect of Planting Position & Drainage Intensity on Height Growth.

Table 1: Relative effects of planting position and drainage intensity on height growth.

Treatment	Mean annual height growth (cm) 1976-1979	Mean annual height growth (cm) 1980-1983	Mean height in 1983 (m)
Direct planting	41	36	4.3
Mound planting	53	42	5.0
Planting beside drains	45	39	4.5
Planting between drains	49	39	4.8
Standard error of means:			
Planting position	2.6**	1.2**	0.16*
Proximity to drain	2.6 NS	1.2NS	0.16 NS
Mounds and drains interaction	3.7 NS	1.6 NS	0.22 NS

***, **, * significant at the 0.1%, 1% and 5% level respectively.
NS – non significant.

The treatments were replicated in three randomised blocks. There was no application of fertiliser at time of replanting or subsequently.

3. **Assessments and Results**

Annual height growth was assessed from 1972 until 1983 in rectangular plots containing 24 trees (6 x 4) within each treatment plot. In 1987 and 1988 the diameter at breast height (DBH) of trees in measurement plots and dominant height (the mean height of the five largest DBH stems per plot) were recorded; plot areas were measured and basal area per hectare determined. Top whorl foliage was sampled and analysed for major plant nutrient concentrations in 1981, 1983 and 1987.

3.1 Effects of treatment on tree growth

Annual height growth of trees 4 to 12 years from planting in each treatment is shown in figure 1. Growth was significantly increased by additional drainage and providing a raised planting position; growth differences between the treatments were statistically significant (at p=0.001) from year 6 (1977) onwards. The initial growth response is clearly related to planting on mounds of spoil; subsequently growth in undrained plots declines steadily while in drained plots it is maintained. From year 9 (1980) onwards significant differences (at p=0.05) in annual height growth between drained plots are apparent, with growth increasing with intensity of drainage. The

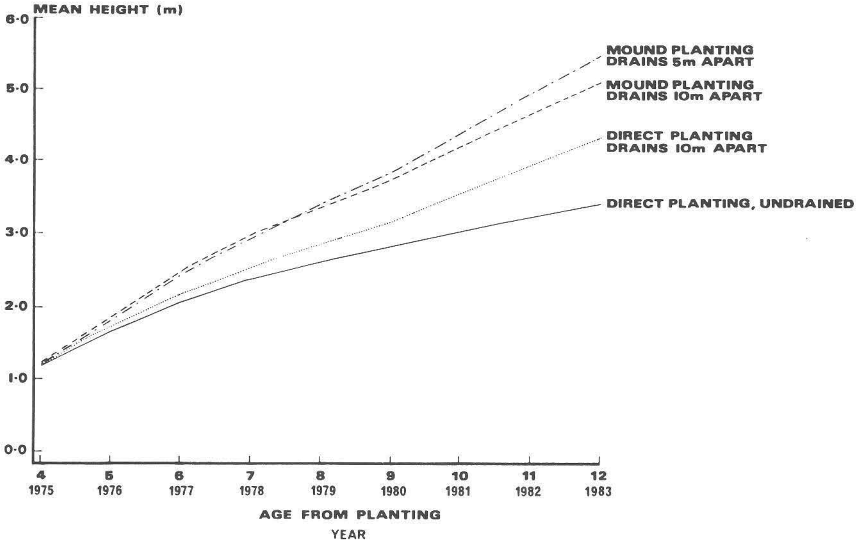

Figure 2: Effect of Planting Position & Drainage Intensity on Mean Height.

annual variation in growth in drained plots may be ascribed to fluctuations in climate and, possibly, aphid defoliation.

The effect of treatment on mean height up to year 12 (1983) is shown in figure 2. From 1980 growth of trees in each treatment appears to be represented by a different curve, reflecting consistent differences in growth response between the experimental treatments.

The relative effects of proximity to drains and planting position were investigated in plots which had drains installed at 10m intervals, and are shown in Table 1. Growth of the 12 trees growing beside drains on the outside rows of measurement plots was compared with growth of the 12 trees growing on the inside rows. Mound planting significantly increased mean annual height growth, compared with direct planting. Irrespective of planting position, planting beside drains had a slightly depressing effect on growth compared to planting between drains, although it was not statistically significant. This suggests that the effects of providing a raised planting position were initially more important for tree growth than locally intensive drainage. The interactions between planting position and proximity to drains were not significant.

Assessment of height and basal area 17 years from planting (i.e. at the end of the 1988 growing season) showed that differences accruing from drainage and raised planting were maintained (Table 2). Basal area does

Table 2: Effects of treatment on dominant height and basal area 17 years from planting (1988) and increment 1987-88.

	Dominant height (m)		Basal area m^2/ha	
Treatment	1988	Increment 1987-88	1988	Increment 1987-88
Direct planting, no drains	6.5	0.27	12.4	1.05
Direct planting, drains at 10m	7.7	0.37	17.0	1.23
Mound planting, drains at 10m	8.5	0.37	23.4	2.12
Mound planting, drains at 5m	9.3	0.53	26.5	2.44
Standard error of means	0.25***	0.14 NS	2.47*	0.23*

not fully represent the growth response to the imposed treatments because of differences in initial spacing between treatments. However, basal area in the undrained treatment is less than half of that in the most effective treatment (planting on mounds between drains at 5m intervals). The same is true for dominant height and basal area increment 1987-88.

3.2 Effect of treatment on foliar nutrient concentration

The effects of treatment on the concentration of N, P and K in top whorl foliage at the end of the 1981, 1983 and 1987 growing seasons are shown in Table 3. In 1981 values of P and K were marginally deficient in all treatments and foliar N concentrations were very low, ranging from 0.76% DM in the undrained direct planted treatment to 1.07% DM where the trees had been planted on mounds in the plots drained at 10m intervals. By 1983 when canopy had closed, the concentrations of N and P had increased slightly but K values remained virtually unchanged. Treatment had no significant effect on nutrient concentration in either year. By 1987, foliar K concentrations were very low in all treatments but were not significantly affected by treatment. Foliar P concentration ranged from 0.12% DM in the undrained direct planted treatment to 0.15% DM in the most intensively drained treatment, but treatment differences were not statistically significant. There was a significant effect of treatment on foliar N concentration in 1987; values ranged from a deficient 1.04% DM in the direct planted control plots to 1.24% DM in the direct planted plots drained at 10m spacing and to a more satisfactory value of 1.55% N in the most intensively drained, mound planted treatment. The concentrations of

Table 3: Effect of drainage and planting position on foliar N, P & K concentrations in 1981, 1983 and 1987.

Treatment	Foliar nutrient concentration % dry matter								
	1981			1983			1987		
	N	P	K	N	P	K	N	P	K
Minimal drainage, direct planting	0.76	0.12	0.52	1.25	0.14	0.47	1.04	0.12	0.39
Drains at 10m intervals direct planting	1.03	0.12	0.44	1.18	0.14	0.44	1.24	0.13	0.39
Drains at 10m intervals mound planting	1.07	0.11	0.51	1.34	0.15	0.50	1.28	0.14	0.42
Drains at 5m intervals mound planting	1.01	0.13	0.47	1.44	0.13	0.49	1.55	0.15	0.41
Standard error of means	0.071	0.010	0.041	0.080	0.012	0.045	0.087	0.016	0.040
Significance	NS	NS	NS	NS	NS	NS	*	NS	NS

Ca, Mg, Fe and Mn were determined only in the 1987 samples. The values of these elements were in the "normal" range and were not significantly affected by treatment; they are not reported.

4. **Discussion**

The range of options for cultivating a clear felled (or windblown) site prior to restocking is limited by (a) cost, (b) the presence of stumps and roots of the previous crop and (c) the presence of harvesting debris (brash) on the ground. Until recently in Northern Ireland, ground preparation for restocking on deep or shallow peat sites has been restricted to cleaning out existing main drains with an excavator and planting directly into the peat. Most of these plantations already restocked were originally planted on hand spaced turves and the intensity of main drains was generally high. With the introduction of open ploughing for planting during the 1950s there was a tendency to instal fewer main drains. In both cases there is uncertainty as to whether simply restoring the original drainage system will provide adequate drainage for the second rotation crop. The present experiment was designed to address this uncertainty in the case of older crops established without the advantages and disadvantages of deep ploughing.

In large measure it appears that simply restoring the original drainage system will not provide conditions conducive to satisfactory growth of the next crop. At age 17, the top height of the directly planted crop with drains cleaned out at the original 40m spacing corresponds to general yield class 12 (Hamilton and Christie, 1971). Increasing the drain intensity to 10m spacing increases the indicated yield class to 16. Planting on mounds between 10m and 5m spaced drains further increases the indicated yield class to 18 and 20 respectively. Assessment of basal area indicates that the growth differences between the experimental treatments are even greater than shown by top height assessment. Comparison of current basal areas in treatment plots with yield models for unthinned Sitka spruce (Edwards and Christie, 1981) at the appropriate planting spacing shows that the local yield classes corresponding with the general yield classes of 12, 16, 18 and 20 are, respectively, 6-8, 12, 14-16 and 20. This reflects uneven establishment and growth in direct planted treatments. If these differences are maintained until maturity the financial implications are obvious (Busby and Grayson, 1981).

The original crop did not receive any fertiliser at planting in 1936. It could be argued that growth of the second rotation in the experiment would have benefited from the application of fertiliser. This is borne out by the result of the foliar analysis presented in Table 3; 10 years after planting (1981) levels of N and particularly P in the foliage from all treatments were below the deficiency level suggested by Binns et. al. (1980). Potassium bordered on the deficiency level. Foliar nutrient levels had increased slightly by 1983 but treatment did not significantly affect values and all were below the optimal levels quoted by Binns et. al. (op. cit.). Treatment significantly increased foliar N concentration in 1987, with values ranging from 1.04% DM in the direct planted undrained treatment to 1.55% DM in the most intensively drained and mound planted treatment. This difference is almost certainly caused by an increase in the rate of mineralisation of the soil organic matter. Although the effect is not statistically significant, there also appears to have been increased mineralisation of P in the closely drained treatment, where foliar P concentration is 0.15% DM compared with 0.12% DM in the undrained treatment. If this increase in mineralisation is maintained it would be expected that relative growth differences will be maintained or increased.

Unfortunately it is not possible to assess separately the effects of drainage, and the spreading of spoil as a result of drainage operations, on growth and nutrient uptake. Digging drains at 5m compared with 10m intervals doubles the volume of additional material available for exploitation by tree roots, even though the mounds provided for planting may have been of similar size. Indeed, Fig. 1 shows that the initial growth response to raised planting is similar at either drain spacing. It is possible that the increased intensity of drainage has lowered the water table within plots, increasing the volume of soil available to roots, and giving deeper roots a greater chance of surviving each winter. This would reduce the annual demand placed on trees in replacing root biomass allowing greater above ground increment. Experiments investigating the effects of drain spacing and depth on deep peat in the first rotation in Northern Ireland show that growth responses to drainage are slow to become apparent. In many of the experiments, which were laid down between 1964 and 1968, the response is now striking. Earlier work (Savill et. al., 1974) suggested that early responses were predominantly brought about by increased nitrogen availability in the peat spread above the original ground surface from drains. This implies that the presence of spoil has a greater effect on growth than drainage intensity per se. However, in practice, the relative effects of spoil addition and drainage intensity are inseparable since there is a direct relationship between the two.

The most effective treatment in terms of growth increment involved digging 1m deep drains at 5m spacing and planting in the resultant spoil. However this treatment has distinct practical disadvantages. Apart from economic considerations, such a system would create immense difficulties for harvesting and any other operations within the crop. Drainage at 10m intervals and planting on the spread mounds is a commercially feasible operation. In this treatment the trees are currently (age 17) growing at a rate corresponding to yield class 18. This represents a considerable improvement compared with the average yield class of 14 of Sitka spruce on similar sites in Co. Londonderry (Schaible and Kilpatrick, 1989). Spacing drains more widely than 10m would have the practical advantages of allowing more regular plant spacing and facilitating later harvesting operations. Since growth response is positively related to drain spacing these advantages would have to be weighed against a probable decrease in production.

Growth in the undrained, directly planted treatment is probably no better than in the previous rotation. This suggests that the first rotation crop has caused no irreversible changes in the physical or nutritional nature of the peat on which it was growing. Although no details of the previous crop are available, the trees were 36 years old when felled and examination of the remaining stumps indicated that the crop was at least moderately vigorous. Examination of the peat has not revealed any 'cracking' and subsequent irreversible drying of the kind reported in pseudofibrous peat under lodgepole pine in Northern Scotland and elseqhere by Pyatt (1987). Whether this is because of differences in species, climate or type of peat is not known.

The results of this experiment have shown that intensive drainage and planting on mounds at restocking on a shallow peat site allows successful establishment and good growth of Sitka spruce at least over the first 17 years of the rotation. In view of the apparent increase in the rate of N (and possibly P) mineralisation, the prospects for future growth are encouraging, even though height increment in the current year (1989) has been poorer than predicted. This may be connected with a severe aphid infestation in the previous 2 years.

Acknowledgements

The foresight of W. T. Wilson and P. S. Savill in initiating this experiment is acknowledged. The authors also wish to acknowledge the efforts of S. A. Mawhinney, R. T. Matthews and D. S. Ridge, who made the growth assessments and collected foliar samples.

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