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THE EFFECT OF OPTIMUM VS. DEFICIT IRRIGATION ON PLANT NITROGEN UPTAKE AND NITRATE LEACHING LOSS FROM SOIL

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Abstract

Nitrate (NO_3^-) leaching, associated with urine nitrogen (N) deposition during grazing is recognised as a significant environmental problem. In this study it was hypothesised that optimum irrigation could increase plant growth and uptake of urine-N deposited, thereby reducing NO_3^- leaching over winter. The objective of this research was therefore to determine the effect of optimum vs. deficit irrigation regimes on N uptake and dry matter yields from diverse and standard pasture species and their effects on annual NO_3^- leaching losses from soil.

In this study ruminant urine was applied at two rates of N, 500 and 700 kg N ha^{-1}, to soil monolith lysimeters in late spring. Urine was labelled with ^{15}N stable isotope at 5 atom% prior to application. Irrigation water was applied at optimum vs. deficit rates. Measurements of NO_3^- leaching, ^{15}N abundance and pasture N uptake were undertaken for a 10 month period following urine application.

Rational and objective

Nitrate (NO_3^-) leaching occurs when there is an accumulation of NO_3^- in the soil profile that is followed by a period of drainage. High nitrogen (N) returns associated with urine N deposition from grazing dairy cows are recognised as a significant environmental problem because they contribute to the rising concentrations of NO_3^- in ground and surface waters (Cameron et al., 2013). One proposed solution to minimise environmental effects is the introduction of diverse pasture species into grazed systems.

Grazed systems in New Zealand are historically perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) mixes. Recently research has begun to investigate the use of diverse pastures which may include herbs such as chicory (*Cichorium intybus*) and plantain (*Plantago lanceolata*), red clover (*Trifolium pratense*) and prairie grass (*Bromus wildenowii*) as a possible strategy to reduce NO_3^- leaching. A review of the literature indicates that diverse pasture species reduce urinary N excretion by grazing animals (Totty et al., 2013; Woodward et al., 2012) and thus potentially decrease NO_3^- leaching losses.

However, there is uncertainty about how diverse pastures respond, with respect to N uptake, under deficit and optimum rates of irrigation. Few studies have investigated the effects of irrigation efficiency on NO_3^- leaching, especially for diverse pasture species. Thus there is a scarcity of knowledge on the relative production of diverse pasture species under both optimal and deficit irrigation, and how this may influence N uptake and N loss from soil. In this study it was hypothesised that optimum irrigation would increase plant growth and uptake of urine-N thereby reducing NO_3^- leaching over winter.

The objective of this research was to determine the effect of optimum vs. deficit irrigation regimes on N uptake and dry matter yield from diverse and standard pasture species and their effects on annual NO_3^- leaching loss from the soil.

Methods

A trial was conducted using forty large, undisturbed soil monolith lysimeters (50 cm diameter × 70 cm deep). The soil used was a Paparua fine sandy loam soil. Two pasture types were used, a ‘standard’ mixture of perennial ryegrass and white clover and a ‘diverse’ mixture of perennial ryegrass, white clover, red clover, chicory, plantain and prairie grass. Pasture mixtures were evaluated under optimum (18 mm/3 days) vs. deficit (9 mm/3 days) irrigation rates (Table 1). Eight treatments, each with five replicates, were randomly allocated to the lysimeters (Table 1). Fresh dairy cow urine was applied to the lysimeters in late spring at rates of 500 or 700 kg N ha^{-1} to simulate a typical dairy cow deposition event (2 L of urine). Urine was labelled with 5 atom% ^{15}N-urea. Soil moisture content was measured using time domain reflectometry with three probes installed at depths of 0-20, 20-40 and 40-60 cm.

Table 1. Description of lysimeter treatments.

Treatment no.	Irrigation regime	Irrigation rate	Pasture species	Treatment (kg N ha^{-1} yr^{-1})	Replicates
1	Deficit	9 mm, 3 d	Standard	700	5
2	Deficit	9 mm, 3 d	Diverse	700	5
3	Deficit	9 mm, 3 d	Standard	500	5
4	Deficit	9 mm, 3 d	Diverse	500	5
5	Optimum	18 mm, 3 d	Standard	700	5
6	Optimum	18 mm, 3 d	Diverse	700	5
7	Optimum	18 mm, 3 d	Standard	500	5
8	Optimum	18 mm, 3 d	Diverse	500	5

Analysis

Leachates from the lysimeters were collected regularly, following rainfall induced drainage events. The leachates were analysed for NO_3^- and ammonium (NH_4^+) by flow injection analysis (FIA). However, that data is not presented here and will be reported later once complete. Pasture on the lysimeters was cut at typical grazing heights and removed every 2-4 weeks. Pasture dry matter yields from individual lysimeters were recorded and a ground sub sample analysed for total N concentration using an ElementarVario-Max CN Elemental Analyser. For soil analysis, lysimeters will be destructively sampled in 10 cm increments to a depth of 60 cm. Soil will be analysed for soil inorganic N (NO_3^- and NH_4^+), total N, and a root distribution analysis will be performed.

Results

There was a difference in soil moisture content between the deficit and optimum irrigation regimes over the summer period, but soil moisture contents were the same for both irrigation regimes over winter (Figure 1). Dry matter yield was higher under optimum irrigation but there was no yield difference between pasture species within each irrigation treatment (Figure 2).

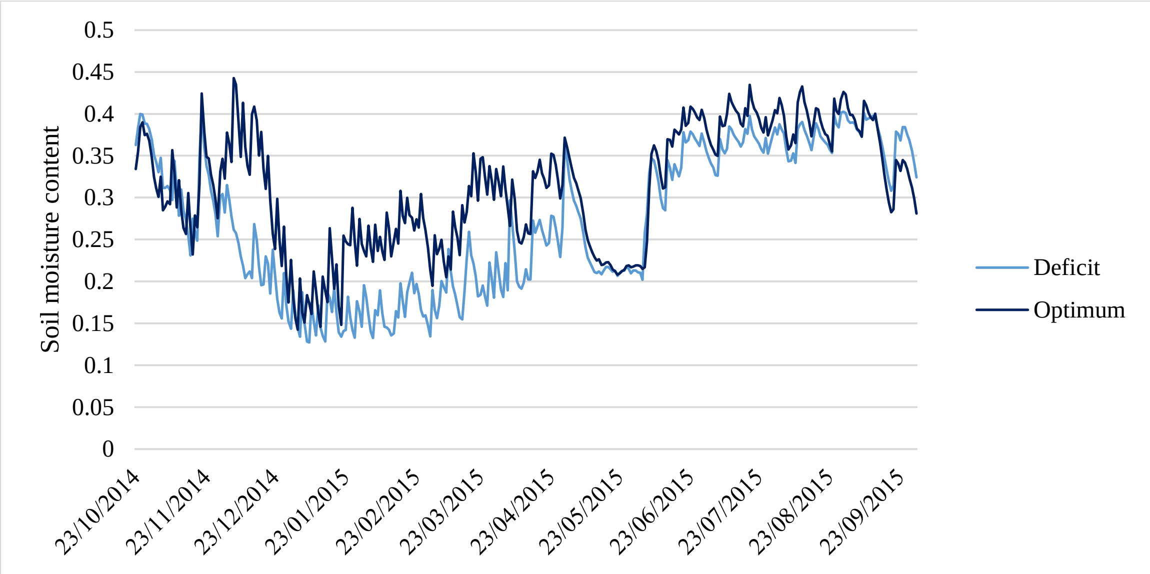

Figure 1. Soil moisture content 0-20 cm over a 10 month period.

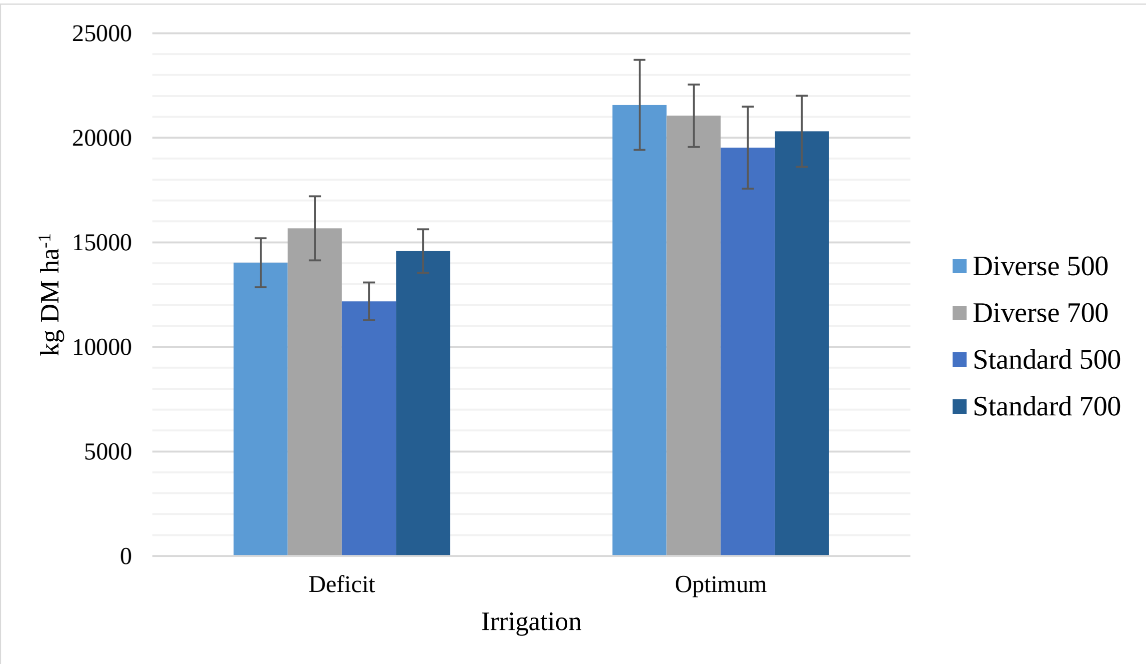

Figure 2. Pasture dry matter yield under optimum and deficit irrigation regimes for standard and diverse pasture species. Urine applied at 500 or 700 kg N ha^{-1}.

Conclusions

- Optimum irrigation resulted in higher dry matter yields for both standard and diverse pastures compared with deficit irrigation regimes.
- There was no difference in pasture dry matter yield between diverse and standard pastures within each irrigation type.
- Preliminary results suggest that very low leaching losses occur from urine applied in late spring.
- Work on this study is currently ongoing. Further analysis will determine the full effect of irrigation on N uptake and NO_3^- leaching losses from late spring applied urine.

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