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'The Future Farm'

21st February 2023 - Whangarei

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Future Dairy Farm Systems for Northland Project

Update - February 2023

These on-farm trials are being run by the Northland Dairy Development Trust (NDDT) in conjunction with the Northland Agricultural Research Farm (NARF). The projects are funded by DairyNZ, Ministry of Primary Industries (Sustainable Food and Fibre Futures) and Hine Rangi Trust with support from commercial sponsors.

Summary

This study compares the normal (current) NARF dairy system (**Current Farm** - 3.1 cows/ha, 190 kg N/ha applied) with a farm that has 75% of land in tall fescue/cocksfoot-based pastures (**Alternative Pastures Farm** - 3.1 cows/ha, 190 kg N/ha) and a farm designed to have significantly reduced greenhouse gas (GHG) emissions (**Low Emissions Farm** - 2.2 cows/ha, no nitrogen applied). This project commenced in June 2021 and will run for 4 seasons.

Pasture growth monitoring showed that with no nitrogen fertiliser application the Low Emissions Farm grew 1,37 tDM/ha less pasture than the Current Farm in the 2021/22 season, and 2.3 tDM/ha less in the 2022/23 season (to date). This indicates a response of 8 and 15 kg DM/kg N applied on the Current Farm for each season respectively.

The tall fescue/cocksfoot pastures on the Alternative Pastures Farm have had similar annual pasture growth to the kikuyu/Italian ryegrass pastures on the Current Farm, however the seasonality has been different with the Alternative species pastures having higher growth in winter/spring and lower growth in summer/autumn. The Alternative Pastures Farm has also shown higher pasture quality during summer/autumn compared to the other farms.

To date, the proportion of clover in the pasture has averaged 10% on the Current Farm, 16% on the Alternative Pastures Farm and 26% on the Low Emissions Farm.

In the 2021/22 season, total milk production was highest on the Current farm (1,284 kg MS/ha) followed by the Alternative Pastures farm (1,213 kg MS/ha) with the Low Emissions farm significantly behind the other two (794 kg MS/ha).

Financial analysis for the 2021/22 season, using a $9.30/kg MS milk price, shows the Current farm was the most profitable with an operating profit of $5,040/ha followed closely by the Alternative Pastures farm with $4,876/ha and the Low Emissions farm with $3,021/ha.

Sowing alternative pasture species did not result in increased full season production or profit. However, it must be noted that they were competing against a relatively productive regime on the other farms where kikuyu is mulched and reseeded with Italian ryegrass annually.

Modelling of the 2021/22 season shows that the Low Emissions farm had a 33% reduction in methane emissions and a 47% reduction in nitrous oxide emissions compared to the Current farm, however farm profit was also 40% lower. Based on this the pricing mechanism to encourage farmers to reduce emissions is unlikely to be near enough to compensate for the significant loss in profit shown in this study for this season.

The 2022/23 season to date is indicating the difference in milk production between the Current and Low Emissions Farms will be less than the 2021/22 season, and when combined with increased on-farm costs it is likely that farm profit will be similar between these two farms.

Background

Northland farm systems are at the forefront of the effects of a warming climate and demonstrate the challenges that the rest of New Zealand will experience over time. In Northland, ryegrass persistence is relatively poor, rust and pest damage are increasing and regression to kikuyu often occurs within three years after sowing new pasture. Kikuyu is productive during summer/autumn, however it is has poorer nutritive value, is difficult to manage and has low winter/spring growth. The performance of alternate pasture species such as tall fescue, cocksfoot, legumes, and herbs seem to be better and the reinvasion of kikuyu considerably slower with these species than ryegrass sown pastures.

Dairy farmers are also being asked to lower GHG emissions. Farmers are uncertain as to whether the strategies to reduce emissions are physically or financially sustainable, particularly the lowering of stocking rate on pastures containing kikuyu.

This project is conducting a farm systems trial at NARF to test and compare three farm systems which may be used in the future to mitigate and adapt to the effects of a warming climate.

Trial Design

This project compares three farm systems:

1. **Current Farm** (Red) – existing ryegrass/kikuyu pastures with imported feed (PKE & Baleage) to fill feed deficits. Stocking rate 3.1 cows/ha and up to 190 kg applied N/ha
2. **Alternative Pastures Farm** (Blue) – 75% of pastures in alternative species to ryegrass - including fescue, cocksfoot, legumes & herbs with imported feed to fill deficits. Stocking rate 3.1 cows/ha and up to 190 kg applied N/ha
3. **Low Emissions Farm** (Green) – existing ryegrass/kikuyu pasture with a target to reduce methane emissions by 25% and nitrous oxide emissions by 50% (compared to the Current Farm). Stocking rate 2.2 cows/ha, no nitrogen application. Little or no imported feed

This farm systems trial commenced June 2021 and will run for four years to test these systems under a range of climatic conditions. Trial measures capture pasture and milk production, milk composition, profit, and people (labour input and management difficulty) data on the three systems.

Introduction of New Pastures

To set up the Alternative Pastures Farm, 9 ha of new pastures were sown in May 2020, 11.6 ha in March 2021. Grass species sown were tall fescue or tall fescue and cocksfoot or cocksfoot, with white clover, red clover and persian clover. In the 2021 and 2022 sowings 1 kg/ha chicory was also added. The farm was a total of 27.8 ha, so these new pastures represent 74% of the farm.

Establishment of pastures sown in 2020 was excellent, whereas establishment of 2021 and 2022 sown pastures was variable with some poor establishment, mainly due to competition from poa annua. Due to this, 4.2 ha was resown in autumn 2022.

Costs of the pasture introduction were similar across the three years, averaging $1,138/ha. This includes tractor and man hours associated with this introduction as well as contractor costs for drilling. All sowings were grass to grass, no cropping.

The other two farms (Current Farm and Low Emissions Farm), and the 26% of the Alternative Pastures Farm that was not sown in new species, have older pastures with approximately 70% kikuyu presence. All kikuyu-based paddocks are mulched each autumn and drilled with Italian ryegrass. This provides control of kikuyu stolon and also a winter/spring active ryegrass to complement the summer/autumn active kikuyu.

Pasture Growth

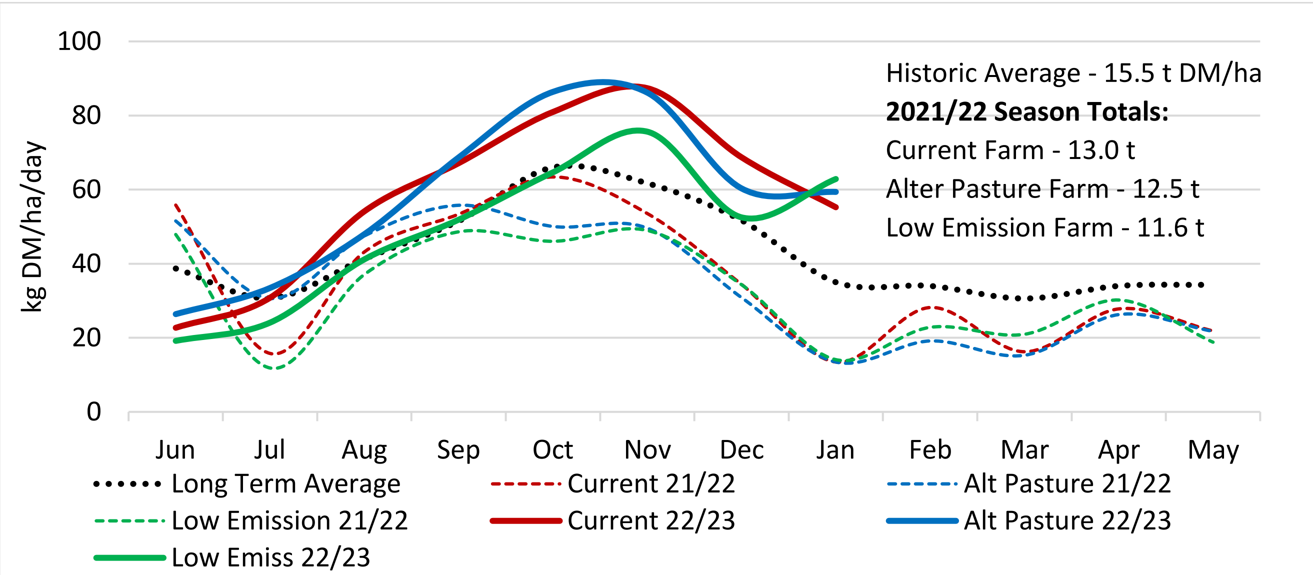
Pasture growth, composition and quality has been compared between the resident kikuyu/Italian ryegrass pastures with and without nitrogen, and the fescue/cocksfoot based pastures with nitrogen, since July 2021.

Figure 1 shows pasture growth differences between farms pastures as calculated by weekly platemeter assessments. During the 2021/22 season, growth on all farms was considerably below the historic average, due to dry conditions during summer/autumn. So far, pasture growth in the 2022/23 has generally been above the historic average.

Overall, the fescue/cocksfoot pastures on the Alternative Pastures Farm showed similar pasture growth to the pastures on the Current Farm.

The difference between the Current farm and the Low Emissions farm shows the effect of nitrogen application on the Current Farm, which grew 1,376 kg DM/ha more than the Low Emissions farm in 2021/22 and 2,297 kg DM more in 2022/23 (to date). With 172 kg N/ha applied to the Current farm in 2021 and 153 kg N/ha in 2022, all between June and December, this calculates to a farm systems response of 8 kg DM/kg N in 2021 and 15 kg DM/kg N in 2022.

Figure 1. *Pasture growth rates for 2021/22 and 2022/23 seasons to date, as calculated by pre – post grazing platemeter assessments.*



Pasture Quality

Pasture samples were collected monthly from the next three paddocks to be grazed on each farm and analysed for feed quality and species presence. Pasture ME (see figure 2) indicates that the fescue/cocksfoot pastures had higher feed quality through much of the first year, especially during summer/autumn. The 2021 sown pastures had 1 kg of chicory in the seed mix and these pastures became chicory dominant over the summer/autumn period.

There was very little feed quality difference between the kikuyu ryegrass pastures that received nitrogen (Current farm) and those that did not (Low Emissions farm).

Figure 2. *Pasture metabolisable energy content (MJ ME/kg DM).*

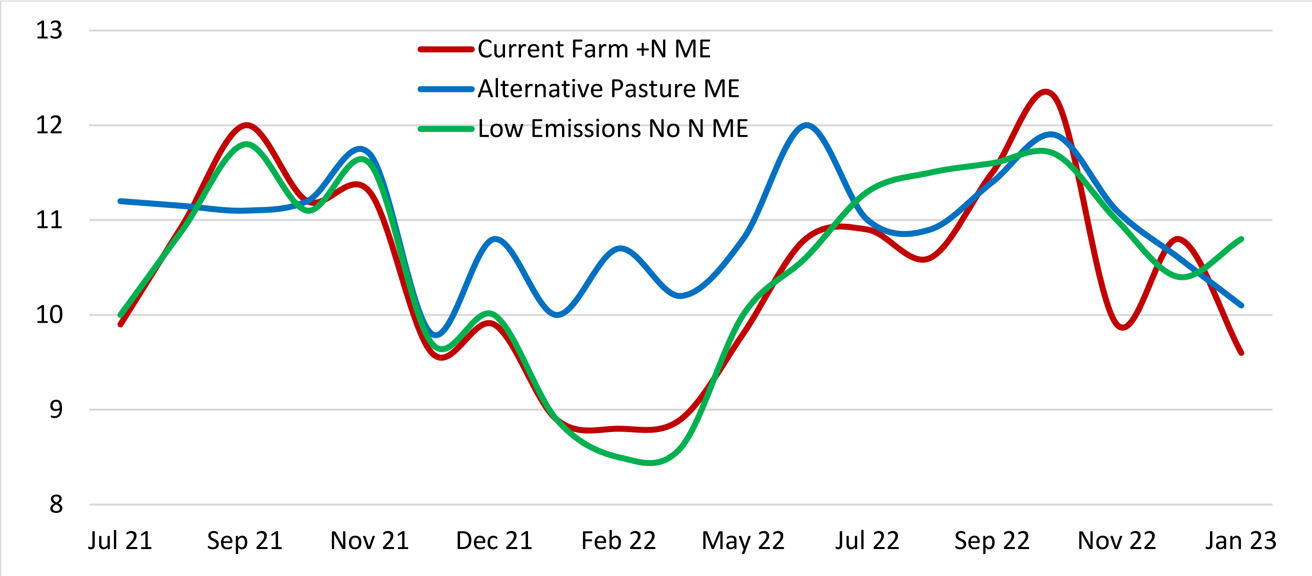
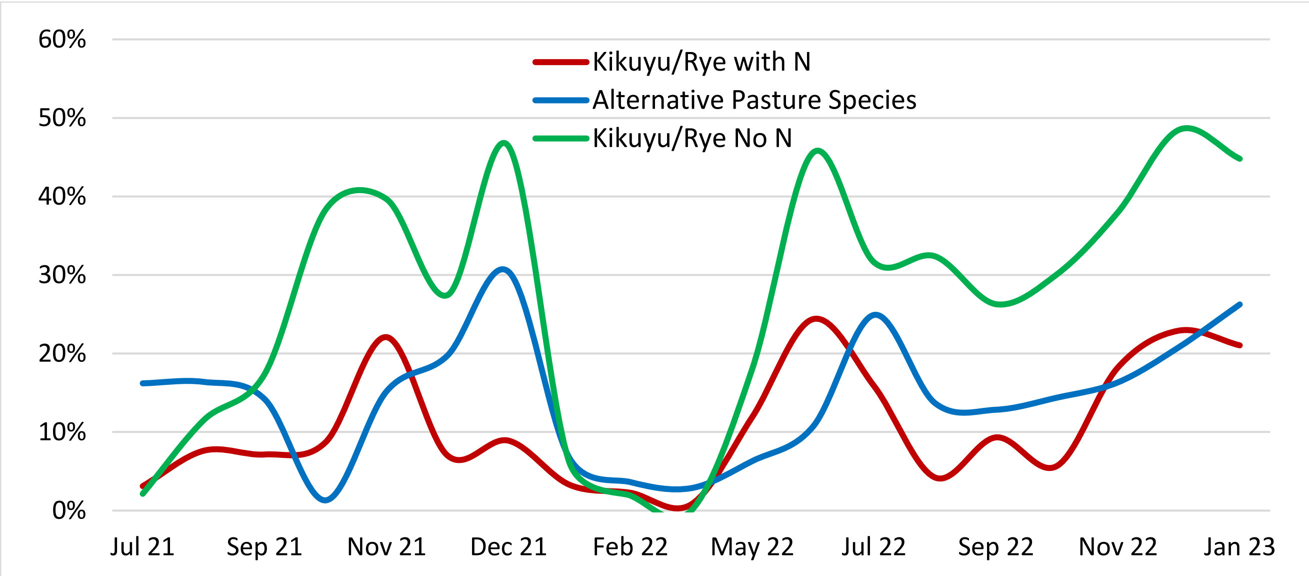


Figure 3 shows the presence of clover in the pre-graze pasture samples collected through the season. This was entirely white clover on the Current and Low Emissions Farms, with some red clover present in the Alternative Pastures Farm. The graph indicates that no applied nitrogen on the Low Emissions farm rapidly resulted in a higher clover presence throughout the study to date, apart from the dry period 2022 summer period.

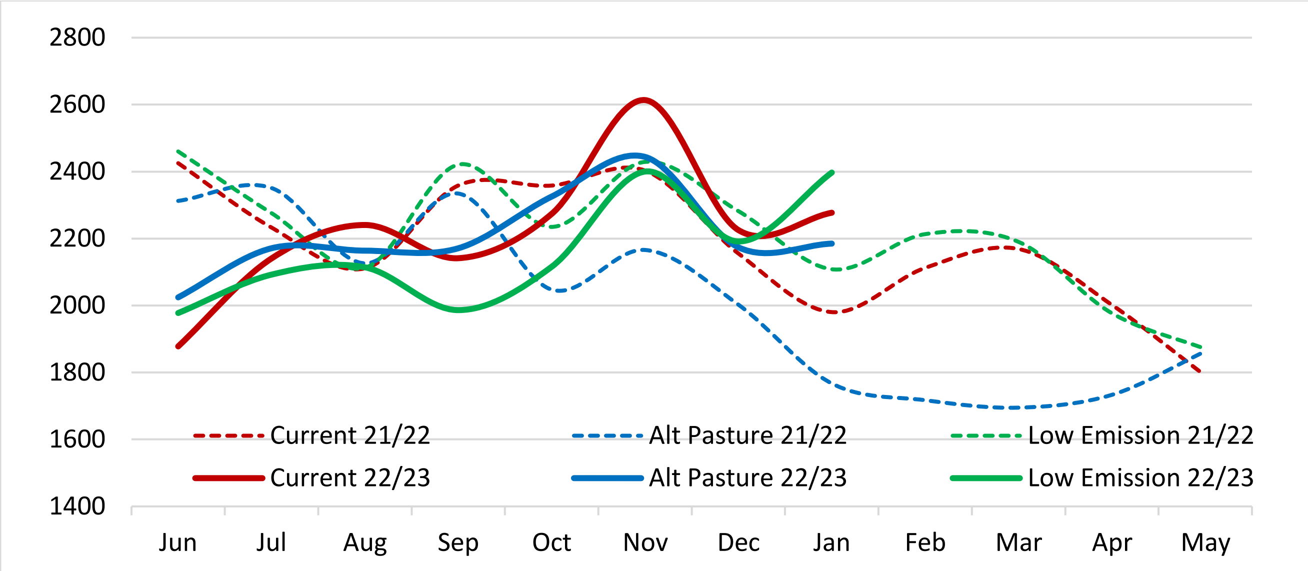
Figure 3. *Clover presence in pre-graze pasture samples (% clover).*



Pasture Covers

Figure 4 shows the pasture cover on the farms to date. The Alternative Pastures Farm had significantly lower pasture covers from late spring through to autumn in the 2021/22 season. The Low Emissions Farm tended to have higher covers during summer, likely in response to the lower stocking rates on this farm.

Figure 4. *Average pasture cover on farms – monthly average.*



Supplement Fed & Pasture Eaten

Table 1 shows the supplement fed during the 2021/22 season, the cost of those supplements, and the calculated feed eaten for each of the farms. The differing cost of homemade silage/kg DM was due to differing bale weights.

In the 2021/22 season both the Current and Alternative Pastures Farms purchased around 800 kg DM/cow of supplement, whereas the Low Emissions Farm purchased only 67 kg DM/cow. The lower stocking rate on the Low Emissions farm allowed a greater quantity of silage to be conserved which was mainly fed out during the late summer/autumn period and eliminated the need for imported supplements.

The calculated pasture eaten data indicates that the Low Emissions farm cows consumed three tonnes less pasture than the Current farm. This does not mean that the Low Emissions farm grew that much less, rather, grazing residuals were generally higher on the farm and more mulching was required.

Table 1. *Supplement made and purchased during 2021/22 season*

Farm	Supplement	Kg DM/cow fed	Cost of Supplement (incl Freight)	Total Cost of Supplement ¢/kg DM	Calculated Pasture Eaten t/ha
Current Farm	Home-made Silage	176	$53/bale	22.6	13.4
	PKE	617	$422/t	46.4	
	Purchased Silage	192	$90/bale	36.0	
	Total	**986**			
Alternative Pastures Farm	Home-made Silage	104	$53/b	27.3	13.0
	PKE	528	$422/t	46.4	
	Purchased Silage	276	$90/b	36.0	
	Total	**908**			
Low Emissions Farm	Home-made Silage	400	$53/bale	25.8	10.4
	PKE	67	$422/t	46.4	
	Total	**336**	**468**		

Milk Production

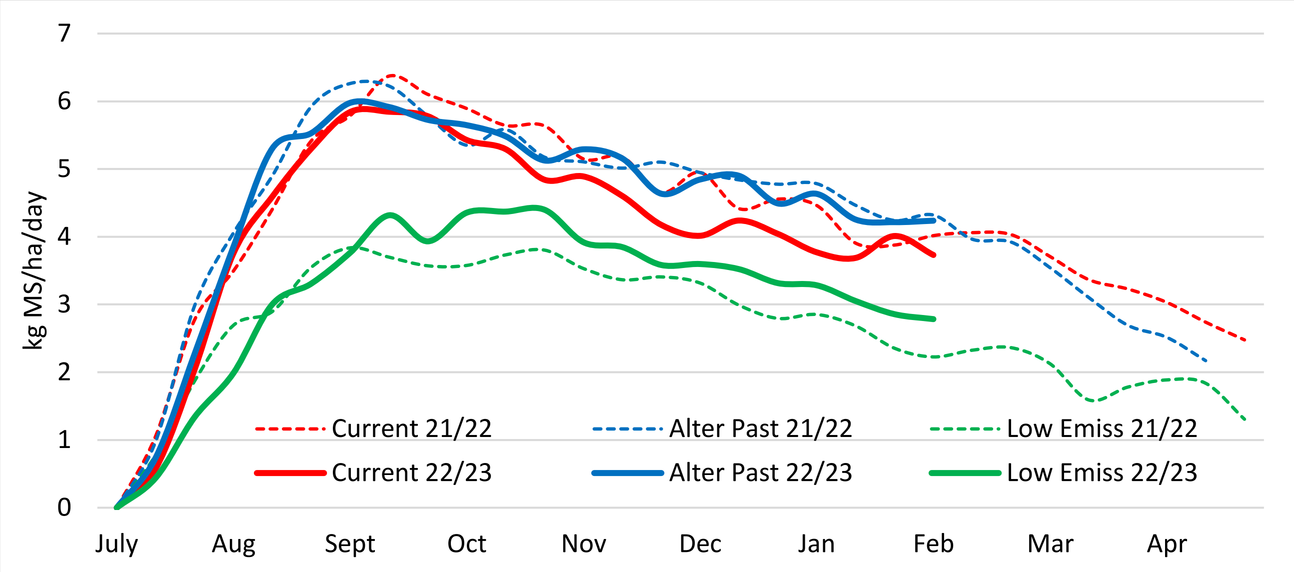
Milk production is shown in table 2 and figure 6. In both seasons milk production was highest on the Alternative Pastures Farm during early spring and summer, likely due to higher quality pasture. However, by late summer 2022 low pasture covers caused production and cow condition to drop and cows were therefore dried off in mid-April 2022. Higher pasture covers on the other two farm enabled cows to be milked through to early May.

The Current Farm had the highest milk production for the 2021/22 season. Milk production on the Low Emissions farm was always expected to be lower than the other farms due to the lower stocking rate, however milk production per cow was also lowest on this farm in the 2021/22 season.

Table 2. *Milk Production for 2021/22 season and 2022/23 up to 4th February (kg MS/ha & kg MS/cow).*

	2021/22 Kg MS/ha	2021/22 Kg MS/cow	2022/23 to 4th Feb Kg MS/ha	2022/23 To 4th Feb Kg MS/cow
Current Farm	1,268	409	894	292
Alternative Pastures Farm	1,213	397	953	308
Low Emissions Farm	794	370	681	297

Figure 6. *Milk Production to 4th February 2023 – kg MS/ha/day (10 day average).*



Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions were calculated using the Overseer model. The Current farm and Alternative Pastures farm had similar emissions. The Low Emissions farm showed significant reductions in GHG emissions compared to the Current farm, especially in the CO_2 profile of the farm inputs which on the other farms were mainly made up by nitrogen fertiliser and imported supplements. Surprisingly, the calculated CO_2 emissions/kg product was also lower on the Low Emissions farm despite it having a 38% reduction in milk production compared to the Current farm.

Table 3. *Calculated GHG Emissions – kg CO_2 equivalent/ha and CO_2/kg milk solids using Overseer model for the 2021/22 season.*

	Methane (CO_2 equivalent)	Nitrous Oxide (CO_2 equivalent)	Input CO_2	CO_2/kg MS
Current Farm	9,626	2,787	2,097	10.3
Alternative Pastures Farm	9,369	2,744	2,048	10.4
Low Emissions Farm Compared to Current farm	6,411 33% reduction	1,484 47% reduction	335 84% reduction	9.2 9% reduction

Financial Analysis

The 2021/22 financial results for the three farms have been analysed and shown in Table 4. Expenses are based on actual expenses with some adjustments for labour and administration to compensate for extraordinary expenses involved in running the research farm. Records of additional labour and tractor time for each farm have been used to adjust the vehicle, R&M, and depreciation expenses. The initial cost of establishing the alternative pastures has not been considered in this analysis, however resowing of pastures this season and mulching/drilling of kikuyu pastures is included.

Farm working expenses per kg milk solids were similar across all farms at around $5.70/kg MS. The Low Emissions farm had 35% lower expenses on a per ha basis, due to reduced stock numbers, no nitrogen inputs, and little imported supplementary feed. However, it also had 38% lower milk production.

With a $9.30/kg MS milk price, farm operating profit per ha was highest on the Current farm at $5,040, followed closely by the Alternative Pastures Farm at $4,786, while the Low Emissions farm was significantly lower at $3,021. Alternative milk prices are overlayed in this analysis and show that the Low Emissions Farm would continue to have the lowest farm profit until milk price was reduced to around $5.00/kg MS.

Table 4. *Income, expenses, and operating profit for the 2021/22 season on the three farms ($/ha).*

Financial Summary 2021/22 Season	Current Farm	Alternative Pastures Farm	Low Emissions Farm
Income	**$/ha**	**$/ha**	**$/ha**
Income from milk ($9.30/kg MS)	$11,793	$11,284	$7,386
Income from stock sales	$24	$24	$24
Dividends and other income	$962	$949	$666
Total Income/ha	**$12,778**	**$12,256**	**$8,076**
Expenses			
Wages	$1,925	$1,762	$1,314
Animal Health	$306	$302	$221
Breeding Expenses	$474	$468	$335
Shed expenses	$188	$186	$144
Electricity	$281	$277	$207
Grazing	$402	$396	$278
Calf rearing	$46	$45	$32
Silage Making	$126	$86	$198
PKE	$875	$748	$66
Purchased Silage	$198	$311	$0
General Fert	$119	$117	$118
Nitrogen Fert	$365	$369	$5
Regrassing	$300	$365	$326
Weed and Pest	$19	$19	$19
Vehicle Expenses	$266	$241	$219
R&M General	$837	$826	$701
R&M Effluent	$56	$55	$35
Administration	$161	$159	$150
Insurance	$93	$92	$84
Rates	$143	$141	$143
Depreciation	$557	$505	$460
Total Operating Expenses/ha	**$7,739**	**$7,471**	**$5,055**
Farm Working Expenses/kg MS	**$5.68**	**$5.74**	**$5.76**
Operating Profit (at $9.30/kg MS)	**$5,040**	**$4,786**	**$3,021**
Alternative Milk Prices			
Operating Profit at $5.00/kg MS	**-$413**	**-$432**	**-$394**
Operating Profit at $7.00/kg MS	**$2,123**	**$1,995**	**$1,194**
Operating Profit at $10.00/kg MS	**$5,927**	**$5,635**	**$3,577**

Discussion & Learnings

This study has shown that there was little difference in profitability between a kikuyu/Italian ryegrass-based farm and a farm that had 74% of pasture sown with tall fescue and/or cocksfoot pastures during the 2021/22 season. This was despite these alternative species pastures having variable establishment success. The better feed quality of the alternative pastures species pastures provided better milk production in early spring and summer, however during what was a reasonably dry summer/autumn, those pastures did not produce as much feed as the kikuyu pasture and cows had to be dried off earlier than the other farms.

The removal of nitrogen fertiliser within the Low Emissions Farm resulted in a fairly consistent reduction in pasture growth during winter and spring. The response to nitrogen on the Current Farm was 8 kg/kg N applied during the 2021/22 season and 15 kg DM/kg N during the 2022/23 season (to date). The removal of applied nitrogen from the Low Emissions Farm pastures quickly resulted in significantly higher clover content, which would have fixed additional nitrogen, somewhat compensating for the lack of nitrogen application.

The Low Emissions Farm was designed to reduce methane emissions 25% and nitrous oxide emissions by 50% compared to the Current Farm. For the 2021/22 season, compared to the Current Farm, the Low Emissions Farm showed a reduction of methane emissions of 33% and nitrous oxide 47%. In addition, CO_2 emissions associated with farm inputs were reduced by 84%, though these emissions are not accounted for on-farm. This reduction was achieved through reducing stocking rate, the removal of nitrogen inputs, and minimal imported supplements.

The relative cost of achieving these emissions targets was a reduction in farm profit of $2,019/ha for the 2021/22 season. This was in a record milk price season. In a lower milk price season this loss in profit would be reduced, however milk price would need to be as low as $5/kg MS before all farms would have had a similar profit. The cost of reducing emissions through reducing stocking rate and removing nitrogen applications and imported supplement was significant and it is unlikely the emissions pricing will be high enough to compensate for the significant loss in profit shown in the 2021/22 season.

The 2022/23 season to date is indicating the difference in milk production between the Current and Low Emissions Farms will be less than the 2021/22 season. On farm costs are also higher, especially nitrogen fertiliser and labour costs which will affect the Current and Alternative Pastures Farms more than the Low Emissions Farm, and therefore farm profit will likely being more similar between farms for the 2022/23 season.

This study will continue until May 2025, allowing the testing of these regimes over different climatic conditions and to see if any of these effects compound over time.

Acknowledgements

Thanks to NARF staff for making this project happen on the ground. Special thanks to NDDT trustees and NARF committee members for their support and commitment in proposing, overseeing, and managing this project.

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Northland Dairy NDDT Development Trust

Pasture Growth Response in Northland to Nitrogen, Sulphur and Potassium

Chris Boom – NDDT Science Manager

Summary

This study investigated pasture growth responses to adding sulphur (S) and potassium (K) to nitrogen (N) applications during late winter and early spring across three soil types in Northland. The initial study was conducted in 2019 during a relatively dry winter/spring and then repeated in 2022 when soil conditions were much wetter for extended periods.

Pasture growth responses to N varied between soil types and between years. Averaged across the two years, the Kaipara Marine Clay sites showed a 21:1 response (additional kg DM grown/kg N applied), the Wharekohe Silt Loam sites 18:1 and Okaihau Gravelly Loam sites 35:1.

The addition of S showed a good response on the Wharekohe soil with an average across the two years of 20:1 (kg DM/kg S applied), while the other soil types showed poor responses, averaging 3:1. These responses were in line with deficiencies observed in soil tests. Applying S in August versus September, or at both times, did not significantly change the response.

Responses to K were also variable across soil types with a reasonable response only on the Kaipara Marine Clay sites (average 9 kg DM/kg K applied) and poor responses on the other soil types (average 1:1). These responses on the Kaipara Marine Clay sites were despite soil tests showing adequate K levels. It is noted that potassium may have provided a longer lasting effect than measured in this study. There was no observed increase in clover content as a result of K application.

Within these studies, N applications were the most cost effective means of boosting pasture growth during late winter/early spring, other than on the Wharekohe soil type where in the 2022 study the addition of S improved the cost effectiveness of the N and S combination. Soil chemical tests were not a reliable means of determining pasture growth response to K applications in this study.

These studies indicate that maximising use of Nitrogen may commonly be a more cost effective means of increasing pasture production compared to adding other nutrients. Farmers should review previous elemental sulphur applications and/or sulphur soil test levels before choosing to apply S in late winter/early spring.

Background

Most Northland dairy farmers apply nitrogen to their pastures during winter and spring to increase pasture production. Many will also include sulphur and/or potassium to ensure these elements are not limiting. This is commonly applied as products such as Sustain Ammo or PhaSedN Quick Start for sulphur or SustaiN 20K for potassium. Some are convinced of the benefits of using these multi element products whilst others are convinced that nitrogen alone gives the best economic response.

Farmers may be adding these elements unnecessarily, or may be missing out because they are not including these elements. These trials tested pasture growth responses to nutrients that farmers commonly apply during late winter and early spring on a range of soil types in Northland.

Trial Design and Methods

Two studies were conducted on three sites/soil types, being a Kaipara Marine Clay (location Dargaville and Ruawai), a Wharekohe Silt Loam (location Kokopu) and a Okaihau Gravelly Loam (location Okaihau). The first study was undertaken in winter/spring of 2019 following a relatively dry autumn and winter. Concern that the results may have been affected by the dry conditions, the study was repeated in 2022 after a wetter autumn and winter. Table 1 shows the treatments applied during both studies on all soil types.

Table 1. Treatments applied to plots in early August and mid-September in studies conducted in 2019 and 2022.

Treatment Name	Early August Application/ha	Mid-September Application/ha
Control	Nothing	Nothing
N only (twice)	30 kg N (as Sustain)	30 kg N
N + S 1st Appl	30 kg N & 14 kg S (as Ammo 30N)	30 kg N
N + S 2nd Appl	30 kg N	30 kg N & 14 kg S
N + S Both Appl	30 kg N & 14 kg S	30 kg N & 14 kg S
N + K	30 kg N	30 kg N & 22 kg K (as MOP)
N + S 2nd Appl + K	30 kg N	30 kg N, 14 kg S & 22 kg K
N + S Both Appl + K	30 kg N & 14 kg S	30 kg N, 14 kg S & 22 kg K

Treatments at each site were replicated 5 times giving 40 plots/site. Plots were 2m x 4m on ryegrass dominant pastures. Plots were mown twice prior to the first treatment being applied. Pasture growth was monitored for four growth periods through cutting and drying pasture samples. A clover presence survey was undertaken prior to the final harvest.

Sites were soil sampled to a depth of 75mm for nutrient analysis at the time of the first treatment applications. Soil test results are shown in table 2.

Table 2. Average of two soil chemical tests taken at each site and nutrient applications in the six months prior to the start of the trial (MAF Quick Test – Hill Laboratories).

	Soil Test Results				**Nutrients Applied (kg/ha) in the six months prior to the study**		
	pH	Olsen P	Sulphate S	Potassium	Nitrogen	Sulphur	Potassium
Kaipara Marine Clay 2019	6.2	62	7	18	37	0	0
Kaipara Marine Clay 2022	6.7	59	12	19	30	0	0
Wharekohe Silt Loam 2019	6.6	38	4	5	30	0	25
Wharekohe Silt Loam 2022	6.0	25	2	4	27	0	25
Okaihau Gravelly Loam 2019	6.0	30	23	7	120	68	45
Okaihau Gravelly Loam 2022	6.0	46	12	9	64	36	35
Medium Range	5.8-6.2	20-30	10-12	7-10			

Results

Rainfall during autumn and early winter 2019 was significantly lower than the historical average on all sites (prior to the commencement of the trial). Rainfall during autumn and winter 2022 was higher than average on the Wharekohe and Okaihau sites and close to the historical average on the Kaipara Clay site.

Tables 3 and 4 show the main treatment effects for the three sites (soil types) reported as kg dry matter per kg nutrient applied, as determined by the pasture growth difference when a nutrient was added. There were no significant interactions between nutrient application time and nutrient type, therefore the two single sulphur application treatment responses have been amalgamated to simplify this data, as have been the three potassium treatment responses.

During the 2019 study, the response to nitrogen was greatest on the Okaihau Gravelly Loam, while in 2022 nitrogen responses were similar on both the Kaipara Clay and Okaihau Gravelly Loam sites. These responses were high compared with published nitrogen responses. In both studies >90% of the nitrogen response had occurred by the first harvest following application (29 – 40 days). At all sites and in both studies, the nitrogen responses were statistically significant ($P < 0.001$).

Response to sulphur was negligible and/or unreliable on the Kaipara Clay and Okaihau Gravelly Loam sites. However, sulphur responses were consistent and relatively high on the Wharekohe Silt Loam site, especially in 2022 study. The greater sulphur responses in the 2022 study may be in response to the higher rainfall that season. Sulphur responses correlated well with soil tests, where the Wharekohe Silt Loam showed very low sulphate sulphur levels but good sulphur responses.

In both studies the response to potassium was greatest on the Kaipara Clay, with little or no response on the other two sites. This was surprising given the potassium levels in the soil chemical tests were high on the Kaipara Clay soil in both studies while the Wharekohe site showed low potassium levels in the soil tests, however showed no response to potassium.

As might be expected, response to potassium appeared to have a slower and longer lasting effect, with most of the response showing in the last two harvests during both studies. Both studies monitored pasture growth responses to potassium for 89 days after nutrient application, it is acknowledged that the effect of potassium may have continued to show after monitoring stopped.

The clover presence survey conducted during early summer of both studies showed no effect as a result of potassium application, however there was a trend (not statistically significant) for the control treatment (no nutrients applied) to have higher clover levels than the other treatments.

Tables 3 & 4. Main treatment effects – total response to nutrient applied (kg of additional DM grown/kg nutrient applied) for the three trial sites (soil types) for the 2019 study and the 2022 study.

2019 Study Kg DM/kg Nutrient Applied	Kaipara Clay	Wharekohe Silt Loam	Okaihau Gravelly Loam	**Average All Soil Types**
Nitrogen	10.0	20.9	39.2	**23.5**
Single Application of Sulphur	2.1	13.0	2.7	**6.0**
Double Application of Sulphur	5.3	8.2	3.7	**5.7**
Potassium	9.4	1.1	1.0	**4.1**

2022 Study Kg DM/kg Nutrient Applied	Kaipara Clay	Wharekohe Silt Loam	Okaihau Gravelly Loam	**Average All Soil Types**
Nitrogen	32.1	16.8	30.9	**26.7**
Single Application of Sulphur	-1.5	42.6	-8.3	**11.0**
Double Application of Sulphur	4.9	17.2	11.0	**11.0**
Potassium	9.0	-1.1	1.5	**2.7**

Tables 5 and 6 show the cost of nutrient based on pricing at September 2019 and September 2022 (including the cost of cartage and application at $160/tonne). The cost of additional pasture growth is then calculated based on the treatment responses. Where negative nutrient responses occurred the dry matter cost is not calculated.

There were large differences in the calculated cost of additional pasture growth between soil types driven by response differences. Averaging over all soil types in the 2019 study, nitrogen was approximately three times more cost effective than sulphur or potassium. In the 2022 study the cost of nitrogen had increased to a greater extent than the cost of sulphur which contributed to the cost effectiveness of sulphur applications, being somewhat similar to that of nitrogen. Only on the Kaipara Marine Clay were potassium applications somewhat cost effective compared to nitrogen.

It should be noted that the response to sulphur or potassium was not investigated without the addition of nitrogen.

Tables 5 & 6. Cost of nutrient (applied) and calculated cost of additional pasture grown/kg DM using 2019 pricing and 2022 pricing (NR = no response).

2019 Study and Pricing	2019 $/kg Nutrient	Cost ($)/kg additional DM grown		
		Kaipara Clay	Wharekohe Silt Loam	Okaihau Gravelly Loam
Nitrogen	$1.85	$0.19	$0.09	$0.05
Single Application of Sulphur	$1.48	$0.69	$0.11	$0.54
Double Application of Sulphur	$1.48	$0.28	$0.18	$0.40
Potassium	$1.77	$0.19	$1.60	$1.86

2022 Study and Pricing	2022 $/kg Nutrient	Cost ($)/kg additional DM grown		
		Kaipara Clay	Wharekohe Silt Loam	Okaihau Gravelly Loam
Nitrogen	$3.39	$0.11	$0.20	$0.11
Single Application of Sulphur	$1.92	NR	$0.05	NR
Double Application of Sulphur	$1.92	$0.20	$0.11	$0.17
Potassium	$3.45	$0.38	NR	$1.18

Conclusions

This study investigated the response to adding sulphur and potassium to nitrogen applications across three soil types and over two climatically different seasons. Pasture growth responses to nitrogen were reliable, being high on Okaihau Gravelly Loam and Wharekohe Silt Loam soils in the dry year of 2019 and high on the Okaihau Gravelly Loam and Kaipara Marine Clay soils in the wetter 2022 study.

The addition of sulphur showed a good response on the Wharekohe soil, while responses on the other soils were unreliable. Sulphur responses were in line with soil test deficiencies. Applying sulphur in August versus September, or at both times, did not significantly change pasture growth responses. Sulphur responses tended to be greater in 2022, which was a wetter season than 2019. Responses to potassium were also variable across soil types with a reasonable response on the Kaipara Clay and poor responses on the other soil types.

Within this study, nitrogen applications were the most cost effective means of boosting pasture growth. The benefit of adding sulphur and potassium was site specific.

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