Proceedings of the New Zealand Grassland Association 46: 51-56 (1985)

SHELTERBELT INCREASES DRYLAND PASTURE GROWTH IN CANTERBURY

J.E. RADCLIFFE
Agricultural Research Division, MAF, Lincoln

Abstract

Pasture production was measured on stony soils at Hororata, Canterbury, at various distances parallel to an established tree shelterbelt. Windrun and temperatures were recorded in a sheltered zone at 3 tree heights distant from the trees and in an exposed zone, 12 tree heights distant. A 60% improvement in dryland pasture production was recorded in the sheltered areas over 3 years. The sheltered zone was half as windy as the exposed zone and soils tended to be warmer at times from October to March. More soil moisture was probably lost from areas most exposed to wind, and this most likely contributed to depressed pasture growth.

Keywords: wind, shelter, dryland pasture production.

INTRODUCTION

Comparatively little work has been carried out to examine the effect of wind shelter on temperate grassland productivity, although the effects of wind on microclimates, soil erosion, horticultural and agricultural crops, windborne diseases and livestock are well documented. In the United Kingdom, mid-season increases of around 30% have been attributed to the provision of artificial shelter (Russell & Grace, 1979). Such improvements have usually occurred in seasonally dry soils (Grant & King, 1970; Alcock, 1973; Alcock *et al.,* 1976).

In Australia, in the summer-dry tablelands of New South Wales, shelter provided by 1 m high iron fences substantially improved sheep production (Lynch & Donnelly, 1980). Sheltered paddocks had more green herbage because more soil moisture was retained during long drying periods (Lynch *et al.,* 1980).

In New Zealand, indirect evidence of shelter effects from agroforestry and tussock grasslands suggest that here, also, shelter may improve grass growth (Radcliffe, 1983).

The experiment reported here is a first attempt to quantify wind shelter effects on pasture in a seasonally dry soil on the windy Canterbury plains. The present landowner at the experimental site has long claimed substantial benefits of tree shelter for minimising soil wind blow and increasing crop yields, as well as reducing wind chill and mortality in newborn lambs and newly shorn ewes. However, effects on pasture growth have been less apparent.

SITE DETAILS AND PASTURE MANAGEMENT

A 5 ha site within a 12.6 ha paddock at Hororata, was chosen for the experiment. The paddock was on the lee side of a mature shelterbelt 550 m long, designed to give protection from the prevailing north-westerly winds. The shelterbelt, planted in 1960, consisted of a row of 4 m tall *Cedrus deodara* on the windward side (2.5 m between trees) with a row of 17 m tall *Pinus radiata* (2 m spacings) on the lee side. The width of the shelterbelt was 8 m. Tree management was designed to allow an optimum 50% porosity wind flow through the trees. This involved mechanical side trimming of alternate *P. radiata* trees as close to the trunk as possible, with side pruning up to a stem height of 8 m, as trees matured. *Cedrus deodara* was not pruned.

Pasture was sown out of crop in October 1980, with 'Grasslands Nui' perennial ryegrass (*Lolium* perenne) (10 kg/ha), cocksfoot (*Dactylis glomerata*) (5 kg/ha), red and white clovers (*Trifolium prafense, T. repens*) (5 kg/ha), and rape. Subterranean clover (*T. subterraneum*) seeds were already abundant in the soil. Grazing was controlled by the farmer. The soil pH was 5.5 and appropriate fertilizers were sown with the pasture.

Pasture cages (3.4 m x 1.5 m) were placed in zones at various distances from the shelterbelt with 4 cages in each zone. The height of the belt was designated 'h', and on 7 August 1981, cages were positioned in zones at 0.3 h (close to shelter), 3 h, 5 h, and 12 h, the last considered to be fully exposed to prevailing winds and at the outer edge of the paddock. Additional cages were placed at the 1.5 h and 8 h zones in February 1983. Pasture growth was measured by the trim technique at monthly intervals, using a reel mower (Radcliffe, 1974). Dry weights and separations of major species were estimated from sub samples.

The yellow-grey earth soil was classified as Lismore stony silt loam, derived from greywacke gravels with a thin cover of loess (N.Z. Soil Bureau, 1968). Soil depth to gravels averaged 24 cm, with no significant differences in soil depth related to distances from the shelterbelt, and no discernible differences due to slight depressions and ridges from old stream beds.

CLIMATE

Equipment was installed to measure rainfall, windrun and temperatures.

Precipitation and soil moisture

Long term rainfall at Hororata, measured approximately 5 km distant from the trial site, averaged 809 mm. The first experimental season received about 60% of normal rainfall from September to March and even well established trees died in this drought. The second season was close to normal, while the third season received 140% of normal rainfall. Snowfalls were uncommon but severe frosts and low winter temperatures limited growth. Periods of low soil moisture limited growth from November to April.

Rainfall from gauges installed 30 cm above ground showed a marked rain shadow immediately in the lee of shelter while rainfall in a sheltered zone (3 h) was similar to that in full exposure (12 h) (Table 1). Intermittent measurements of soil moisture (gravimetric sampling to 10 cm depth) generally showed no consistent differences among distances from shelter.

Table 1: RAINFALL (MM) IN THREE ZONES DISTANT FROM A SHELTERBELT OF HEIGHT 'H'.

	Aug-Nov	Dee-Mar	Apr-July	Total
1981-2				
0.3 h	NA[1]	30	118	148
3 h	NA	44	201	245
12 h	NA	40	187	227
1982-3				
0.3 h	124	136	172	432
3 h	220	197	326	743
12 h	212	182	326	720
1983-4				
0.3 h	171	313	NA	484
3 h	233	490	NA	723
12 h	239	462	NA	701

[1] Not Available

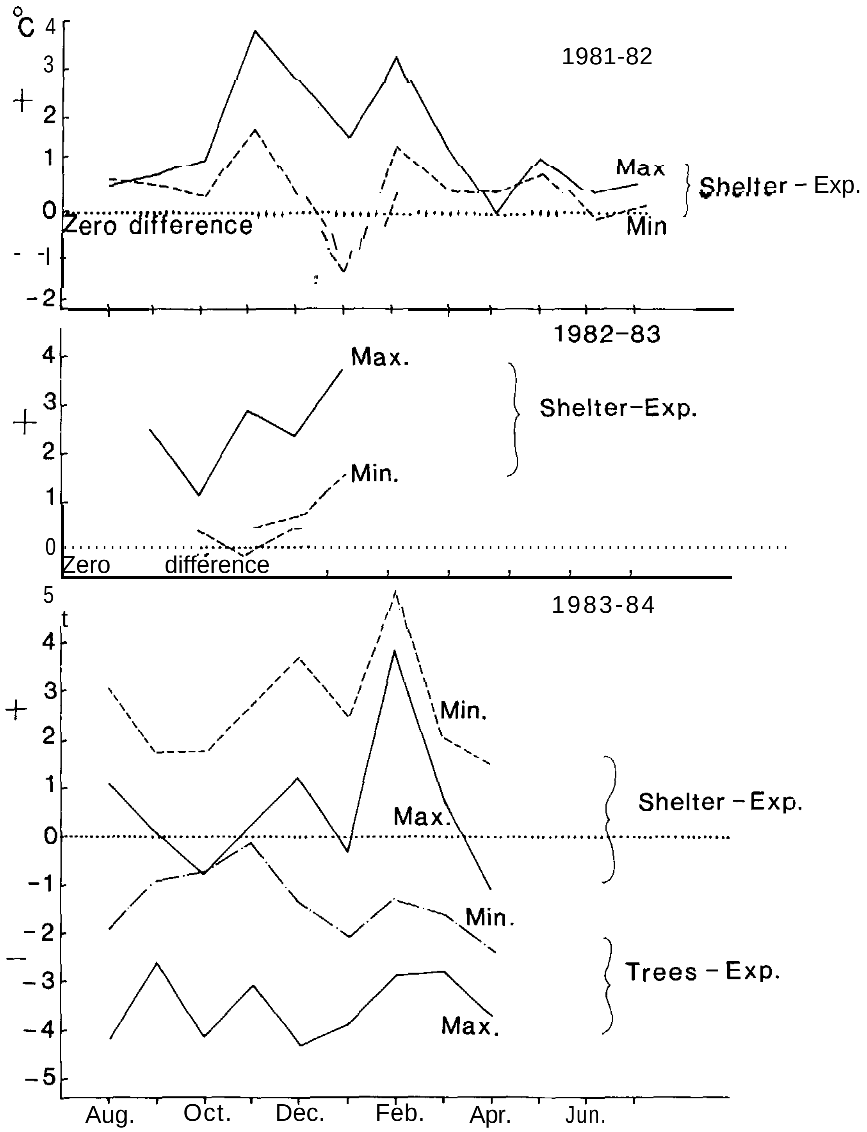

Figure 1: Soil temperature expressed as the difference in temperatures (“C) between a sheltered zone (3 h) and an exposed zone (12 h) for 3 seasons; and between a zone adjacent to trees (0.3 h) and an exposed zone (12 h) for 1 season. Temperatures are the differences in monthly means of daily maxima or minima at 10 cm for each zone.

Windrun

Totalizing anemometers installed 2 m above ground showed that windrun in the sheltered 3 h zone was only 58% of that recorded in the exposed 12 h zone, over a 2 year period.

Temperatures

Daily soil temperatures at 10, 20, and 30 cm depth were measured at 3 h and 12 h zones from August 1981. In Fig. 1, temperatures are expressed as the difference in temperature between zones. Results are inconclusive with incomplete records. In the 1981-2 and 1982-3 growing seasons, maxima were up to 3 to 4°C higher in sheltered soils than in exposed soils, reaching a summer peak of 28°C in shelter (January 1981). Minimum temperature differences between sheltered and exposed soils were smaller in the first two seasons, although sheltered minima were generally higher (at 17°C) than exposed minima especially in the 1983-84 growing season. In autumn and winter, temperature differences between sheltered and exposed soils were much smaller with a low maximum at 5°C and a low minimum at 2°C in July 1982. At 20 cm, the above trends were smaller, as expected, and at 30 cm were negligible.

An additional thermograph installed at 0.3 h in August 1983 showed that soils close to the shelterbelt at 10 cm depth were appreciably cooler than soils exposed to wind (Fig. 1).

Daily air temperatures at 3 h and 12 h zones were also measured for 18 months from thermographs resting on wooden boards on the soil surface with bimetallic sensors 3 cm above ground. Daily maximum, minimum and mean temperatures were similar in sheltered and exposed zones with monthly means often differing by less than 0.5°C.

PASTURE GROWTH

Over 3 years, about 60% more pasture dry matter was harvested from zones 3 h and 5 h distant from the shelterbelt, compared with those either 0.3 h or 12 h distant (Table 2). Limited data (from 1 year only) suggest that this increase was also shared by zones 1.5 h and 8 h. The increased production came from both grasses and clovers.

Table 2: TOTAL ANNUAL YIELDS AND COMPONENTS OF YIELDS IN t DM/ha IN ZONES DISTANT FROM A SHELTERBELT OF HEIGHT 'h'.

		0.3 h	1.5 h	3.0 h	5.0 h	8.0 h	12.0 h	lsd (5%)
1981-2	Total	3.30		5.51	5.40		3.28	0.60
5 cuts	Grass	2.24		4.18	4.14		2.21	0.66
	Legume	0.64	NA	1.03	1.08	NA	0.89	0.52
	Other[1]	0.42		0.30	0.18		0.18	ns
1982-3	Total	3.80		5.99	5.63		3.70	0.81
6 cuts	Grass	2.41		3.61	3.23		2.18	0.90
	Legume	0.69	NA	1.62	1.50	NA	0.99	0.48
	Other	0.70		0.76	0.90		0.53	ns
1983-4	Total	3.65	7.37	8.08	8.22	7.32	5.07	1.01
6 cuts	Grass	2.29	4.78	5.80	5.44	5.04	2.88	0.72
	Legume	0.56	1.06	1.59	1.94	1.23	1.57	0.39
	Other	0.80	1.53	0.67	0.84	1.05	0.62	ns
Mean[2]	Total	3.58	(6.4)	6.52	6.42	(6.2)	4.01	0.48
	Grass	2.31	(4.0)	4.53	4.27	(4.0)	2.42	0.44
	Legume	0.63	(1.0)	1.41	1.51	(0.9)	1.15	0.27
	Other	0.64	no est.	0.58	0.64	no est.	0.44	ns

[1] Others. Mainly dead grass with some live weeds
[2] Yields from 1.5 h and 8 h zones adjusted for years effect.
NA Not Available

Pasture composition reflected the droughty nature of the site. Perennial ryegrass and cocksfoot (sown) were mixed with resident Yorkshire fog (*Holcus lanatus*), goosegrass (*Bromus mollis*), browntop (*Agrostis capillaris*), sweet vernal (*Anthoxanthum odoratum*), and Chewings fescue (*Festuca rubra* ssp. *commutata*). Sown white clover was mixed with resident subterranean and suckling clovers, with little trace of sown red clover. No conclusions can be drawn from the present data about the tolerances or responses of particular species to wind exposure.

Growth rates altered among zones as the season advanced. In 1982-3 when the first cut was made in mid September, production was similar in all zones. However, in 1981-2 and 1983-4, when the first cut was unavoidably delayed until mid October, production at 12 h was already significantly lower than that elsewhere. From November to the end of the season in May-June, less dry matter was harvested in 0.3 h and 12 h zones.

DISCUSSION

Substantial responses to wind shelter were measured in a dry, a normal, and a wet season. However, stony bouldery soils must restrict the amount of water available to plants and probably even in "wet" seasons, soil moisture may often be inadequate for optimum growth.

There is no doubt that windspeed was substantially reduced in the zones of pasture response. What is not clear is how this reduction in wind altered microclimate and possibly soil conditions to promote plant growth. On this particular site it is unlikely that more sheep dung and urine was deposited in the sheltered part of the paddock, so giving the opportunity for more grass to grow from enhanced fertility. Such grazing behaviour was not observed. Also soil sampling to 10 cm revealed higher levels of potassium and phosphate only in the 0.3 h zone near the shelterbelt.

During the growing season, soils tended to be warmer in the sheltered 3 h zone compared with the exposed 12 h zone, although as temperature records were incomplete, the findings are inconclusive. There was limited tree shading at 3 h, so these results confirm work elsewhere in Canterbury (Radcliffe & Lefever, 1981), that wind exposure lowers soil temperatures. However, optimum temperatures for grass and clover growth (21 to 24°C, Mitchell, 1956), would be reached earlier in the season with shelter. So these zones could respond to warmer temperatures before soil moisture supplies became too depleted.

The most likely cause of improved pasture growth is that wind reduction reduced water evaporation rates and so conserved more soil moisture, as reported elsewhere (Lynch et *al.*, 1980). It is also likely that our restricted gravimetric soil moisture sampling did not detect this. More intensive and frequent samplings to a much greater soil depth would have been needed.

Conversely a rain shadow effect plus water use by the shelterbelt must have contributed to depressed production near trees. Another contributing factor may have been the cooler soils (Fig. 1) and appreciable tree shading. More pine needles fell in this zone, but their effects are unknown.

In the experimental paddock of 12.6 ha, 3.5% of the paddock was occupied by the fenced shelterbelt, while another 2% adjacent to the shelterbelt, had lowered pasture yields. However, at least 75% of the paddock was considered to be well sheltered with substantially higher yields than pasture in exposed areas.

The present 12 h zone was located as far as possible from the shelterbelt within the paddock boundary. Although it was assumed to be fully exposed to the prevailing north-west winds, it may well have received some shelter. More yield measurements between 8 h and 12 h zones as well as beyond 12 h would have been desirable to determine more precisely, the extent of the sheltered zone.

Low annual yields without shelter in 1981-2 and 1982-3 (Table 2) reflected very dry seasons in mid Canterbury. Winchmore Research Station, some 25 km from the trial site, recorded 82 and 62 days of 'agricultural drought' respectively in these seasons, with correspondingly low annual yields of 3.7 and 3.4 t DM/ha, using the same measurement technique. These are well down on the long term average yield of 5.9 t DM/ha of dryland pastures at Winchmore, with an average of 45 days of agricultural drought (Rickard & Radcliffe, 1976). Although low soil moisture supplies were undoubtedly the main cause of low yields, other contributing factors on the present trial site may have been low soil phosphate values, and the incomplete ground cover of the young pasture, which in 1981-2 was still spreading from drill rows.

The present findings are a preliminary step towards quantifying shelter effects on pasture in Canterbury. There is a need to examine whether such increases are sustained elsewhere on soils with different textures and water holding capacities. The research programme will be extended to quantify the effects of wind shelter not only on plant growth, but also on irrigation efficiency and water use by pasture plants.

In this paper, trees have been considered only from the view point of reducing wind speed and altering conditions for pasture growth. With wise management, additional benefits could be the supply of timber, pollen or nectar, nutritious browse for stock and visual enrichment of landscapes. Such benefits are already being realised by many landowners.

However, in the final analysis, farmers will accept the benefits wind shelter can provide, only if these benefits can be translated into dollar returns from enhanced livestock production, and from timber returns from shelter trees. In this country there is an increasing determination to address these questions.

ACKNOWLEDGEMENTS

Mr R.T. Alexander, MAF, for technical support, Mr P. Smail, 'Lynton', Hororata for use of land, Mr C. Thomas, Hororata, for collecting temperature data, and laboratory staff at Winchmore Research Station, for herbage dissections.

REFERENCES

Alcock, M.B. 1973. *Int. J. of biometeorology 17: 385-389.*

____________; Harvey, G.; Tindsley, S.F. 1976. *Fourth symposium on shelter research* held at Warwick University 1975. MAFF/ADAS. p. 88-104.

Grant, S.M.; King, J. 1970. Third symposium on shelter research held at Cambridge 1969. MAFF 1970, p. 77-86.

Lynch, J.J.; Donnelly, J.B. 1980. *Aust. J. of agric. Res. 31: 967-979.*

Lynch, J.J.; Elwin, R.L.; Mottershead, B.E. *1980. Aust. J. of exper. Agric. anim. Husb. 20 (103):* 170-174.

Mitchell, K.J. 1956. N.Z. *J. Sci. Tech.* 38a: 203-216.

N.Z. Soil Bureau 1968. N.Z. Soil *Bur. bull. 27:* l-404.

Radcliffe, J.E. 1974. N.Z. *J. exp. Agric. 2:* 337-340.

____________ 1983. *Ibid. 11:* 5-10.

____________; Lefever, K.R. 1981. N.Z. *J. agric. Res. 24: 55-66.*

Rickard, D.S.; Radcliffe, J.E. 1976. N.Z. *J. exp. Agric. 4: 329-335.*

Russell, *G.;* Grace, J. 1979. *J. appl. Ecol. 16:* 319-330.