The Progress of Peatland Afforestation in Britain

M. V. EDWARDS,

Forestry Commission, Research Branch, Edinburgh.

A high proportion of new afforestation in Britain is carried out on peatland. Any attempt to specify a figure immediately raises the question as to what is meant by 'peat'. It is very difficult to find any precise definition in spite of the detailed information about peat, on the one hand from ecologists and on the other from engineers. Recently the Soil Survey of Britain, in conformation with international usage, has described peat as an organic soil if over twelve inches deep, and peats below that depth as either peaty podsols or peaty gleys. This makes a convenient definition for foresters. Peat under a foot in depth is usually covered with heather (*Calluna*) or grasses (for instance *Molinia*) and with modern methods of ground preparation these peaty podsols or gleys are not usually a problem in establishing trees.

The twelve-inch limit is not necessarily a hard and fast one, but it is the most convenient depth at which to draw the line on the average. It is considered better than any definition based on the rooting depth of trees, as this can be varied by treatment.

The fen peats exceed a foot in depth, but they are usually in the hands of the agriculturists and are rarely a forest problem. Blanket, valley or raised bogs are all classified by foresters as the poor peats, 'poor' in the sense that they are too infertile to support vigorous *Molinia coerulea* and bear instead the Eriophoretum, Trichophoretum (Scirpetum) or Sphagnetum communities. In the Trichophoretum the scale of poverty is apparently related to the lack of vigour, or even in the last extremity the complete absence, of *Molinia.*

Early History.

Older writers on the afforestation of peat, e.g. Steele (1826) in Scotland, appear to have been concerned mainly with fen peat, and in spite of searches in the last ten years or more, none of their successful examples of afforestation have been found to be on poor peat, though they were sometimes marginal. It seems probable that where they overstepped the margin the plantations were not successful, though survivors may have remained alive.

Hence foresters have had good reason to believe that it was impossible to grow trees on poor peat successfully. James Brown (1861) remarked that "Moss (i.e. peat) land, even after draining, is found of a dull and inert character and not apt to give life and energy to the growth of useful plants:" and Boyd, as lately as 1918, after experience both at Corrour and at Inverliever in the west of Scotland, stated that no areas bearing *Scirpus,* (*Trichophorum*), *Sphagnum, Eriophorum* or *Narthecium* should be planted.

Turfing had been in use in Ireland in 1805, and on *Molinia* peats the Prussians and Belgians had developed a planting system based on turf planting and the use of phosphate, and this was adopted in Scotland at the beginning of this century (Stirling-Maxwell, 1907). The extension of these methods to poor peat commenced at Inchnacardoch forest in 1923 (Experiment No. 6), and in 1924 at the Lon Mor experimental area. This became an important centre for research on poor peat, while parallel experiments were carried out at Achnashellach, Glen Righ, Beddgelert and other forests. The results up to 1954 were published in Forestry Commission Bull. No. 24—Experiments in Tree Planting on Peat.

Choice of Species.

Many of the experiments were carried out with various species of spruce, because spruces are traditionally associated with wet sites, but they went repeatedly into check, and no suitable technique for raising any species of spruce was found. It is not difficult to grow Sitka spruce (*Picea sitchensis*) for a few years. When it slows up, application of compound N P K fertilizers may give remarkable effects, but we do not yet know how to do this efficiently. Only one plot has been brought to the crop stage, and in spite of applications of P, N, K and Mg, its growth is not continuing satisfactorily.

It is evident that pines are less demanding and easier to grow. Scots pine has been successful on sites that are climatically satisfactory for it, and mountain pine on exposed sites. But lodgepole pine (*Pinus contorta*) of many provenances grows best of all and is proving to be the most productive.

Many trials were made of numerous other species to find one specially suited to peat, but without great promise. More recently, Wood (1955) has emphasised that both *Pinus contorta* and *Tsuga heterophylla* are less demanding than the spruces in their native habitats, and recent experience in Britain is substantiating the conclusion that they are likely to be the most suitable trees to grow on peat. Search for an even more oligotrophic species than lodgepole pine has therefore been terminated. So has the attempt to grow other species by nursing with the pine, and clearly little is likely to be gained on peat by nursing to suppress heather, as on the more fertile Upland Heaths, also the problem is not basically one of providing shelter for a tender species. The larches, Japanese and hybrid, proved extremely sensitive to the absence of phosphate, but it is now becoming evident that, given adequate mineral phosphate, they have a lower requirement for nitrogen than Sitka spruce, the most successful species of spruce, so that, next to lodgepole pine and western hemlock, Japanese or preferably hybrid larch appear to be the most suitable species.

LON MOR EXPERIMENTAL AREA

Table

PRODUCTION DATA

Age	No. of trees/acre	Top Ht.	Mean Girth	Basal area	Volume (Estimated) Main Crop	Total	Periodic Ann. Increment		Mean Ann. Increment
		ft.	in.	sq. ft. q.g.	H. ft.	H. ft.	1953-55	1956-59	to 1959
Lodgepole pine		*Experiment 47 P.28*			(plots 3-6)				
31	770	37.8	17½	101.6	1,590	1,930	190	140	60
Lodgepole pine		*Experiment 52 P.29*			(2 replications)				
A.30	930	40.1	14½	82.2	1,460	1,680	170	130	60
B.30	1,050	36.8	14	81.7	1,280	1,500	140	110	50
Scots pine		*Experiment 19 P.26*			(plot 10)				
33	790	30	16	88.3	950	1,010	80	70	30

Expt. 47. Drained at 8 ft. and turfed. 6.3 cwt. G.M.P. per acre.

Expt. 52. A. Intensive draining, 12 ft. spacing, deepened, 5 cwt./acre phosphate.

B. Moderate draining, 18 ft. spacing, undeepened, 3½ cwt./acre phosphate.

Expt. 19. Groups of shallow turves. About 6 cwt. basic slag per acre.

Only if the necessity for heavy and repeated fertilization is accepted, and a reliable system of doing it worked out, might it be desirable to determine the kinds and amounts of fertilizers necessary to grow Sitka spruce, with a view to comparing the production of spruce and pine in cubic feet of timber per ton of fertilizer, on a cost basis.

In the past, lack of knowledge about the timber quality of lodgepole pine and the attempt to use it as a nurse for other species has resulted in the establishment of many mixed crops in which the nursed species is proving a failure. This results in the effective spacing of the pine nurse being much greater than normal, so that the trees grow coarse and branchy. Especially is this the case with the most vigorous provenances of coastal lodgepole pine, so that an attempt is now being made to establish pure crops of both coarse vigorous and finer less vigorous provenances of pine with a view to the determination of the productive potential of lodgepole pine under normal forest conditions.

Fertilization.

Problems of nutrient supply have already been dealt with in earlier papers, but there are some practical points about the application of fertilizers which require mention. It seems likely that repeated applications will be necessary, and if that proves to be the case, it is not improbable that aerial application may come to be normal practice. But at present, applications of phosphate at the start can now be done with a considerable reduction in cost by a machine attached to the plough—a hopper fitted with an archimedean screw and agitator feeding ground mineral phosphate through a hose pipe into the vegetation layer between ground surface and plough ridge as the ridge turns over and upside down.

The efficacy of machine application has been tested by simulated hand applications in 1952, and as the results from a stream of G.M.P. under the plough ridge have proved satisfactory, the machine has been developed by the South Scotland Conservancy and Messrs. Clark of Parkgate. This means that we are reverting to the old practice of putting the fertilizer under the turf. Problems of how and where to put the fertilizer round the plant after planting, and also of damage to plants by application of fertilizer too soon after planting are thus eliminated.

Perhaps the chief objection to placing the fertilizer in a strip under the ridge is thought to lie in the danger that it might accentuate root development along that line. It was long ago noted that tree roots tended to exploit the turf before spreading out into the peat, and that with ploughing there is a serious danger that roots might be concentrated in a line along the plough ridge and furrow (Zehetmayr, 1954). Excavations in 9 year old small lodgepole pine and in the oldest (16 year) lodgepole pine planted on Cuthbertson ploughing have confirmed that this does in fact happen, though roots have also been found to cross shallow furrows filling up with litter. Though phosphate stimulates the growth of the root system greatly, there is no evidence to suggest that applying it in any particular position affects the direction of root development.

The use of basic slag was superseded by ground mineral phosphate in the war-time when high quality basic slag was unavailable; and as the P (or P_2O_5) content of the G.M.P. is greater, and the total weight of material to be applied less, it has retained its place. In some areas a change has been made to superphosphate or triple superphosphate, which has reduced the weight of material to be applied. There is no doubt that on a short-term view the critical factor is the amount of P, and that the form in which it is applied is less important. But on the long-term view the non-phosphatic content of the fertilizer may be of importance, either the Ca, trace or other elements, and in the absence of proof on this matter, many foresters still continue to use G.M.P.

Ground Preparation.

The modern method of ground preparation on poor peat, as described by Zehetmayr (*ibid,* p. 29) consists of two turf ridges from a single-furrow double-mouldboard plough alternating with deep single-furrow plough drains. Alternatively continuous double-mouldboard ploughing crossed at intervals by single-furrow plough drains was suggested. However, it has been found in practice that the early growth of trees is generally faster on the deep ridges produced by an S.F. plough than on the wide, shallow ridges produced by a D.M.B. plough, and it is easier to use only one kind of plough on a bog, with the result that continuous S.F. ploughing has often been carried out in practice. Under the former system the drains are spaced at approximately 17 ft. whereas in the latter the deep S.F. drains are at approximately 5 ft. to 6 ft. intervals. Clearly in this case not all the furrows are expected to continue as permanent drains, and the question of ultimate drain spacing is left undetermined.

As already mentioned, there is evidence that the roots tend to follow the line of the ridges, and that though they will cross furrows which fill up, they are unlikely to cross permanent drains. In fact such roots would be a source of future trouble if they were allowed to cross. Thus it appears that maximum early growth resulting from draining, the application of phosphate and the subsequent rapid mineralization of nitrogen is obtained with deep closely-spaced drains, but maximum stability of the future crop is likely to be obtained with widely-spaced drains, between which complete cultivation is desirable to allow roots to spread horizontally in all directions.

In depth roots will go down to a level approximating to that of the bottom of the drains and sometimes lower. The precise level is a matter about which we have little knowledge and it obviously depends on the range of influence of drains (according to their depth and spacing) on the water-level in the peat between them. No doubt this depends to a great extent on the rainfall, both annual and in its distribution over the year, and also on the characteristics of the peat itself. In Norway the depth at which the water lies in the growing season is measured but in Britain the level in winter is thought to be critical in determining rooting depth. Finally, though the trees may be limited by the actual water level when they are young, as the crop matures and transpiration increases the trees may themselves determine, to some extent, the level of the water. Tree species apparently differ in their capacity to root deeply and there is evidence that small lodgepole pine may be able to root below the level of the drain depth, whereas Scots pine does not root so deeply (Binns, 1959).

It appears to be possible for a tree crop on a bog to suffer from drought, at any rate in a dry season. (See Forestry Commission Annual Reports 1955-56 to 1958-59). Overdraining may be expected to lead to a reduction in the nitrogen supply, and if severe, perhaps to irreversible changes in the peat. Though regulation of water level by blocking drains might be valuable, ceasing to cut drains which are not really necessary would be better.

Thus, there is a case for keeping the drains as wide apart as possible as is consonant with the successful establishment of the crop, and it will be better if drain-spacing is determined for the needs of growth and stability when the trees are tall, rather than for quick establisment in youth.

The functions of drainage and cultivation need separate consideration. Drainage may be considered as the removal of water from the mass of the peat by gravity, and although it is known that the effect of a drain in a mass of peat is limited at first, it may extend in time. Cultivation may be considered as the superficial breaking down of the peat to allow of aeration, the mobilization of nutrients, penetration of tree roots and inversion and suppression of the pre-existent vegetation. It is thought that complete cultivation should be reconsidered in the light of developments in modern machinery, in spite of the fact that as recorded by Zehetmayr (*ibid.* p. 30) it proved a failure in 1945. However, it may be that as at present the product of the double-mouldboard plough will have to be accepted in place of complete cultivation.

The problem then is how to drain away the moisture released either by the complete or the double-mouldboard ploughing in the early stages and from the site as a whole later on when the double-mouldboard ploughing becomes blocked by litter and tree roots. It is suggested that this should be done by means of a secondary draining system cut by the S.F. plough (either normal Cuthbertson or deep-going pattern) working at a suitable gradient into which the D.M.B. furrows or equivalent shallow drains between bands of complete cultivation would discharge. There is some evidence that the secondary draining system should work on a gradient of about $\frac{1}{2}°$ or 1 :120. The spacing of these drains should be adequate to remove surplus water later on when the tree crop is transpiring freely in times of maximum rainfall, conversely it may be found desirable to restrict the flow during dry periods. No trees would be planted on the ridges beside the drains which would be kept clear so as not to hinder drain cleaning. Access rides or roads would normally lie on one side of these drains.

The secondary draining system would discharge into an arterial draining system, which on blanket bog normally exists in the form of streams or gullies, though the latter may need to be opened by ploughing. On raised or valley bog, the main drainage system must needs be artificial and may often have to follow the line of maximum gradient, often much less than 1 : 120. These main drains must be large deep ditches, and hitherto they have not been constructed in forest practice in Britain. Such deep ditches are however common where bogs are being drained for agriculture, and they are also the basis of forestry practice in Northern Europe and Russia.

Steele (1826) gave a good description of such draining in the west of Scotland. His drains were 8 ft. wide at the top, 2½ ft. wide at the bottom and 4½ ft. deep, apparently spaced at about 8 to 10 chains. Between the drains, strips of complete cultivation 18 to 21 ft. broad were divided by secondary drains 2 ft. wide. The depth of these were "regulated to dry the moor enough but not too much."

In short, it appears that although we have developed a method of ground preparation which ensures the rapid establishment of a tree crop, we are by no means satisfied that it is the best method in the long run. In matters of draining, as well as cultivation, nutrition and choice of species, we have evidently a great deal to learn before we can claim to have solved the problem of maintaining productive forests on deep poor peat.

General Practice.

In general practice, on the basis of the results obtained to date, afforestation of poor peat mosses is going ahead on a small scale. As a rule only bogs contained within areas of better ground are planted and sometimes fertilizer is applied at a specially high rate (e.g. 3 cwt. G.M.P. per acre). Attempts to raise mixtures of species are now less frequent and lodgepole pine either pure or with a small admixture of other species, possibly Japanese or hybrid larch or *Tsuga* rather than Sitka spruce, is planted.

In order to gain more information than can be obtained from small trials, several trial forests are being set up in the North of Scotland where blanket bog is the prevailing formation. These will be managed by the local staff and not by the Research Branch, and they will be used to apply the latest experimental results under normal conditions of management with a view to determining the possibilities and value of forestry on poor peat.

References.

Binns, W. O., 1959. The physical and chemical properties of deep peat in relation to afforestation. (Thesis, University of Aberdeen).

Boyd, John, 1918. *Afforestation.* W. & R. Chambers, Edinburgh, p. 89.

Brown, James, 1861. *The Forester.* 3rd edn. Edinburgh, p. 539.

Steele, A., 1826. *The natural and agricultural history of peat-moss or turf-bog.* Edinburgh, p. 45-7.

Stirling-Maxwell, Sir John, 1907. The planting of high moorlands. *Trans. Roy. Scot. Arbor. Soc.* **20.** (1-7).

Wood, R. F., 1955. Studies of North-west American forests in relation to silviculture in Great Britain. *Bull. For. Comm.*, Lond. **25.**

Zehetmayr, J. W. L., 1954. Experiments in tree planting on peat. *Bull. For. Comm.*, Lond. **22.**