SOIL WATER EXTRACTION PATTERNS UNDER PASTURE AND LUCERNE ON TWO SOIL TYPES IN MID-CANTERBURY

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ABSTRACT

Soil water profiles were monitored by a neutron moisture meter under irrigated pasture and lucerne over two growing seasons on a Wakanui clay loam and an Eyre stony silt loam in Mid-Canterbury. The maximum soil moisture deficit measured under pasture was 128 mm to a depth of 1.25 m on the Wakanui soil, and 80 mm to a depth of 1.1 m on the Eyre soil. In contrast, the deficit measured under lucerne was 175 mm to a depth of 1.4 m on the Wakanui soil and 125 mm to a depth of 1.25 m on the Eyre soil. Pasture withdrew water from the upper part of its rooting zone preferentially but lucerne showed little preferential extraction over its entire rooting zone. With one exception, the maximum deficit measured in any layer of the soil profile was greater under lucerne than under pasture.

Additional Key Words: Neutron moisture meter, irrigation, Wakanui clay loam, Eyre stony silt loam, plant available moisture.

INTRODUCTION

The majority of irrigated soils of Mid-Canterbury are free draining but they mostly have shallow stony topsoils (0.2 - 0.3 m) that overlay deep beds of greywacke gravel and sand (e.g. Eyre, Chertsey and Lismore). Because of the concentration of pasture roots in the topsoil (Troughton, 1957) and the low available moisture per unit depth in the sub-soil, the assumption has often been made that the greater proportion of water used by pastures comes from the topsoil. On the Lismore stony silt loam, for example, values of 50-60 mm of plant available moisture in the top 0.3 m have been used (Rickard, 1960). Although it was realised that variation in top soil depth could alter these values and that the soil could dry to below permanent wilting point, values of 50-60 mm of available moisture for the shallow stony Canterbury soils have been adopted as a general figure. Such values have been used to suggest that surface irrigation schemes, which apply 100 mm or more at each irrigation, are inefficient users of water. It is also the basis on which sprinkler irrigation schemes in Canterbury are commonly designed with a capacity to apply 50 - 70 mm of water on a 3 - 4 week return interval.

Several factors have recently indicated that it is necessary to look more closely at the effective rooting depth of plants growing on stony Canterbury soil and perhaps revise the figures for plant available water.

Stoker (1982), working at Winchmore Irrigation Research Station, measured a total water deficit of 92 mm to a depth of 0.9 m under pasture by digging pits during a dry period. Water had been extracted to at least the sampling depth of 0.9 m. This information coincided with widespread farmer comment that pasture growth during long dry spells was better under border strip irrigation than sprinkler irrigation. The inference is that the sprinkler systems, as presently designed and operated, do not replenish the soil water deficit as fully as border strip irrigation.

A major reason for the historical lack of information on the soil water status at depth on stony soils has been the difficulty of regular gravimetric samplying of such soils. Although the neutron moisture meter is well suited to regular soil moisture monitoring of fixed sites, its use on stony soils was also hampered by problems of installing the access tubes. However, after testing several methods, access tubes were installed in two soil types in Mid-Canterbury in 1978. This paper reports the data obtained with a neutron moisture meter from plots of irrigated pasture and lucerne on these soils over two growing seasons.

METHOD

Irrigation trials on lucerne and pasture have been carried out on eight sites in the Ashburton County since 1975. The irrigation plots consisted of level basins (8 m x 4 m) which could be individually flood irrigated with a portable pump. (Hayman and McBride, 1979). In 1979 two neutron probe access tubes were put in each of two lucerne plots and two pasture plots on three sites, one on an Eyre stony silt loam and two on Wakanui clay loam soils. A pointed solid rod of the same diameter as the neutron probe access tubes was driven into the plots, withdrawn, and the access tubes were inserted in the holes. The vegetation around one access tube in each pair was killed with herbicide and the surface covered with straw to provide a reference profile subject to drainage but not evapotranspiration losses.

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TABLE 1: Soil Physical Properties

Depth Interval (m)	Bulk Density		% Stones		Field Capacity (%w/w)		Wilting Point (%w/w)	
	Wakanui	Eyre	Wakanui	Eyre	Wakanui	Eyre	Wakanui	Eyre
0.00-0.15	1.4	1.5	0	7	29.2	15.8	11.5	7.4
0.15-0.30	1.5	1.4	0	25	24.8	14.6	11.7	7.4
0.30-0.45	1.6	1.4	0	46	20.3	17.6	11.6	5.4
0.45-0.60	1.6	1.6	0	57	19.1	16.5	10.5	3.2
0.60-0.75	1.7	1.3	0	62	18.8	17.1	8.0	3.7
0.75-0.90	1.6	1.8	30	58	18.0	16.8	6.7	4.0
0.90-1.05	1.2	1.6	58	56	22.5	17.0	5.6	7.3
1.05-1.20	1.3	—	67	—	26.4	—	7.1	—

The plots were irrigated whenever the deficit in the top 0.1 m of the vegetated profile reached wilting point (soil moisture percentage equal to 15 bar deficit). Moisture profiles were measured weekly throughout the 1979/80 and 1980/81 seasons. Standard soil physical measurements were taken at each site in conjunction with neutron probe calibration. Daily rainfall was recorded at each site.

Neutron probe data were converted to millimetres of water stored in each profile interval and then to millimetres of water deficit by deducting the amount stored at any one time from that stored at 'field capacity'. 'Field capacity' was determined by averaging the two wettest vegetated profiles which did not differ significantly from the 'steady state' of their paired bare plots, i.e. did not contain water subject to drainage.

Maximum deficits quoted in Table 3 are the average of the two greatest deficits recorded when the top 0.1 m was at wilting point. The 20 mm and 60 mm deficits were interpolated using a quadratic regression formula derived from the recorded interval deficit — total deficit relationship.

RESULTS

Results are presented for the Eyre stony silt loam and one of the Wakanui clay loam soils. The Eyre soil was very stony (Table 1) and prone to rapid drying out necessitating frequent irrigation (Table 2). The Wakanui soil was a deep, stone-free and moisture-retentive clay loam overlaying gravel. Unlike many Wakanui soils, this was relatively free draining and not subject to a perched water table.

Table 3 records that soil water deficit under pasture and lucerne in each 0.3 m layer of these soils when the total deficit was 20 mm, 60 mm and maximum profile deficit. When the total deficit on either soil was less than the maximum (i.e. 20 mm or 60 mm) the deficit in the upper layers (to 0.6 m) was greater under pasture than lucerne. Below a depth of 0.6 m the deficit under lucerne was always greater. At maximum deficit on both soils, the lucerne had extracted more water than pasture from every layer, except the 0.6 - 0.9 m layer on the Wakanui soil.

TABLE 2: Number of irrigations for the period November 1979—January 1981.

	Wakanui	Eyre
Lucerne	2	6
Pasture	3	10

DISCUSSION

These results have confirmed that plant roots do penetrate the gravelly subsoils of Mid-Canterbury and obtain quite large amounts of water from these layers of the profile even when the gravels are overlaid by 750 mm of stone-free soil. Lucerne has a greater ability to do this than pasture.

These results also support Evan's (1976) conclusion that lucerne tends to withdraw water uniformly from the first 1.5 m over a range of soil water deficits, but pasture species tend to withdraw water initially from the upper part of their rooting zone.

Table 3 illustrates the magnitude of error that can occur in estimating soil water deficits if common assumptions are accepted that the effective rooting depth on stony soils is confined to the top soil. On the stony Eyre soil, 38% of the deficit under pasture and 58% of the deficit under lucerne came from below 0.3 m on the driest measured profiles (i.e. when the 0 - 0.1 m layer was at wilting point). Such a deficit would probably be reached more than once each summer on a rostered irrigation scheme. Even on the deeper Wakanui soil, 32% and 40% of the deficit under pasture and lucerne respectively came from the gravel substrata on the driest measured profiles.

Some implications for irrigation scheme design

The size of the deficits measured have important implications for irrigation scheme design in Mid-Canterbury. Past assumptions based on deficits of 50-60 mm in the top 0.3 m of the profile will have to be revised.

For instance it can no longer be assumed that a border strip irrigation system which applies 100 mm to 125 mm at each irrigation is necessarily wasteful of water. Also it is not sufficient to design sprinkler irrigation systems to replenish

TABLE 3: Soil moisture deficit in mm at 0.3 m depth intervals when total deficit reached 20 mm, 60 mm and maximum deficit.

Depth (m)	Eyre 20	Eyre 60	Eyre Max	Wakanui 20	Wakanui 60	Wakanui Max
			Pasture			
0.0-0.3	10	37	50	9	27	44
0.3-0.6	6	14	18	6	18	23
0.6-0.9	3	8	10	4	13	41
greater 0.9	1	1	2	1	2	20
TOTAL	20	60	80	20	60	128
			Lucerne			
	20	60	Max	20	60	Max
0.0-0.3	5	17	53	4	14	52
0.3-0.6	2	9	20	4	10	28
0.6-0.9	5	15	27	7	20	35
greater 0.9	8	19	25	5	16	60
TOTAL	20	60	125	20	60	175

a deficit of 50 mm every 3 or 4 weeks unless it is explicitly understood that these systems are designed to supplement rainfall and will provide insufficient water in prolonged dry periods.

Currently used estimates of water lost to drainage and evapotranspiration rates of pasture growing on stony soils have also been calculated on the basis of 50 - 60 mm of plant available water. These will now have to be recalculated. However, this trial, designed to test the neutron probe in stony soil and record the depth of water extraction, did not obtain sufficient data to make an accurate estimate of evapotranspiration. Consequently, new trials have been established in Mid and North Canterbury to collect the data required to estimate evapotranspiration rates from pasture and lucerne at two levels of irrigation on a range of soils and climate.

These data are required so that the rapidly expanding irrigation systems are designed for optimum efficiency.

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