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Foliar Feed for Grassland

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Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
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Executive summary

Most nitrogen (N) fertilisers are applied to grassland systems in solid (prill) form. The nutrients are washed into the topsoil by rain and subsequently taken up by the roots of the plants. There is another, more direct, method of getting nitrogen into the plant which is through the pores in the leaves. Previous trials have shown that foliar feeding, applied as a spray, can decrease the amount of nitrogen applied while maintaining dry matter yields (Schofield et al, 2013). The project tested this on 4 dairy farms in mid and south west Wales.

On each farm, one field (approximately 6 Ha) was divided into three plots of equal size and the following fertiliser regimes implemented:

- Plot 1: **Conventional** prilled nitrogen (N) application every 21 days
- Plot 2: **Foliar feed** (a mixture of urea and humic acid) was applied at intervals of 21 days during the grazing season
- Plot 3: A control of **No nitrogen**

Plots were mostly grazed, but in 2020, additional plots were set up on one of the farms to look at this approach in the context of silage systems.

The rates applied varied from farm to farm and from year to year (Table 1). This was because:

- Differences in soil types, elevation, and production systems meant that appropriate levels of N application varied from farm to farm
- The first two years' results suggested that, while in absolute terms, the yields were higher on the conventional fertiliser plots, the Nitrogen Use Efficiency (NUE) (the increase in dry matter (DM) yield per Kg N applied) was much higher in the foliar fed plots. The farmers were interested in whether, by increasing the N concentration in the foliar feed mix, absolute yields could be increased to be comparable with the conventional plots.

	Total N applied (2019) (Kg/ Ha)		**Total N applied (2020) (Kg/ Ha)**		**Total N applied (2021) (Kg/ Ha)**	
	Conv	***Foliar***	***Conv***	***Foliar***	***Conv***	***Foliar***
Site 1	250	46	275	75	275	110
Site 2	250	64	205	47	245	92
Site 3	212	72	275	93	275	110
Site 4 (Grazed)	268	72	240	65	270	92
Site 4 (Silage)			460	182	425	224

The following data was collected on each plot:

- *Total N applied*
- *Dry matter yield* (t/ha) using a rising plate meter. Data was collected weekly from March – October, fortnightly in November and February and monthly in December and January
- The *Nitrogen Usage Efficiency* of the plant. This was calculated by subtracting the yield in the 'no fertiliser' plots from the treatment plots to give a figure for the increased yield

attributable to N application. This was then divided by the Kg N applied to give an increase in yield per kg N applied for conventional and foliar feed plots

- *Clover assessments* were recorded annually. The purpose was to enable us to explain variation in the data that was not attributable to the method of N application
- *Cost of N applied* per tonne of DM yielded, and per additional litre of milk produced
- *Grass quality.* In the final two years of the project, forage from the silage plots on site 4 were analysed for quality including dry matter, digestibility, crude protein, sugars, and metabolizable energy

Key findings were:

- It is possible to achieve comparable yields to the conventional plots using foliar feed systems
- At lower rates of N application, yields were lower in the foliar fed systems. However, the (NUE) was much greater (between 2 and 3 times higher) in foliar fed systems
- Foliar fed systems achieved higher yields in adverse conditions, for example cool and/or dry conditions. This could be because absorption through the leaves was less affected by adverse soil conditions compared to uptake through the roots
- The data was unable to show any relationship between the method of N application and nitrate levels in leaf tissue. Peaks were observed in the plots with no fertiliser, which are likely to be linked to the higher clover levels in these plots
- The higher NUE means that, at lower rates of N, foliar feed systems could potentially deliver significant benefits in terms of reducing the N costs per litre of milk produced
- Grass quality was only measured on one site over two years, so the results need to be treated with appropriate caution. Digestibility (D) values and metabolizable energy (ME) was similar between foliar feed and conventional fertiliser regimes. Crude protein appeared to be higher in conventional plots which is likely to be related to the high total amounts of N applied. The sugars and the dry matter were higher in the foliar plots.

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1. Introduction

Most nitrogen (N) fertilisers are applied to grassland systems in solid form. The nutrients are washed into the topsoil by rain and subsequently taken up by the roots of the plants. A host of factors such as soil compaction, drainage, bioactivity, soil temperature, dry or wet weather can affect the nutrient release and uptake by the grass with this method.

There is another, more direct, method of getting nitrogen into the grass which is through the pores in the leaves. Previous trials have proven that foliar feeding, applied as a spray, can decrease the amount of total nitrogen applied while maintaining dry matter yields and minimising nitrogen losses through runoff (Schofield et al, 2013). This project tested this on 4 dairy farms in mid and south west Wales.

2. Methodology

The trials were carried out on 4 dairy farms in mid and south west Wales (Table 1). On each farm, one field (approximately 6Ha) was split into three sections of equal size with the following fertiliser regimes implemented.

- Plot 1: **Conventional** prilled nitrogen application every 21 days
- Plot 2: **Foliar feed** – a mixture of urea and humic acid - at 21 day intervals during the grazing season
- Plot 3: Control of **no nitrogen**

2.1 Site locations

Details of the farms involved were as follows:

Farm	Location	Description
1	Haverfordwest, Pembrokeshire	550 cows plus followers on ~ 300 Ha. South facing land rising to 30 metres above sea level. Holstein Friesian herd, autumn calving. Rotational grazing system.
2	Clynderwen, Pembrokeshire	250 cows plus followers on ~ 130 Ha. South and north facing land rising to 300 metres above sea level. Peaty soil. Friesian cross bred herd, split block calving. Grass based system.
3	Llanfyrnach Pembrokeshire	180 cows plus followers on 130 Ha. North facing land rising to 150 metres above sea level. Friesian cross bred herd, late spring calving. Grass based system.
4	Aberystwyth, Ceredigion	400 cows, housed system on ~100 Ha of combinable crops system. Holstein Friesian autumn calving herd.

2.2 Fertiliser application

Fertilisers were applied to the plots as follows:

Treatment	Conventional	Foliar Feed
Preparation		Low rate: 20 Kg urea and 1.5 l humic acid diluted in 20 l water and then applied at 200 l/Ha. High rate: 40 Kg urea 1.5 l humic acid diluted in 20 l water and then applied at 200l/ ha. Silage Average 80 Kg Urea product Solution prepared 24 hours prior to application
Timing	After grazing	Grass heights 7-10 cm (10-12 days post grazing)
Frequency of application	Every 21 days (approx.) March - October	Every 21 days (approx.) March - October
Method	Broadcast	Sprayed

Total N application varied from farm to farm and from year to year (Table 1). This was because:

- Differences in soil types, evaluation and production systems between the three farms meant that appropriate levels of N application were different on three farms (see section 2.2).
- The first two years' results suggested that, while in absolute terms, the yields were higher on the conventional fertiliser plots, the NUE was much higher in the foliar fed plots. The farmers were interested in whether, by increasing the N concentration in the foliar feed mix, absolute yields could increase to be comparable with the conventional plots.

	Total N applied (2019) (Kg/ Ha)		Total N applied (2020) (Kg/ Ha)		Total N applied (2021) (Kg/ Ha)	
	Conv	***Foliar***	***Conv***	***Foliar***	***Conv***	***Foliar***
Site 1	250	46	275	75	275	110
Site 2	250	64	205	47	245	92
Site 3	212	72	275	93	275	110
Site 4 (Grazed)	268	72	240	65	270	92
Site 4 (Silage)			460	182	425	224

Table 1: Total N application

2.3 Plot management

Plots were grazed on a 21-day cycle. Within each farm, grazing was identical on the three plots in terms of timing and stocking rate.

In 2020, the group decided to include a silage system in the project on farm 4. An additional set of plots was set up on this farm, and 5 cuts were taken from each.

2.5 Data collection

The following data was collected on each plot on each farm:

- *Dry matter yield*, using a rising plate meter. Data was collected weekly from March – October, fortnightly in November and February and monthly in December and January
- *Clover content* was assessed by randomly throwing a 0.5m x 0.5m quadrat at 20 points within each plot. At each sampling point, the % of clover leaf cover was placed in one of the following 'bandwidths': 0; >5%; 5 – 10%; 6-10%; 11- 20% 21 – 30%; 31-40%; 41 – 50% 51 – 60%; 61-70% 71 – 80%; 81-90%; 91- 100%. For the purposes of illustration, the data for an individual plot was recorded as follows:

% Clover	**Number of occurrences**
0	1
>0-5	2
6-10	5
11-20	6
21-30	5
31-40	1
41-50	0
Total No. sample points	**20**

The median bandwidth was calculated for each field. So in the above example the median sample falls in the 11-20% band

Band	0	>5%		6-10%					11-20%						21-30%					31-40%
Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

The purpose of collecting this data was to enable us to assess the degree to which variation between the treatments was due to clover content rather than fertiliser regimes.

- *Nitrate content of foliage,* using a conventional nitrate meter. Data was collected weekly from March – October, fortnightly in November and February and monthly in December and January. This data was collected as a measure of N uptake under the different treatments
- *Grass quality.* In the final two years of the project, forage from the silage plots on site 4 were analysed for quality including dry matter, digestibility, crude protein, sugars, and metabolizable energy,
- *Costs* in relation to N application were recorded for each treatment

During the course of the project, the team became aware of other work suggesting that the fertiliser regime could also affect grass quality. In years 2020 and 2021 the following were measured in addition on the silage plots on farm: crude protein; D value, ME; and sugars. While it would have been desirable to make similar assessments on all plots, these measurements were not planned as part of the original project, and there was insufficient budget to take measurements on all sites.

2.6 Data analysis

The data was analysed to compare the 'Conventional,' 'Foliar Feed' and 'No Nitrogen' treatments in terms of:

- *Total N applied*
- *Dry matter yield* (t/ha)
- The NUE of the plant. This was calculated by subtracting the yield in the no fertiliser plots from the treatment plots to give a figure for the increased yield attributable to N application. This was then divided by the Kg N applied to give an increase in yield per kg N applied for the conventional and foliar feed plots
- *Cost of* N applied per tonne of DM yielded and per litre of milk

These analyses were used to:

- Assess the extent to which foliar feeding can replace mineral N applications while maintaining productivity as measured by DM yield and the N content
- Detect differences between the treatments in terms of nitrate content and grass quality
- Carry out a cost benefit analysis on using foliar feed

3. Results

3.1 Yield and Nitrogen Use Efficiency

3.1.1 Lower rates of foliar fed N

Absolute yields varied significantly across the sites, and this is a reflection of the differences in growing conditions and elevation; the lowest farm (Site 2) was south facing at about 30 metres in altitude, whilst the highest (Site 3) was north facing at 300 metres. However, broadly speaking, the *relative* differences were similar across all sites in both years (2019 and 2020). Yield was highest in conventional plots, lowest in the 'no fertiliser' plots and approximately midway between the two on the foliar feed plots. In general terms, yields were between 1 and 3 t/Ha higher in conventional plots compared to foliar feed plots (Figures 1 and 2). This was not unexpected as the conventional plots received significantly more nitrogen (Tables 2 and 3). However, there were exceptions:

- In 2019, the foliar feed plots grew 0.5 – 1.0 t/Ha DM more than the conventional plots up to the end of April, indicating faster early growth. This could be because of more rapid uptake of N through the leaves compared to absorption through the roots at lower soil temperatures
- In 2020, the foliar feed plots had *higher* yields at site 2 and 3 (2.5 and 0.8 t/Ha DM more respectively). This is possibly due to soil moisture conditions; the spring of 2020

was exceptionally dry, and therefore the uptake from the conventional fertiliser through the roots may have been greatly reduced. The application of foliar feed bypasses the need for nutrients to be taken up through the roots, and therefore for high soil moisture content.

The results suggest that foliar feeding may lead to increased yield in cold and or dry conditions, compared to conventional, due to improved N uptake. This is an interesting observation arising from the project that warrants further investigation. As weather patterns are changing due to the effects of climate change, it is important that farmers can maintain high quality yields of forage for their production systems.

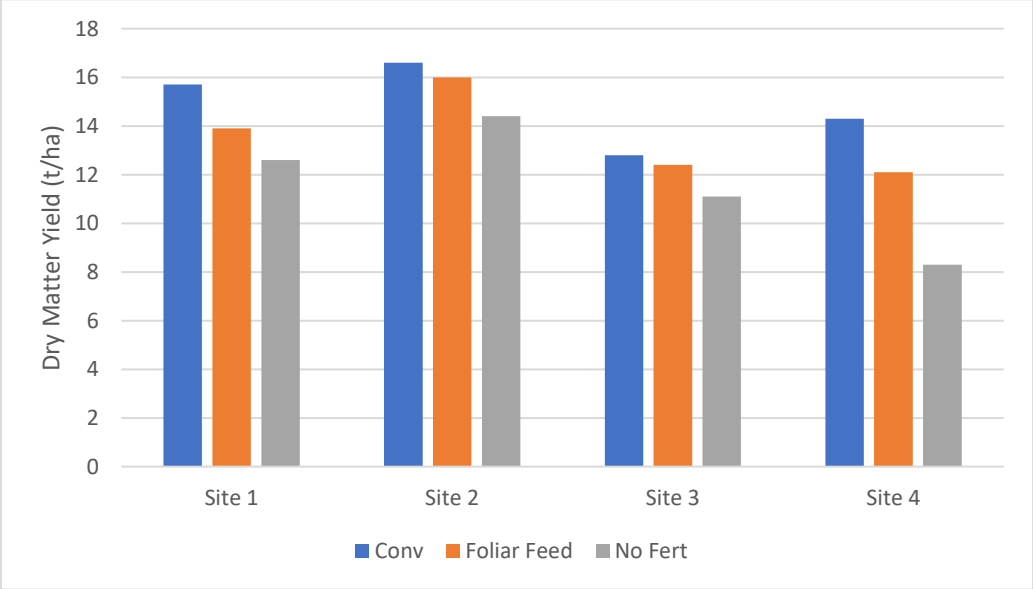

Figure 1: Dry matter yields 2019 (Low Foliar Fed N)

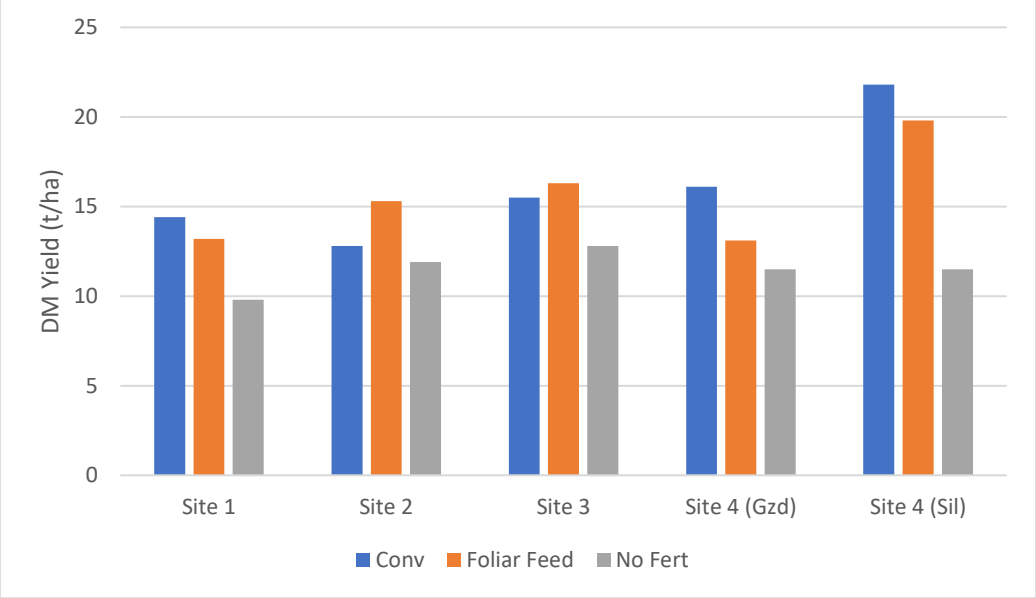

Figure 2: Dry matter yields 2020 (Low N Foliar Feed)

The data from the project suggests that at lower N concentrations, the foliar feed substantially increases NUE compared to conventional applications. In this context, NUE is defined as the increase in DM yield per additional Kg of N applied. In most cases, NUE was between 2 and 4 times (200% – 400%) higher on the foliar fed plots compared to the conventional plots (Tables 2 and 3). In one instance it was 16.5 (1600%) times higher, although this is likely to be an anomaly in the data.

This increase in NUE is likely to be down to a number of factors:

- The humic acid in the foliar feed actively carries the N into the plant. This process is more efficient than absorption through the roots.
- The humic acid is also a source of carbon which means the energy required for absorption is more readily available and does not need to draw on the soil's reserves
- Where the foliar feed runs off into soil, humic acid is known to aid soil activity and make mineral and trace elements more readily available to the plant
- Uptake of N through the leaves may be higher than root uptake when soil moisture and soil temperature are lower

	Conventional			**Foliar Feed**			**FF NUE compared to conv (%)**
	Total N applied (Kg/ Ha)	***Additional Yield (Kg/ Ha)***	***NUE (Kg DM/ Kg N)***	***Total N applied (Kg/ Ha)***	***Additional Yield (Kg/ Ha)***	***NUE (Kg DM/ Kg N)***	
Site 1	250	3100	12.4	46	1300	28.3	228
Site 2	250	2200	8.8	64	1600	25.0	284
Site 3	212	1700	8.0	72	1300	18.1	225
Site 4	268	6000	22.4	72	3800	52.8	236

Table 2: Nitrogen Use Efficiency at lower concentrations of N in foliar feed – 2019

Site	**Conv**			**Foliar Feed**			**FF NUE compared to conv (%)**
	Total N applied (Kg/ Ha)	***Additional Yield (Kg/ Ha)***	***NUE (Kg DM/ Kg N)***	***Total N applied (Kg/ Ha)***	***Additional Yield (Kg/ Ha)***	***NUE (Kg DM/ Kg N)***	
Site 1	275	4600	16.7	75	3400	45.3	271
Site 2	205	900	4.4	47	3400	72.3	1648
Site 3	275	2700	9.8	93	3500	37.6	383
Site 4 (Gzd)	240	4600	19.2	65	1600	24.6	128
Site 5 (Sil)	460	10300	22.4	182	8300	45.6	204

Table 3: Nitrogen Use Efficiency at lower concentrations of N in foliar feed – 2020

3.1.2 Higher rates of foliar fed N

In the final year of the project, we looked at whether, given the greater NUE of foliar feed, increasing the N concentration of the feed would proportionately increase the yield. The N applied by foliar feeding was increased from an average of approximately 70 Kg N/ Ha to 100Kg N/ Ha.

As Figure 3 shows, the increase in N concentration in the foliar feed resulted in broadly similar yields on conventional and foliar fed plots, in both grazed and silage systems. There was one exception (Site 1). This could be due to field conditions in the foliar fed plot compared to conventional, rather than the applications of N. Possibilities include: low levels of magnesium on this site, which may lock up nutrients and reduce the benefit of applying N; and a lighter soil on the foliar fed plots which may have had an impact especially during the drought in late spring of 2021.

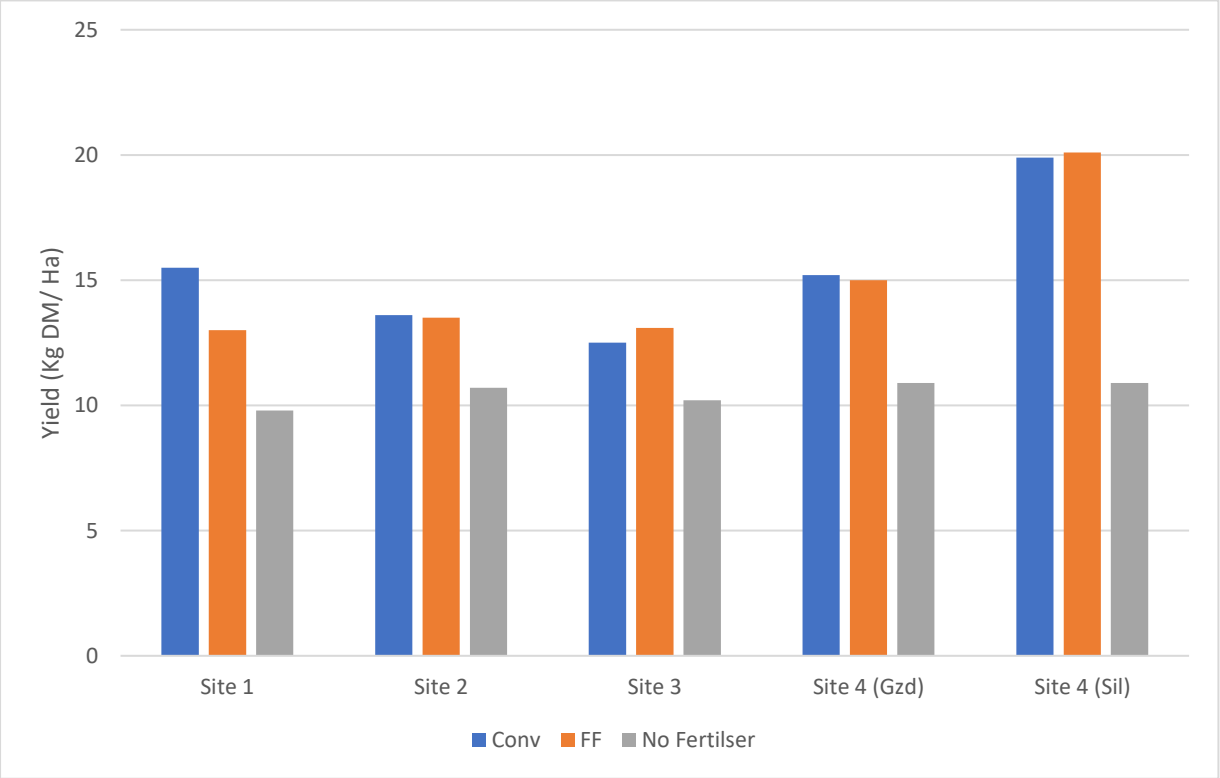

Figure 3: Dry matter yields 2021 (High N Foliar Feed)

On all sites with exception of Site 1, NUE continued to be significantly higher in foliar fed plots, achieving similar DM yields to conventional plots by applying only 40 – 50% of the nitrogen, depending on the specific site. The variation between sites and years makes it difficult to draw firm conclusions about the relationship between the concentration of N in the foliar feed and NUE.

	Conv			Foliar Feed			Foliar Feed NUE compared to conventional (%)
	Total N applied (Kg/ Ha)	Additional Yield (Kg/ Ha)	NUE (additional Kg DM/ Kg N	Total N applied (Kg/ Ha)	Additional Yield (Kg/ Ha)	NUE (additional Kg DM/ Kg N	
Site 1	275	5700	20.7	110	3200	29.1	140
Site 2	245	2900	11.8	92	2800	30.4	257
Site 3	275	2300	8.4	110	2900	26.4	315
Site 4 (Gzd)	270	4300	15.9	92	4100	44.6	280
Site 4 (Sil)	425	9000	21.2	224	9200	41.1	194

**The project ended in September 2021. In order to obtain a measure of the NUE, grass growth from October – December 2021 was estimated from figures for the two previous years of the project*

Table 4: Nitrogen Use Efficiency at higher concentrations of N in foliar feed – 2020

3.2 Clover content

Table 5 shows the median clover cover on each site in each year. It is well established that application of granular fertiliser to the soil supresses clover, and this is therefore no surprise that clover is more abundant in the no fertiliser plot compared to the conventional plots. However, the foliar feed plots also had higher clover content than the conventional plots and were either similar to the no fertiliser plots, or intermediate between the no fertiliser and the conventional plots. Given the management was identical on the conventional and FF plots, is difficult, on the basis of the data available, to explain the difference.

There were also differences in clover coverage between sites and between years. Generally, 2019 had lower clover cover than the other years, possibly because the assessments were taken slightly earlier in that year. Overall, Site 4 had the highest content, partly due to good growing conditions, and partly because management of clover is a priority for the farm. Historically site 1 also had high clover levels for the same reasons, but in 2020, a herbicide application was made to manage docks and this knocked the clover back.

It should be noted that the clover assessments were not a major part of the project – only one assessment was taken in each year. However, the data has thrown up some interesting patterns that might be worthy of further investigation.

Site		2019	2020	2021
1	Conventional	5-10%	0	0
	Foliar Feed	21-30%	<5%	0
	No Fertiliser	5-10%	<5%	0
2	Conventional	<5%	<5%	<5%
	Foliar Feed	<5%	5-10%	11-20%
	No Fertiliser	<5%	5-10%	11-20%
3	Conventional	0	0	>5%
	Foliar Feed	0	>5%	5-10%
	No Fertiliser	0	6-10%	5-10%
4	Conventional	<5%	6-10%	>5%
	Foliar Feed	5-10%	11-20%	11-20%
	No fertiliser	<5%	21-30%	11-20%

Table 5: Median clover content 2019-2021

3.3 Tissue N Content

The N content of leaf tissue was monitored as a direct measurement of the uptake into the plant. There was no clear relationship between the N content of the leaves and the N application method (Figures 4 – 8). There were large annual peaks in samples from the 'no fertiliser' mostly occurring in late spring/ early summer. This could be related the higher clover in these plots (see above).

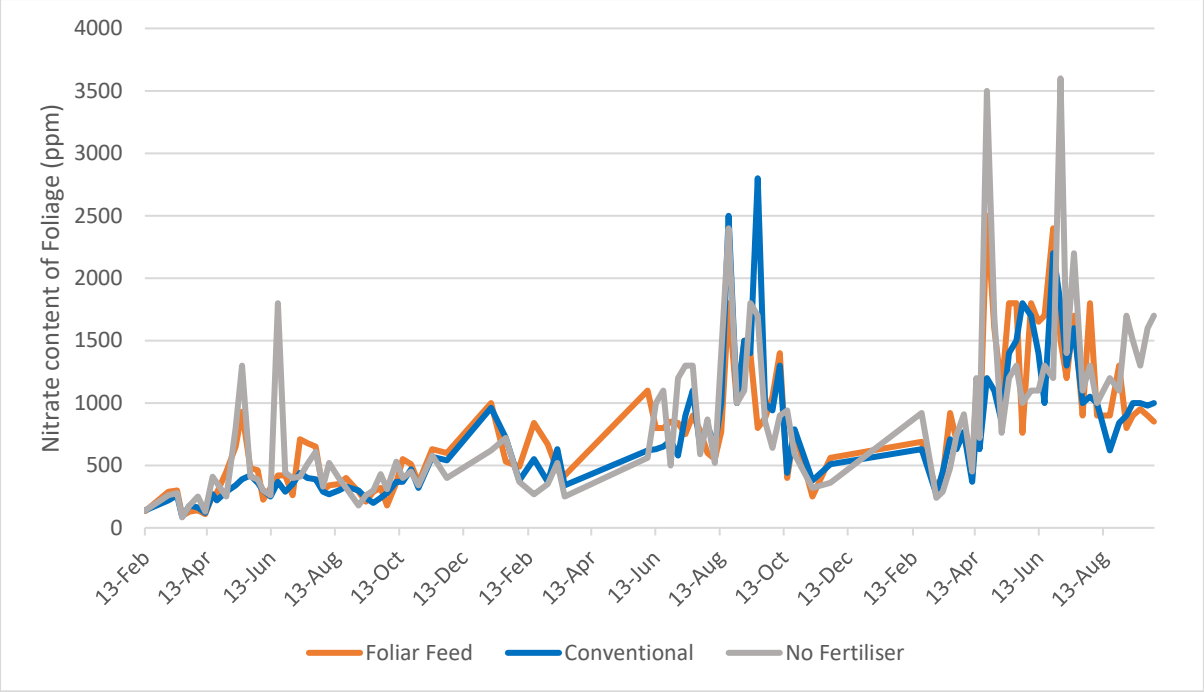

Figure 4: Nitrate content of foliage – Site 1

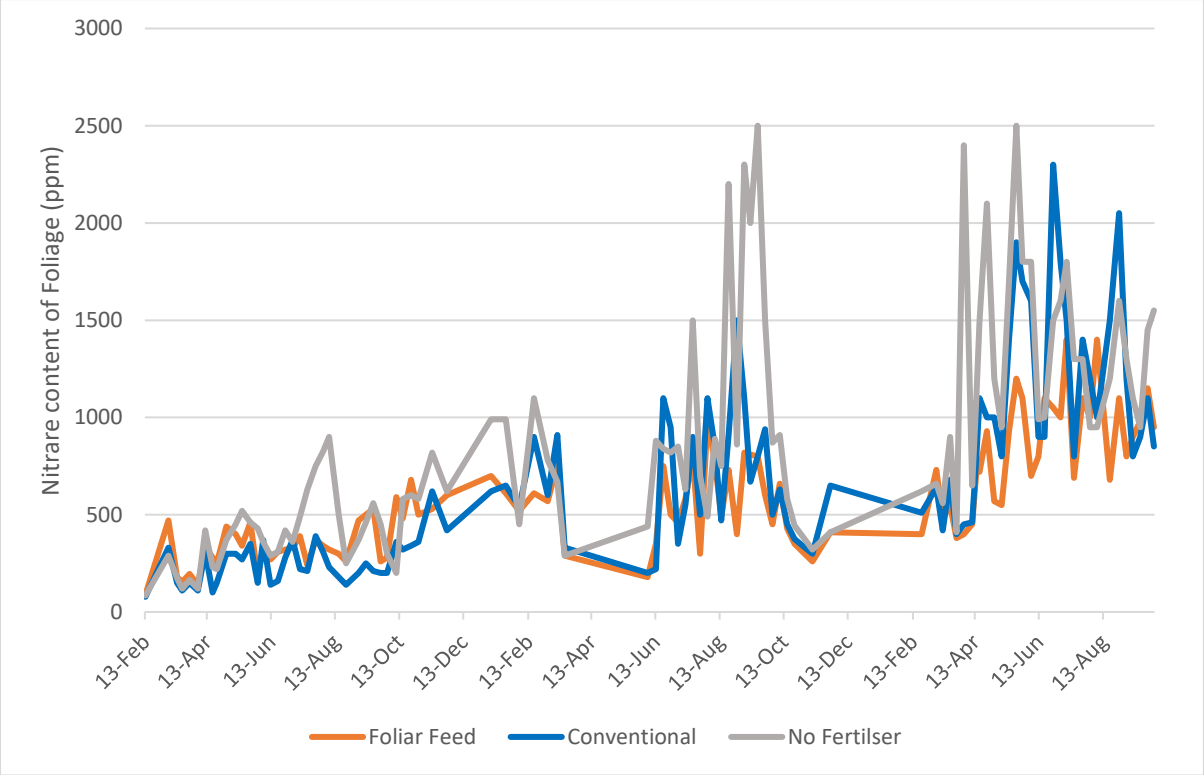

Figure 5: Nitrate content of foliage – Site 2

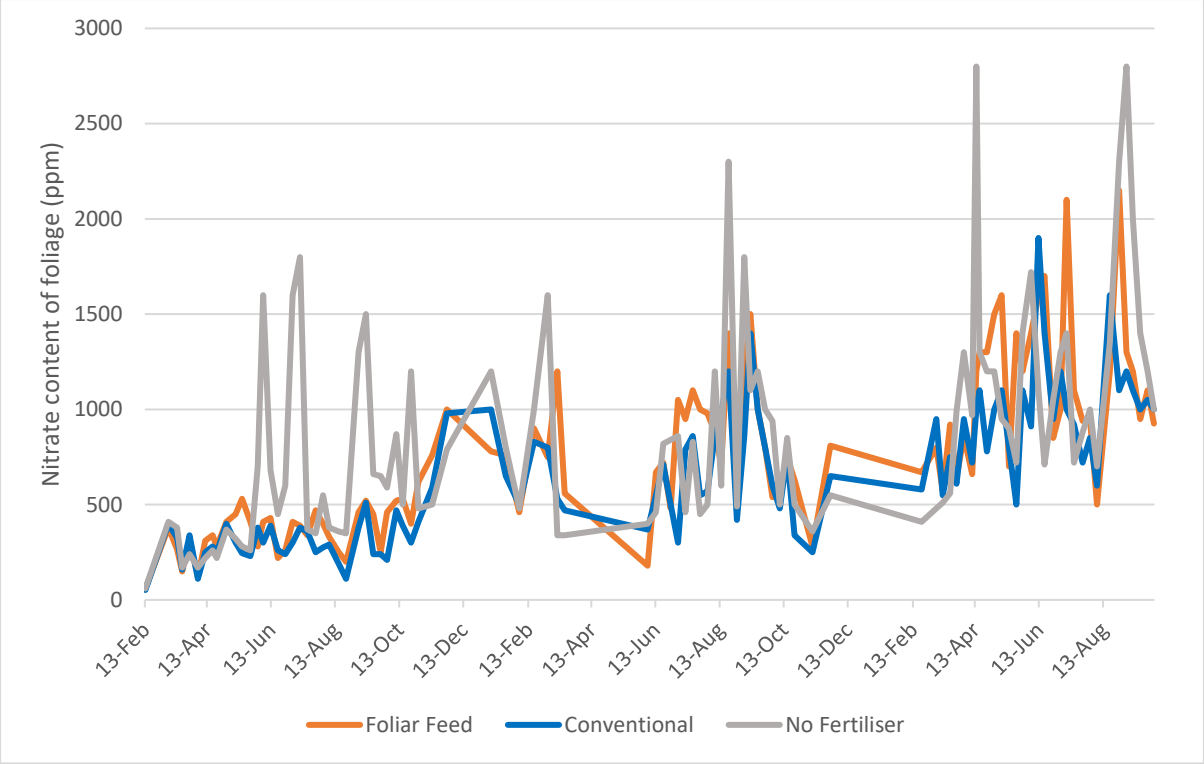

Figure 6: Nitrate content of foliage – Site 3

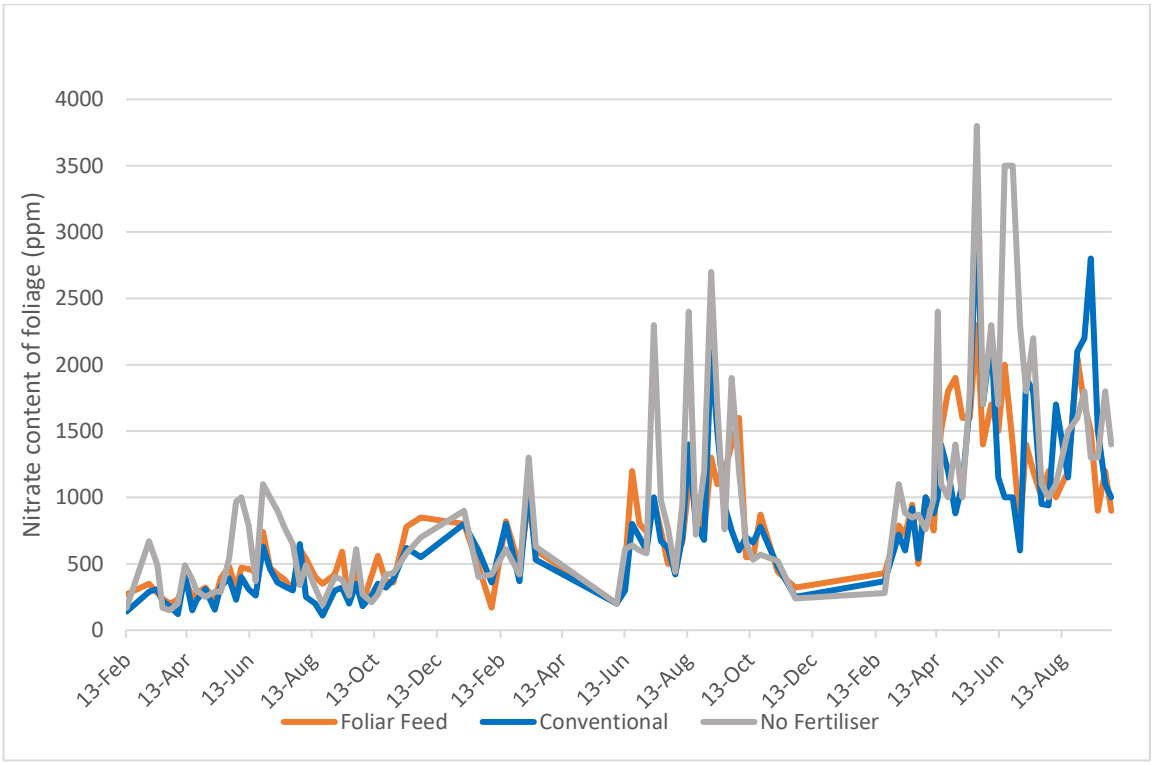

Figure 7: Nitrate content of foliage – Site 4 (grazed)

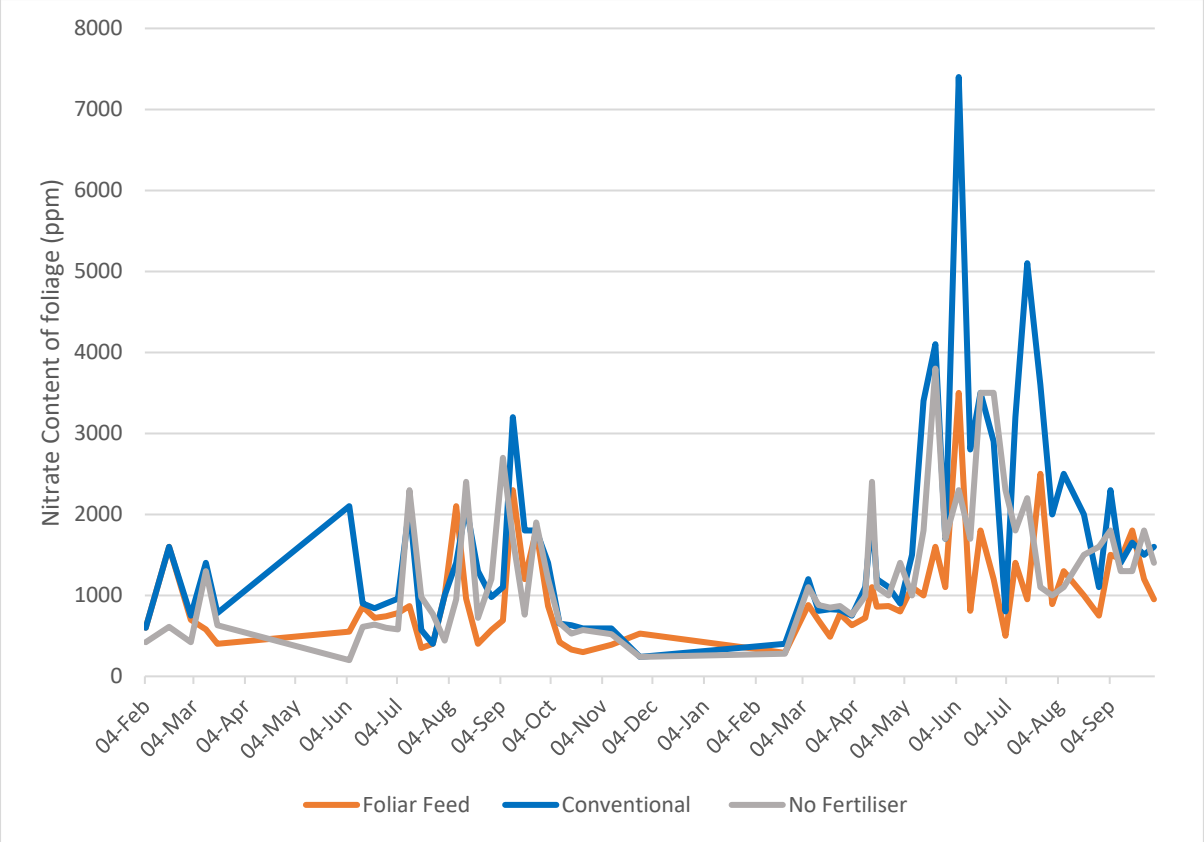

Figure 8: Nitrate content of foliage – Site 4 (Silage)

3.4 Grass quality

The 2020 grass dry matter values on the foliar fed plots were consistently higher (2-5%) than the conventionally applied fertiliser. This is possibly due to the grass growing slower than the conventional plot, as faster growth tends to lead to higher water/moisture content.

The levels of sugar in the grass plant were also consistently higher in the foliar feed plots over the 2 years. One explanation could be due to the use of humic acid as a carbon source for the dilute urea to use immediately, placing less demand on the plants' own reserves. Also, as urea is a more readily available form of nitrogen with a shorter chemical chain, the process of assimilation is more efficient, therefore less demanding on the grass plant's own energy source.

Crude protein was higher in conventional plots and could be related to high total amounts of N applied to these plots. The sugars and the dry matter were higher in the foliar plots.

D values and ME were similar between foliar feed and conventional plots.

The differences in quality were small, and data was only collected on one site over two years. These findings therefore need to be treated with caution and validated by further research.

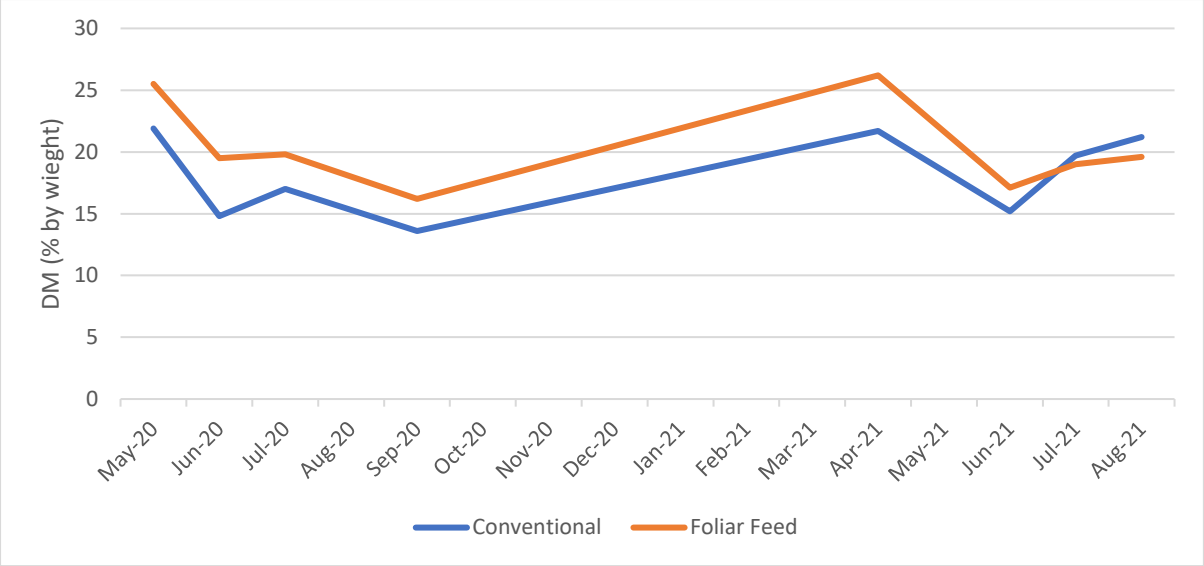

Figure 9: Dry Matter content

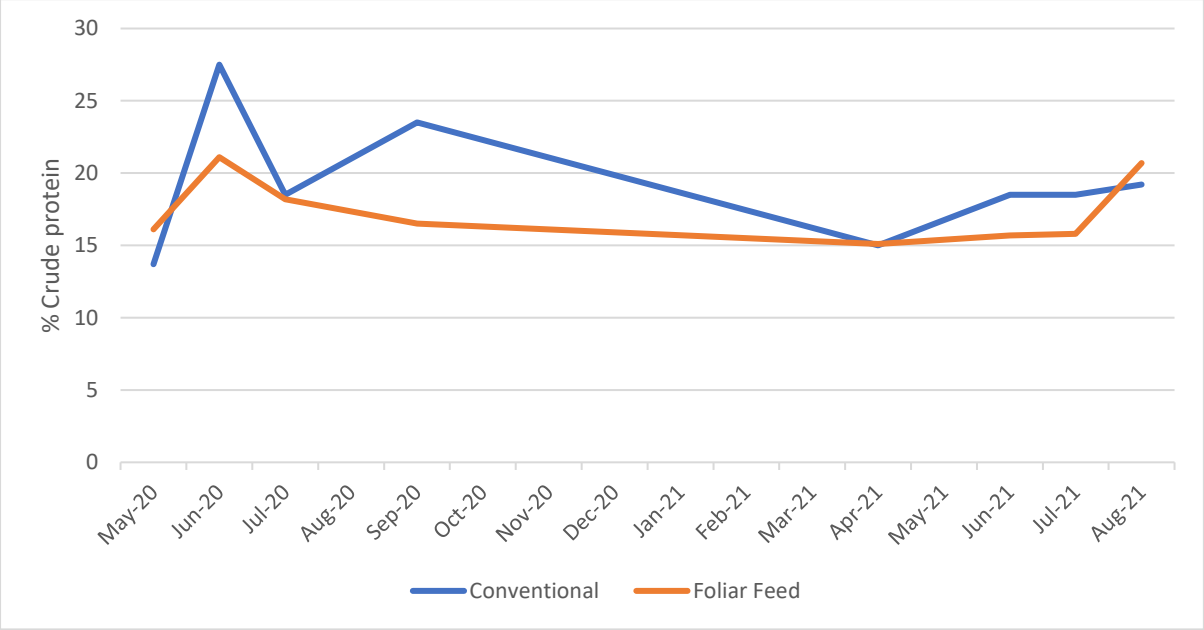

Figure 10: Crude protein

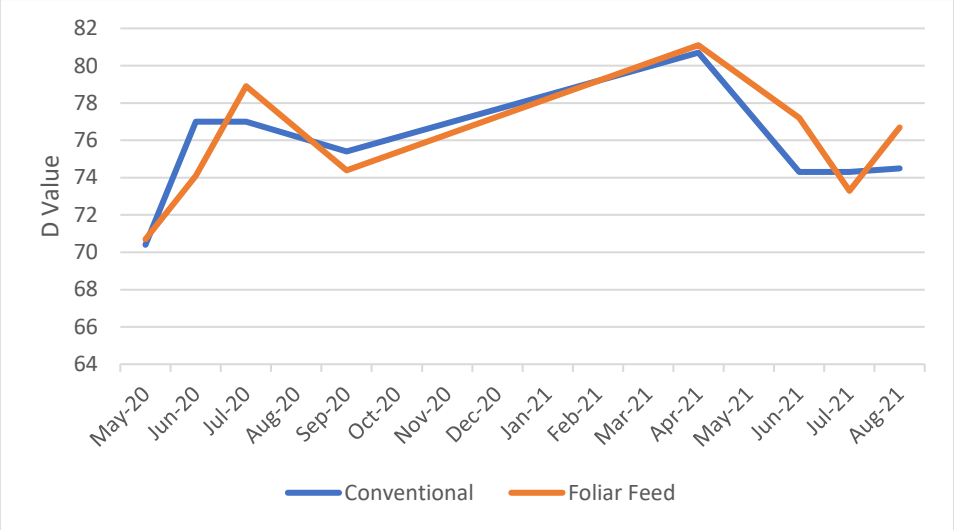

Figure 11: D Value

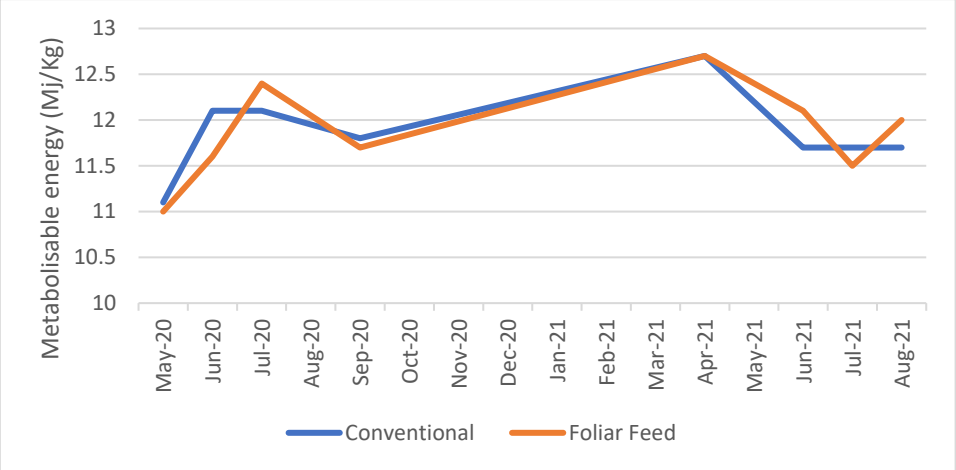

Figure 12: Metabolisable energy

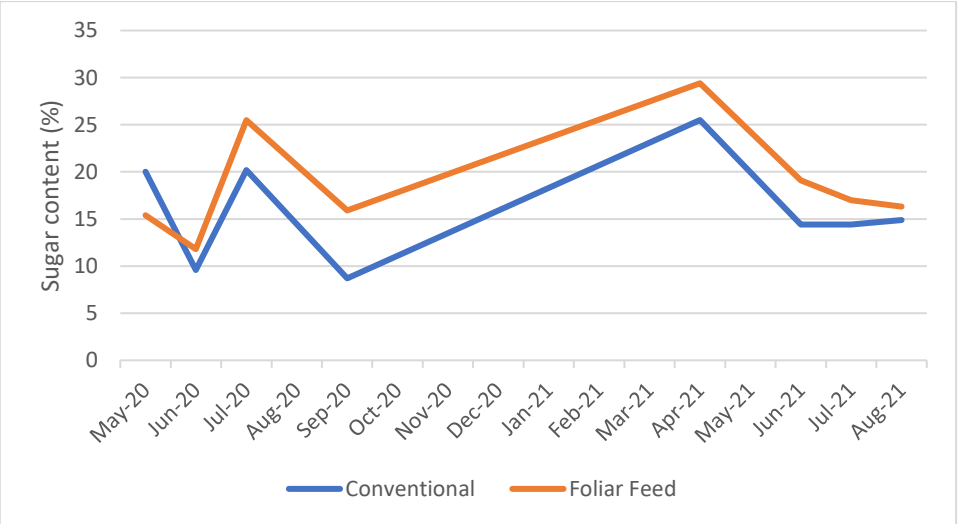

Figure 13: Sugars

3.5 Costs and benefits

Table 6 compares the cost of N per litre of additional milk (i.e. over and above that produced on the 'no fertiliser plots') for conventional and foliar fed systems. Energy requirements were used to estimate the volume of milk produced in each system, assuming that 5.5 MJ of energy are needed to produce a litre of milk and that forage contained approximately 11.5 MJ/ Kg DM (based on forage analysis of the plots).

The cost of the foliar feed ingredients was about 25% higher compared to conventional fertiliser. This is partly because foliar feed requires unprotected urea to be used which is more expensive (£360 £/t) and partly because of the cost of humic acid (approximately £2.25/ ha) The application costs for foliar feed are also much higher than for conventional fertiliser (about £7.5/ ha for applying granular fertiliser compared to about £15/ ha for spraying foliar feed).

However, these additional costs were more than compensated for by increased NUE in the foliar plots. With two exceptions (Site 4 grazed in 2020, and Site 1 in 2021) the cost of N per additional litre of milk was lower in foliar fed compared to conventional plots. The difference varied (range 18 – 89% across all sites in all years) but on average the cost of N per litre of additional milk produced was 39% lower in foliar fed systems.

The end of the project coincided with a very sharp increases in energy prices, which fed through to high fertiliser prices at the end of 2021/ beginning of 2022. The calculations presented in table 6 are based on prices at the time of data collection - prior to these price increases. As N costs increase, the higher NUE in foliar feeds becomes even more important in reducing costs. At the present time (February 2022), therefore, the economic benefits of reduced N application are likely to be higher than the figures below suggest.

3.6 Farmer perspectives

The farmers involved in the project felt they had benefited from direct involvement in the project. Collecting data on their individual farms gave them a high degree of confidence in the results, and in the relevance of the findings to their commercial farming operations.

The opportunity to feed into the direction of the project was also valued. For example, the decisions to extend the trials to silage plots and to look at higher rates of N application in the third year resulted from feedback from the farmers, after detailed analysis and discussion of the data from the previous years.

The direct experience of the participating farmers, to whom the wider farming community can relate, is an extremely important factor in the effective dissemination of the project findings.

'*After being part of the Foliar feed Project for the last 3 years, i have had my eyes opened as to the benefit of this different way to apply fertiliser on my grassland, and as a result i will be Foliar feeding the farm ongoing'*

Farmer at Site 3

'*I was pleased to see the results obtained from the Foliar Feed project and have decided to use it on my silage ground along with slurry and some dry product. I will be using Foliar feed on 300 acres of arable crops as well"*

Farm manager at Site 4

4. Conclusions

- At higher rates of N, foliar feeds achieved comparable yields to conventional application systems
- At lower rates of N application, yields were lower in the foliar fed systems. However, the NUE was much greater (between 2 and 3 times higher) in foliar fed systems
- Foliar fed systems achieved higher yields in adverse conditions, for example cool and/or dry conditions. This could be because absorption through the leaves was less affected by adverse soil conditions compared to uptake through the roots
- The data was unable to show any relationship between the method of N application and nitrate levels in leaf tissue. Peaks were observed in the plots with no fertiliser, which are likely linked to higher clover levels in these plots
- The higher NUE results of this project means that, at lower rates of N, foliar feed systems can potentially deliver significant benefits in terms of reducing the N costs per litre milk.

5. References

Phillip Schofield[1], Nicky Watt[2] Max Schofield[3] 'Using humic compounds to improve the efficiency of fertiliser nitrogen '.

[1]Abron Farm Consultant, 3/129 Maraekakaho Rd Hastings [2]Operations Manager, Cloverdale Holding Ltd, Ferrimans Rd, Ashburton [3]Masters Candidate, School of Biological Science, Victoria University, Wellington

2019 (Low N)	System	kg N applied	Ingredients (£/Kg N)	Application	Total Cost of N	Additional* DM Yield (Kg/ Ha)	Additional* ME (MJ/Ha)	Additional* Milk (l/ Ha)	Cost N (ppl additional milk)
Site 1	Conventional	250	£200.00	£7.50	£207.50	3100	35650	5185	**4.00**
	FF	46	£56.58	£15.00	£71.58	1300	14950	2175	**3.29**
Site 2	Conventional	250	£200.00	£7.50	£207.50	2200	25300	3680	**5.64**
	FF	64	£78.72	£15.00	£93.72	1600	18400	2676	**3.50**
Site 3	Conventional	212	£212.00	£7.50	£219.50	1700	19550	2844	**7.72**
	FF	72	£88.56	£15.00	£103.56	1300	14950	2175	**4.76**
Site 4 (Gzd)	Conventional	268	£214.40	£7.50	£221.90	6000	69000	10036	**2.21**
	FF	72	£88.56	£15.00	£103.56	3800	43700	6356	**1.63**

**Increase over the 'no fertiliser' plots*

2020 (Low N)	System	kg N applied	Ingredients (£/Kg N)	Application	Total Cost of N	Additional* DM Yield (Kg/ Ha)	Additional* ME (MJ/Ha)	Additional* Milk (l/ Ha)	Cost N (ppl additional milk)
Site 1	Conventional	275	£220.00	£7.50	£227.50	4500	51750	7527	**3.02**
	FF	93	£114.39	£15.00	£129.39	3400	39100	5687	**2.28**
Site 2	Conventional	205	£164.00	£7.50	£171.50	900	10350	1505	**11.39**
	FF	47	£57.81	£15.00	£72.81	3400	39100	5687	**1.28**
Site 3	Conventional	275	£220.00	£7.50	£227.50	2700	31050	4516	**5.04**
	FF	75	£92.25	£15.00	£107.25	3500	40250	5855	**1.83**
Site 4 (Gzd)	Conventional	240	£192.00	£7.50	£199.50	4600	52900	7695	**2.59**
	FF	65	£79.95	£15.00	£94.95	1600	18400	2676	**3.55**
Site 4 (Sil)	Conventional	460	£368.00	£7.50	£375.50	10300	118450	16152	**2.32**
	FF	182	£223.86	£15.00	£238.86	8300	95450	17355	**1.38**

**Increase over the 'no fertiliser' plots*

2021 (High N)	System	kg N applied	Ingredients (£/Kg N)	Application	Total Cost of N	Additional* DM Yield (Kg/ Ha)	Additional* ME (MJ/Ha)	Additional* Milk (l/ Ha)	Cost N (ppl additional milk)
Site 1	Conventional	275	£220.00	£7.50	£227.50	5700	65550	9535	**2.39**
	FF	110	£135.30	£15.00	£150.30	3200	36800	5353	**2.81**
Site 2	Conventional	245	£196.00	£7.50	£203.50	2900	33350	4851	**4.20**
	FF	92	£113.16	£15.00	£128.16	2800	32200	4684	**2.74**
Site 3	Conventional	275	£220.00	£7.50	£227.50	2300	26450	3847	**5.91**
	FF	110	£135.30	£15.00	£150.30	2900	33350	4851	**3.10**
Site 4 (Gzd)	Conventional	270	£216.00	£7.50	£223.50	4300	49450	7193	**3.11**
	FF	92	£113.16	£15.00	£128.16	4100	47150	6858	**1.87**
Site 4 (Sil)	Conventional	425	£340.00	£7.50	£347.50	9000	103500	14114	**2.46**
	FF	224	£275.52	£15.00	£290.52	9200	105800	14427	**2.01**

Assumptions	***Conventional***	***FF***	***Notes***
Cost ingredients (£/Kg N)	*£0.80*	*£1.23*	*FF Calculated from project costs*
Cost of application (£/ Ha)	*£7.50*	*£15.00*	*FF assumed same as spraying*
ME requirement/ l milk (MJ)	*5.50*	*5.50*	*Std Industry*
Energy in forage (MJ / Kg DM)	*11.50*	*11.50*	*From forage analysis*
Energy Utilisation (grazing)	*80%*	*80%*	
Energy Utilisation (silage)	*75%*	*75%*	

Table 6: N costs per additional litre of milk