

NITRATE LEACHING UNDER SHEEP GRAZING DIFFERENT FORAGES

Nitrate leaching in pastoral systems is influenced by factors including forage type and grazing species. This article outlines the influence of different forages on nitrate leaching under sheep grazing during a three-year study at Massey University.

Nitrogen and nitrate leaching

Nitrogen (N) leaching losses in drainage and run-off from agricultural soils, particularly from intensively grazed pasture, is a significant cause of water quality deterioration in many parts of the world including New Zealand. Nitrate (NO_3^-) is the most common form of N leaching in drainage water. This is largely due to its negative charge, which means it is repelled by cation exchange sites in the soil, rather than being sorbed, so when water percolates through soil after rain or irrigation it carries nitrate with it. In contrast, the other important source of N in soil, ammonium (NH_4^+),

does not generally move much through the soil because it is sorbed at cation exchange sites.

Nitrogen cycling in grazing systems is influenced by diet and the partitioning of ingested N in grazing animals. Between 75-95% of N ingested is excreted, with about 70% of that being urea (urine). Faecal N is in an organic form not rapidly mineralised, so it is not a significant contributor to N leaching.

Nitrate leaching may be lower under sheep grazing compared with cattle, but inferences about leaching losses from previous studies have been limited by the



Overview of the sheep drainage trial plots on Keeble's farm at Massey University (four drainage pits can be seen below the plots)

In the future, N leaching cap restrictions may be extended to livestock industries other than dairy, including intensive sheep farming.

indirect assessment of leaching losses, including soil moisture balance and porous ceramic cup samplers. To remain economically viable, sheep production systems in New Zealand (especially those on flat or undulating landscapes) have intensified over time, with greater use of N fertiliser and higher stocking rates than in the past.

The potentially adverse environmental effects of intensive farming on water quality has resulted in many regional councils placing N leaching caps on dairy farms. In the future, N leaching cap restrictions may be extended to livestock industries other than dairy, including intensive sheep farming. Knowledge of potential leaching rates under intensive sheep grazing systems is essential information for policy-makers.

Four forages

This research quantified and compared N leaching under sheep grazing on four different forages:

- Perennial ryegrass/white clover
- Plantain/white clover
- Italian ryegrass/white clover and forage brassicas
- Turnips year 1, swedes year 2 and kale year 3.

Different brassicas were used depending on the time of sowing (autumn year 1, late spring years 2 and 3) and the need to minimise the risk of clubroot (*Plasmodiophora brassicae*). Perennial ryegrass/white clover was compared with three alternative forages. Plantain has been shown to reduce urine N concentration in grazing animals, but data for sheep is limited.

Italian ryegrass was included as a treatment because it is winter active, which can increase the uptake of soil N when leaching risk is high due to wet soils. The brassica crop treatment was included because it remains an important supplementary feed in sheep systems, but may result in high N leaching after winter grazing.

Materials and methods

This study was carried out at Massey University's Keeble's farm near Palmerston North. The research site included an area with 20 drainage plots (five plots/forage treatment). Each plot was 40 × 20 m and had a hydrologically isolated mole pipe drainage system (see first photo).

The drainage plots were sown with the appropriate forage species on 21 March 2019 with a roller drill and chain harrows:

- The plantain/white clover and Italian ryegrass/white clover plots were oversown in April 2020

- Swedes were sown by direct drilling in the spring of 2019 and kale in spring 2020
- N fertiliser (urea; 46:0:0) was applied to the swede plots (30 kg N/ha) in March
- Nitrophoska (12% N) and urea were applied to the other three treatments (30 kg N/ha) in April and October 2020, respectively.

The drainage plots were grazed according to the cumulation of forage and best grazing management practices for these forages. Sheep (ewes) used to graze the drainage plots were run on adjacent farmlets which, for ewes grazing alternative forages, included an area (25% of the farmlet) in one of the alternatives. This allowed ewes grazing alternative forages to be transitioned from ryegrass/white clover prior to being grazed on the drainage plots (see second photo).

Each farmlet was stocked at 14 ewes/ha for the entirety of the experiment (46 ewes per farmlet). This stocking rate was chosen to reflect an intensive sheep farming operation for this farm class and area.

Drainage water from each individual plot was hydrologically isolated using mole drains that channelled water into pipes with individual tipping-bucket (~5 L) flow meters at the outlets, which were located in nearby drainage sampling pits (see third photo). Each tipping bucket was calibrated dynamically to account for larger tip volumes at higher flow rates. All tipping buckets were instrumented with data loggers to provide continuous flow rate measurements. A small sub-sample (~0.5 ml) of the drainage water from every second tip was automatically collected to provide a representative sample for water quality analysis.

Monitoring of drainage water commenced in late April 2020. After the completion of each drainage event, water samples (~100 ml) were collected manually. Filtered sub-samples were analysed for NO₃⁻-N using a Technicon Auto Analyser. The amount of NO₃⁻-N, losses (kg/ha) were calculated as the product of the measured drainage volume and NO₃⁻ concentrations.

The performance of the sheep used in the study was also monitored, which comprised production data (including liveweight, lambing % and lamb liveweight), as well as information on N metabolism (including urine urea content – seasonally). Only the N leaching information is presented here.

Results

The nitrate leached annually under each forage was generally low, ranging from just 0.22 kg/ha for plantain/white clover in 2019 to 11.78 kg/ha for plantain/white clover in 2021.

Table 1: Annual nitrate N leached (kg H/ha) under different forages grazed by mixed age ewes

Treatment	2019	2020	2021
Perennial ryegrass/white clover	1.36	0.90	2.06
Italian ryegrass/white clover	0.35	0.43	6.7
Plantain/white clover	0.22	0.44	11.78
Brassica	2.45	8.96	4.46

The annual pattern for the three permanent forages was similar, with the highest N losses occurring in 2021 for all forages apart from brassica. For the first two years of the study the brassica crop produced the highest leached N totals, whereas in 2021 only perennial ryegrass/white clover had lower N losses.

The annual N leaching losses in **Table 1** are much lower than N losses measured on the same soil type and same year under dairy cow grazing (also at Massey University). The brassica plots were intensively grazed during winter, followed by a period where the soil was left bare until soil conditions allowed replanting, which was typically in late spring. This demonstrates the potential for higher losses of NO_3^- -N resulting from urine patches in the absence of vegetation and plant uptake. Recent research has shown that N leaching losses from forage crops grazed by dairy cows during winter could be more than twice those under grazed pasture.

In the current study, ewes began grazing brassica plots in the latter part of the winter and had not completely eaten all the bulbs before set stocking for lambing. As a result, the

total NO_3^- -N leached could have been greater if the ewes had been able to continue grazing and harvest all the bulb material. On the other hand, the N content of swede bulbs is generally lower than the leaf.

The results from the first two years of the study indicate that swards with plantain are effective at reducing N leaching under sheep grazing. Plantain contains bioactive compounds (aucubin and acteoside), which can reduce the production of NH_3 in the rumen, and they also have a

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Romney ewes grazing one of the ryegrass-based treatment (each treatment was replicated five times)

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diuretic effect. Urine N content collected from the ewes in this study revealed that urea concentration in the urine of ewes grazing the plantain sward was significantly lower than for other treatments in most seasons.

The 2021 year appears to be an aberration, with the plantain/white clover and Italian ryegrass/white clover treatments producing comparatively high N losses. Both of these treatments had become degraded by 2021 – the plantain/white clover due to ingress of a significant dock infestation and the Italian ryegrass/white clover from low vigour (low tiller density).

As a result, plots with these treatments were sprayed with herbicide (glyphosate) and resown on 14 April 2021 using a direct drill. Consequently, after grazing in February 2021 vegetative cover in these plots was minimal until early May 2021. Urine N deposited between late 2020 and February 2021 was probably converted into nitrate N, but with little plant uptake, so more was available to be leached once drainage commenced (June 2021).

In 2021, kale was used as the brassica crop and the plots were grazed between June and July. Nitrate leaching under brassica was low compared to that observed under brassica (swedes) in 2020 (8.96 kg N ha⁻¹). The kale crop was the third successive crop in this treatment, meaning that available soil N was probably low, contributing to the low forage N content observed in the kale crop (the leaf N content of the kale was about half that of the previously grazed turnips and swedes).

There have been large annual and seasonal fluctuations in climatic conditions during the time of the study. For example, winter 2021 was the warmest winter on record in Manawatu, which resulted in good plant growth and potentially high rates of N uptake compared with previous winters. Ongoing research is required across multiple years with contrasting rainfall and temperatures to adequately understand N losses under different forages grazed by sheep.

The results from this study suggest that the drainage system is capable of picking up subtle differences in N leaching from different treatments and in response to seasonal and management factors. The trial will be continued with some modifications to include a direct comparison between sheep and cattle grazing and the use of a brassica/Italian ryegrass mix to maintain vegetative cover post-grazing in the winter.



PhD student Sarmini Maheswaran checking drainage flow meters in a drainage pit at Massey University

Implications

This study confirms the difference in N leaching potential between sheep and cattle grazing systems, and cattle (especially dairy systems) typically produce much higher N leaching losses. In sensitive catchments, the use of forage crops (such as swedes and kale) to feed sheep rather than cattle over the winter period may be a useful strategy to reduce N losses through leaching on sheep and beef farms. There is good evidence that plantain can be used to reduce N leaching under sheep grazing. Italian ryegrass may also be useful, a function of its winter activity.

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