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THE POTENTIAL OF PLANTAIN BASED PASTURES TO REDUCE NITROGEN LOSSES FROM DAIRY SYSTEMS

Soledad Navarrete, M.J Rodriguez, P.D. Kemp, M.J. Hedley, D.J. Horne and J.A. Hanly

School of Agriculture and Environment, Massey University, Palmerston North, New Zealand
Email: S.Navarrete@massey.ac.nz

Abstract

Plantain (*Plantago lanceolata*) appears a sustainable option to reduce urinary nitrogen (N) excretion from cows thereby minimising the nitrate (NO_3-N) leaching from pastoral dairy systems. The potential of plantain to decrease NO_3-N leaching while maintaining, or increasing, milk production is being evaluated in a dairy systems experiment at Massey University's Dairy Farm No 4. Three pasture treatments were established in a complete randomised design with five replicate plots (800 m^2), with an isolated mole-pipe drain system for each plot to collect drainage water samples. The pasture treatments are: (i) plantain, (ii) plantain-clover mix, containing plantain, red (*Trifolium pratense*) and white clover (*T. repens*), and (iii) ryegrass (*Lolium perenne*)/white clover. They were grazed by lactating dairy cows over 10 consecutive days in March and in April, 2017 (autumn). The milk production of cows, the N and urea concentrations in the cows' urine, and the NO_3-N leached in drainage were measured. After 10 days of grazing, cows grazing the three pasture treatments had similar ($P>0.05$) milk solids production, but urinary N and urea concentrations were significantly ($P<0.01$) lower in cows grazing plantain and the plantain-clover mix. Cows grazing both plantain and plantain-clover mix excreted a urinary N concentration 50 and 53% less ($P<0.01$) than cows grazing the ryegrass/white clover in March and April, respectively. The urea concentration in the urine of cows grazing plantain was 28% lower compared to those cows grazing the plantain-clover mix during autumn and 80 and 67% less than urea concentrations from cow's urine on the ryegrass/white clover pasture in March and April, respectively. There was an overall 388 ± 65 mm (mean ± SD) of drainage for the winter-spring period with no consistent difference in the drainage volumes from the treatments. The quantity of NO_3-N leached in drainage was 90 and 85% lower ($P<0.001$) from the plantain and plantain-clover mix plots than from the ryegrass/white clover pasture, however, overall losses were low from all treatments. These results demonstrate the potential benefit of plantain pastures as a natural mitigation option to reduce the urinary N excretion from dairy cows and the NO_3-N leached from dairy farm systems.

Introduction

Pastoral dairy systems require technologies and good environmental practices to meet with future regulations that limit the nitrogen (N) loss, principally reduce nitrate (NO_3-N) leaching

into ground waters from dairy farms. The high N loading in urine patches by cows, in surplus to N uptake for plant growth, lead to the N excess being lost in the form of NO_3-N leaching in grazing systems. Dairy farming reliance on pasture production and the incorporation of plantain and plantain-based pastures has been shown to produce similar or more milk than ryegrass pasture. Several researches have consistently reported a lower N concentration in the urine of cows, when cows graze pastures containing 20% or more plantain. A recent research under laboratory conditions showed that bioactive compounds in plantain (acteoside and aucubin) decreased ammonia (NH_3) loss in the rumen, which suggests their potential to reduce the amount of urinary N excreted from grazed pastures, while still increasing or maintaining milk production (Navarrete et al., 2016). Therefore, the objective of this research was evaluated whether plantain (*Plantago lanceolata*) based pasture dairy systems decrease the NO_3-N leaching from dairy farming in comparison to traditional ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture.

Materials and Methods

Experimental Site and treatments

The research was carried out at Massey University Dairy Farm N°4 in Palmerston North, New Zealand (40° 23' S; 175 ° 36' E) with the approval of Massey University Animal Ethics Committee (Protocol 16/137). Three pasture treatments were established (1st December, 2016) on a series of plots on Tokomaru silt loam soil were grazed by lactating dairy cows. Each plot is 40 x 20 m (800 m^2) and has an isolated mole-pipe drain system to collect drainage water samples. The pasture treatments were sown as: (i) plantain, (ii) plantain-clovers mix, containing plantain, red clover (*Trifolium pratense*) and white clover (*T. repens*), and (iii) perennial ryegrass/white clover. There were five replicates of each treatment and these were laid out in a complete randomised design. Three additional paddocks (approximately 1 ha) of each pasture treatment were also established near the experimental plots. These additional paddocks were used to fully adapt the cows' diet to the pasture treatments before grazing in the experimental plot treatments.

Cows management

Thirty-six lactating dairy cows were selected from the Dairy Farm Herd and separated in three groups (n=12). Each group grazed one of three pastures treatments over 10 consecutive days in March and in April, 2017 (autumn). During days 1 to 5 (adaptation period) cows were grazing in the additional paddocks to allow cows to acclimatise to the experimental pasture treatments. On day 6 the cows were transferred to the experimental plots (experimental period) and they grazed in sequence through each experimental plot from days 6 to 10, spending one day in each replicate plot.

Measurements

Pasture treatments

Pre- and post-grazing herbage mass (kg DM/ha) and botanical composition pre-grazing were determined by cutting to ground level three samples randomly chosen from each experimental plot (0.1 m^2 quadrats) using an electric shearing handpiece. The Pre- and post-grazing

samples were washed to remove soil contamination and oven dried at 70 °C for approximately 48 h. The botanical samples were manually separated into the each species and dead material, oven-dried individually at 70 °C (approximately 48 h). The proportion for each species in the DM was then calculated. One grab sample (200 g fresh weight) of each plot was taken pre-grazing for nutritive analysis. The pastures were hand pluck sampled by walking at random within each plot.

Cows

Milk volume (L/day) was recorded daily during days 6 to 10 (experimental period). Cows were milked twice daily (0700 and 1430) in March, 2017 and once a day (0700) in April, 2017. Milk samples were collected for each cow at the milking on days 8, 9, and 10 in March and in April and analysed for milk protein and fat concentration.

Urine samples were collected immediately after morning and afternoon milking on day 8 and 10 in March, and after the morning milking on day 8, 9, and 10 in April. Urine samples were taken from each cow by manual stimulation of the vulva. Samples were acidified with sulphuric acid (6N) to reduce the urine pH to 3.0 - 4.0 and analysed for N and urea concentration.

Statistical analysis

Data were analysed using the PROC MIXED procedure of SAS 9.3 (SAS Institute, 2009) using a model for a complete randomise design. Means were compared using the least squares means test and significance was declared at $P<0.05$.

Results and Discussion

Pasture intake, protein intake, and milk solids production from cows grazing the pasture treatments are presented in Table 1. Pasture intake (kg DM/d) was similar between ryegrass, plantain, and the plantain-clovers mix pastures both in March and in April (Table 1). There was no difference in crude protein (CP) intake between pasture treatments in March; however, in April cows grazing plantain-clovers mix pasture obtained a greater CP intake compared to those grazing ryegrass and plantain pastures (Table 1).

Plantain and plantain-clover mix pastures reduced significantly ($P<0.01$) the N concentration in the urine of cows compare to ryegrass both in March and in April (Figure 1a). Previous studies have reported a N concentration 20-50% lower in cows' urine, when cows graze pastures containing 20% or more plantain (Woodward et al., 2012; Totty et al., 2013; Edwards et al., 2015). In this study, the urinary N concentration excreted from cows grazing both plantain and plantain-clover mix was 50 and 53% lower ($P<0.001$) than ryegrass in March and April, respectively; and plantain intake was a 50 and 55% of the total dry matter intake (Kg DM/d) in cows grazing plantain and the plantain-clovers mix in March and April, respectively.

Table 1. Pasture intake, crude protein (CP) intake and milk solids production on cows grazing ryegrass, plantain, and plantain-clovers mix pastures in March and April.

	Pasture Treatments			P value
	Ryegrass	**Plantain**	**Plantain-clovers**	
Intake[1]				
Pasture (kg DM/d)				
March	10.48 ± 1.25	12.87 ± 2.01	11.14 ± 1.56	0.61
April	7.80 ± 0.49	7.62 ± 0.90	10.72 ± 1.14	0.07
Protein (kg CP/d)				
March	1.87 ± 0.24	1.82 ± 0.34	2.02 ± 0.37	0.06
April	1.39 ± 0.08[b]	1.08 ± 0.17 [b]	2.11 ± 0.27[a]	0.01
Milk Production				
Milk solids (kg/d)				
March	1.22 ± 0.03	1.33 ± 0.04	1.50 ± 0.05	0.29
April	1.08 ± 0.04	1.00 ± 0.04	1.08 ± 0.03	0.39
Protein (kg/d)				
March	0.58 ± 0.01	0.60 ± 0.02	0.68 ± 0.03	0.37
April	0.50 ± 0.01	0.46 ± 0.02	0.53 ± 0.01	0.08
Fat (kg/d)				
March	0.64 ± 0.02	0.73 ± 0.03	0.82 ± 0.03	0.15
April	0.57 ± 0.04	0.54 ±0.02	0.55 ± 0.03	0.82

[a, b] superscripts indicate values within column that are significantly ($P<0.05$) different

[1] Total fed supplements was: 6 kg DM/cow in March and 5 Kg DM/cow in April.

The urea concentration in the urine of cows grazing plantain and plantain-clover mix pastures was also reduced ($P<0.01$) when compared to ryegrass (Figure 1b). The urine of cows grazing plantain had 28% less urea concentration in comparison to those cows grazing plantain-clover mix during autumn and 80 and 67% less than urea concentrations from cow's urine on the ryegrass/white clover pasture in March and April, respectively (Figure 1b). Recent research showed that plantain bioactive compounds, aucubin and acteoside, reduced NH_3 production in the rumen (Navarrete et al., 2016). Further, a lower rumen NH_3 concentration has been reported when 40% of plantain was included in the cows diet compare to those fed ryegrass pasture only (Minneé et al., 2017). This finding suggested less NH_3 was absorbed from the rumen and converted into urea to be excreted in the urine of cows grazing plantain and plantain-clover mix (Pacheco and Waghorn, 2008).

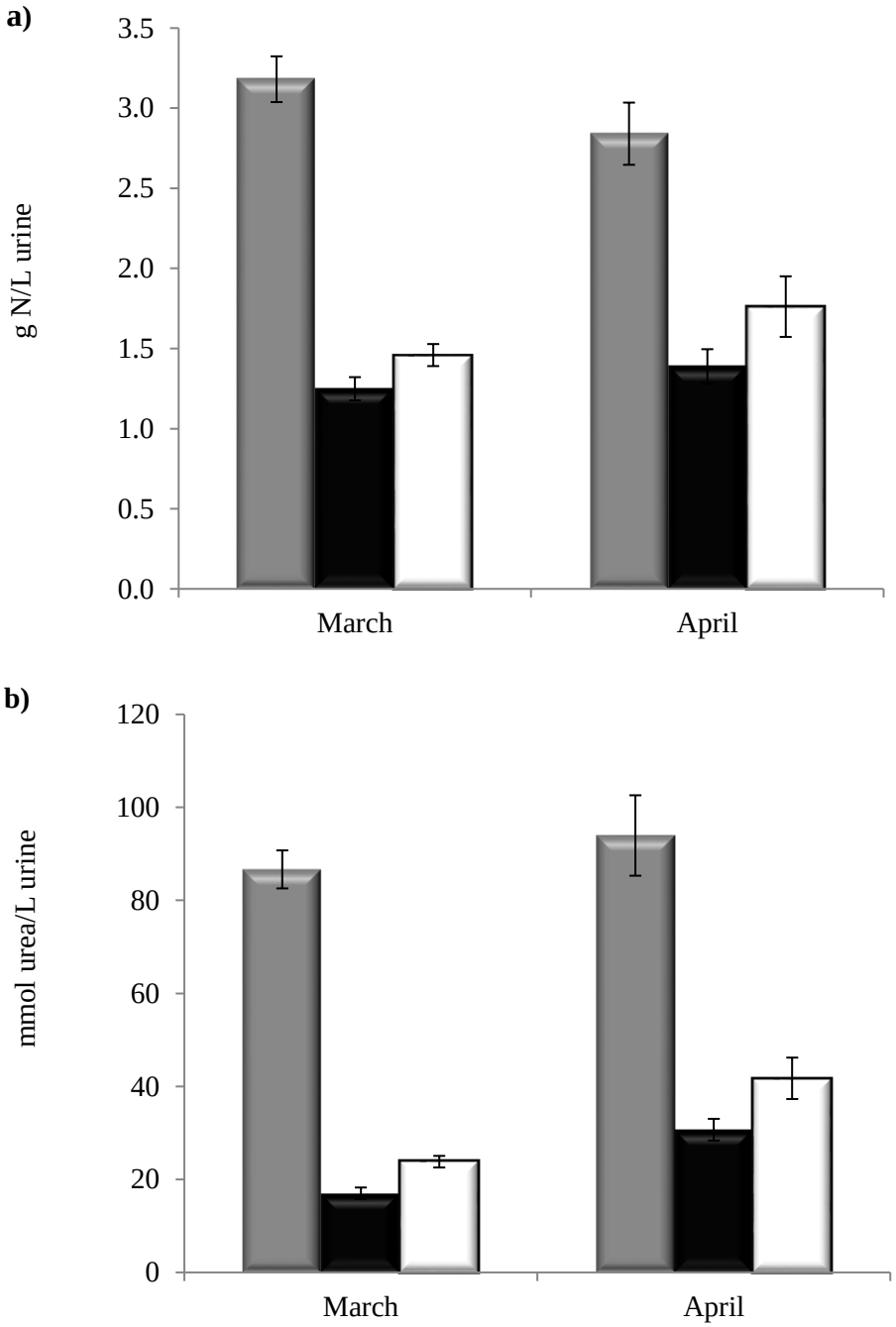

Figure 1. (a) Nitrogen (g N/L) and (b) urea (mmol/L) concentration in the urine of cows grazing ryegrass (grey), plantain (black), and plantain-clovers (white) mix pastures in March and April

Research on plantain has been suggesting an N urinary dilution effect due to greater urine volume from cows grazing plantain (Box et al., 2017). In this study, there was no difference in the drainage volumes from the pasture treatments (388 ± 65 mm) for the winter-spring period. However, the quantity of NO_3-N leached in drainage was 90 and 85% lower ($P<0.001$) from the plantain and plantain-clover mix plots than from the ryegrass/white clover pasture (Figure 2).

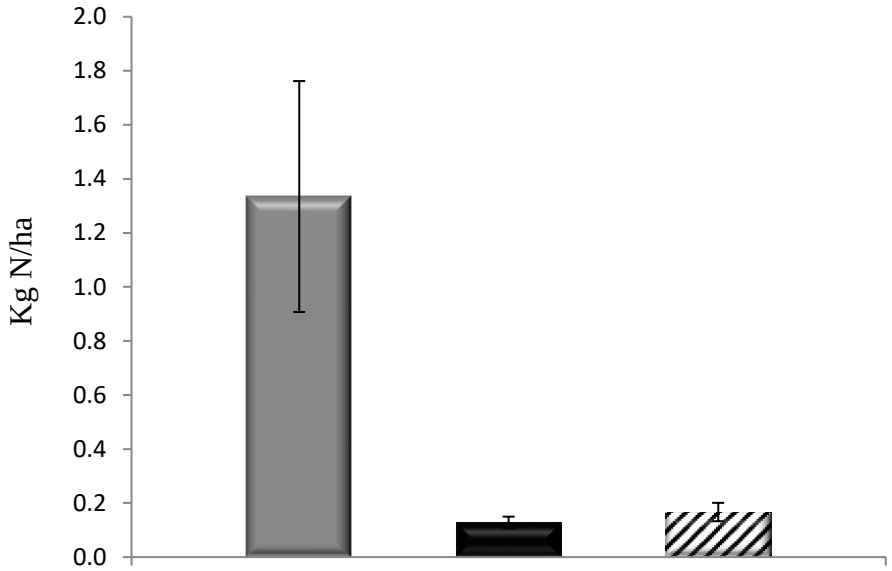

Figure 2. Nitrate (N-NO_3) leaching in drainage water from ryegrass (grey), plantain (black), and plantain-clovers mix (white) pastures during the winter-spring (April to October, 2017) season.

Conclusions

This research demonstrate the benefit of plantain pastures as a natural mitigation option to reduce the urinary N excretion from dairy cows and the NO_3-N leached from dairy farm systems.

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