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USE OF LOW-COST, TEMPORARY STAND-OFF PADS TO CAPTURE URINARY NITROGEN: FIELD AND LABORATORY EVALUATIONS

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Abstract
Lower cost alternatives to traditional stand-off infrastructure are sought that deliver similar benefit in terms of nitrogen (N) leaching reductions and animal welfare performance. This study evaluated, in both the field and laboratory, the practicality and potential benefits of using a temporary stand-off pad system, constructed from a mix of sawdust and lignite, to accommodate cows during winter in Southland. Novel aspects of the field-tested system were (i) its location in a field used to provide winter feed, which reduced travel distances associated with a fixed stand-off pad, and (ii) the use of a sawdust-lignite mix for the stand-off surface.
The field trial demonstrated that on-off grazing management of the prototype crop-pad system was a feasible approach for wintering cows in terms of labour and animal welfare. An associated lysimeter experiment showed a reduction in inorganic N leaching from a simulated sawdust stand-off pad treatment but no extra reduction with the addition of lignite. Less drainage was observed from the lysimeters in response to effluent slurry application in combination with simulated treading damage of the wet soil and in practice this could result in loss of nutrients via surface run off. Ponding was also observed on the stand-off pad. If temporary stand-off pads are further explored, changes in the configuration of the pad would be needed to overcome this drainage issue.

A supporting laboratory incubation study was conducted where sawdust and lignite were mixed with soil, treated with urine and incubated at 6 or 17ºC. At 6ºC none of the sawdust or sawdust-lignite treatments showed any significant reduction in soluble N (water soluble organic N + nitrate + ammonium) concentrations compared with the soil-only urine treatment at any stage of the incubation. A small reduction in soluble N developed in the sawdust treatment at 17ºC during the later stages of incubation. A laboratory adsorption test showed that sawdust and lignite adsorbed very little of the ammonium-N present in solution, the soil used in the incubation study was more effective. The sawdust and lignite had high total C:N ratios but very little of the C was soluble, a requirement to immobilise urinary N. Provision of a soluble carbon source (to temporarily immobilise urinary N) is recommended if further testing of sawdust-lignite mixtures for use in temporary stand-off pads is undertaken. Further research is required to refine the management of the system to minimise soil damage and to determine if real benefits to N loss are delivered.

Introduction

The use of off-paddock facilities such as stand-off pads has proven useful for reducing the environmental impacts of intensive dairy farming through the protection of soil during wet grazing periods and the reduction of N inputs to pasture from urine during the higher risk autumn period (Shepherd et al. 2017, Beukes et al. 2017, Christensen et al. 2012, Ledgard et al. 2006, Luo et al. 2006). Traditional off-paddock infrastructure is expensive, with costs including the construction of effluent management systems capable of collecting, storing and conveying all excreta and rainfall inputs. A research project was conducted in 2016/17 which investigated lower cost stand-off options, one of which was the use of in-field soil amendment(s) to capture excreta N during risk periods for N leaching loss. One strategy tested was the use of a temporary stand-off area within a grazed winter forage crop, whereby a soil amendment provided the stand-off surface and captured excreta from grazing animals. The aim of this project was to evaluate the practicality and potential environmental benefits of using a temporary stand-off pad, made from sawdust and lignite, to accommodate cows during winter in Southland.

Methodology

Field pad evaluation

Novel aspects of the prototype field-tested system were (i) its location in a field used to provide winter feed, which reduced travel distances to a fixed stand-off pad, and (ii) the use of a sawdust-lignite mix for the stand-off surface (two cost-effective materials readily available in Southland). In a cross-over experimental design, two 30 m by 30 m temporary stand-off pads designed to accommodate 99 cows for 21 days each were constructed in a winter crop paddock on a Southland dairy farm on the free draining Riversdale stony sandy loam. The pad surface consisted of sawdust (135 T/ha) spread over lignite (45 T/ha) (Plate 1).

Plate 1: Sawdust being laid over a lignite base to form a temporary stand-off pad.

In an on-off grazing system cows were break-fed an adjacent winter forage crop (fodder beet) for 6 hours per day and confined to the feed-pad for the remaining 18 hours. Animal welfare measurements, including cow lying times (hr day^{-1}), stride length, gait score, body condition score (BCS), dirt score and lying surface moisture, were taken and compared to a control herd that grazed a neighbouring paddock of fodder beet for 24 hours per day. Stride length and gait and dirt scores were difficult to measure in the commercial dairy farm operation.

Attempts to quantitatively measure the amounts of excretal N immobilised by the field pads were also unsuccessful due to a combination of a very wet spring and the inability to sample the pad until the following summer.

Lysimeter experiment

A lysimeter trial was also conducted that compared N leaching losses from a control (soil only) treatment with those from mini-lysimeters containing either soil plus sawdust or soil plus sawdust and lignite. Twenty mini-lysimeters 150 mm diameter and 300 mm long were repacked to a depth of 140 mm with sieved (to 16 mm) Riversdale stony silt loam soil. A 20-mm layer of washed river sand was included at the base of each lysimeter to prevent blockages of the drainage outlet port. Sawdust was applied to two of the four treatments at a rate of 15.6 kg m^{-2}, equivalent to a depth of 64 mm when freshly spread. Lignite was applied to one treatment at a rate of 4.5 kg m^{-2} (6 mm per column) in addition to sawdust. With the exception of the control treatment, the mini-lysimeters received inputs of slurry (a combination of dung and urine) applied every three days over a 21 day period. All treatments received simulated treading to mimic the effects of cows in the field. The lysimeters were placed in a raised wooden housing and their exterior surrounded by soil to buffer against temperature extremes, thus more closely simulating in-situ soils. The upper surface of each lysimeter was exposed to natural winter weather conditions. A 5 L collection vessel was placed beneath the columns to collect drainage. The volume of drainage was measured approximately weekly during the experiment. On each occasion subsamples were retrieved and sent to a commercial laboratory and analysed for ammonium- and nitrate-N concentrations. A weather station was installed at the site to monitor soil temperature and rainfall.

Laboratory experiments

Laboratory adsorption and incubation experiments were conducted to test the ability of the treatments to adsorb and immobilise urinary N under controlled conditions. These experiments used an Oropi Sand (Pumice Soil Order) from the Rotorua region. This soil was chosen because of its free-draining nature and moderate C content.

Laboratory assays were conducted to measure NH_4^+-N adsorption by the sawdust, lignite and soil. Four solutions of ammonium sulphate-N (ranging between 0 - 150 mg N/L) were made up in a matrix of 0.01 M calcium chloride. One hundred millilitres was mixed with sawdust (~5.5 g), lignite (~2 g) or soil (~37 g) and shaken for 24 hours at 20°C. The quantities of N in the three solutions combined with the different material weights represented rates that could be expected in the field if 100, 200 and 400 kg N ha^{-1} was excreted as urine onto a pad of the same configuration as the field study described above. Solutions were filtered and analysed for residual NH_4^+-N.

The ability of sawdust and/or lignite to immobilise N was evaluated at two incubation temperatures: 6 and 17°C, chosen to represent contrasting soil temperatures in the southern

South Island and central North Island during N loss risk periods of winter and autumn, respectively. Immobilisation was determined by measuring changes in total soluble N (TSN) concentrations throughout a 56 day incubation period. A closed incubation with treatments of soil, soil plus sawdust, soil plus lignite and soil plus sawdust and lignite with and without bovine urine (~400 mg N/kg dry soil) was established in re-sealable plastic bags (Plate 2). There were 3 replicates of each treatment.

Plate 2: Soil incubation experiment.

Extractions of soil for water soluble N and C were undertaken at days 2, 4, 7, 13, 20, 35 and 56. Extractions of soluble N were performed using water, instead of (the more typical) potassium chloride (KCl) extractant, in order to better measure the ‘mobile’ pools of nitrogen, rather than including exchangeable pools adsorbing to amendments or soil. For the purposes of this paper, immobilised N is defined as the pool of applied N that was not extracted by water. In a closed incubation this pool could include microbial N, adsorbed/exchangeable N, and gaseous losses. Because the latter was not measured, any N lost via this pathway is included in our calculations of N removal, which we hereafter refer to as “immobilisation”. The effectiveness of the amendment to reduce soil total soluble N was calculated as the difference between the urine only treatment and the amendment treatment at each sampling time and expressed as a percentage of applied N (400 mg kg^{-1}).

Results and discussion

Field pad evaluation

The on-off grazing management of the crop-pad system proved a feasible approach for wintering cows in terms of labour and animal welfare requirements (Plate 3).

Plate 3: The stand-off pad in use.

The moisture contents of the pad surfaces increased over time, reflecting the cumulative inputs of incident rainfall and the dung and urine deposited whilst the cows were confined to the pads for 18 hours per day. This was visually observed to impede drainage through the pad medium. Ponding and impeded drainage was observed on the field pads; there was a rapid deterioration in the condition of one of the pad surfaces within the first two weeks of use. As a result cow lying times tended to decrease as time on the pad increased, although lying times for cows using the stand-off pad (9.4 lying hours per day) were slightly greater than for cows remaining on the crop (8.9 hours per day). Approximately half the time there was a statistically significant difference in lying times between the Pad and Crop mobs, however neither was consistently better or worse. The pad did not appear to cause any lameness. Body condition scores were consistent with targeted improvements in both treatments

Lysimeter experiment

The lysimeter experiment highlighted the effects of effluent slurry application on soil drainage. Due to the free-draining nature of the chosen soil, drainage was not expected to be impeded on any of the treatments. However, drainage was significantly reduced in each of the treatments receiving inputs of slurry (Table 1; $P<0.001$). Ponding of slurry and rainfall on the surface of the lysimeter was observed in these treatments. If not contained, in a field setting this would be likely to result in losses of excretal material and nutrients via surface run off. The impeded drainage, and consequent anaerobic conditions in the soil, could explain the greater quantities of NH_4^+-N leached from the soil + slurry treatment, compared with the treatments containing sawdust and sawdust with lignite that were not significantly different from each other. The reduced amounts of ammonium-N leached from lysimeters treated with the sawdust and lignite amendments could, in large part, be attributed to the addition of sawdust. Lignite appeared to have little effect on N leaching.

Table 1: Drainage volumes and quantities of inorganic N leached from the mini-lysimeters.

		Nitrogen lost in drainage (kg ha^{-1})	
Treatment	**Drainage volume (mm)**	**NH_4-N**	**NO_3-N**
Soil only	207*	2*	42
Soil+slurry	130	118	29
Soil+sawdust+slurry	118	22*	27
Soil+sawdust+lignite+slurry	124	37*	36

* = significantly different, $P<0.001$

Laboratory experiments

The soil, sawdust and lignite used in the laboratory studies were analysed for a range of attributes; a selection of these is presented in Table 2. Although the sawdust and lignite had high C:N ratios, little (<2%) of this carbon was immediately soluble.

Table 2: Selected baseline measurements of soil, sawdust and lignite used in laboratory studies.

	Moisture content (g 100 g^{-1} dry weight)	**pH**	**Total C (%)**	**Total N (%)**	**TC:TN ratio**	**Soluble Organic C (mg kg^{-1} dry material)**	**Nitrate-N (mg kg^{-1} dry material)**
Soil	52.6	4.9	5.1	0.44	11.6	14	3.8
Sawdust	78.4	4.7	49.0	0.13	377	5760	0.0
Lignite	57.6	5.0	55.0	0.63	87	115	0.0

Table 3 shows that adsorption of NH_4^+-N by lignite on a weight basis increased as the solution N concentration increased. The percentage of NH_4^+-N adsorbed by lignite was similar for all N concentrations. The sawdust results were quite variable. This was likely to be due to it being much less homogeneous in terms of particle size and composition than the lignite. Unlike the lignite, there was no significant increase in the amount of N adsorbed per unit weight of material. The laboratory adsorption assay showed sawdust and lignite adsorbed no more than 11% of the ammonium-N presented in solution.

Table 3: The quantities of NH_4^+-N adsorbed by soil, sawdust and lignite materials over a range of N application rates. Units presented are mg N adsorbed kg^{-1} dry material; values in brackets represent the percentage of added N that was adsorbed by each material.

	Applied N Rate (kg ha^{-1})		
	100	**200**	**400**
Soil	18 (19)	30 (15)	46 (11.9)
Sawdust	55 (8.9)	74 (5.8)	84 (3.3)
Lignite	160 (9.7)	356 (10.4)	611 (9.0)

The Oropi soil used in the incubation study was more effective in adsorbing NH4-N than the lignite or sawdust, indicating that these latter amendments provided no practical advantage to the adsorption of NH_4^+-N. If available and economically feasible, incorporation of a material capable of rapid NH_4^+-N adsorption, such as zeolite, could be investigated in any future evaluation of temporary stand-off pads.

The incubation study, designed to determine if sawdust and lignite had immobilisation potential, showed little reduction in total soluble N in response to these soil amendments (Figure 1). This appeared to be the case throughout the 56-day incubation period.

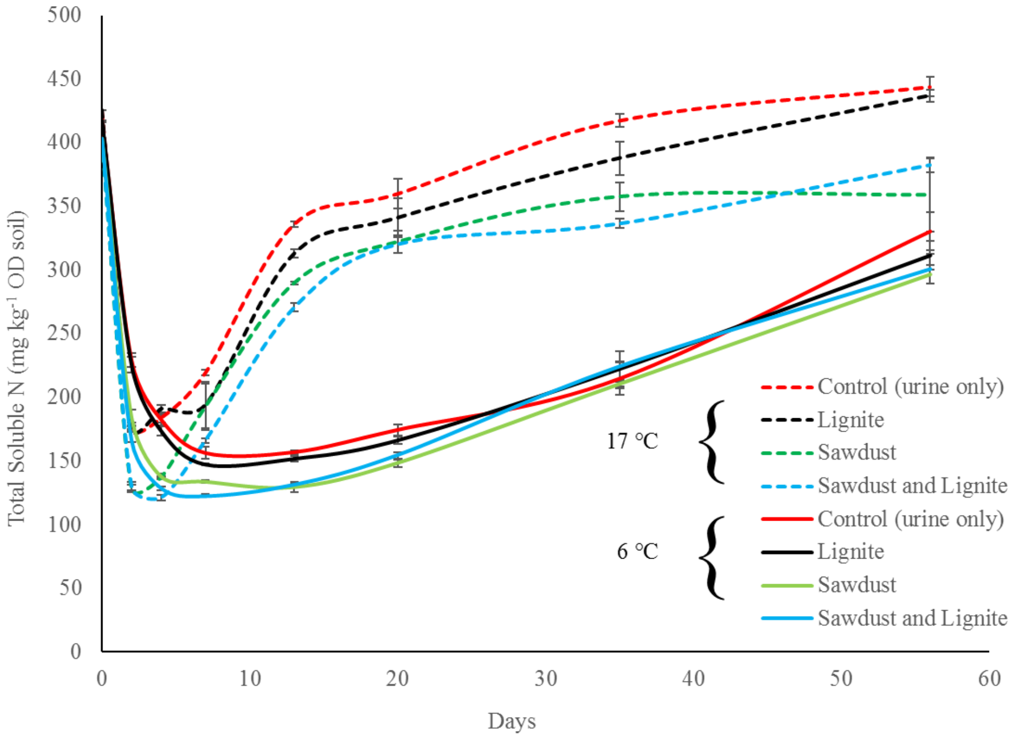

Figure 1. Total Soluble N concentrations in incubated soils amended with sawdust, lignite or sawdust + lignite. Error bars represent ±1 SEM.

As observed in the lysimeter study, lignite did not appear to reduce soil TSN concentrations, alone or in combination with sawdust. At a typical Southland winter soil temperature of 6°C neither sawdust nor lignite nor their combination showed any significant immobilisation potential during the 56 days of incubation. However, sawdust alone showed signs of N immobilisation at 17°C (which more closely represents soil temperatures in the North Island) during the latter stages of the incubation. This could be the result of the release of soluble C from the sawdust as it began to break down in the soil at this higher temperature. Our observations were, however, made in a closed system; under field conditions TSN will likely be transported down the soil profile in drainage and any delayed provision of soluble carbon may occur too late to reduce N leaching risk. Soil soluble C:N ratios never exceeded 4:1 for the duration of the incubation. Although the sawdust and lignite materials had high total C:N ratios, very little of the C was soluble and thus was not available to immobilise urinary N.

The soil amendments evaluated under the conditions of our study appeared to have limited effectiveness at removing urinary N from soil solution. Under the study conditions, pursuing lignite as an option appears futile; however, some suggested options to improve the effectiveness of sawdust would include the provision of a readily-available source of soluble carbon as a means to hasten N removal via immobilisation; composting of the sawdust to start the breakdown process prior to laying down the stand-off pad; or laying down the temporary stand-off pad well in advance of use to allow soil contact and initiate microbial decomposition of sawdust prior to the input of cow urinary-N. If temporary stand-off pads are further explored, changes in their configuration to encourage a wider spread of excreta over the pad surface will also be required to overcome the drainage issues observed in this study.

Conclusions

A temporary stand-off pad constructed from sawdust and lignite performed well in terms of practical management and meeting some key cow welfare requirements. Experimentation to evaluate its ability to potentially reduce N leaching was, however, inconclusive. Sawdust was shown to remove TSN from soil solution and reduce ammonium-N leaching. Laboratory and lysimeter studies showed that the addition of lignite did not appear to add any value to the sawdust-only treatments. Visual observations from the field and measurements of drainage from the mini-lysimeter study indicated that impeded drainage was an undesirable consequence of adding cow excreta to the soil and pad amendments. Alternative combinations of materials and pad configurations will need to be investigated to overcome this limitation and reduce the potential risk of overland flow.

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