Coniferous Growth and Rooting Patterns on Machine Sod-Peat Bog (Cutover) and Trench 14, Clonsast

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Introduction

LARGE areas of bog are being cut over for fuel and other purposes in Ireland by Bord na Mona, the Irish Peat Development Authority. By far the greater number of bogs concerned are of the raised (*Hochmoore*) type in the Central Plain; the remainder are blanket bogs (*Terrainbedeckende Moore*) which occur mainly in the western half of the country. A total area of approximately 68,000 ha is involved in the scheme.

Clonsast, Co. Offaly (mean annual rainfall 849 mm.) is a raised-type bog 2,000 ha in extent, resting mainly on calcareous till, over carboniferous rock. Drainage began in 1936, mechanical turf-cutting in 1940. In 1955, with a view to investigation of the tree-growing potential of the cutover peat types, 3.8 ha were leased, with additions since then, to the Forestry Division (now Forest and Wildlife Service) of the Department of Lands by Bord na Mona. A 1.6 km length of Trench 14 cutover, 36m wide, comprised the original lease in 1955 (Grid Reference N. 57 21). The bog floor is 68 to 72 metres above sea level.

Trench 14 is one of the fourteen parallel main outfalls, 230 metres apart, by means of which the bog was drained. Sod peat excavators work back from each such outfall, widening the cut-over strips or fields annually, at first spreading the sod peat for air drying on the bog-top; later on the cutover itself, so that ground for land-use trials can be allocated only at the expense of output during the fuel-production life of the bog.

Mechanical sod peat extraction entails the removal of peat to a depth of 4.5 m (maximum) from the cutting face. The top 45 cm or so of this is "stripping", consisting mainly of young sphagnum

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moss peat and other vegetable debris from the bog surface. It is placed on the cutover surface. The quantity and nature of undisturbed peat left behind, beneath the stripping layer, vary considerably in accordance with variations in the original (pre-drainage) depths of peat from point to point, which in turn are closely allied to irregularities in the configuration of the bog floor, (1).

In 1936, prior to drainage, peat depths along the 1.6 km of Trench 14 now under consideration varied between 8.5 m and 3.6 m. On present showing, peat residues left behind, undisturbed, beneath the stripping layer on the same ground (immediately following fuel-peat extraction) will vary between 30 cm and 275 cm.

In 1955, it was found possible to subdivide the trench-length used for planting into three well defined regions running from south to north (2). These are listed below with additional data from more recent surveys.

(i) Plots 1—12*. 550 metres of trench length typical of average mechanical-cutover conditions. Moderate depths of peat left behind, 60 cm to 120 cm consisting of fossil forest debris, or woody fen, sometimes overlying mixed woody fen and reed swamp plants, resting on mineral soil that usually had a decalcified layer at its surface.

(ii) Plots 13—22. 400 metres of trench length typical of cutover conditions over morainic ridges and eskers. Undisturbed peat residues very shallow, 30 cm to 60 cm consisting of forest debris only, resting on mineral soil with a well-defined decalcified zone at the surface.

(iii) Plots 23—38. 650 metres of trench length of untypical deep cutover, the profile beneath the stripping layer consisting of 30 cm to 60 cm or more of older-sphagnum/eriophorum bog peat, a thick layer of large fossil pine (*Pinus sylvestris*) *in situ,* then sometimes another 30 cm of acid bog—or forest-peat, then some fen peat. Total depths of undisturbed peat 240 cm to 335 cm, over mineral soil of clay or silty clay texture showing no decalcification.

With reference to region (iii) above, this "untypical" deep cutover region is so named here on account of the presence within it of a thick layer of oligotrophic bog peat and of the pine layer, undisturbed. Normally on Bord na Mona spread grounds no such timber-layer is left *in situ,* nor is there any appreciable amount

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*Plot numbers for the various species appear on Table 1.

of acid peat, undisturbed. In fact, in the 1964-68 cutover peat surveys, less than 3% of the 8,000 ha covered were of this kind, and then only on parts of two bogs that probably have been cut more deeply since then.

Typically, deep sod-peat cutover following mechanical harvesting shows 150 cm to 270 cm *of fen peat only*, undisturbed, beneath the stripping layer. At Clonsast Trench 14, north end, however, a local basin caused an acute drainage difficulty which could not be overcome until a new outfall had been blasted through a bedrock uplift, clear of the plantation line, in the late fifties.

Following levelling, the area was pit-planted with various species and mixtures, one half of the area being fertilized with ground rock phosphate. Details, and early results, have been published (9). Results to date from this and later planting show that a wide range of species can be successfully established on sod peat cutover, and for several species production figures are well in excess of the national average (16 m^3/ha/annum for Sitka spruce in Ireland—see Table 1). In view of these high production figures, and some concern regarding the stability of plantations on peat, it was decided in 1972 to carry out a preliminary investigation into the rooting behaviour of the more important species.

Methods

Due to the time-consuming nature of root excavation it was necessary to restrict the sample to two carefully selected trees per plot. Pairs of adjacent dominant or co-dominant trees were therefore selected in fertilized plots. The excavation procedure involved the digging of a pit 3 m long by 2 m wide, beside the trees, so that one side of the pit approximately bisected the root systems. Excavation was done manually using spade, shovel, saw and penknife. The pit was deepened to at least 20 cm below the level of the general root system. Roots were cut off flush with the sides of the pit once their general pathways had been recorded.

To facilitate accurate sketching of the root systems a sheet of 500 gauge P.V.C. polythene was pressed closely to the side of the trench next to the trees being studied. Root distribution was then traced in on this using quick-drying felt pens. The boundaries between the various horizons in the profiles were traced in a similar manner. The sketches were worked up indoors with the aid of field notes. (See Figures 1-6).

Results

Data on the species investigated are presented in Table 1, and

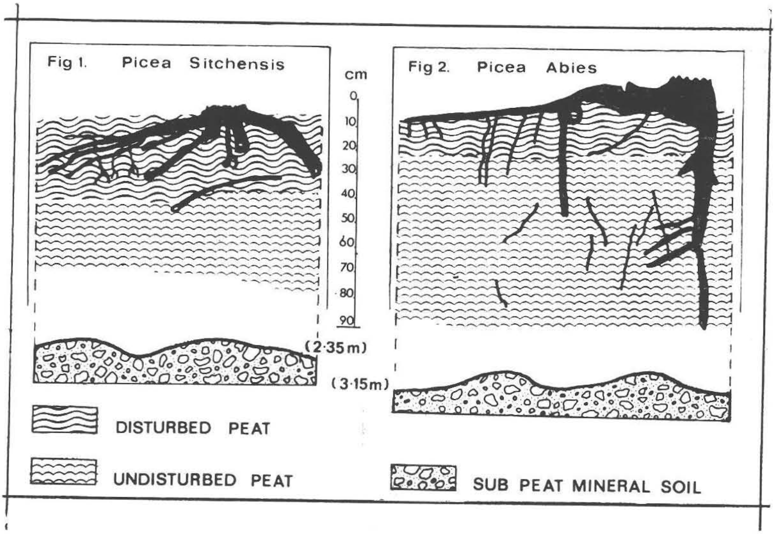


Fig 1. Picea Sitchensis
Fig 2. Picea Abies
cm
0
10
20
30
40
50
60
70
80
90
(2·35m)
(3·15m)
DISTURBED PEAT
UNDISTURBED PEAT
SUB PEAT MINERAL SOIL

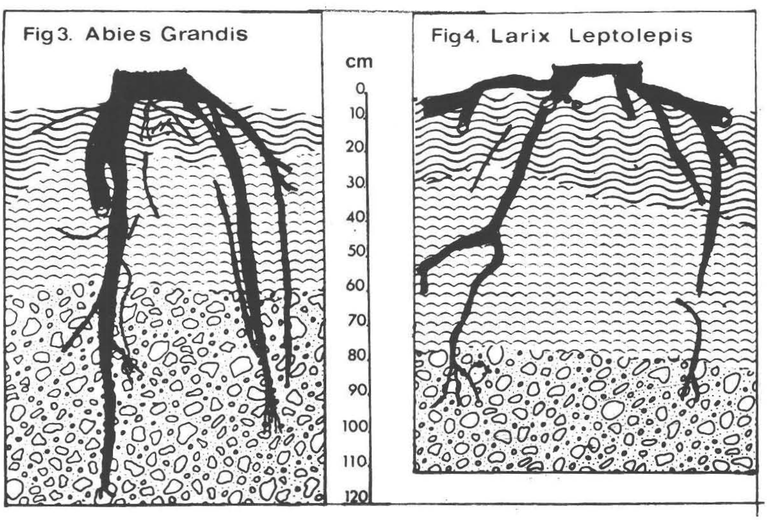
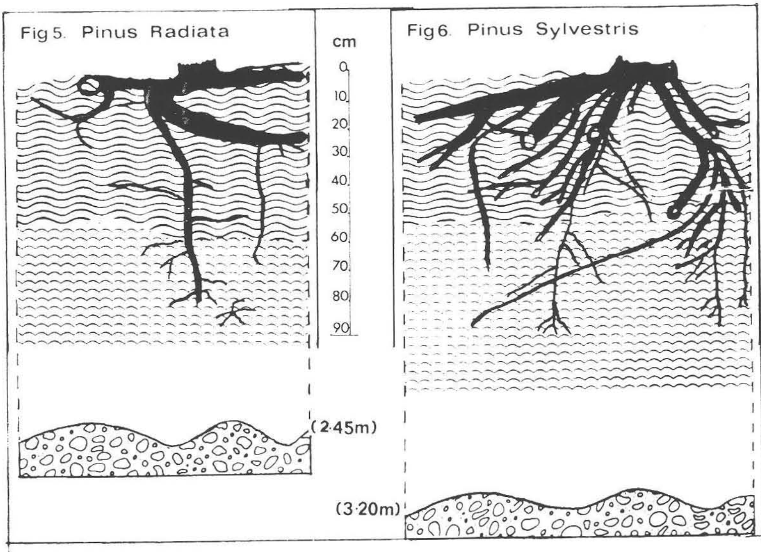


Fig3. Abies Grandis
Fig4. Larix Leptolepis
cm
0
10
20
30
40
50
60
70
80
90
100
110
120



the root-development records of some of them are shown in Figs. 1-6. Yield class was determined using Forestry Commission Management Tables (8).

The growth and root penetration of thirteen conifers were as follows, all aged eighteen years, except contorta pine which was nine years old, having been added later in the replanting of certain plots which had failed.

Grand silver fir (*Abies grandis*): The most productive conifer with a top height of 10 metres and a yield class (metric) of 22. Root-penetration 120 cm through 60 cm of birchwood peat in an A/B situation (see Table 1, Note 3), and then into 60 cm of compact mineral soil at first decalcified—pH 5.4 and then calcareous —pH 7.3 (Figs. 3 and 7). The lower 25 cm of the root system, which includes most of the fine feeding roots is in fact embedded in this calcareous layer.

Monterey pine (*Pinus radiata*). Top height 10.4 m, yield class 20 in a U situation. Roots penetrating 90 cm in a profile of 245 cm peat-depth, including 60 to 70 cm of undisturbed older-sphangum/eriophorum peat and an intact fossil pine layer (Fig.

5). Yield Class determined using Yield Tables for Corsican pine (*Pinus nigra*), as recommended by Hamilton and Christie (8).*

Norway spruce (*Picea abies*). Top height 9.5 m, yield class 20 where grown in mixture with Japanese larch on 145 cm of woody fen peat in a B situation; but drops to 14th place (yield class 10 and top height 5.4 m) in the U region further north. (Fig. 2 shows the latter situation).

Western red cedar (*Thuja plicata*). Takes fourth place with top height of 7.9 m and yield class 16; penetrating 63 cm into 65 cm of woody fen and forest debris, in an A/B situation.

Sitka spruce (*Picea sitchensis*). Top height 7.7 m, yield class 16 in mixture with Japanese larch on 80 cm of woody fen peat in a B situation; Drops to 15th place with yield class 10 and top height 5.0 m in the A region further north. (Fig. 1 shows the rooting system in the latter situation).

Western hemlock (*Tsuga heterophylla*). Top height 7.7 m, yield class 14, penetrating 75 cm into woody fen peat in a B situation.

Noble silver fir (*Abies procera*). Top height 7.2 m, yield class 14. Roots penetrating 60 cm through peat of woody fen/forest debris in an A/B situation, and then a further 30 cm into the underlying mineral soil.

Scots pine (*Pinus sylvestris*). Top height 8.4 m, yield class 12. Excellent root penetration (95 cm), growing on 320 cm of peat in the U region. (Fig. 6).

Serbian spruce (*Picea omorika*). Top height 6.1 m, yield class 12 with only poor penetration (40 cm) growing on 225 cm of peat in the U region.

Hybrid larch (*Larix eurolepis*). Top height 10.4 m, yield class 10. This is a shallow-peat (A region) where on 50 cm of peat, composed solely of forest debris, its roots went down only 40 cm.

Japanese Larch (*Larix leptolepis*). Top height 10.1 m, yield class 10. Grown pure on shallow peat (75 cm) in an A situation. Feeder-roots penetrating to 95 cm (Fig. 4—Plot 7). In mixture with Norway spruce on 145 cm of woody fen peat in the B region it reached a top height of 10 and a yield class of 10. Mixed with Sitka spruce on 80 cm of woodyfen within the same B region however, it drops to last place among the oldest conifers, with yield class 8 and top height 8.5 metres.

Douglas fir (*Pseudotsuga taxifolia*). Yield class 10, top height

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*A recent paper (7) has suggested the production of Monterey pine on a height/age basis, may be much lower than this.

TABLE 1
DATA ON CONIFEROUS SPECIES PLANTED IN 1955 ON TRENCH 14, CLONSAST BOG

	Growth Data			Edaphic Characteristics			Root Data		
Plot no. and species (assessed at age 18)	Top Ht. (m)	Yield class m³/ha/annum)	National Average yield Class[1]	Peat depth (cm)	Peat types in Profile[2]	"Natural Region" of cutover[3]	Depth to which main root mass penetrates (cm)	Max. rooting depth (cm)	Penetration into sub-peat mineral soil (cm)
(4) Grand silver fir	10.0	22	20	60	For	A/B	100	120	60
(29) Monterey pine	10.4	20	16	245	Bog/For	(U)	30	90	—
(9) Norway spruce (mixed with Japanese larch)	9.5	20	17	145	W.F.	B	15	85	—
(7) Western red cedar	7.9	16	13	65	For	A/B	15	63	—
(11) Sitka spruce (mixed with Japanese larch)	7.7	16	15	80	W.F.	B	30	80	—
(6) Western hemlock	7.7	14	19	85	W.F./For	B	20	75	—
(2) Noble silver fir	7.2	14	11	60	For/Min	B	20	75	—
(27) Scots pine	8.4	12	9	320	Bog	U	55	95	—
(31) Serbian spruce	6.1	12	—	225	Bog	U	15	40	—
(15) Hybrid larch	10.4	10	—	50	For/Min	A	10	40	—
(13) Japanese larch	10.0	10	8	75	For/Min	A	25	90	10
(9) Japanese larch (mixed with Norway spruce)	10.0	10	8	145	W.F.	B	10	50	—
(23) Douglas fir	7.7	10	13	200	W.F./Bog Transit-ion	B/U	30	45	—
(33) Norway spruce	5.4	10	16	315	Bog	U	10	55	—
(35) Sitka spruce	5.0	10	16	235	Bog	U	20	50	—
(11) Japanese larch (mixed with Sitka spruce)	8.5	8	8	80	W.F.	B	10	80	—

7.7 metres. At a transition between A (shallow) and U (untypical, deep) regions its roots went down 45 cm into 200 cm of peat; of which the top 35 cm were bog peat, then a fossil pine layer, followed by woody fen.

Contorta pine (*Pinus contorta*). No yield class estimation as yet, but showing excellent root development; through 80 cm of forest peat in an A/B situation, and a further 10 cm into the decalcified layer of the underlying mineral soil.

Discussion

On this site, considerable variation is evident in peat type, peat depth, rooting depths and timber production. Peat types vary as described earlier, with peat depths ranging between 60 and 320 cm; indicated production varies between 8 and 22 m^3/ha/annum.

1. Forest and Wildlife Service plantations.
2. Peat types in profile:
 BOG=Oligotrophic bog peat, in the present case older-sphagnum/eriophorum peat with fossil pine layer intact. Very well humified, more or less impermeable.
 WF =Woody fen peat, birchwood and non-sphagnum mosses, rather poorly humified, highly permeable.
 FOR=Peat composed solely of oak, yew and pine forest debris. Poorly humified, brittle and highly permeable.
 MIN=Mineral substratum. Here of glacial till, of Carboniferous origin.
3. The "natural regions" are those established during cutover peat surveys 1964-68 and described in Barry *et al.* (3) except that we have here an area of completely untypical deep cutover. This (U) situation is one which, if the sub-region had been cut to normal depth and developed as spread ground prior to tree planting, would have been transformed into a B/C or C area.

A regions of the cutover raised-type bog sof Ireland, following machine sod peat production, are those over convexities of the mineral floor having 30 to 60 cm of peat (or forest debris) resting directly on a mineral floor which shows a decalcified layer.

A/B situations are intermediate. Most often they are B-type profiles (see below) that have been cut unusually deep.

B regions, often on slopes of slight gradient, are characterised by the presence of 90-120 cm of undisturbed woody-fen peat resting on variable mineral soils, that may or may not show a decalcified zone.

B/C situations show mixed woody fen and reedswamp peats in profile.

C, D and E regions occur over concavities of the floor. With 120-275 cm. of reedswamp peat (character-plant *Phragmites* resting on (C) deep calcareous silt of silty clay, (D) shall marl or (E) sapropel.

U region is a term used in the present paper to denote untypical profile conditions in a particular area found to have much oligotrophic bog peat and an intact fossil pine layer, features which are normally absent from machine sod peat cutover.

Maximum rooting depths (the lowest points in profiles at which live roots were seen) vary between 40 and 120 cm.

It is noteworthy that of the first seven species in order of productivity (Table 1) six are growing in B or A/B situations, that is in woody fen or forest peats of fairly shallow or moderate depth, 60 to 145 cm. The exception is Monterey pine which, although growing in untypical oligotrophic bog peat of the U region, shows the second-greatest degree of root penetration of all the conifers on like ground (90 cm)—through to the underlying woody fen peat. Scots pine, in the same U region, has 95 cm root penetration, the maximum for any conifer in that kind of profile. Performance of the two most commonly grown and most important spruces, Norway and Sitka, seemed to depend on local profile conditions to a high degree. On typical woody-fen peat alone, of moderate depth (80-145 cm), they thrive; in the U region, where untypical undisturbed oligotrophic peat and a fossil pine layer intervened above the woody fen, growth with present treatments has been unsatisfactory.

Root development may be described, in general terms, in one of two ways (see Table 1 and Figures 1-6)—either by reference to the main roots, which provide anchorage, or to the feeder roots, "dippers" or "sinkers", which give access to soil moisture and nutrients. Many of the latter are not shown in the diagrams.

Referring first to main-root systems it is seen that grand silver fir is the outstanding tap rooter with tap and lateral roots large enough and deep enought to afford complete stability, on present showing. Several other conifers, notably noble silver fir and Scots pine are seen to be moderately deep-rooting (55-60 cm downward). Monterey pine, Sitka spruce (only when on woody fen) and Douglas fir are next-best—their main root masses penetrating 30 cm.

It could be suggested perhaps that any species whose main root-mass remains within 30 cm of the cutover surface, whether on deep or shallow peat, will be susceptible to wind-throw. This situation would be most pronounced in situations where this 30 cm level coincides with the disturbed/undisturbed peat junction. From Table 1 it would appear that all the conifers on Trench 14 whose root systems were examined, with the exception of the two silver firs and Scots pine, fall within this category. Yet when their root systems were examined more closely a significant number of sturdy developing roots were found descending at an angle of 45° or more steeply—even in Norway spruce (the classical flat-rooter) at least when growing on woody-fen (see Fig. 2). One might also recall that the trees in question were only eighteen years old at the time of the root-investigation. Further evidence for the optimistic view is perhaps provided by the absence of wind-throw so far, despite (e.g.) the gales of January 1974, in any of these quite small plots, of a mere 0.1 ha each.

When downward penetration by the finer feeder-roots is considered grand silver fir is again the leader, with 120 cm depth at least. Scots pine is next (95 cm); Noble silver fir, Monterey pine and Japanese larch (on woody fen) are next with 90 cm. These are followed by Norway spruce, 85 cm, and then Sitka spruce, both spruces only when on woody fen—and Japanese larch, with 80 cm penetration. On the other hand, Norway and Sitka spruce in the U region of deep *bog* peat show absolute penetration of only 50-55 cm. Serbian spruce in the same region shows only 40 cm absolute penetration, with its main root-mass lying only 15 cm below the surface.

It would appear that downward root development, particularly in the spruces, is strongly affected by some factor of the peat types in profile. This factor is very likely permeability, acting directly through the easier passage that open structure affords, and indirectly through the better drainage and hence lower water tables thus provided. At any rate there is excellent correlation between rooting depth and permeability of peat-type in profile, throughout Table 1, using Dowling's scale of values (6) and especially his findings that woody fen peat was the most permeable and older-sphagnum/eriophorum the least permeable of all those peat-types he tested. Clearly, on Tr. 14 leaving out of account the necessarily shallow rooting of larch species on the morainic ridge (A region); the deepest rooting systems, and the best growth generally to date, are associated with forest-peat and woody fen profiles whereas the poorest growth is associated with the untypical cutover, oligotrophic peat-profiles of the U region.

It should be borne in mind that the initial fertiliser treatment of the conifers in question was not up to the standard now adopted. Indications are not wanting from Trench 14 today, from later experimental plantings, that P and K at planting time may be the key to still better growth in the early years, even in the rather unsatisfactory U region.

Conclusion

Research work to date on Clonsast Bog has shown that a wide range of conifers can be established on machine-cutover sod peat bog of the Central Plain. For many of the species, production rates are well in excess of the national averages, and interim results from more recent experiments on the same ground suggest that potential production from certain conifers, in particular Sitka spruce and contorta pine of coastal provenance, may well exceed that now reported.

Of the seventeen root profiles recorded, thirteen had live roots at or below 50 cm from the surface, with indications that development downward will continue.

The most striking feature in the results is the deep penetration of the underlying mineral soil by the roots of *Abies grandis* (Fig. 3). Although this may appear surprising initially it should be borne in mind that fir species in general tend to develop tap like root systems and secondly, although the mineral soil beneath is derived from limestone boulder till its upper 30 cms. is acid in reaction (pH 5.4). However, the fact remains that most of the fine and persumably feeding roots are well below this acid layer in a medium with a pH in excess of 7.

This particular subpeat mineral fossil soil shows many affinities with the Grey Brown Podzolic soils of more upland areas and is the most commonly occurring mineral soil beneath the raised bogs of the Central Plain of Ireland (4, 5). Many of these soils are known to have supported forests of oak (*Quercus*), pine (*Pinus sylvestris*), yew (*Taxus baccata*) and alder (*Alnus*) prior to being encroached upon by the developing peat some three to five thousand years ago. Evidence for this is to be found in the presence of large numbers of fossil stumps embedded in the sub-peat mineral soils.

Acknowledgements

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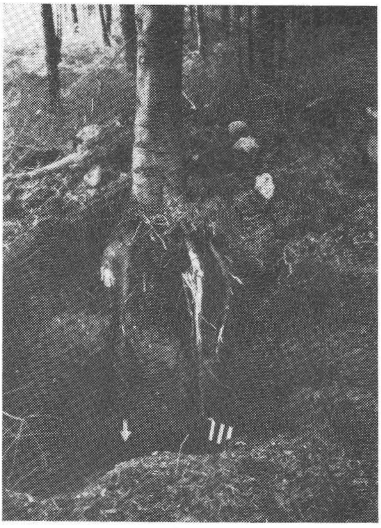

Fig. 7—Pit showing roots of *Abies grandis*