Proceedings of the New Zealand Grassland Association 46: 25-30 *(1985)*

IRRIGATION OF A HIGH COUNTRY MACKENZIE SOIL

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Abstract

Pasture production and water use data are presented for a border strip irrigation trial in the Upper Waitaki Basin.

Pasture development on the shallow, poorly structured Mackenzie soil was slow and irrigated pasture remained clover dominant for 6 years. With irrigation at 25% awc pasture herbage production over 3 years of this initial development stage averaged 7.2 t DM/ha/yr, 5 times more than improved dryland pasture. Grazing days (12 - 19 month old ewes) provided during the September to April growing season were 960 under dryland conditions and 5940 under irrigation at 25% awc. Of the 3 irrigation treatments (irrigation at 0%, 25%, 50% awc), irrigating at 25% awc was the most efficient giving near-maximum pasture production and the greatest herbage response per irrigation,

Mean annual water use efficiency at 25% awc was high (63%) and irrigation water requirement low (470 mm) for such a naturally, highly permeable soil and was probably due to soil compaction by earth-moving machinery during border strip preparation.

Keywords: Irrigation, high country, Mackenzie soil

INTRODUCTION

In the Upper Waitaki Basin (450 - 750 m asl), pasture growth is largely restricted to spring and autumn by cold winters and hot, dry summers. Improved, unirrigated pastures in much of this area are therefore of low productivity (1 - 3 t DM/ha/yr) and persistency (3 - 5 years; M.H. Douglas *pers. comm.*).

Irrigation substantially increases pasture herbage production and has been described as the key to maximising the effectiveness of dryland development (Willis 1980). Surveys of the Upper Waltaki have shown that of a total irrigable area of approximately 90,000 ha there are water resources to irrigate 20,000 - 30,000 ha of suitable soils (Kerr 1979). T.H. Webb (*pers. comm.*) has classified the soils according to suitability for irrigation based on factors such as permeability, available rooting depth, stoniness and available water capacity.

Pasture herbage production in excess of 15 t DM/ha/yr under irrigation and 2 - 5 t DM/ha/yr without irrigation was measured on a deep Streamland soil by Scott & Maunsell (1981). At the other extreme irrigation of very shallow, stony Labreck soils yielded only 3.7 - 5.7 t DM/ha/yr (Scott *et al* 1982). At Tara Hills High Country Research Station near Omarama, an irrigated shallow, stony Mackenzie soil, typically produces 9.5 t DM/ha/yr from established pasture (Greenwood unpub.)

Border strip irrigation of such soils has often been inefficient in terms of the proportion of the water applied being retained in the rooting zone of the soil (Cossens 1982, Greenwood unpub.), and must be well designed to reduce excess drainage through the permeable soil profile (T.H. Webb *pers. comm.*).

Pasture establishment on the stony soils in the Upper Waitakl Basin is slow and, under irrigation, pastures can remain clover dominant for many years (Scott *et al* 1982). It is important that this phase of pasture development be taken into account in the economic planning of irrigation schemes.

This paper reports pasture herbage production, grazing days and water use data from the development stage of a border strip irrigation trial on a shallow Mackenzie soil near Omarama. As part of investigations into a proposed community irrigation scheme, the trial was established to study pasture herbage production and water usage of this soil, which is representative of a large proportion of the irrigable soils in the Upper Waitaki.

MATERIALS AND METHODS

The 5.5 ha trial was on Glenbrook Station 25 km north of Omarama at 600 m asl. Mean annual rainfall over 9 years at Twizel, 10 km north of the trial, was 640 mm.

The soil was a shallow Mackenzie sandy loam (T.H. Webb *pers. comm.*) of low natural fertility (pH 5.3, K 2, P 6, SO4 2, OM% 1.5) and of variable depth due to numerous, relict stream channels. The mean stone-free soil depth was 22 cm underlain by 40 cm of very stony, loamy sand. Pasture roots were confined to the top 220 mm of soil which had an available water capacity of 53 mm.

After burning the low producing native fescue tussock sward (annual herbage production 200 kg DM/ha/yr; M.H. Douglas *pers. comm.*), the area was prepared for border strip irrigation, cultivated, and sown with Nui ryegrass (10 kg/ha), Kahu timothy (3 kg/ha), red, white and alsike clover (2 kg/ha each), in September 1977.

Following 3 years of establishment trials, 3 irrigation treatments, irrigation at 0%, 25% and 50% available water capacity (awc) were imposed in a 3 replicate randomised block design in 1960. Plots received 375 kg/ha superphosphate annually and consisted of individual, 10 m wide, border strips, 2 replicates being 300 m long and the other 200 m.

All irrigations were conducted with a flow of 60 l/s, and individual border strips were automatically irrigated with a pneumatic gate release system. Moisture levels in the 0 • 300 mm soil depth were determined thermogravimetrically at 3 - 10 day intervals and the timing of irrigations based on these results.

Pasture herbage yield was measured at 3-weekly intervals by cutting an area of 3.7 m^2 within moveable cages, to 25 mm height (Lynch 1966). Sward composition was determined annually by point analysis at 150 points per plot in early December.

Plots were rotationally grazed at 19-30 day intervals with 12-19 month old ewes. Grazing normally began in mid October and all stock were removed at the end of April. Records were kept of grazing days per plot.

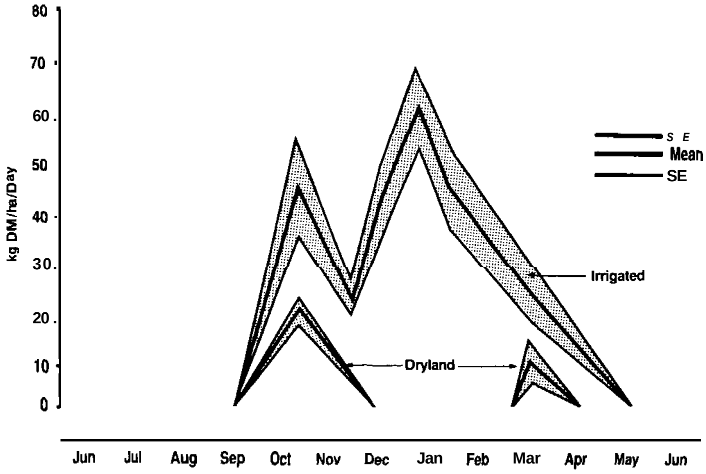

***Figure 1:** Rates of pasture growth for pasture irrigated at 25% awc, and for dryland pasture, 1980-83.*

RESULTS AND DISCUSSION

Growth curves for pasture irrigated at 25% awc and for dryland pasture are shown in Fig. 1. Mean herbage production, grazing days and herbage responses per irrigation and per mm of irrigation water for the 3 years 1980181 - 1982183 are given in Table 1. Dryland production given is from pasture sown in 2 border strips within the trial area but not subsequently irrigated. On Mackenzie soils in this environment dryland herbage production is likely to vary from 1 to 3 t DM/ha/yr (Scott 1979, Cossens 1982, M.H. Douglas *pers. comm.*).

Table 1: THE EFFECT OF IRRIGATION ON PASTURE HERBAGE YIELDS, GRAZING DAYS, AND HERBAGE RESPONSES PER IRRIGATION AND PER mm OF IRRIGATION WATER APPLIED.

	Pasture Herbage Yield (t DM/ha)				Grazing days (Sep - Apr)	Herbage Response (kg DM)	
	Spring	Summer	Autumn	Annual		Per irrigation	Per mm Water Applied
Irrigation treatment							
25% awc (6.3)[1] / [illegible]5% awc (4.3)	2.07 / 1.73	3.60 / 2.70	0.93 / 0.83	7.20 / 5.12	5940 / 4940	830 / 870	13.6 / 12.6
50% awc (9.0	2.38	4.20	1.04	7.62	6330	700	8.9
Dryland	1.13	0.03	0.20	1.36	960	—	—
SED	0.09	0.27	0.08	0.37	230	52	0.6

[1] Mean annual number of irrigations

Dryland herbage production

Dryland pasture which provided 960 grazing days from September to April produced 83% of the annual yield during spring and 15% in autumn. Summer growth was negligible (2%). In the dryland plots, the frequency of occurrence of clover diminished during 1980 to 1983 from 43% to 15% and ryegrass from 10% to 1% while other species (mainly sweet vernal and hairgrass) increased from 24% to 49% and bare ground from 23% to 35%.

Irrigated herbage production

Irrigated pasture was slow to establish and remained clover dominant until the end of the 1982183 season, 6 years after sowing. Over the 3 year period studied, frequencies of occurrence of pasture species in the irrigated plots were: clover 53%, ryegrass 18%, other species (mainly timothy, sweet vernal, red and alsike clovers) 17%, bare ground 12%. The 6 year period of clover dominance was similar to that reported by Scott (1982) on a stonier soil in the Mackenzie Basin. Because of the long period involved clover dominance is an important feature in the development of irrigated pastures on the soils studied.

Pasture irrigated at 25% awc produced 5.3 times more dry matter, and provided an extra 4990 grazing days over the growing season than the dryland pasture. Annual variability in dryland yield between years indicates that increases with irrigation of from 2.4 to 7.2 times can be expected. On similar soils in Central Otago increases of 2.5 - 4 times have been achieved from mature pasture (Cossens & Radcliffe, 1974), and on a deep soil in the Mackenzie Basin increases of 2 - 3.5 times were gained (Scott & Maunsell 1981).

Irrigation reduced the marked spring and autumn seasonality of dryland growth but the pattern of irrigated growth reflected the clover dominance and low grass content of the sward (Fig. 1). Grass production peaked in spring but was insufficient to maintain a high level of production through to summer when clover growth was vigorous. Approximately 35% of annual production occurred in the spring, 50% in the summer and 15% in the autumn. Nevertheless, although irrigation resulted in large increases in production and extended the growing season through the summer and by an extra month at the end of autumn, the growing season was still short with no growth for at least 4 months during the cold period starting from mid to late May.

Increased irrigation frequency, from 0% awc to 25% awc required an additional 2 irrigations, significantly increased spring and summer herbage production, and raised annual herbage production by 40% (Table 1). Consequently there were an extra 1200 grazing days at the 25% awc irrigation treatment over the growing season. Because of the large difference in herbage yields and the small number of extra irrigations involved between the 0% awc and 25% awc treatments, the best herbage response to irrigation (in kg DM per irrigation) was obtained from the 25% awc treatment. The response was considerably greater than recorded on similar soils in Central Otago (Cossens 1982) and on stony Eyre and Lismore soils in Canterbury (Hayman & McBride 1979). As in both Central Otago and Canterbury irrigating at 50% awc yielded little extra annual production (6% over 25% awc) in spite of a requirement for a further 3 irrigations annually. Although summer accounted for 2 of the 3 extra irrigations, and summer production increased by 17%, a reduction in early spring growth precluded any significant increase in annual yield over 25% awc. Nitrogen availability in early spring, may have been reduced by increasing leaching during the previous season, resulting in poorer early spring growth.

The extra herbage produced over and above dryland production per mm of irrigation water applied clearly illustrates the diminishing returns from increases in irrigation frequency. Although highest returns were gained from minimal irrigation, irrigating at 25% awc still gave comparatively good returns. Irrigating on average 9 times per season at 50% awc gave 33% less herbage per unit of water applied.

Water use efficiency

Mean irrigation data for the 1981182 – 1982183 seasons are summarised in Table 2.

Water use efficiencies were calculated as

$$\% \text{ efficiency} = \frac{\text{water retained in the root zone of soil}}{\text{water applied}} \times 100$$

Mackenzie soils are channelled with numerous former stream channels and are rapidly permeable. Accordingly they require careful irrigation design (i.e. flow rate, border strip level and length) to minimise wastage of water through deep percolation losses (T.H. Webb *pers. comm.*). Most border strip irrigation systems on similar soils near Omarama have given high water requirements and low water use efficiencies (Greenwood unpub.). In Central Otago, border strip irrigation of a Molyneaux soil, the properties of which are vey similar to Mackenzie soils, gave high water usage, and a mean water use efficiency over 12 years of only 34% (Cossens 1982). However, in the present study small amounts of water could be applied quite efficiently although this was influenced by both border strip length and irrigation treatment. Increasing irrigation frequency which led to higher water usage, reduced efficiency. At 0% awc a very high water use efficiency (94%) was achieved mainly because pastures were normally shorter than on the 25% awc and 50% awc treatments (mean pasture length at irrigation 25 mm at 0% asw, 38 mm at 25% and 50% awc) resulting in faster irrigation times and less deep percolation losses. Furthermore, the drier soil was able to retain more of the water applied. At the 25% and 50% awc frequencies, although similar amounts of water were applied at each irrigation, irrigating at 25% awc was 23% more water efficient than at 50% awc. Again this was because the drier soil was able to retain more of the applied water.

Table 2: EFFECT OF IRRIGATION TREATMENT AND BORDER STRIP LENGTH ON WATER APPLICATION AND WATER USE EFFICIENCY, 1981-83.

	Irrigation Water Applied Per Irrigation (mm)	Annual (mm)	Water Use Efficiency (%)
Irrigation treatment			
0% awc	62	277	94
25% awc	71	471	63
50% awc	72	685	40
SED	5	36	5
Border Strip Length			
200 m	59	422	74
300 m	73	506	62

Although it was not included in the trial as a replicated treatment, the effect of border strip length is quite evident. Irrigation of the longer 300 m strips required, on average, a further 85 mm of water per season and gave water use efficiencies 12% lower than did irrigation of the 200 m strips.

A mean water application of approximately 70 mm/irrigation at 25% and 50% awc was considerably lower than that achieved on a similar soil in Central Otago (100 mm: Cossens 1982) or on stony Lismore soils in Canterbury (90 - 100 mm; A.R. Taylor *pers. comm.*). As a result the water use efficiency achieved in the Mackenzie was significantly higher than in Central Otago and compared favourably with that normally attained in Canterbury.

Over a 12 year period on the Central Otago soil, efficient irrigation was difficult to achieve, as with a gradually increasing water infiltration rate, the depth of water applied per irrigation nearly doubled over that time (Cossens 1982). This was attributed to a gradual reduction in soil bulk density from an initial compact state, and an apparent soil loss through deep percolation. In the present study border strip preparation resulted in a similarly compacted soil (Jan. 1982 dry bulk densities, O-220 mm soil depth; 1.5 g/cc in irrigated plots, 1.0 g/cc under surrounding virgin tussock), and led to a reduced water infiltration rate. The saturated infiltration rates measured by the double ring technique (Griffiths 1975) were 20 mm/hr in the irrigated plots and 90 mm/hr under the surrounding virgin tussock. Soil compaction was probably the major factor influencing water application depths and water use efficiencies. Consequently the low quantities of water applied and high efficiencies achieved must be interpreted with caution. It is likely that, in the future as occurred in Central Otago, the irrigation water requirement may significantly increase and water use efficiency decrease.

CONCLUSIONS

1. Following border strip preparation, establishment of irrigated pasture on shallow stony Mackenzie soils is slow. It is important therefore that in the economic planning of irrigation of these soils account be taken of the productivity of clover dominant pasture. This stage of development when herbage production is likely to be considerably lower than that from a fully developed grass/clover sward may last for many years. In the present study it lasted 6 years from sowing.
2. Clover dominant pastures irrigated at 25% - 50% awc on Mackenzie soils in the Upper Waitaki Basin produce, on average, 7.0 - 7.5 t DM/ha/yr. This represents an

increase in production over improved dryland pasture of approximately 3-5 times.

3. Irrigation at 25% awc is the most efficient as it gives near maximum irrigated pasture production and herbage produced per mm of water applied, and the highest herbage response per irrigation.
4. Because of soil compaction during border strip formation, irrigation of shallow, poorly structured and highly permeable high country soils can be very water efficient for many years after initial development. However, water use efficiency is likely to gradually decrease with time.

ACKNOWLEDGEMENTS

J.M. and T.G. Kelland for kindly allowing the use of their land and stock.

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