# MANAGEMENT OF ACIDIFYING LEGUME BASED PASTURES FOR SUSTAINABLE PRODUCTION IN SOUTHERN AUSTRALIA

A.M. Ridley[a], R.E. White[b] and R.J. Simpson[c]

[a]Institute of Integrated Agricultural Development, Department of Natural Reseources and Environment, R.M.B. 1145 Rutherglen, Vic, Australia, 3685

[b]Faculty of Agriculture and Resource Management, University of Melbourne, Royal Parade, Parkville, Vic, Australia, 3052

[c]Division of Plant Industry, CSIRO, G.P.O. Box 1600, Canberra, A.C.T., Australia, 2601

**ABSTRACT**

A field experiment was used to determine nitrate leaching losses under perennial (*Phalaris aquatica* and *Dactylis glomerata*) and annual (*Lolium rigidum*) grass pastures under control and high N treatments. Previously published results and assumptions were made to extrapolate results to typical grazed pastures, and best bet practices to manage soil acidification were suggested. Nitrate leaching losses of approximately 14 and 28 kg N/ha/year were estimated for grazed perennial and annual pastures (equating to soil acid addition of 1 and 2 kmol $H^+$/ha/year). Other sources of acid addition known to occur in this environment accounted for a further 1 kmol $H^+$/ha/year (1 kmol $H^+$ equating to 50 kg lime required to balance acid addition). Best bet management practices to reduce soil acidification include deciding how far the soil should acidify, using lime to balance alkalinity lost through agricultural production, sowing perennial grasses, altering grazing management and using acid tolerant species to maintain production in the short term.

**KEYWORDS**

Acidification, nitrate leaching, perennial pastures, southern Australia, *Phalaris*

## INTRODUCTION

Soil acidification is a major land degradation problem in above 500 mm/year rainfall areas of southern Australia (Anon, 1995) where pastures are legume based. Soil acidification is caused by acid production associated with the biological C and N cycles (Helyar and Porter, 1989). Nitrate leaching is often the single largest contributor to acidification, occurring from the leaching of mineralised N (Simpson, 1962) and from urine patches (Ball and Ryden, 1984). Causes of acidification in Australia have been well quantified (Helyar and Porter, 1989, Ridley *et al*., 1990) with the exception of nitrate leaching. The aims of this study were to determine whether the perennial grasses, *Phalaris aquatica* (phalaris) and *Dactylis glomerata* (cocksfoot) could reduce nitrate leaching compared with *Lolium rigidum* (annual ryegrass) in the field under control and high N treatments. In addition, conclusions were drawn about the likely best practices for managing soil acidification under *Trifolium subterraneum* (subterranean clover) based pastures in southern Australia.

## MATERIALS AND METHODS

The field experiment was located at Rutherglen (36° S., 146 (E.) on a red brown earth (Stace *et al*., 1968). A randomised block design was used and the experiment was established in March, 1989, comprising four pasture treatments (Sirosa phalaris, Porto cocksfoot, Wimmera annual ryegrass and fallow). Each pasture treatment had 2 N treatments (control and 500 kg N/ha/year, chosen to be similar to the concentration of N occurring under a urine patch), with N being applied in autumn each year following establishment of annual ryegrass. The experiment was measured for four years from 1990-93.

Plant density and N uptake of pastures were measured but reported elsewhere (Ridley, 1995). Nitrate leaching was calculated for each treatment as the product of amount of water calculated to drain below 110 cm depth (the estimated effective rooting depth of pasture) and the soil solution nitrate concentration. The amount of water draining below 110 cm was estimated by solving the water balance equation, and assuming that evapotranspiration ($E_t$) equalled modified Penman $E_t$ (Doorenbos and Pruitt, 1984) for periods when drainage was calculated. Soil water content was measured using a calibrated neutron moisture meter and runoff was assumed to be zero. Drainage was calculated once the soil reached the winter mean water content (White *et al*., 1983), defined as the mean soil water content over July-September. Matric potentials as measured by tensiometers supported this choice of soil water content above which drainage was estimated.

Soil solution was sampled from piezometers (2/plot installed at 110 cm depth) each season once the soil had wetted up sufficiently. In 1990 nitrate concentrations were analysed colorimetrically using a continuous flow autoanalyser, whereas the 1991-93 samples were analysed on an HPLC. Calculated nitrate leaching was summed over the individual time periods to give annual calculated leaching (kg N/ha/year). Analysis of variance was used to determine differences between treatments.

## RESULTS

The annual rainfall for 1990-93 was 671, 515, 901 and 684 mm/year respectively, the 80 year average being 597 mm. Both 1990 and 1992 were considered wet years, with rainfall exceeding evapotranspiration over the growing season (April-October).

Calculated leaching of nitrate (kg N/ha) showed that there were no differences between pastures in 1990 (Table 1). In 1991 both phalaris and cocksfoot had less nitrate leached than for annual ryegrass and fallow, with no differences between N treatments. Higher nitrate leaching occurred in 1992 where N was applied (277 on +N and 35 kg N/ha on the control, $P<0.05$), however there were no differences between pasture types. Nitrogen treatments had similar nitrate leaching in 1993 and there was less nitrate leached under phalaris ($P<0.05$) than for fallow. Averaged over 1991-93 when data was collected from both N treatments, nitrate leaching was higher where N was applied (105 on +N and 35 kg N/ha/year on the control, $P<0.05$).

## DISCUSSION

These and previously published results (Ridley, 1995) suggest that phalaris has greater potential than cocksfoot to reduce soil acidification and improve production, and that both species are better than annual grass based pastures.

The variation in N leached was large and speculating about average leaching losses is problematic. Nevertheless, as no guidelines exist for temperate Australian pastures, some speculation is warranted. The N losses of the control phalaris and cocksfoot treatments were 6 and 16 kg N/ha/year (Table 1), which equate to acid addition of 0.4 and 1.1 kmol H+/ha/year respectively. Losses under the +N treatments were 77 and 119 kg N/ha/year respectively. High fertility areas and stock camps commonly comprise at least 10% of paddock area (Ruz-Jerez *et al*., 1991), and thus acid addition in such areas would add a further 0.6 and 0.9 kmol $H^+$/ha/year. The rates of acid addition due to nitrate leaching were thus estimated as 1 and 2 kmol $H^+$/ha/year for phalaris and annual ryegrass pastures respectively. A further 1 kmol $H^+$/ha/year acid addition commonly occurs under grazed pastures containing subterranean clover (Ridley *et al*. 1990). Acid addition under grazed phalaris and annual ryegrass pastures containing clover is thus estimated to require 100 and 150 kg lime/ha/year to balance acid addition (1 kmol $H^+$ requiring 50 kg lime to balance acidification).

Many landholders are unaware that soil acidification is a major land degradation problem (Anon. 1995). In many areas of southern Australia where rainfall exceeds 500 mm/year, soil $pH_{CaCl2}$ is already less than 4.5, and continued acid addition is resulting in increasing toxicities of aluminium and manganese, other acid soil related nutrient problems and degradation of soil clay minerals. Subsoil acidification is also a major issue because amelioration of subsoil acidity is presently considered uneconomic and lower production is the inevitable consequence.

An integrated approach is needed to decide how to manage soil acidification and landholders need to give careful consideration in balancing short term profitability with soil degradation. Best bet practices to manage soil acidification will involve:

(1) Making a decision as to how far the soil should acidify in terms of which agricultural species can be grown
(2) Use of lime to balance alkalinity lost in removal of plant and animal products and acidity generated through nitrification and subsequent nitrate leaching
(3) Where profitable, sowing perennial grass-based pastures which can make maximum use of soil water and N
(4) To reduce acid addition from the C cycle through altered grazing management where compatible with management and profitability
(5) Use of acid tolerant species where necessary to maintain production and profitability in the short term, while addressing the management of soil acidification by the other management options available.

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**Table 1**
Calculated nitrate leaching (kg N/ha) under pastures at Rutherglen, southern Australia

| | 1990 | 1991 | 1992 | 1993 | Average (1991-93) |
|---|---|---|---|---|---|
| Phalaris +N | 42 | 1 | 229 | 0 | 77 |
| Phalaris control | *[a] | 0 | 10 | 7 | 6 |
| Cocksfoot +N | 50 | 0 | 231 | 26 | 86 |
| Cocksfoot control | * | 1 | 6 | 29 | 12 |
| Annual ryegrass +N | 72 | 11 | 314 | 32 | 119 |
| Ryegrass control | * | 7 | 19 | 21 | 16 |
| Fallow +N | 84 | 15 | 334 | 62 | 137 |
| Fallow control | * | 1 | 105 | 61 | 56 |
| L.S.D. (P=0.05) | | | | | |
| N | * | 5 | 80 | 37 | 35 |
| Pasture | 35 | 7 | 114 | 52 | 50 |
| Pasture x N | * | 10 | 161 | 74 | 71 |