Effect of Ploughing Direction and Method on the Stem Form of South Coastal Lodgepole Pine

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ABSTRACT

The effect of ploughing direction and method on the stem form of lodgepole pine was assessed in two replicated field experiments on low level blanket peat in Co. Mayo. Four ploughing directions were tested: NE/SW, E/W, SE/NW and S/N. Ploughing in the SE/NW direction, at right angles to the prevailing wind, produced three times the amount of stem lean as in the treatment ploughed parallel with the prevailing wind. Three ploughing methods were compared: open furrow ploughing at 1.83 and 3.66m spacing and tunnel ploughing. Tunnel ploughing, a form of subsurface drainage, resulted in significantly less sweep than the open furrow methods.

INTRODUCTION

Over the past 30 years about 80,000 ha of blanket peat have been afforested in the west of Ireland. The two main species planted have been lodgepole pine and Sitka spruce. Although a variety of provenances of lodgepole pine were planted up to 1968, since then coastal provenances from Washington and Oregon have generally been used. Growth rates for these provenances on blanket peat vary from 12-18m^3/ha/year at maximum MAI.

Most of the west of Ireland is extremely windy with a mean annual wind speed of 6-7 metres/second. In addition gales occur frequently with an average of 34 days with gales each year. (Rohan, 1975). Precipitation of 1,500mm or more is spread evenly through the year. Drainage is, as a result, essential to successful afforestation. Open furrow ploughing, creating shallow ditches 25-30cm deep at 4m spacing, is the normal drainage method but in recent years tunnel ploughing (O Carroll *et al* 1981) is being used to a greater extent. Both techniques leave peat ribbons which are usually continuous, although they are frequently broken when extruded from the tunnel plough, expecially where the peat is well humified. Trees are planted on the top of the ribbon, usually by making a slit in the peat and firming-in the plant. During the early years, roots tend to concentrate in the well aerated peat ribbon. These eventually form the main supporting roots and the main stem and structural roots take on an inverted T-shape (Fig 1). Few roots cross the furrow

Fig 1. Typical inverted T-shape of stem and roots of lodgepole pine at Gweesalia 1/64 (Bangor Erris Forest).

bottom even after canopy closure and those that do are of small diameter and give little or no support to the tree. The purpose of this paper is to discuss results from two experiments which show the effect of root alignment on stem form and to make recommendations as to how stem form can be improved.

METHODS

Two experiments were established in 1964 and 1967 to examine the effect of ploughing direction and method respectively on the growth and stem form of lodgepole pine and Sitka spruce.

Experiment 1

Gweesalia 1/64 (Bangor Erris Forest), is located in north-west Co. Mayo (national grid reference F75 22) within 200m of the shore of Blacksod Bay at about 5m above sea level. Exposure is severe (tatter flag readings at Belmullet synoptic weather station gave a mean tatter rate of 5.1cm^2/day for the period February '81 to September '83). The vegetation over the general area before ploughing consisted mainly of *Molinia caerulea, Schoenus nigricans, Calluna vulgaris, Erica cinerea* and *E. mediterranea.* The soil is blanket peat with a small admixture of wind blown sea sand. The object of the experiment was to examine the effect of ploughing direction on tree growth under conditions of severe exposure. There were four ploughing directions: NE/SW, E/W, SE/NW and S/N. The site was ploughed by a double mouldboard Cuthbertson plough in 1963. Planting took place the following spring into V-shaped notches cut to half the height of the ribbon with the apices facing SE, S, NE and E respectively. Both Sitka spruce and lodgepole pine of Washington coast origin were planted in two separate 4 x 4 latin squares. Plot size in each case was 40.2 x 20.2m. Plant spacing was 1.83m (6 feet) along the ribbons which were 1.83m apart. Following ploughing an initial fertiliser treatment of ground rock phosphate supplying 36 and 18kg P/ha was applied to the spruce and pine respectively. Copper was also applied at 2.8kg Cu/ha to both species. A further fertiliser treatment supplying 91kg P/ha and 150kg K/ha was applied in August 1969.

Experiment 2

The second experiment, Glenturk 8/67 (Glenamoy Forest), is also located in north-west Co. Mayo, 14km north-west of Experiment 1 (national grid reference F 86 29). The site has an elevation of 15m and a slope of 1°. Exposure is moderate. The vegetation before ploughing consisted mainly of *Calluna vulgaris, Erica tetralix, Schoenus nigricans,* with the occasional *Myrica gale.* The soil is blanket peat, about 1.5m deep which is typical of much of the North Mayo area. The object of the experiment was to compare the effects of tunnel ploughing and single and double mouldboard Cuthbertson ploughing on the establishment and growth of Sitka spruce and lodgepole pine. The ploughing treatments were carried out in 1966 as follows:

1. Tunnel ploughing at 3.05m (10 feet) spacing. A line of mounds was cut from each tunnel ribbon and placed mid-way between ribbons. Plants were planted 1.83m (6 feet) apart on the ribbon and mounds resulting in a 1.83 x 1.52m spacing.
2. & 3. Double and single mouldboard Cuthbertson ploughing at 3.66m (12 feet) and 1.83m (6 feet) spacing respectively. In both treatments, plants were 1.52m apart on the plough ribbon.

The ploughing treatments were replicated in four randomised blocks with two plots of tunnel ploughing each so that the tunnel plough was replicated eight times. However, there was only one replicate of each of the Cuthbertson ploughs in each block. The ploughing plots, each 27.4 x 18.5m (0.05 ha) were split equally for the two species. The lodgepole pine was of south coastal origin (Oregon or Washington) derived from seed collected in a stand in Cloosh Valley forest, Co. Galway. Initial fertiliser treatment was a spot application of ground phosphate supplying 36 and 18kg P/ha to the spruce and pine respectively. This was followed in October 1972 with a broadcast application which supplied 90kg P, 150kg K and 4kg Cu/ha.

Measurement of basal sweep and direction of lean

In August 1979 stem form and direction of lean were measured at Gweesalia. This was confined to the lodgepole pine since there were no apparent differences in stem form between Sitka spruce treatment plots. Stem form was assessed by measuring the horizontal deviation of the stem 60cm above the centre of the stem base. Twenty trees were measured in each plot. The same trees were also assessed for direction of lean. Direction was assigned to one of the eight cardinal bearings. A further assessment of stem form was carried out in February 1983 at Glenturk and Gweesalia and again was confined to the lodgepole pine. This was done measuring the horizontal distance from the centre of the stem base to the point where the stem became vertical (Fig 2). This point was found using a height rod with a spirit level attached and the horizontal distance was measured to the nearest decimeter. Every third tree in a 20 x 20m assessment plot in the centre of each sample plot was measured. Trees with broken tops and dead trees were omitted and the next tree measured instead. An average of 27 trees were measured in each assessment plot.

Fig 2. Method of measuring maximum stem deviation from the vertical.

Wind direction frequency

Wind direction frequency data are collected at Belmullet synoptic weather station which is about 14km from both experiment sites. Data are presented as the number of simultaneous occurrences of specified ranges of mean hourly wind speed and direction. The period of measurement investigated was from January 1963 to December 1982. Frequencies of wind direction, including all wind speeds up to 28 metres/second (55 knots/hour), blowing to each of the eight cardinal bearings, were then calculated.

RESULTS

Ploughing direction

Ploughing direction had no effect upon survival or growth at Gweesalia up to the end of the 15th growing season (1978). However, the basal sweep assessment taken in 1979 showed quite large and significant effects. The amount of lean in the SE/NW treatment was almost twice that in the NE/SW treatment (Table 1).

Table 1: Effect of ploughing direction on stem form at Gweesalia 1/64.

Ploughing Direction	Deviation from vertical at 60cm height m
NE/SW	0.22
E/W	0.34
SE/NW	0.40
S/N	0.34
Standard error of difference	0.061
NE/SW v SE/NW F = 8.54 significant at P 0.05 level	

The 1983 stem form assessment showed the same trend but the magnitude of the differences was much greater with up to three times the amount of lean in the SE/NW treatment than in the NE/SW treatment (Table 2).

Table 2: Effect of ploughing direction on stem form at Gweesalia 1/64.

Ploughing Direction	Horizontal distance to vertical stem m
NE/SW	0.70
E/W	1.30
SE/NW	2.10
S/N	1.30
Standard error of difference	0.37
NE/SW v SE/NW F = 11.12 significant at P 0.05 level	

Ploughing method

At the Glenturk experiment, tunnel ploughing improved the growth of lodgepole pine compared to both double and single mouldboard (O Carroll *et al* 1981). Stem lean was affected by ploughing method. Tunnel ploughed plots had significant less lean than open furrow ploughed plots (Table 3).

Table 3: Effect of ploughing on stem form at Glenturk 8/67.

Method	Horizontal distance to vertical stem m
DMB	0.44
SMB	0.39
Tunnel	0.34
Open furrow v tunnel F = 6.76 significant at P 0.05 level	

Ploughing direction was not, however, consistent between blocks. In two blocks ploughing was at 30°/210°and in the other two at 110°/285°. Because of the complete confounding of direction with blocks it is not possible to test the hypothesis regarding wind direction, nevertheless the maximum deviation in the ploughing treatments in the blocks ploughed at 30°/210° was on average 0.37m, whereas in the other blocks ploughed at a more oblique angle to the prevailing wind it was 0.47m.

Wind direction frequency

The modal wind direction for the measurement period was 220°, almost due SW/NE. Wind direction frequencies together with the proportion of trees leaning in the same directions are shown below (Fig 3). Most trees were leaning away from the direction of the prevailing wind and only four from the total sample were leaning in a SW direction.

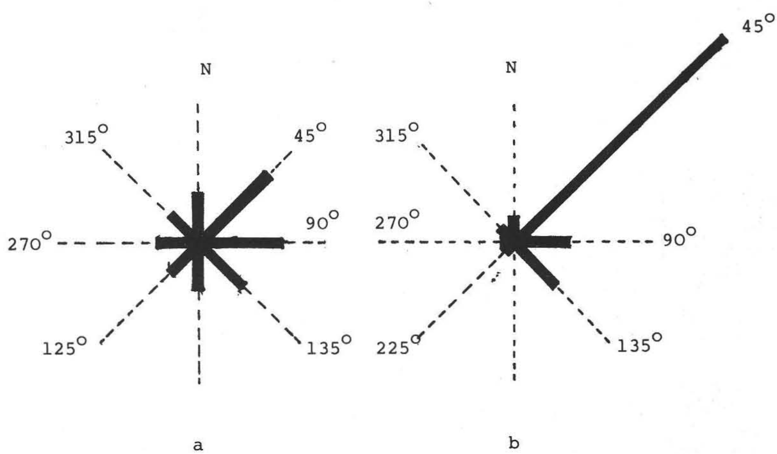
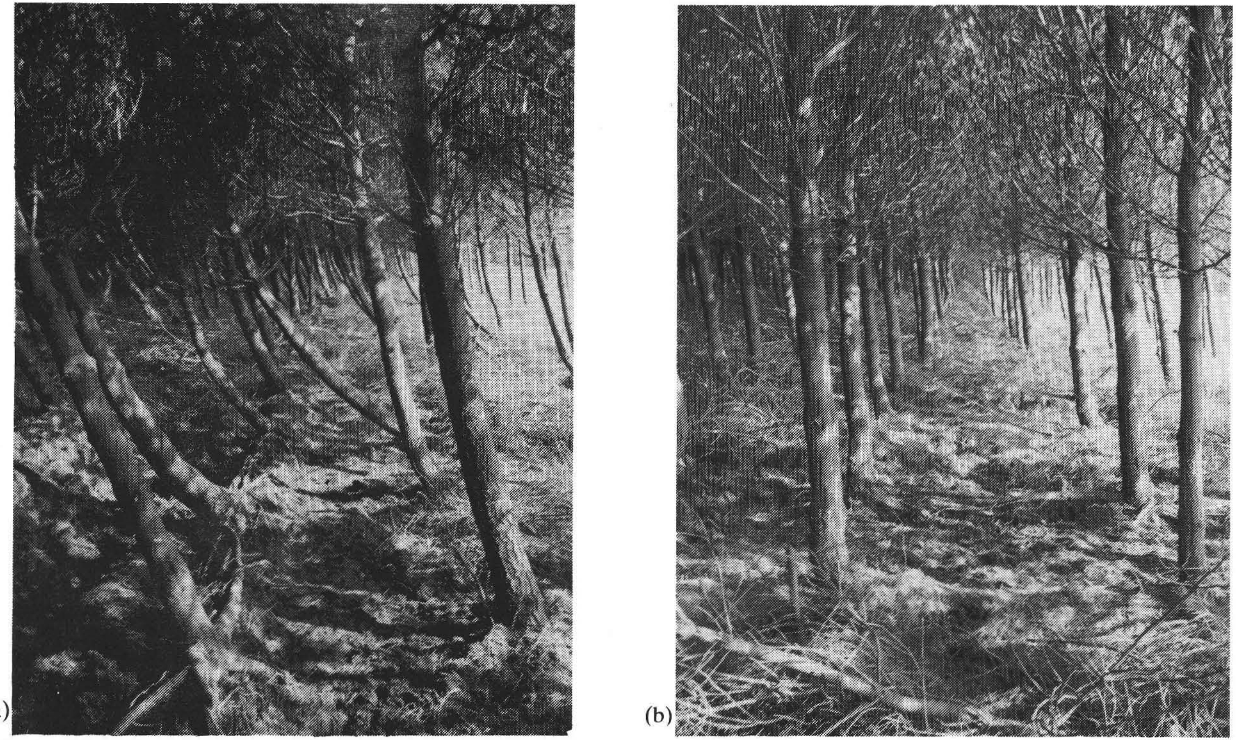


Fig. 3. (a) Frequencies of wind blowing to each of the eight cardinal bearings at Belmullet synoptic weather station (January 1963 — December 1982) and (b) proportion of trees leaning to each bearing.

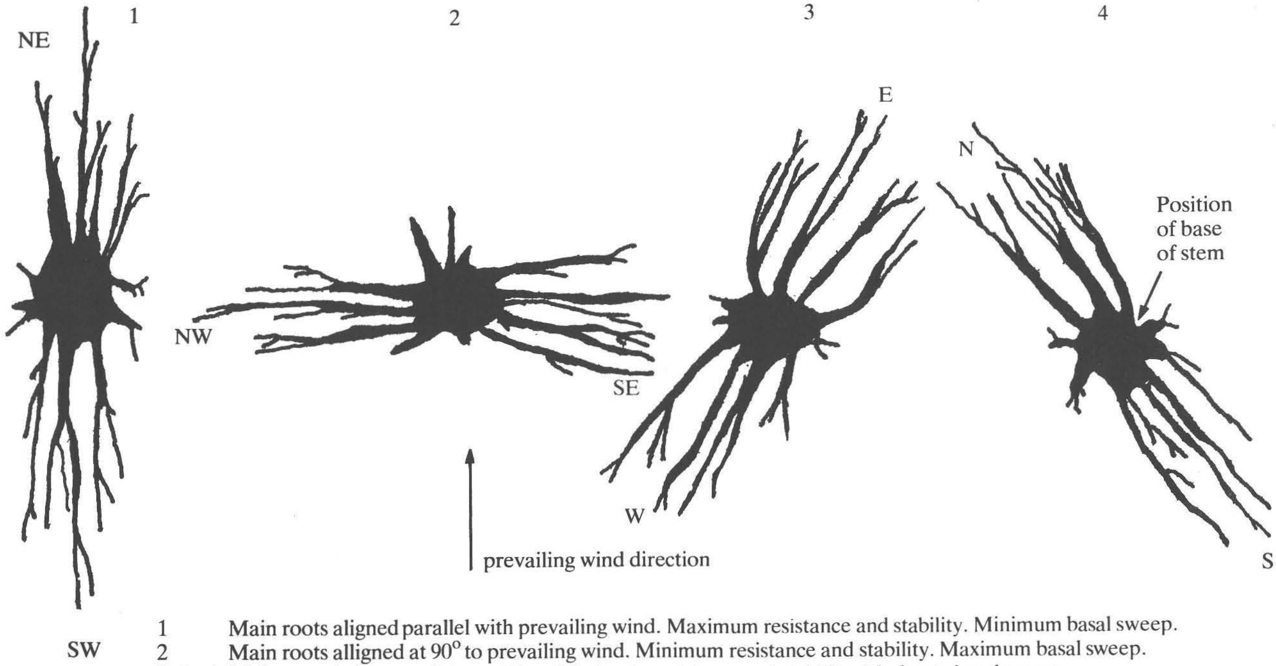
DISCUSSION

Lodgepole pine of the south coastal provenance is particularly susceptible to basal sweep. The main predisposing factors appear to be low root/shoot ratios of transplant stock, method of planting and type of ground preparation (Pfeifer 1982). Plough ribbons encourage the development of roots in the direction of ploughing. Trees lean away from the prevailing wind (Fig 3) and where root support is in that direction it is to be expected that there will be more resistance to lean than where roots are running at oblique angles. This is confirmed in the results shown in Tables 1 and 2. It can be seen that the greatest deviation from vertical is associated with the ploughing direction SE/NW, which is at or near right angles to the



(a) (b)

Fig 4. Ploughing a) at right angles and b) parallel to the direction of the prevailing SW/NE wind at Gweesalia 1/64 (Bangor Erris Forest).



1 Main roots aligned parallel with prevailing wind. Maximum resistance and stability. Minimum basal sweep.
2 Main roots alligned at 90° to prevailing wind. Minimum resistance and stability. Maximum basal sweep.
3 & 4 Main roots in intermediate position. Moderate resistance and stability. Moderate basal sweep.

Fig 5. Relationship between main root aligment (resulting from alignment of plough ribbon), wind direction, and severity of basal sweep in a lodgepole pine crop.

prevailing wind. This gives the inverted T-shaped tree/root systems aligned in the most unstable direction, with little or no structural support in the necessary direction. Least deviation is associated with ploughing which is alligned parallel with the prevailing wind direction (SW/NE) thus giving a tree/root system having maximum support in relation to that direction. The other two ploughing directions, being at about 45°deviation from the prevailing wind, are intermediate in their effects (Figs 4 and 5). Some indication of the severity of lean and the difference between ploughing parallel and at right angles to the direction of the prevailing wind is shown in Fig 4.

Method of ploughing is also important in relation to stem form. Cutting the ribbons in the tunnel-ploughed treatment at Glenturk resulted in roots spreading in all directions (Hendrick, 1978) which in turn gave greater support and less sweep (Table 3). While this difference is significant, it is small when compared with the differences between ploughing directions at Gweesalia. It is likely, however, that on exposed sites tunnel ploughing would result in a considerable improvement in stem form.

Stem malformations of the kind described above reduce timber yield because of difficulties in sawing. The compression wood that results reduces chemical pulp yield and timber quality following drying (Low, 1964). As a result, the improvements in form described will have important economic consequences. Stem form can be improved by using tunnel ploughing wherever feasible and ensuring that ribbon breakage occurs as much as possible.

Where open furrow ploughing is resorted to it is recommended that it should be in or as close as possible to the direction of the prevailing wind, after taking other considerations, such as slope, into account.

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