WATER USE IN A NEWLY ESTABLISHED PASTURE AS INFLUENCED BY GRAZING MANAGEMENT

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ABSTRACT
The objective of this study was to determine the effects of grazing system and stocking rate on spring profile soil water, soil water extraction and evapotranspiration (ET) of a newly established grass/legume pasture. The experiment, located on a fine sandy loam soil in western Manitoba, was a two replicate RCBD with continuous and rotational grazing at stocking rates of 1.1 and 2.2 steers/ha. The pastures contained alfalfa (*Medicago sativa* L.), meadow bromegrass (*Bromus biebersteineii* Roem and Shult.) and Russian wild ryegrass (*Elymus juncea* L.). Growing season ET averaged 38.4 cm and was consistently highest for the rotationally-grazed/low stocking rate treatment. Amount of soil water present in spring and the proportion of spring soil water extracted during the grazing season was also highest in the rotationally-grazed/low stocking rate treatment. Higher levels of spring soil water were attributed to greater overwinter water conservation, while greater extraction of available water by the rotationally-grazed/low stocking rate system was attributed to superior root activity. This study showed that grazing management affects soil water conservation and soil water use in dryland pastures in western Canada.

KEYWORDS
water use efficiency, pastures, stocking rate, rotational grazing, continuous grazing, cattle

INTRODUCTION
Water is a major factor limiting growth of pastures in western Canada. Two major objectives in efficient water management are 1) maximization of soil water recharge and 2) capture of available water by plants. Pierce and Rice (1988) described water recharge and water capture as recovery efficiency. Because approximately 30% of annual precipitation in western Canada is in the form of snow, which is redistributed by wind during winter months, enhancing soil water recharge in this region must involve improved snowtrapping.

While relationships between stored soil water, seasonal soil water supply and forage production of hay crops have been reported for the North American northern Great Plains region (Smika et al. 1965; Sonmor 1963; Ries and Hofman 1993), few studies have considered the impact of grazing management on efficiency of water use. The objectives of this study were to determine the impact of grazing management on soil water conservation and use during the first four years of a newly established pasture.

METHODS AND MATERIALS
The field study was conducted at Brandon, Manitoba on a fine sandy loam soil. Pastures were established in 1990 and grazing treatments were initiated in 1991. Composition of the pasture once established was approximately 70% alfalfa, 20% meadow bromegrass, and 10% Russian wild ryegrass. Pastures were fertilized to soil test recommendations in the spring of each year.

The four grazing treatments used in the study were: continuously-grazed/low stocking rate, continuously-grazed/high stocking rate, rotationally-grazed/low stocking rate, and rotationally-grazed/high stocking rate. The high stocking rate was 2.2 head ha^{-1}; grazed to a residual of 990 kg ha^{-1} dry matter, while the low stocking rate was 1.1 head ha^{-1}; grazed to a residual of 2,160 kg ha^{-1}. Each experimental unit consisted of a 3.7 ha pasture. In the case of the rotationally-grazed treatments, each pasture was divided into 10-0.37 ha paddocks. Each paddock was usually grazed for 2-3 days in spring and 6-9 days in summer, however this was adjusted depending on plant growth conditions. The experimental design was a randomized complete block with two replicates.

One neutron access tube was installed in each pasture; in paddock five in the rotationally-grazed treatments, and in a similar location in the continuously-grazed plots. Soil water determinations to a depth of 210 cm were conducted at the beginning and end of each grazing season. Precipitation was recorded at a nearby weather station and evapotranspiration (ET) was calculated as growing season precipitation plus soil water use. Previous research (Hofman et al. 1983) found very little runoff or deep percolation in pastures, hence, it was assumed that water loss by runoff and deep percolation was negligible in this study. Annual growing season (early May to Sept.) precipitation was 35.9 cm, 20.7 cm, 43.3 cm and 24.9 cm in 1991, 1992, 1993 and 1994, respectively.

Analysis of variance was used to test treatment differences and the 10% level of significance was used in the analysis.

RESULTS AND DISCUSSION
Evapotranspiration Total ET values for the four year study are given in Table 1. Evapotranspiration was lowest in the driest year (i.e. 1994) and highest in the wettest year (i.e. 1993). Between 1992 and 1994, the rotationally-grazed/low stocking rate treatment (rotational/low) consistently had the highest amount of seasonal ET.

Soil Water at Beginning of Grazing Season The amount of soil water present in spring allowed evaluation of treatments on the basis of soil water conservation during the non-grazing period; the fall, winter and early spring period. The amounts of spring soil water each year were positively related to fall and overwinter precipitation (data not shown), however treatment effects were also observed. Among treatments, the rotational/low system consistently had the highest amount of soil water in spring (Table 1). This was followed by the rotational/high treatment, while the continuous/high treatment had the least amount of spring soil water. Higher levels of spring soil water in rotational/low treatment were attributed to better snow-trapping as more standing plant material was left to intercept snow (see methods section). The continuous/high treatment, on the other hand, was relatively bare in late fall, resulting in little snow-trapping.

Seasonal Soil Water Extraction Soil water extraction is that fraction of seasonal ET which is derived from the soil; it does not include precipitation water. Greater soil water extraction should increase a system's recovery efficiency (Pierce and Rice 1988) and forage yield (Ries and Hofman 1993). In the present study, the proportion of seasonal ET which was derived from water present in spring was highest in the first two years of the study (23 and 30%, respectively) and lowest in years three and four (10 and 9%, respectively). Lower percentages in later years were attributed to exhaustion of subsoil water reserves, a common observation in established perennial forage crops (Hoyt and Leitch 1983). These observations point out just how dependant established forage crops are on precipitation, either growing season precipitation or snow trapped in winter, for their water supply.

Among management treatments, the rotational/low system consistently extracted the most soil water (Table 1). In 1994, for example, the rotational/low treatment extracted 5.8 cm more soil water than the continuously grazed treatments. This amount of additional water is significant as it represents over two-thirds of normal June precipitation in western Manitoba. One obvious reason for greater soil water extraction by the rotational/low system was that it had the greatest amount of water available in the soil profile at the beginning of the grazing season. However, the rotational/low system also captured a higher proportion of soil water present in spring than the other treatments. Averaged across years, percent spring water extracted by pasture systems was 27.9% for the rotational/low system compared with 21.1, 15.3 and 18.2% for the continuous/low, continuous/high and rotational/high systems, respectively. Observations of profile water extraction for the different grazing system and stocking rate combinations (Figure 1) suggest that plants in the rotational/low system had deeper and more extensive root activity than other treatments. There is a considerable body of literature to support the suggestion that plants which are defoliated less frequently will have healthier and more extensive root systems.

CONCLUSIONS

Results of this study indicate that despite the fact that pastures exhaust indigenous soil water after several years of production, grazing management can strongly influence water use and water use efficiency. It was shown that grazing systems which result in less defoliation (i.e. lower stocking rates) generally had more soil water available in spring and higher ET levels. The benefits of low stocking rates were greater in the rotationally grazing than in the continuously grazed pastures. Superior water conservation in the rotational/low system was attributed to better snow-trapping, while superior soil water extraction in this system was attributed to a healthier and more extensive root system.

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Table 1

Influence of grazing system and animal stocking rate on total seasonal evapotranspiration (ET), amount of soil profile water in spring, and amount of soil water extracted between spring and end of the grazing period.

Grazing System	Stocking Rate	1991 Seasonal ET	1991 Spring soil water	1991 Soil water extracted	1992 Seasonal ET	1992 Spring soil water	1992 Soil water extracted	1993 Seasonal ET	1993 Spring soil water	1993 Soil water extracted	1994 Seasonal ET	1994 Spring soil water	1994 Soil water extracted
		cm water											
Continuous	Low	47.8	36.3	11.9	29.5	30.7	8.8	48.0	29.6	4.7	26.2	25.9	1.2
	High	48.5	33.6	12.6	28.5	26.6	7.8	45.8	26.5	2.5	26.2	24.5	1.2
Rotational	Low	48.5	37.4	12.6	32.9	36.4	12.2	52.5	40.9	9.2	32.0	34.0	7.0
	High	45.3	35.8	9.4	28.8	32.7	8.1	47.5	36.2	4.2	25.0	24.7	0.5
LSD (0.10)		—	NS	NS	—	NS	3.2	—	14.2	6.7	—	NS	6.3

Figure 1
Water extraction (difference in soil water content between spring and fall) for four grazing management systems in a) 1991, b) 1992, c) 1993, and d) 1994. Symbols: solid square - continuously-grazed/high stocking rate; open square - continuously-grazed/low stocking rate; solid triangle - rotationally grazed/low stocking rate; open triangle - rotationally grazed/high stocking rate. * indicates significant differences (P=0.10); n.s. indicates no significant difference.