The Effect of Cultivation Method on the Growth and Root Anchorage of Sitka Spruce

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Summary
Tree pulling, using a hand winch, showed that 14 to 16 year old Sitka spruce trees, established on surface-water gley soils following mole drainage, had an average maximum turning moment almost double that of trees established on DMB plough ribbons. Root excavations showed that this was due to improved rooting depth and spread in the mole draining treatment. Mole draining gave better diameter growth than ploughing on drumlin slopes; on inter-drumlin flats it resulted in poorer growth.

Introduction
Surface-water gleys are the most productive forest soils in Ireland. In south Co. Leitrim, for example, the mean Yield Class of Sitka spruce is 24 cubic metres ha/year. These soils reach their greatest extent in the drumlin belt of the north midlands. Most of the land below 180 metres elevation in counties Cavan, Leitrim and Monaghan is comprised of drumlins.

In Ireland the great majority of gleys are surface-water gleys. These have high combined silt and clay contents (often exceeding 80%). This results in a predominance of small pores which restrict drainability, as these hold water at high tensions. There is, in addition, an annual surplus of rainfall over evapotranspiration in the drumlin region which leads to high water tables and surface run-off. Ground water gleys occur along valley bottoms, where they are caused by springs and upward seepage of groundwater but these are necessarily limited in extent.

All gleys present problems for agriculture. Tillage is rarely practised due to the heavy nature of the soil and grazing is generally limited to the period May to September owing to soft ground conditions and the danger of poaching. In addition, the steep slopes of many drumlins (often exceeding 12°) makes forage harvesting difficult and expensive. These factors, combined with the small average farm size, have resulted in a movement from the land in the drumlin counties, with holdings often being sold for forestry development.

Large scale forestry development began in this region in the late 1950s. Ploughing was the cultivation method used, although some early private plantations, such as at Drumheirney in Co. Leitrim, were successfully established using hand mounding. From an early stage, however, it was realised that ploughing might lead to extraction difficulties during thinning. It was also observed that when crops were windthrown that the supporting roots were largely confined to the plough ribbon and their spread was severely restricted on the side of the plough furrow.

A research programme was initiated in 1971 to examine a range of site preparation treatments, with the objective of improving root spread and depth and ultimately of making crops more windfirm. This programme was extended to include root excavations and more recently, tree pulling to determine root anchorage, on which this paper reports.

Methods

1. *Field experiments*

A large number of drainage/cultivation trials was established on surface-water gleys between 1971 and 1980. Three of these are described: Ballyfarnon 1/71, Cuilcagh 2/73 and Scotstown 1/74 (planted in 1971, '73 and '74 respectively). All are located within the drumlin region (Figure 1). Six treatments were included in each trial. Two of the treatments were variations in planting position and as these did not result in any appreciable growth differences they are omitted from discussion. Descriptions of the other four treatments are given in Figure 2. Each experiment has three randomised blocks; two of the blocks in each case are located on the drumlin slope, the third on the inter-drumlin flat. This has implications for the performance of some of the treatments which are discussed below. The slopes of the drumlins in question vary from 7° to 12°. In each case Sitka spruce 2+1 transplants were planted on top of the ribbon or into the mole slit at an espacement of 2m×2m.

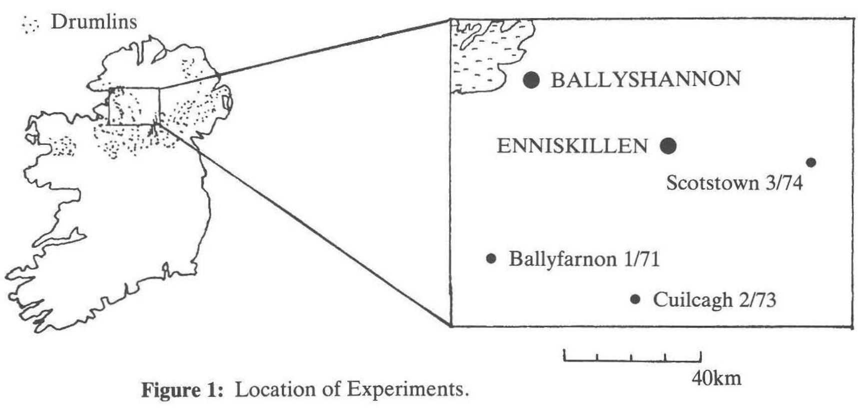

Figure 1: Location of Experiments.

TREATMENT | DESCRIPTION

Control (not cultivated)

Single mouldboard ploughing (SMB)

Double mouldboard ploughing (DMB)

Mole drainage

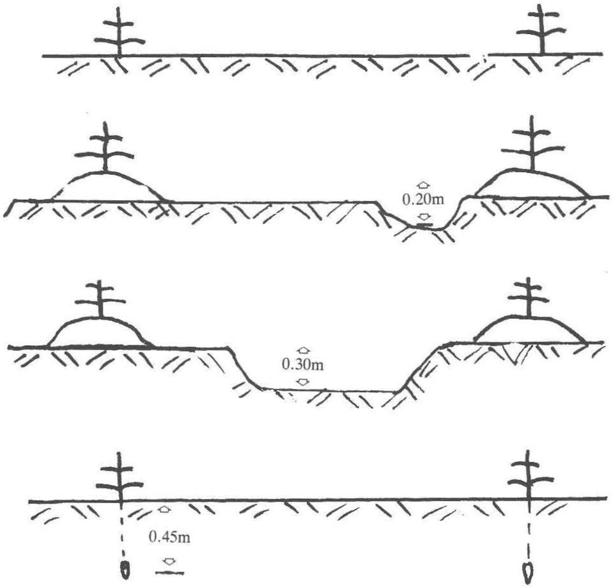

Figure 2: Site Preparation Treatments.

2. *Root excavations*

All of the root excavations were carried out at Ballyfarnon in 1985 following a 1 in 3 line thinning. Two stumps were chosen at random in each block in the DMB and mole treatments. The soil was first removed to a depth of 300-400mm around the main structural roots. These were then cut at 800mm from the centre of the stump which was then winched vertically from the ground using a block and chain tackle mounted on a horizontal beam supported at either end. The root systems were described and photographed.

Table 1: Number of trees pulled by experiment and treatment.

EXPERIMENT	TREATMENT	
	MOLE	DMB
Ballyfarnon 1/71	5	5
Cuilcagh 2/73	9	9
Scotstown 1/74	7	7
Total	21	21

3. *Tree pulling*

Tree pulling was carried out at the three experiments, Ballyfarnon in May 1987 and at Cuilcagh and Scotstown in June 1988 (Table 1). The mean diameter breast height (dbh) of the DMB treatment was first determined in each block. Two trees per block of the mean dbh size were then chosen for pulling in both the DMB and mole draining treatments. Each tree was cut at about 4m above ground level to avoid having its crown caught up in adjoining trees during pulling. A point of attachment for a nylon sling was marked on the tree, usually below the top-most remaining whorl to keep the sling from slipping off the stem. The vertical distance to ground level was measured. The sling was hooked to a wire rope and fed through a hand winch which was attached to an anchor tree, chosen at the same elevation as the object tree and about 20m distant from it. Trees were pulled at right angles to the direction of ploughing and away from the plough furrow. A load cell was placed between the winch and the anchor tree to measure the pulling force (F) on the object tree. The force was recorded at predetermined 10 second intervals using a single channel data logger and printer (Figure 3). Using the distance (D) of the anchor tree to the object tree and the height of attachment (H) of the sling the horizontal pulling force on each stem was derived as:

$$F(h) = F \cos \frac{(H)}{(D)}$$

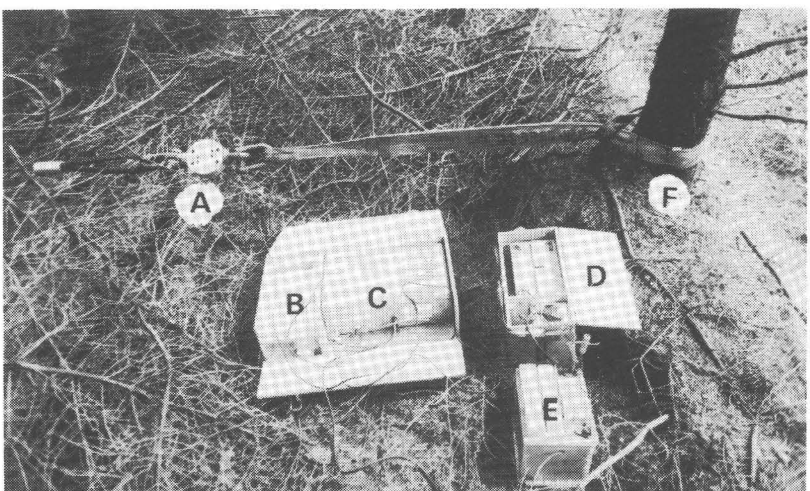

Figure 3: Equipment used to measure pulling force, A: Load Cell, B: Printer, C: Data Logger, D: Battery, E: Back-up Battery, F: Sling attached to anchor tree.

Trees were gradually winched over until either the tree was uprooted or the stem broke. The maximum force recorded during the pulling was then used to calculate the maximum turning moment for each tree.

Results

1. *Growth*

Basal area was assessed in all three experiments at the end of 1987. At Cuilcagh and Scotstown there was little difference between SMB, DMB and mole treatments but all three were significantly (P=0.05) better than the control; at Ballyfarnon the differences were not significant (Table 2).

Table 2: Effect of site preparation treatment on basal area production.

Treatment	SITE			Mean
	Ballyfarnon 1/71	Cuilcagh 2/73 m^2/ha end 1987	Scotstown 1/74	
Control	35.46	13.92	30.33	25.57
SMB	37.57	29.98	48.90	38.82
DMB	38.93	29.11	42.05	36.70
Mole	38.36	31.00	46.52	38.62

Mole draining gave better growth than DMB on the drumlin slopes but poorer growth on the inter-drumlin flats (Table 3).

Table 3: Effect of location on growth differences between moling and ploughing.

SITE	Inter-drumlin flat 1 block		Drumlin slope 2 blocks	
		R		
Ballyfarnon 1/71	-0.11		0.14	0.05
Cuilcagh 2/73	-0.18		0.34	0.22
Scotstown 1/74	-0.10		0.55	-0.07
Mean	-0.13		0.21	

$$R = \frac{\text{mole draining plot basal area - DMB plot basal area}}{\text{DMB plot basal area}}$$

Student's t (slope v flat)=3.02 (significant at P=0.05 level)

2. *Rooting*

There were consistent visual differences in both root spread and depth. Root spread in the DMB treatment was largely confined to the plough ribbon and the inter furrow flat. In the mole draining treatment roots grew

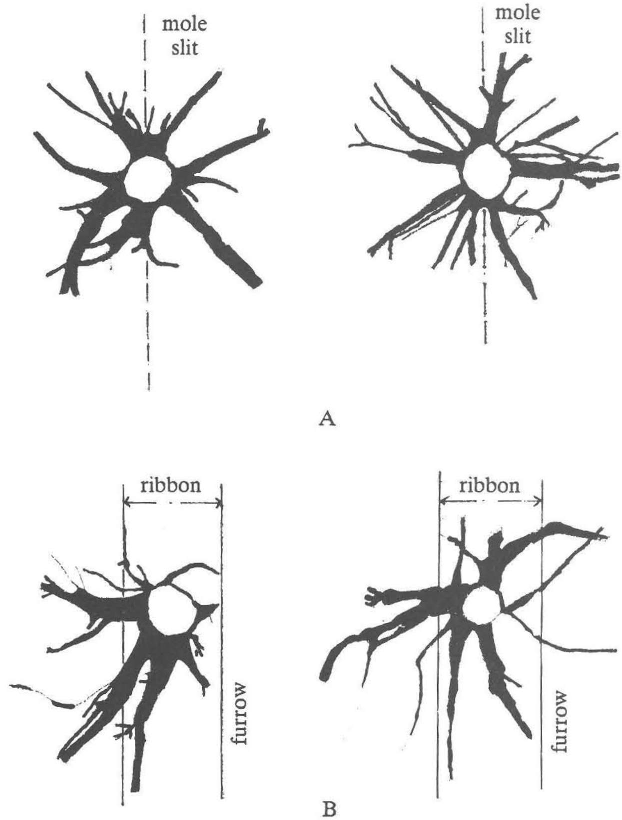

Figure 4: Typical root patterns shown in plan for A – Mole Draining and B – Double Mouldboard Ploughing.

in all directions and the root system therefore had a more symmetrical shape in plan (Figure 4). Roots grew down to the level of the mole and in a 10-15cm wide band along the mole slit. In the DMB treatment roots grew down to the level of the bottom of the furrow and no deeper.

3. *Tree Pulling*

All trees pulled in the DMB treatment at the three sites were successfully uprooted by pulling. At Cuilcagh, however, the stems of four of the eight trees in the mole draining treatment snapped near ground level. This also occurred in one of the mole draining treatment trees at Scotstown (Figure 5). The force on the stems in both the DMB and mole draining treatment increased steadily for about 100 seconds pulling (the strain rate was about 0.02 to 0.03m s^{-1}). Thereafter the force either remained static or slowly declined in the DMB trees but increased steadily in most of the mole draining trees until uprooting or stem breakage occurred (Figure 6). At all three sites the maximum turning moment in the mole draining was significantly greater than in the double mouldboard treatment ($P=0.001$) (Table 4).

Table 4: Maximum turning moments of Sitka spruce in DMB and mole draining treatments.

Site	Maximum turning moment (kNm)	
	Mole	DMB
Ballyfarnon 1/71	18.5	10.0
Cuilcagh 2/73	21.9	11.5
Scotstown 1/74	17.1	12.0
Mean	19.5	11.3

Figure 5: Stem snap near ground level in mole draining treatment at Scotstown.

The maximum turning moments obtained are similar to those obtained by Blackburn *et al.* (1988) for Sitka spruce growing on ploughed peaty gley in south Scotland. Using their equation relating dbh to turning moment (maximum turning moment (kNm)=0.0016 dbh^3+2.61) predicted and measured turning moments can be compared for trees in the present study (Table 5).

Table 5: Measured and predicted turning moments for Sitka spruce

Site	**Treatment**	**DBH** cm	**Maximum Turning Moment** kNm	
			Measured	Predicted*
Ballyfarnon 1/71	DMB	16.0	10.0	9.2
	Mole	16.0	18.5	9.2
Cuilcagh 2/73	DMB	14.5	11.5	7.5
	Mole	14.5	21.9	7.5
Scotstown 1/74	DMB	16.4	12.0	8.0
	Mole	16.4	17.1	8.0

* Using Blackburn *et al.* equation.

The Blackburn *et al.* equation was statistically valid for the DMB treatment at Ballyfarnon and Scotstown. It underestimated the maximum turning moments, however, for the DMB treatment at Cuilcagh and for the mole draining treatment at all sites. Trees in the mole draining treatment had a different relationship between maximum turning moment and dbh. There was an almost linear increase in force with increasing strain until uprooting or stem breakage occurred (Figure 6).

Discussion and Conclusions

Mole draining resulted in deeper and more symmetrical rooting than DMB ploughing and this was reflected in the doubling of maximum turning moments measured. Trees in the DMB treatment had their maximum turning moment accurately predicted by the Blackburn *et al.* equation, except for those at Cuilcagh. Turning moments estimated by static pulling tests are useful for comparison between treatments but do not, however, simulate the effect of windloading. Windloading is a dynamic process which results in high instantaneous bending moments. Milne (personal communication, 1989) estimates that an 18ms^{-1} (65km/hour) wind imparts a turning moment of up to 30kNm at the bottom of a 15m tall Sitka spruce tree of 15cm dbh.

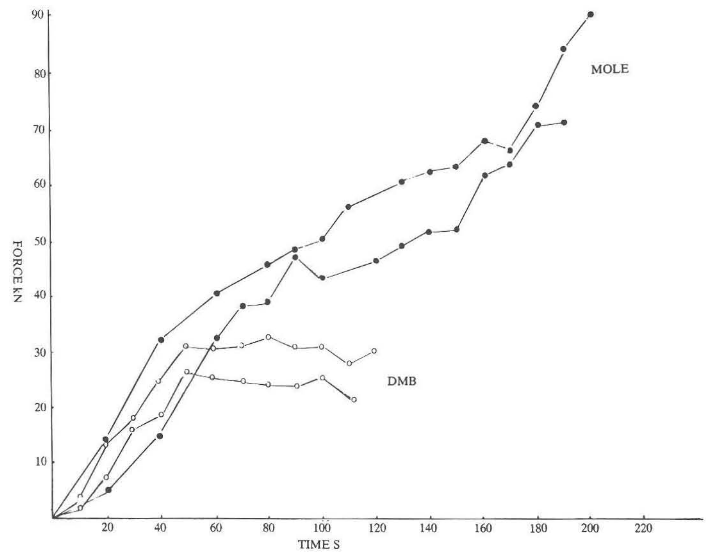

Figure 6: Plot of Force against Time for two DMB and two mole draining trees at Cuilcagh 2/73. All trees 14.5cm dbh. Both trees in the mole draining treatment snapped near ground level.

The constant loading and unloading of soil from winter gales can be simulated under laboratory conditions. In a study of soil from Ballyfarnon 1/71, Rodgers *et al.* (1988) found that cyclic loading, such as is encountered under root plates, reduced soil shear strength by half. Observations lend support to this finding as windthrown trees on gleys frequently have little root breakage and roots appear to have been torn from the soil and are often damaged only at their extremities, probably as a result of rocking. The measurement of forces imparted to soil under root plates is the objective of a study under way at present.

Recommended Practice

Mole draining works best on fine textured gley soils where the clay content exceeds 45% and the sand content is less than 20% (Nicholson, 1972). At Ballyfarnon, however, the soil failed to meet both criteria but the moles are still discharging water 18 years after installation. Observations suggest that soils with clay contents from 30% to 50% are suitable for moling. The minimum gradient for moling is 4%, at lower values small depressions and large stones lead to ponding of water. The optimum depth is 400 to 450mm. Collector drains to collect the water running in the moles are essential and should be 100 to 150mm deeper than the moles.

Acknowledgements

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