A comparison study between Biohelp NZ biological treatment of pastures and conventional fertilised pastures on nitrogen leaching from cow urine

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Abstract

This field study compared the effect of Biohelp NZ's biotechnology products (CM3 and Microlife), against conventional fertiliser practices on urine nitrogen (N) leaching from lactating dairy cows grazing ryegrass/clover pastures. Biohelp NZ manufactures natural biotechnology products using soil bacteria and fungi.

Cow urination samples were collected throughout Spring 2018, and Autumn 2019 from a 320 cow mixed Fresian herd on very light (Eyre) soils. When cows were grazing the Biohelp treated paddock there were consistent reductions in the volume of urinations (2.1 vs 1.7L/urination $p<0.09$), number of urinations (27 vs 13 per milking $p<0.03$) and the concentration of nitrogen per urination (8.2 vs 5.5gmN/urination $p<0.02$). The result was a calculated leaching reduction of 67% (36 vs 12KgN/Ha $p<0.0001$) in favour of the Biohelp treated paddock. This was in spite of just 24 hours grazing the Biohelp treatment.

The overall level of urine nitrogen excreted per cow per day was very low when cows were on the Biohelp treated paddock. (51gmN/day in Spring compared to 524gmN/day from DairyNZ s' high quality pasture figures with similar production - 2.2KgMS/cow/day). However they were consistent with other unpublished studies done by Hobson (2017&2018). Lactating cows grazing Biohelp treated ryegrass/clover pasture with 3.8%N excreted approximately 60gmN/day. Dairy heifers winter grazing kale excreted just 6gmN/day (average 0.6gmN/urination).
During this study, the conventionally fertilised pasture received per hectare 144Kg Nitrogen, 112Kg Sulphur and 61Kg Phosphorus, with total fertiliser costing $472.00. In comparison, the Biohelp treated Paddock 20 received 90Kg Nitrogen, 17Kg Sulphur and 25Kg Phosphorus + 2 applications Biohelp costing $393.00.

Pasture production figures were supplied by the farmer for Spring 2014, one year after starting Biohelp treatment. They showed that in spite of the Biohelp treated paddock receiving 80% less nitrogen fertiliser (25 vs 125KgN/Ha for Spring 2014), grass production on the Biohelp treated paddock was superior to the conventional fertiliser paddocks (61 vs 45KgDM/Ha/day). Growth rate comparisons over May 2018 and May 2019 indicate even greater advantages in favour of the Biohelp treatment areas (over 100%).

The results showed a consistent pattern with other field studies on dairy farms treated with Biohelp products including lower total nitrogen per urination, grass production gains and reduced costs/Ha compared to traditional treatments.
There appear to be metabolic changes within the cow resulting in significantly less dietary nitrogen being excreted in the urine and more in the dung, when on Biohelp treated soils/pasture. This may have benefits for reducing methane emissions. However further study is needed to determine this.

Cameron *et al* (2000) found leaching of around 33KgN/Ha from cows grazing pasture (with no added nitrogen fertiliser applied) on significantly better soils. As nitrogen fertiliser application was increased to the leaching increased. By contrast, results from the Biohelp treatment are particularly encouraging as they show that in spite of significant nitrogen fertiliser use it was still possible to have leaching below approximately 13KgN/Ha/yr with high stocking rates and very light soils.
Two different carbon emission formulas showed reductions of approximately 871-1214 tons/annum (or 29-40%) when cows were grazing Biohelp treated pasture. These reductions were a result of lower fertiliser inputs and less projected nitrous oxide emissions (609 tons CO_2/annum) due to 80% less urine nitrogen per day being excreted compared to most research done on conventional farms.

Introduction

New Zealand needs a new way of farming that addresses all the issues: production, profitability, water quality and carbon/methane emissions. True 'Biological Farming' using truly biologically-based products (not chemistry marketed as 'biological') shows immense promise in ticking all the boxes. Some farmers have been embracing these products for over 10 years with excellent production gains, yet exceptionally low fertiliser inputs. This study aims to explore the difference in nitrogen leaching from cow urine when cows eat a biologically stimulated pasture compared with a conventionally fertilised pasture.

All fertilisers and biostimulants create a reaction in the soil Microbiome affecting both the balance and number of soil organisms. Wikipedia states that "… many soil bacteria produce auxins which in turn influence plant physiology". These affect plant growth in many ways including oil and fat production, flavour, sugars, proteins and possibly water content. Plant compounds acts as a prebiotic on an animal's body. Prebiotic's affect the gut microbiome which in turn may affect the way the body excretes protein. The ratio of Nitrogen excreted in dung and urine changes depending on diet. It is possible that a difference will occur in leaching from cow urine nitrogen (N) when the plants are grown with a different combination of auxins coming from a different soil microbiome.

It is well known that Urea fertiliser increases the water content of the plant and plant protein. This can significantly increase the water and protein intake in livestock, which must be excreted. Biohelp NZ Limited - a manufacturer of soil biostimulants and inoculants - have focused on creating/manufacturing products that grow as much dry matter as Urea but with less water and less nitrogen in the plant. The physical changes in plant growth, by applying these plant stimulants, have shown a positive change in the soil microbiome on many properties Biohelp NZ is/has been involved with.

Hypothesis: This study will show that nitrogen leaching from cow urine will be reduced by the application of Biohelp's CM3 compared to Urea treated paddocks. Urine volume will be lower and nitrogen concentrations lower. Pasture production will be higher with lower costs and carbon outputs lower.

Literature review

Other researchers' data for comparison purposes:

There are many studies on cow urine N and leaching from it. But much has been done on properties with completely different soils and climatic factors compared to this study farm. Nearly all of the research is on dairy pastures using over 200KgN fertiliser/Ha.

Lilburn *et al* Sept (2013) published on the Environment Canterbury (ECAN) website: estimated that nitrate nitrogen losses for irrigated dairy platforms with 4-5 cows/Ha respectively wintered off as:

- 65-80Kg/Ha on extremely light soils
- 50-60Kg/Ha on very light soils
- 30-40Kg/Ha on light soils
- 27-37Kg/Ha on medium soils.

Heather Chalmers (2018) reported that the Ngai Tahu property at Eyrewell in North Canterbury is planning to run 2.1 cows/Ha (14,000 cows on 6757Ha) on very light land. Their consent is for 60KgN/Ha leached but Lysimeters are averaging 29Kg/Ha/year from three years of measuring.

On soils with low to medium risk of N leaching (such as Templeton fine sandy loam), leaching of 6-17KgN/Ha was reported when 200KgN/Ha from dairy shed effluent (DSE) plus 200KgN/Ha from Urea had been applied, over four applications in the absence of any cows. Applying the same volumes but split into just two applications produced leaching of 13-49KgN/Ha/yr. <u>Cows grazed</u> on pasture on the same soils with zero nitrogen fertiliser applied produced leaching of 33Kg/Ha when 25% urine paddock coverage was assumed. The amount of leaching was increased by a further 40% up to 60Kg/Ha, when the pasture was fertilised with the DSE and Urea at 400KgN/Ha (Di & Cameron, 2000).

More recently, Lysimeters on Eyre soils on the Lincoln University Dairy Unit have been recording leaching of around 50KgN/Ha/year. We believe this data has been included in the ECAN website data above.

Lucy Birkitt from the Fertiliser and Lime Research Centre at Massey University said in her review of leaching losses: "Nitrate leaching losses following N fertiliser treatments were higher in New Zealand studies (~40KgN/Ha following 0 Kg fertiliser N/Ha and ~80KgN/Ha following 200Kg fertiliser N/Ha)".

Dave Clarke, DairyNZ's Principal Scientist included the following data in DairyNZ's technical series on their website. We have added J Tanner's data for 'Biohelp Paddock 20' on the end in blue:

PASTURE QUALITY

	Low	High	Mixed Ration	J Tanner's Biohelp Pdk 20
Urine N gm/day	162	524	197	51
Intake Kg/day	15	17.9	20	18
% N in diet	2.9	4.6	2.8	5.1
Milk solids/day	1.4	2.2	2.5	2.2

In April 2010 Vibart *et al* estimated urine N losses of 220-194gm/day with urine N concentrations of 5-6.18gm/L while the N in milk was around 80gm/day and milk solids ran out at 1.2Kg/day. Pastures contained 20-23% dry matter; 22% crude protein (3.5% N); 13.5KgDM/cow/day. Based on 200gm/day N loss and 6.1gm N/L concentration at 2.2L/urination, these cows had to be peeing ~15 times/day.

Sprosen *et al* (1997) found no significant difference in leaching when nitrogen was provided by natural clover increases versus nitrogen fertiliser. In the third year of their study when drainage increased due to a wet winter, the leaching was approximately 38Kg/Ha. They ran 3.8 cows/Ha on Bruntwood silt loam soils with low-to-very-low N leaching vulnerability. Total N inputs ranged from 146-200Kg/ha (which is similar to the inputs on the conventional areas of this study farm).

In 2017 an unpublished study by the author was carried out on a long term Biohelp treated dairy farm using 35KgN/Ha/yr. Pastures were 3.3-3.8%N content. Urine analysis showed an average volume of just 1L/urination (range 0.7- 1.2) in Spring and Autumn regardless of whether the urine was collected in the morning or afternoon. Urine N concentrations averaged 6gm/L (4.5–8gm) . Assuming 10 urinations/day this equates to a mere 10L of urine/day and total urine nitrogen excretion of 60gmN/day. Milk Ureas were between 20-24.

In winter 2018 urine analysis was conducted from six dairy heifers grazing kale grown with 5 tons chicken litter and Biohelp CM3. Samples were collected naturally at 3pm in the afternoon. The heifers had been grazing the kale for 6 weeks. The average volume per urination was 0.98L (Std Dev 0.29) and the average concentration an incredibly low 0.59gmN/L (Std Dev 0.27). The calculated leaching on the Biohelp treated kale was just 3.4KgN/Ha. It was a huge difference to the 53-83KgN/Ha obtained from 2 separate Lincoln University studies carrying similar stock numbers (we used the same methods of calculation). This was an unpublished study by the author.

Method and Materials

The Farm and Study Paddock:

This work was carried out on the property of Mr John Tanner, Leeston, mid-Canterbury. The soil on the property is mainly Eyre (loam) with some Barrhill (loam). ECAN states that Eyre soils are very light, with high N and high phosphorus (P) leaching vulnerability. Barrhill soils are considered to have medium N and P vulnerability. The property has a 165 Ha milking platform.

Production:

The farm has 2 herds of 365 cows (predominantly mixed Fresian) each separated into 2 sides of the farm. Herd 2 (the main study herd) has a higher portion of young stock in it. Production from 165 Ha is 308,000KgMS or 1860KgMS/Ha. Stocking rate is 4.5 cows/Ha. The per cow production is 421KgMS/cow with a lactation period of approximately 285-300 days. Peak production is around 2.2-2.3KgMS/cow/day in November.

Site:

The Biohelp treated site is Paddock 20 on the property. It has been treated with Biohelp products beginning in 2013, when it was the worst paddock on the farm.

Paddock 20 and other Biohelp treated areas on the property do receive low levels of solid N fertiliser but no effluent or liquid N as they are outside the centre pivots' coverage area and consequently suffer from inadequate soil moisture during the hot dry summer months.

Twice yearly Paddock 20 has been treated with Biohelp products CM3 @ 25L/Ha + Microlife @ 0.5L/Ha. When moisture stress is not a problem, Paddock 20 is grazed three times compared with only two from all the other 4 Ha paddocks on the farm. In spite of 3-4 months of seriously compromised growth due to inadequate soil moisture, Paddock 20 now sits in the middle of the per year paddock production on the property. The average farm pasture production for the 2019 milking season has been 48KgDM/Ha/day.

From 2013 to 2017 farm policy was 250KgN/Ha/yr as Urea to all paddocks except Paddock 20 which got only 50KgN/Ha/yr + Biohelp.

During the study, the conventionally fertilised pasture received per hectare 144Kg Nitrogen, 112Kg Sulphur and 61Kg Phosphorus, with total fertiliser costing $472.00. In comparison the Biohelp treated Paddock 20 received 90Kg Nitrogen, 17Kg Sulphur and 25Kg Phosphorus, plus 2 applications Biohelp costing $393.00.

In late August 2018, 120Kg/Ha Ammo 31 was applied to the whole farm. In late September herbage tests returned figures of 4.9%N and 5.1%N for the conventional based pasture and Biohelp Paddock respectively.

Beginning in Spring 2018, liquid N was applied through the centre pivot at roughly 5 units N/Ha every 2 weeks. Solid N applications were reduced significantly through this irrigation period.

Collection Method:

Two people collected urine as the cows urinated naturally (ie not stimulated) while travelling around the rotary milking platform.

Most sampling was done during the afternoon milking except for the last two when cows moved to once-per-day-milking at the end of the season. However, consistency of collection was maintained. If samples had to be collected in the morning for Paddock 20 then we also collected in the morning for conventional paddocks.

As many urination events as possible were collected as the cows came around the rotary milking platform. The total number and volumes of urinations were recorded. The first 10-15 urinations were sent away for total nitrogen analysis using Dumus Combustion at Hill Laboratories.

Finding a dairy farm that has been using a biological product on one paddock only for 6 years is rare. With only 1 paddock treated on the farm the cows had just 24 hours for their digestive system to adjust to this new type of feed. We had no certainty if detectable changes in urine N would show after just 24 hours. Therefore a preliminary test was carried out in Spring.

On 30 October a comparison between the 2 herds was done. Due to the low number of urinations from cows on Biohelp treated Paddock 20, only six samples were available for laboratory testing. Despite this, a strong probability of differences $p<0.066$ was obtained. This showed that further extensive testing was likely to be more productive statistically. Therefore, more extensive sampling was carried out during April and May 2019.

Samples were collected from Herd 2 when they were on Paddock 20 for 24 hours. Samples were then collected from the same herd several days later under similar weather conditions.

From early April the cows received a fodder beet break immediately after milking for 1 hour in the morning then went to the pasture. The final set of collections were carried out in the morning so they were on pasture overnight.

We combined all the Autumn data for statistical analysis using a Paired T-Test analysis from an 'App' called Acastat, because it was recommended for uneven sets of data.

To calculate leaching volume we assumed:

- 13 urinations per day for conventional based pasture in Spring
- 10 urinations per day in Autumn
- 7.5 urinations per day for Biohelp Paddock 20 in Spring and 5 urinations per day for Autumn
- 300 days milking on pasture
- 4.5 cows/Ha
- 33% of total N load in urine patch will be leached

Urination area (patch area):

When water was poured onto the soil from a height of 150cm at approximately 150ml/second: 1,000ml covered 0.3m2, 2,000ml covered 0.6m2 and 3,000ml covered 0.9m2. From these figures the patch area for different volumes of urine was calculated.

Leaching calculations:

The following equations were taken from a Lincoln University study for calculating leaching losses:

A leaching calculation for the cows on Urea grass follows

(this example is based on 10 urinations/day for cows on conventional pastures):

- Urine N concentration = 4.28gm/L
- Average urination = 2.1L
- Average patch area = 0.63m2
- Urine N load per urination = 9gm

The leaching calculation follows:

- Urine patch N load = 9gm/0.63m2 x 10 = 142Kg/Ha
- Leaching losses from urine patches is 142Kg/Ha x 33% = 47Kg/Ha

Given 4.5 cows on 1 Ha for 300 days:

- Urine patch coverage based on 10 urinations/day x 0.63m2 per urination x 4.5 cows x 300 days = 8,505m2
- Total grazing area is 1 Ha (10,000m2) so the urine patch coverage = 85%
- Leaching is therefore 47Kg x 85% = 39.8Kg/Ha

Paddock Growth Rates:

A FarmKeeper Feed Wedge Report was supplied to us for the 2014 season. Biohelp treatment on Paddock 20 started in 2013.

Our purpose with this data was to provide evidence that - in spite of Paddock 20 receiving only 50KgN/Ha/yr + Biohelp products - it still competed well against all the other paddocks receiving 250KgN/Ha/yr.

Results

Autumn 2019 Study

Total of 56 samples analysed (Paired T-Test data)

	Average Urine Volume	GmN/ Urination	Calculated Leached N KgN/Ha	Urination Events	Pasture N% April
Conventional	2086	8.17	**36**	26.7	5.1
Biohelp treated	1709	5.47	**12**	13	5.1
A-B	377	2.71	23.4	13.7	
	$p<0.089$	**$p<0.0222$**	**$p<0.0001$**	**$p<0.03$**	

Spring Tester

Total of 16 samples for analysis (6 from Paddock 20, 10 from conventional–based pasture)

	Average Urine Volume	GmN/ Urination	Calculated Leached N KgN/Ha	Urination Events	Pasture N% Sept	Oct
Conventional	2216	8.083	**47**	22	4.9	NA
Biohelp treated	1816.7	6.87	**23**	9	5.1	3.2
A-B	400	1.217	23.7			
	$p<0.32$	**$p<0.36$**	**$p<0.066$**			

Table 2
Spring 2014 Pasture Growth (KgDM/day)

Soil type	Eyre	Eyre	Eyre	Eyre	
KgN applied	*22*	*120*	*120*	*120*	
Paddock	Biohelp Pdk 20	Conventional Pdk 18	Conventional Pdk 8	Conventional Pdk 9	
Growth Rates					
18/09/14		14	37	31	
2/10/14	49	39		53	
16/10/14		33	52		
30/10/14	63		71		
13/11/14		57		59	
27/11/14	71				
13/12/14			84	74	
27/12/14			0		
					Conventional average
Averages	**61**	**35**	**53**	**47**	**45**

Grass Growth Comparisons supplied by farmer:

Comparison measurements in May 2018 and 2019 on Paddocks 4 and 5 showed Biohelp areas growing over 100% faster than the untreated areas: 30 vs 15KgDM/Ha/day in May 2018 and 21 vs 6KgDM/Ha/day in May 2019 (Tru Test pasture meter).

Carbon emissions - Using 2 different models (Gelling and Parameter 2004 and Lincoln Universities Farm Carbon Footprint Calculator) we got a range of 262-605 ton /annum reduction in CO_2 emissions (9-20%) from reducing fertiliser.

To give a more meaningful reference of what could be achieved across the country we have used the 2013-2017 fertiliser programs which is when these models were created.

In addition to this the calculated reductions in nitrous oxide emissions would be approximately 609 tons/annum in favour of Biohelp from reduced daily nitrogen excretion. See discussion for more details.

Discussion

Using Paired T-Test Analysis strong confidence levels were obtained between the means.

Leaching reduced by 67% ($p<0.0001$) **in Autumn and 52%** ($p<0.066$) **in Spring when the cows were on Biohelp Paddock 20**.

Both Aland *et al* (2002) and Ahmed and Aaron (2016) showed a large range in frequency of urination events for lactating dairy cows: 4-18 urinations/day with an average of 9-10. Urination volume also varied substantially: 8-40L/day for lactating dairy cows on pasture (Ahmed Aaron, 2016). Rivera *et al* (2015) reported a range of 8.7-47L/day also for cows on winter feed.

Frequency of urinations:

The trend in the number of urinations (frequency) was 100% consistent and statistically valid. It was also consistent regardless of the herd. For example, in October herd 1 (the mature cows) went from urinating 22 times with 2.2L average to just 6 urinations with 1.3L average after being on a Biohelp break overnight. For Herd 2 (the main study cows) the number of urination events when on Paddock 20 was consistently lower: 52% lower in Autumn, in spite of only 24 hours grazing the Biohelp treated paddock. The average number of urinations per day was calculated for the control group at 10/day in Autumn. The number of urinations per day for the treated paddock was reduced by 52% or 5 urinations per day. Both figures are within the margins of other more extensive studies mentioned above.

Could results be due to different fertiliser or effluent?

The most obvious reasons for the differences in leaching would be differences in the N levels in the plant or differences in plant dry matter content (created by differences in fertiliser and or dairy effluent application to the conventional pastures). However no evidence for either was found. The herbage tests in Autumn had the same levels of N in the plant (5.1%). Dry matter analyses in late May 2019 between effluent treated areas and Biohelp treated areas showed that the Biohelp pasture contained less dry matter: 33% dry matter versus 38% for conventional pasture. This may have been due to the fact that, over May 2019, Biohelp pasture had grown 600KgDM more than the conventional pasture and had more leaf mass. The data points towards Biohelp being the only common denominator in the different data trends. We have no explanations for this yet. More work needs to be done to establish the reasons behind the differences.

The leaching levels for the conventional pasture in Spring (49KgN/Ha) are consistent with ECAN expected leaching figures: 50-60KgN losses from very light soils. The Autumn level of 38Kg is lower.

Vibart *et al* (2010) reported concentrations of 5-6gmN/L in their study. In this study figures of 3.9 and 3.2gmN/L were obtained for the conventional pasture and Biohelp pasture respectively.

The average volume of a urination, in this study, was consistent with other research ie 2.0-2.2L per urination for conventional pasture. The averages from the morning milking were 2.6L for Urea pasture and 1.9L for Biohelp Paddock 20.

Differences in overall expected urine N excreted/day for the cows grazing conventional pasture in Spring - between this study (13 urinations x 8.1gmN/urination = 105gmN/day) and DairyNZ and Vibart studies (196gmN/day) - can largely be explained. Russelle (1996) obtained a good correlation between Digestible Crude Protein concentration (%) and urine N levels in lbs/100lbs DM intake (see below references cited). Plugging in our figures, Vibart's cows (22.5% protein or 3.6%N) would have ~190gm/day in urine N (DairyNZ and Vibart had 197gmN/day). In this study the cows on the conventional pasture in Spring (20% protein or 3.2%N) would theoretically produce 108gm/day. That is 13 urinations/day at 8gm/urination. This is consistent with expected urinations of 10-12/day. A figure of 13 urinations/day/cow for the Spring leaching calculations was therefore used for the conventional pasture in this study. Autumn grass was dryer at the time of sampling with high dry matter percentages. This would result in less water intake from feed so we used the industry standard of 10 urinations/day/cow for the conventional pasture, obtaining 81gmN/day excreted as urine. The results obtained for Paddock 20 were 51 and 27gmN/day excreted in urine for Spring and Autumn respectively. This includes the 50% drop in urination events. So Russelle's graph explains quite nicely the differences between excreted urine N for the conventional pasture but does not adequately explain the very low levels obtained on Biohelp treated Paddock 20. The results of this study challenge the belief that excreted urine nitrogen is closely correlated to dietary protein intake regardless of pasture treatment products.

The pasture N levels were high in Autumn but fodder beet was also grazed in the morning and this might have reduced the overall N intake. In spite of this, the calculated overall dietary N was still around 4.6% in Autumn.

This study calculated that cows on the conventional pasture in Spring urinated 27L/day (from 13 urinations/day) and in Autumn 22L/day (from 10 urinations/day). This is consistent with other research (20-25L/day). Assuming the frequency data is accurate the Biohelp pasture (Paddock 20) would average 13.5 and 8.6L/day for Spring and Autumn respectively. This is low but consistent with the lower results from other research. The low urine volumes were consistent with the unpublished studies done by the author in 2017 and 2018 on a Biohelp treated dairy farm and on kale grown on this study property in Winter 2018. The Autumn was dry-ish and grass grew but not lushly. In the Vibart *et al* Study (2010), cows were urinating ~32L/day (200gm divided by 6.18gm/L). These cows received 13.5KgDM/day at 22% DM which equates to 61Kg/day/cow fresh grass consumed. While not reported in this study, the pasture in May had a DM content of 33%. The cows would only consume 41Kg freshweight of pasture to get 13.5KgDM intake. A difference of 20L of water or 4L/100Kg body weight has to change something and so it is highly likely that the cows in this study urinated less volume and less frequently than those in the Vibart study.

Both Ngai Tahu farming at Eyrewell Forest and the Tanner property have soils with very high risk of N leaching vulnerability. The 4.5 cows/Ha in this study on the Tanner property showed average leaching on conventional pastures over Spring and Autumn of 42KgN/Ha. Lysimeters at Ngai Tahu have shown, after three years, that

27KgN/Ha is leached for 2.1 cows/Ha (equivalent to 58KgN/Ha for 4.5 cows/Ha). ECAN expects 50-60KgN/Ha to be leached from this soil type. At the Tanner property it is possible that replacing solid Urea with liquid Urea over Summer and controlling N use in Autumn to keep the dry matter of the plant higher may have already helped reduce N leaching by 10-15KgN/Ha. Many research studies have shown that Autumn is the most critical time of the year for leaching. Given the Autumn leaching on the Biohelp pasture was just 12KgN/Ha, the implications are significant. Introducing Biohelp products across this whole property could realistically get the leaching to below 15KgN/Ha while continuing to run 4.5 cows/Ha on very light land. This is in spite of N fertiliser use of 90KgN/Ha.

The vast majority of the protein in the daily ration either goes into milk or is excreted in urine or dung. The low levels of urine N in this study tend to indicate that a much higher percentage of nitrogen is being excreted in the dung than previous research suggests is normal under conventional based pastures. The results from Usshers' unpublished study in 2017 and Tanners' heifer urine analysis on kale in Winter 2018 also support this. It is possible that these specifically created Biohelp products are in some way altering biochemical compounds or pathways in the pasture. Their effect on gut bacteria may be influencing nitrogen excretion within the cow. This might also have an impact on methane production. Further research needs to be done to establish if these hypotheses are correct.

What is very clear from the data collected so far is that the leaching of urine N on dairy farms can be reduced to acceptable and environmentally friendly levels without loss of production or the need for stock reductions. This can be done on an all-grass system without the need for changing pasture composition.

Pasture growth rates:

The farmer supplied the only records he had that could allow us to calculate a growth rate through the period of the year where moisture stress is not a significant factor between the treated and untreated study areas. There were major differences in irrigation effectiveness between the study areas, therefore growth analysis was limited to the Spring period. In spite of 80% less nitrogen fertiliser being applied, the Biohelp treated paddock had 35% more growth than the conventional pastures (45 vs 61KgDM/Ha/day). The more recent comparison measurements in May 2018 and 2019 supported these growth advantages with over 100% increase in pasture growth on the Biohelp treated areas. The overall paddock treatment costs were also lower for Biohelp compared to the conventional fertiliser inputs.

If the same percentage drop in Urea usage was applied across all NZ dairy farms, this would reduce NZ's dairy carbon footprint by approximately 1.3 million tons of CO2/yr from the Urea fertiliser component alone. Reduced fuel use from fertiliser spreading, freight and shipping would be an additional bonus.

Many studies have concluded that nitrogen fertiliser increases pasture production and therefore milk production. The concern of many farmers is reducing nitrogen fertiliser and losing production. Sprosen (1997) determined that nitrate leaching is not reduced by simply removing Nitrogen fertiliser use on pasture. The subsequent increase in clover production when N fertiliser is removed increases plant protein and negates potential reductions in leaching. Potentially there is a lose - lose situation from simply removing Nitrogen fertiliser. The results of this study indicate that treatment with Biohelp products can be an effective answer to solving both production and leaching concerns plus it provides significant reductions to carbon emissions.

Carbon emissions:

This farm represents the average NZ dairy farm. The NZ Government has set targets for reducing carbon emissions. Carbon emissions tax may become mandatory. DairyNZ CEO has commented that 'the 10% (CO2) reduction by 2030 will be very challenging… ' and stated 'our modelling indicates an average annual cost could be up to $13000 per farm between 2020 and 2030' (article Canterbury Farming, August 2019).

Nitrous oxide emissions are the second biggest contributor to carbon emissions from livestock and have been included in carbon footprint programmes. They have been developed for conventional dairy farms with conventional urine nitrogen excretion rates (over 200gmN/day) which (via the urea within the urine) creates 80-90% of total nitrous oxide emissions (Chadwick *et al,* 2014). However the cows on Biohelp treated pasture excreted only 39gm/day (average for Spring and Autumn). This is 80% less than the conventional 200gm/day. Therefore it is highly probable there will also be an 80% decline in nitrous oxide emissions.

Lincoln University's carbon calculating formula attributes 762 tons CO2 to nitrous oxide (N2O) when 250KgN fertiliser is applied to the Tanner property. In comparison, the results of the Biohelp treated pasture indicate this could be reduced by as much as 609 tons CO2/annum (762 x 80%).

Fertiliser also contributes to CO2 emissions. There is a lot of variation in carbon emissions modelling. Gelling and Parmenter (2004) calculated the energy requirement to mine, manufacture, distribute and apply nitrogen/phosphorus fertiliser. Their model suggests a 605 ton/annum (20%) carbon emissions drop from lower fertiliser inputs, as used on Biohelp Paddock 20, compared to the conventional fertiliser inputs (from 2013-2017).

Lincoln University's carbon calculating formula shows 262 ton (9%) reduction in CO2 emissions from lower fertiliser and fuel inputs.

The combined effect of fertiliser and N2O reductions would create 871-1241 tons (29-40%) less CO2 emissions from the two different predictive models. Any influence from possible reductions in methane would further add to this.

Interestingly, as a comparison, reducing stock numbers from 4.5 to 3.5 cows/Ha and maintaining 200KgN fertiliser reduces the CO2 emissions by only 523 tons/Ha or 19%. Several hundred thousand dollars in reduced income would also occur.

This study suggests the NZ dairy industry could achieve reductions well beyond its 2030 carbon emissions targets with the addition of Biohelp's technology being applied to pasture once or twice per year. Unpublished Biohelp studies on other properties support these conclusions.

Conclusion

Biohelp products gave strongly significant reductions in calculated leaching rates compared to conventional fertiliser (including liquid N) pastures. In spite of just 24 hours grazing time this field study showed a consistent pattern of a reduced number of urination events, reduced volumes per urination and reduced concentrations of N per urination, every time the cows were grazing the Biohelp treated Paddock. Calculated leaching from cow urine declined by approximately 67%. The actual reason for this has yet to be established. In spite of having drastically less fertiliser inputs the Biohelp treated paddocks had large advantages in pasture production compared to conventional fertiliser treatment volumes and at less cost. These products have changed the soil microbiome and the resulting pasture, which changes the way Nitrogen is excreted from the cow. In addition, the combined effect of less fertiliser and less urine nitrogen created a potential reduction of 29% in CO_2 emissions. Further work is advised to establish methane output. This study showed positive benefits in all the most important environmental and production issues facing the NZ Dairy industry today . It was consistent with smaller unpublished Biohelp studies.

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References Cited

Aarons S.R, Gourley C.J, Powell M, Hannah M.C: (2016) 'Estimating nitrogen excretion and deposition in grazing dairy systems, International Nitrogen Initiative Conference', Melbourne, Australia.

Aland A, Lidfors L, Ekesbo I: (2002) Diurnal distribution of dairy cow defecation and urination. *Applied Animal Behaviour Science* 78, 43-54.

Chadwick D, Cardenas L, Donovan N, Misselbrook T, Williams J, Thorman R, McGeough K, Watson C, Bell M, Anthony S, Rees B. (2014) Nitrous Oxide emissions from urine and dung. GGAA2016 conference.

Dave Clarke DairyNZ Principal Scientist: DairyNZ's technical series 2013 on their website.

Di H.J, Cameron K: (2000) Dairying and the Environment; Centre for Soil and Environmental Quality, Lincoln University.

Gellings W.C, Parmenter K.E , (2004), Energy efficiency in fertiliser production and use , in *Efficient Use and Conservation of Energy* , [Eds. Clark W. Gellings, and Kornelis Blok], in *Encyclopedia of Life Support Systems (EOLSS),* Developed under the Auspices of the UNESCO, Eolss Publishers, Oxfo rd ,UK, [http://www.eolss.net]

Glassey C.B, Roach C.G, Lee J.M, Clark D.A: (2011) The impact of farming without nitrogen fertiliser for ten years on pasture yield and composition, milksolids production and profitability; a research farmlet comparison. *Proceedings of the NZ Grassland Association* 75; 71-78 (2013).

Heather Chalmers reported on Oct 30 2018 in i.Stuff X: Ngai Tahu farming in Eyrewell.

Lucy Birkitt of the Fertiliser and Lime Research Centre at Massey University in her review of leaching losses.

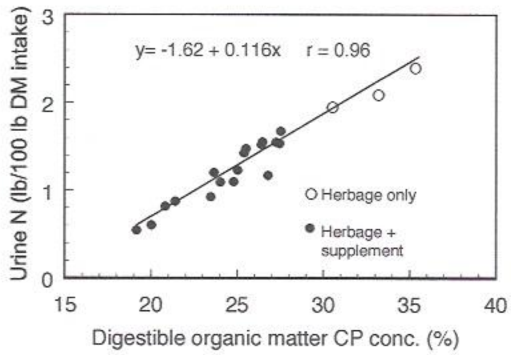
Lilburn L, Webb T, Robson M, Watkins N (2013) Estimating nitrate-nitrogen leaching rates under rural land uses in Canterbury . Environment Canterbury Regional Council Report No 14/19 . Posted on ECAN website.

Ravera B, Bryant R, Cameron K, Di H, Edwards G, Smith N: (2015) 'Use of a urine metre to detect variation in urination behaviour of dairy cows on winter crops, New Zealand Society of Animal Production', Dunedin, New Zealand.

Russelle M, US Dairy Forage Research Centre: (1996) Nitrogen Flow in Intensely Grazed Pastures. The relationship between N concentration in ingested feed and N excreted in Urine of lactating dairy cows fed freshly cut highly fertilised herbage (redrawn from Volk and Hobbelink 1992).

Sprosen M.S, Ledgard S.F, Thom E.R: (1997) Nitrate leaching is similar in N2-fixing grass-clover pasture and N-fertilised grass-only pasture at similar N inputs. *Proceedings of the NZ Grassland Association* 59: 125-128 (1997).

Vibart V, Pacheco D, Lowe K, Barrett B: (2010) Performance, Nitrogen utilisation and grazing behaviour from late lactation dairy cows offered a fresh allocation of a ryegrass-based pasture either in the morning or in the afternoon. Ag Research Grasslands Research Centre, Palmerston North.



<u>Table 3</u>

Figure 2. The relationship between N concentration in ingested feed (based on the digestible organic matter of the diet) and N excretion in urine of lactating dairy cows fed freshly cut, highly fertilized herbage or herbage plus different dietary supplements (redrawn from Valk and Hobbelink 1992). Ni-