URINE NITROGEN IN HILL COUNTRY PASTURE SOILS

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ABSTRACT

In New Zealand the traditional way of building up nitrogen (N) fertility in pastures has been to apply phosphorus (P) fertilisers to provide adequate soil fertility for legume growth, which then provides N through biological N fixation. However, the marked responsiveness of hill pastures to N fertiliser indicates that this traditional approach may be placing a serious constraint on hill country production. At the same time, there is concern that the resulting elevated soil P levels may pose some environmental risk.

Although the importance of soil N availability to hill country pasture production has long been recognised, there is surprisingly little infonnation available on N cycling in hill country pastures. This is because the limited research funding available has been directed mainly at detennining the requirements for P and sulfur (S) fertilisers, which have constituted the bulk of fertiliser expenditure in hill country. In order to develop best practice in the use of fertiliser N in hill country, infonnation is required on N flows in the soil-plant-animal system on the contrasting topographic land units that comprise hill pastures. The role of grazing animals and particularly the N transformations associated with urine patches are very important components of these N cycles.

In this study, two field experiments were conducted at contrasting locations in North Island hill country pastures to investigate the fate of urine N. These field experiments were then followed by a laboratory incubation experiment that sought to clarify the effect of soil properties on subsequent transfonnations of urine N. The experimental results were then used, together with data from the literature, to model the N cycle for hill country pasture. In addition, to assess the N availability in hill pastures, an *in situ* N measurement technique using ion exchange resin membrane spikes was developed and evaluated.

The first preliminary field experiment was carried out at the AgResearch Grassland hill country research site in Waipawa, North Island, New Zealand from 09 June 1999 to 29 October 1999. The major soil type was Waipawa Stony Silt Loam (Pallic Soil). Three synthetic urine treatments (0, 200, 400 kg N/ha) were applied in a randomised complete block design and the experiment was repeated in a flat campsite and a steep site. At 1

day after urine application (DAUA), the increase in the soil mineral N pool was close to or greater than the quantity of added urine N. The dominant form of mineral N throughout the experiment was NH_4^+-N. This suggested that nitrification rates were low and that leaching losses of NO_3^--N would therefore be low. Only 18-27% of the urine N was recovered by the pasture. Estimates of the loss of urine N by ammonia volatilisation were large, ranging from 21-34% of added urine N. At the end of the experiment (142 DAUA), 34 -50% of added urine N appeared to have been immobilized into complex organic matter.

The second field experiment was carried out at Ballantrae AgResearch hill country research station from 14 July 2000 to 12 December 2000. The soil was Ngamoko Silt Loam (Brown Soil). Three different rates (0, 280, 560 kg urine N/ha) of synthetic urine were applied as treatments and the experiment was repeated as a randomised complete block design on a flat campsite and a steep slope. Shortly after application, recovery of urine N as soil mineral N was greater than 100% (113-141%) in the flat site. This increase in mineral N corresponded to a decrease in mineralisable N, suggesting organic matter mineralisation after urine application. During the first month after urine application, NH_4^+-N was the dominant form of mineral N, but during the second month, NO_3^--N was the dominant mineral N form. At the end of the experiment (88 DAUA), urine N recovery as mineral N was very low, ranging from 0-3%. The rate of nitrification after urine application was higher in flat campsites than in steep slopes. Soil NO_3^--N levels in the 0-10 cm soil depth in urine-treated plots at both sites decreased considerably between 30 and 45 DAUA. A simple model developed in Microsoft Excel suggested that substantial leaching of urine N (9-33% of added urine N) was likely to have taken place. Urine N recovery by herbage in this experiment was low (1-14% of added urine N). Estimates of the loss of urine N through volatilisation were large, ranging from 24-51% of added urine N. At the end of the experiment the amounts of urine N estimated to have been immobilised into the soil organic matter ranged from 8-57% of that added.

A laboratory incubation experiment was conducted using four soils collected from the flat and steep sites of the field experiments at Waipawa and Ballantrae together with three other soils collected from lowland sites (Kairanga silt loam, Karapoti silt loam and Manawatu sandy loam (Fluvial Recent Soils)) that had received substantial quantities of excretal N over several years. Field moist soil, equivalent to a weight of 100 g of dry soil, was placed in each of 36 small plastic cups for each soil type. Urine was collected from four cows during milking two weeks before the experiment. Urine was applied to 18 cups of each soil at the rate of 6 mL of urine/100 g dry soil (40 mg urine N/100 g dry soil). The remaining 18 cups were used as controls. No solution was added to the control cups.

In contrast to the field experiments, there was little evidence of an initial priming effect, with mineral N levels 3 DAUA ranging from 64-81% of added urine N. Nitrification rates were highly variable (0.3 to 18.3 μg NO_3^--N/g soil/day) across the seven soils. All lowland soils had higher nitrification rates than hill soils, while those soils collected from campsites had higher nitrification rates than soils collected from steep slopes. Although nitrification could account for most of the disappearance of soil NH_4^+-N from 3-45 DAUA, it was evident that mineralisable N and soil microbial biomass N also increased after urine application.

A simulation model of a hill country N cycle developed in Microsoft Excel confirmed the importance of urine N in hill country pastures. The model indicated that N outputs in animal products, together with losses through ammonia volatilisation and leaching from urine patches were likely to exceed the N inputs to hill pastures by legume N fixation, non symbiotic fixation and atmospheric deposition. This may be the reason for the observed high N responsiveness in hill country pastures. Pasture utilisation and excretal distribution in the paddock were the most important factors influencing the overall N balance in the paddock. More work is required to obtain information on these parameters in hill country pastures.

The *in situ* N measurement technique using ion exchange resin membrane spikes proved to be a useful approach to monitoring the continuous changes in soil mineral N in the field experiments as well as in the incubation experiment. Resin spikes were able to detect apparently real differences in the availability of soil N - even when the standard 2 M KCl extraction could detect no differences. The potential of resin spikes to detect spatial variability in soil N status was also demonstrated.

A simple model developed in Visual Basic in Microsoft Excel to simulate the N adsorption by resin spike in soils demonstrated that soil moisture, soil temperature, soil N concentration and the time the resin spike is in the soil are all major determinants of the amount of N adsorbed to resin in soil.

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