WIND-DAMAGE PROFILES IN A PINUS RADIATA STAND

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ABSTRACT

A recent example of wind damage in a **Pinus radiata** D. Don stand on the Canterbury Plains clearly demonstrated that:

(1) Wind-damage was greater in the immediate lee of two exposed stand edges. One edge was caused by adjacent open ground and the other by a taller stand to windward.

(2) There were turbulent eddies and high-force backdrafts in the lee of a tall relatively non-porous stand.

INTRODUCTION

Strong nor'west Föhn winds that have from time to time damaged pine plantations are a feature of the Canterbury Plains. Somerville (1980) examined this wind damage and discussed the phenomenon he termed "edge effect". Edge effect is the localised increase in potential for wind damage in and immediately in the lee of exposed windward stand boundaries that confront high-force winds. Such exposed stand boundaries are created by wide breaks and abrupt increases in stand height.

Many workers (e.g., Caborn 1957) have modelled the turbulence and backward eddying flow of wind in the lee of relatively impermeable stands and shelterbelts.

This paper reports examples of both the eddying flow of wind in the lee of a tall stand and the "edge effect" phenomenon as they occurred in a young stand of *P. radiata,* damaged by high-force winds on 3 January 1980.

Site

The damaged stand, which is part of North Canterbury Catchment Board's Shellocks Block, is a narrow 280-m wide × 750-m long strip of 1974-planted *P. radiata.* Topography is flat and soils are shallow and lie over compacted gravels. The stand is located several kilometres inland from the main highway south and is approximately equidistant from Christchurch and Ashburton. The damage-causing south-westerly wind intersected the 750-m long, windward, stand boundary at approximately right angles. Of this boundary, 200 m lie downwind from open ground. The remaining 550 m lie downwind from a taller *P. radiata* stand, separated from it by a 15-m wide break. The taller stand (18 m high and stocked at about 700 stems/ha) was not damaged by the storm. The whole downwind boundary of the damaged stand borders open ground. It has five large slash-windrows (7–10 m across and 1.5–2.5 m high) running along its length. Tree spacing is approximately 3.7 m between rows by 2 m within rows, and tree rows are parallel to windrows. At the time of wind damage, tree heights averaged 3–4 m with some trees as high as 5 m. *Acacia dealbata* Link. regrowth had been removed from the stand 2 months beforehand. This may have contributed to the wind damage but is unlikely to have affected its distribution since the growth was even over the whole stand (W. P. Studholme, Plantation Board Manager, pers. comm.).

METHODS

A ground assessment of 274 plots of 20 trees each (i.e., about 22% of all trees) recorded the number of damaged trees and the direction of tree lean and tree fall. Plots sampled the whole stand but were more concentrated in the areas with the greatest damage. Vertical aerial photographs were taken to assist the damage survey.

The stand was divided into two strata: Stratum 1 – that part of the stand downwind from open ground; Stratum 2 – that part of the stand downwind from the larger stand. Damage profiles were examined (i.e., percentage damage by distance downwind) for both strata. Trees that had fallen or were leaning to the extent that their value in the final crop would be significantly impaired were considered damaged.

RESULTS

The damage profiles for both strata are very similar (Fig. 1). Only in the fifth inter-windrow was there a significant difference between strata in damage figures (Chi-square test, $p < 0.05$) with means of 18% damage for Stratum 1 and 28% damage for Stratum 2. There were large differences in damage between inter-windrows for the two strata, as the profiles in Fig. 1 show.

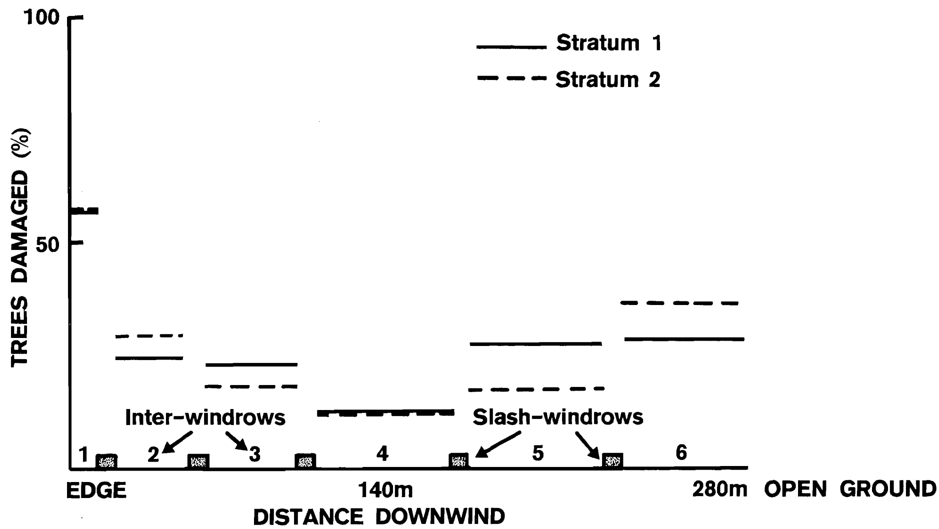

FIG. 1—Damage profiles (average percentage damage for each inter-windrow by distance downwind): Stratum 1 = stand downwind from open ground; Stratum 2 = stand downwind from taller stand.

An analysis was carried out by strata for inter-windrows 2, 3, 4, and 5, comparing the damage to the row of trees to windward of the windrow with the damage in the inter-windrow. Of the eight examples tested, five showed significantly more damage in the row of trees to windward of the windrow.

The mean directions of tree fall and lean by strata for each inter-windrow are given in Table 1.

TABLE 1—Percentage of fallen trees by position, direction, and strata

Orientation of fallen trees	Stratum*	Distance downwind					
		Edge			140 m		112 m
Upwind	1	1	0	0	0	0	0
	2	26	7	1	0	0	2
Downwind	1	90	99	100	98	100	99
	2	52	86	93	97	100	97
Other	1	9	1	0	2	0	1
	2	22	7	6	3	0	1
Inter-windrow no.		1	2	3	4	5	6

* Stratum 1 = stand downwind from open ground
Stratum 2 = stand downwind from the taller stand

DISCUSSION

The effect of the five slash-windrows on the degree and distribution of damage is unclear. The main patterns of damage could have been predicted (Caborn 1957; Somerville 1980) and it is probable they would have occurred in the absence of the windrows. The windrow height was on average only half that of the stand height and the fairly solid wind barrier provided by the 2-m within-row tree spacing lends weight to this argument.

Both the open-ground edge and the larger stand caused "edge effects" resulting in a concentration of wind damage in their lee. Although the trees downwind of both edge types were apparently under similar stress, the nature of the wind was quite different. Behind the open-ground edge the wind had constant direction corresponding to that of tree lean and tree fall. In the lee of the larger stand, wind descended with considerable force with turbulent eddies and high-speed backdrafts (Fig. 2 and Table 1). In forests where hazardous wind direction is known, stand arrangements that cause "edge effects" should be kept to a minimum.

This example of a damaging wind resulting in the lee of a larger stand has implications for shelterbelt design, and supports Caborn (1957) and the other proponents of permeable shelterbelts. The low-pressure zone in the lee of an impermeable barrier causes the downward movement of turbulent eddies. A permeable shelterbelt allows air movement through the belt, increasing the pressure in the lee zone which may eliminate the eddy effect.

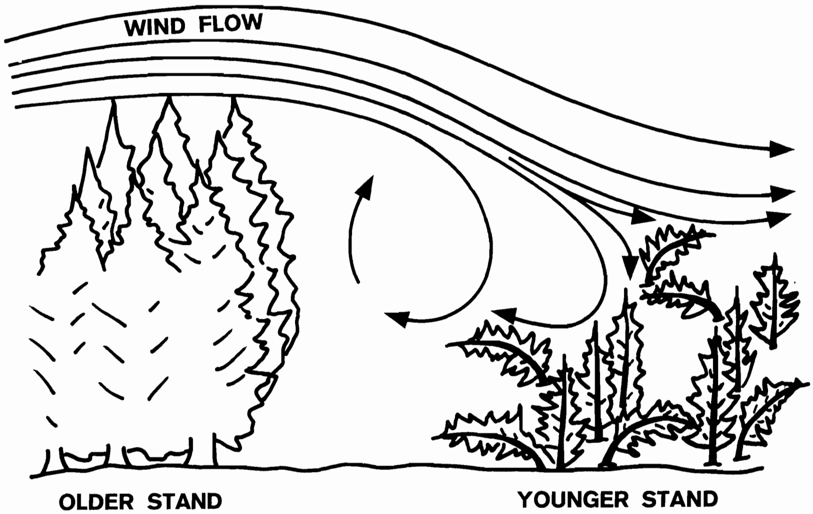

FIG. 2—Wind flow over a tall stand and the consequent damage inflicted in its lee.

Nageli (1954, quoted by Caborn 1957) measured wind speeds near the ground in a 600-m-wide stand. He found wind speed increased before the lee edge in response to the low-pressure zone associated with the increase in windspeed downwind of the stand. A similar increase in wind speed in the lee part of the young Canterbury stand could account for the increase in damage in the two leeward inter-windrows (Fig. 1). On a smaller scale, the increase in damage in the last tree rows to windward of slash windrows could be a consequence of a similar but localised increase in wind speed; the gap in canopy across windrows could have acted to increase wind speed. This would be assisted by increased wind speed associated with wind flow over the impermeable slash barrier.

ACKNOWLEDGMENTS

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