Reducing Nitrogen And Fertilizer Application On Grazing Grass (Pasture)

Using a biocatalyst together with fertilizer in grazing pastures to decrease nitrogen use by 95-99%, reduce fertilizer use by 39-84% and greatly increase soil microbiome health.

The purpose of this four-month Irish study was to assess the use of PC3, an organic biocatalyst produced by Bio-Organic Catalyst, Inc. (www.bio-organic.com), together with a new biodynamic fertiliser from Innoparmis Agroscience, and their ability to substitute traditional chemical Urea (UreaMax46 46% Nitrogen from Bayer), while maintaining (or improving) crop yield and quality. The impact on soil fertility and health was also monitored.

Key findings:

- Nitrogen use decreased between 95.1% and 99.2%
- Fertilizer use decreased 39.8% to 84.4%
- Crop yield and quality were unchanged
- Soil organic content increased up to 13%
- Soil moisture content increased 14% to 19%
- Soil fungi content increased 275% to 838%
- Soil active bacteria content increased 409% to 1280%

The full report follows. It has been edited for context and clarity.

REPORT
ON SCIENTIFIC AND RESEARCH WORK

Grazing Grass Plot Trial; Reduction of Nitrogen

Tinahely, Ireland

September – December 2022

May 17, 2023

Tomas Tubritt, PhD
Jack Murphy
Omar E.F. Osman

Teagasc
Agriculture and Food Development Authority

Innoparmis™ AgroScience

Agrozotic

BIO-ORGANIC CATALYST
THE POWER IN NATURE®

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Tomas Tubritt, PhD

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Jack Murphy

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Omar E.F. Osman

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INTRODUCTION

Irish agricultural land use

Ireland's primary crop is considered to be grazing grass, otherwise referred to as "pasture". Ireland has an estimated 6.9 million hectares of land, where 4.44 million hectares[1] (64%) is suitable for agricultural purposes.

The distribution of use of agricultural land can be summarized as follows;

- 4.09 million hectares are used for growing grass, such as silage, pasture and hay, (80% of utilizable land);
    - Ireland is well-suited for ryegrass growing, a cheap but effective means for feeding livestock.
    - 0.44 million hectares are dedicated towards commonage and rough grazing (10% of utilizable land).
- 0.35 million hectares used for growing cereals, mostly wheat and barley[2], (8% of utilizable land).
    - Farming of other crops have decreased in scale, and form the remaining 2%.
    - Potato cultivation occupies a little over 8,500 ha.

Irish soil fertility

Soil fertility is defined as optimum pH, Phosphorous and Potassium levels. Ireland is facing emerging concerns with regards to soil fertility which may be due to both under and over utilization of fertilisers where certain soils may not be receiving adequate levels of fertilisation to replace offtakes from crop harvests or where excess nutrients beyond the carrying capacity of the soil are being applied resulting in nutrients run-off and pollution of water courses.

In Ireland, Teagasc delivers a soil testing service part of its fertiliser planning (NMP Online) service for farmers to advise on the efficient use of nutrients for crop

[1] https://www.askaboutireland.ie/reading-room/life-society/farming/farming-in-ireland-overvi/land-use-in-ireland/#:~:text=Ireland%20has%20an%20estimated%206.9,and%20the%20Marine%2C%202020)
[2] https://www.teagasc.ie/rural-economy/rural-economy/agri-food-business/agriculture-in-ireland/

production. Over the last number of years there has been an increased focus on the role of soil testing and fertiliser planning to improve the efficiency of all applied nutrients and especially nitrogen. Improving farm N efficiency will help reduce nutrient losses from both organic and chemical Nitrogen sources to help meet both air and water quality targets over the next decade. The increasing pressure to halt climate change and control fertiliser costs makes soil testing key low-cost technology to ensure the efficient use of applied nutrients.[3]

Getting the soil basics right such as optimising soil pH and applying P and K in a balanced programme is critical to a sustainable production systems. The drive to maximise grazed grass production during the growing season and the production of sufficient grass to ensile for the winter period is now key goal for livestock farmers.

In 2021, lime use increased by approximately 50% compared to the average lime applied in Ireland over the last 10 years. The application of lime during the year can be heavily influenced by the weather as there is a tradition to apply lime in the final quarter of the year. Optimising and maintaining soil pH is the first step in improving the efficiency of applied Nitrogen. This will help accelerate the improvement in soil pH on these farms. Over the last decade the use of applied P and K fertilisers has increased due farmers acting on soil test results. This increase of P and K's use has resulted in a steady improvement in soil fertility between 2016 to 2019.

In the last 2 years, soil fertility has started to decline especially on grassland farms and in 2021 a similar trend is now evident for tillage soil samples. The challenge in the next number of years will be to halt this new emerging soil fertility trend, while controlling fertiliser costs. We need to keep in mind and find solutions that are critical to farm profitability, without sacrificing soil fertility levels. Maintaining good soil fertility will especially be central to improving the utilisation of Nitrogen and reducing Nitrogen losses.

Many different regions of Ireland were also found to be deficient in sulfur (S).[4] Soils also tended to suffer from suboptimal pH levels.

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[3] Teagasc Soil Fertility Report 2021, August 2020
[4] https://www.teagasc.ie/crops/soil--soil-fertility/grassland/

Despite relatively high application of fertilisers and lime, most of soils sampled lacked phosphorous and potassium,[5] and 84% of soils can be considered to having sub-optimal soil fertility[6]:

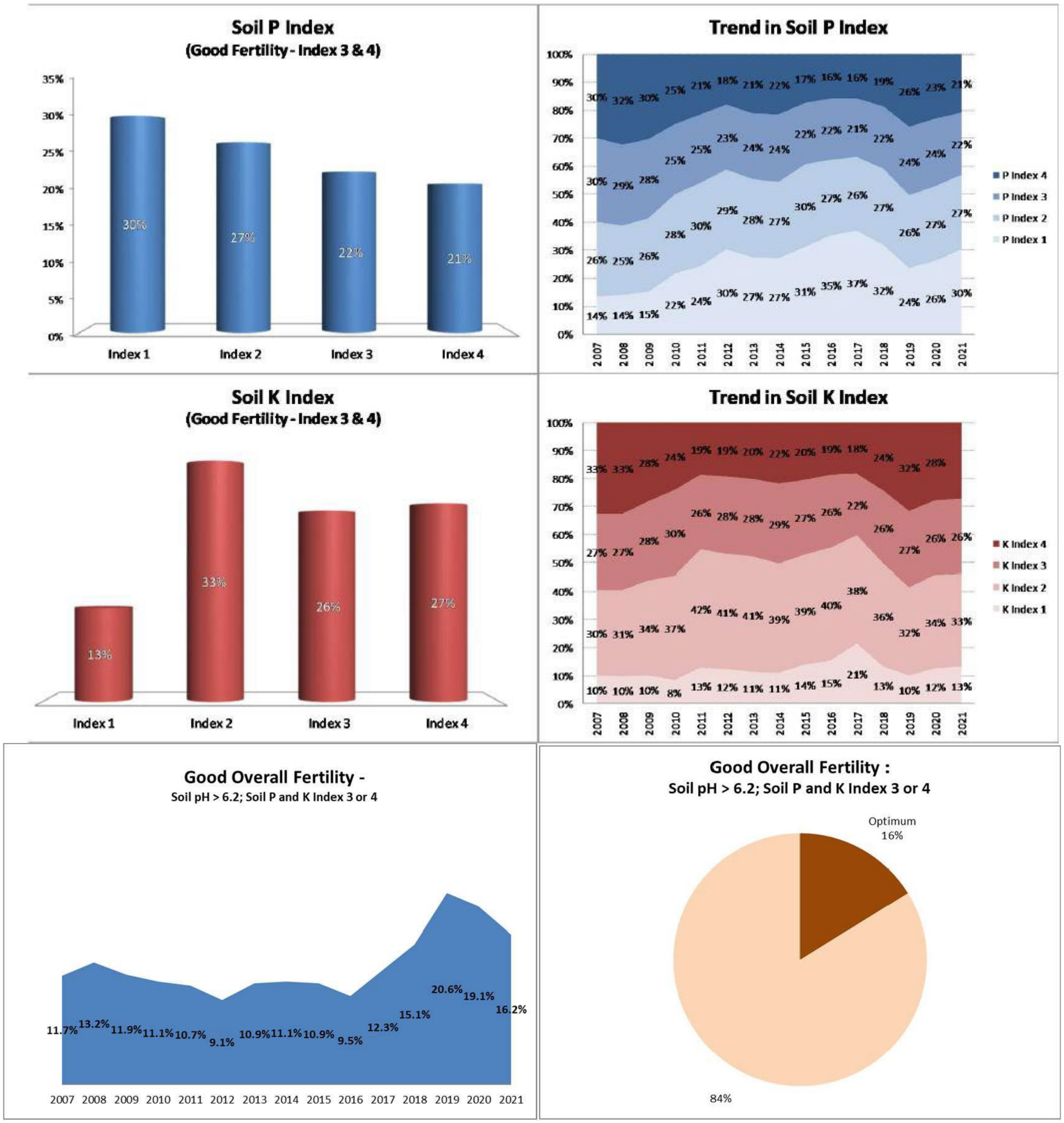

Figure 1: Soil fertility parameters - Ireland 2021

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5 https://www.agriland.ie/farming-news/90-of-irish-soils-are-nutrient-deficient-heres-why/
6 Teagasc Soil Fertility Report 2021, August 2020

The importance of soil fertility

Phosphorus, potassium, and pH are all important factors that contribute to soil fertility;

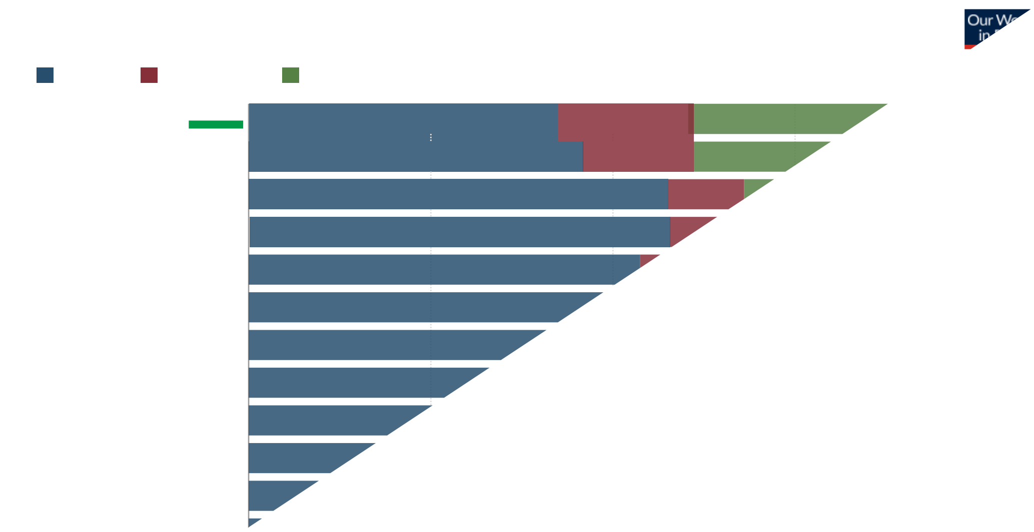
- Phosphorus is a key nutrient for plant growth and development, particularly in terms of root development, seed formation, photosynthesis and energy transfer within the plant. It is often found in soils in forms that are not easily available to plants, so fertilisers containing phosphorus are commonly used to supplement soil levels. A lack of phosphorus can lead to stunted plant growth and reduced crop yields.

- Potassium is also important for plant growth, particularly in terms of water regulation and stress tolerance. It helps regulate the opening and closing of stomata, which are the tiny pores on plant leaves that allow for gas exchange. Potassium also helps strengthen plant cell walls, making them more resistant to disease and pests. Like phosphorus, potassium can become depleted in soils over time and may need to be replenished through fertilisers.

- The pH of soil refers to its level of acidity or alkalinity. This can affect the availability of nutrients to plants, as different nutrients are absorbed best at different pH levels. Most plants prefer a slightly acidic soil with a pH between 6 and 7. If soil pH is too low or too high, certain nutrients may become unavailable to plants, leading to nutrient deficiencies and poor growth.

In summary, maintaining adequate levels of phosphorus and potassium, and ensuring the appropriate pH level in soil, are all important for promoting soil fertility and ensuring healthy plant growth.

Irish agricultural fertiliser use



https://ourworldindata.org/grapher/fertiliser-per-hectare?country=OWID_WRL~USA~POL~Europe+%28FAO%29~European+Union+%2828%29+%28FAO%29~Eastern+Europe+%28FAO%29~Western+Europe+% 28FAO%29~Northern+Europe+%28FAO%29~Southern+Europe+%28FAO%29~FRA~DEU~ESP~IRL

Figure 2: European use of fertilisers – 2019

Figures for fertiliser application in Ireland vary widely due to the reasons mentioned above. The FAO estimates that the average Irish farmer uses an estimated 200kg per hectare (FAO).

- Nitrogen fertiliser (N): 83 kg/ha
- Phosphorus fertiliser (P): 36 kg/ha
- Potassium fertiliser (K): 79 kg/ha

This places Ireland 60kg above the EU average of 140kg/ha[7].

Ireland has limited fertiliser production, meaning it imports over 1,560,000 tonnes annually, worth approximately $620mn USD.[8] In 2022, large price increases in fertiliser price was experienced in Ireland due to the COVID-19 pandemic, supply

[7]https://tradingeconomics.com/ireland/imports/fertilisers#:~:text=Ireland%20Imports%20of%20fertilisers%20was,updated%20on%20December%20of%202022.

[8]https://tradingeconomics.com/ireland/imports/fertilisers#:~:text=Ireland%20Imports%20of%20fertilisers%20was,updated%20on%20December%20of%202022.

chain problems and the outbreak of war in Ukraine. A survey conducted by Teagasc found that:

- Around 87% of Irish farmers were planning to reduce fertiliser application.
- 40% experienced difficulties getting fertiliser delivered.
- 20% reported that fertiliser sales merchants could not guarantee delivery.

In addition to the financial and geo-political complications, the EU has established strict guidelines to reduce the use of fertilisers, reduce soil toxicity, limit leaching in water plates and rivers, as well as increasing the content of organic farming in the national food chain of EU members [9].

As mentioned above, Irish farm systems vary widely. This means that the average fertiliser use of an Irish farm in unimportant. In the case of this study, the field used to carry it out was intensively grazed grassland for dairy production so typical levels of fertilisation in these studies should follow the national Major Micro Nutrient Advice for Productive Agricultural Crops[10,11];

[9] European Commission Farm to Fork Strategy, 2020
[10] Modelling the effects of stocking rate, soil type, agroclimate location and nitrogen input on the grass DM yield and forage self-sufficiency of Irish grass-based dairy production systems, 2022
[11] Major Micro Nutrient Advice for Productive Agricultural Crops, Teagasc, 2020

Table 12-1: Suggested timing of available N applications for grass swards, with low levels (<15%) or, no, clover present, grazed by dairy cows at various stocking rates										
		------------------------ N rates[1] (kg/ha) for approximate application dates ----------------------								
Stocking rate										**Total N Rate[1,6]** (kg/ha)
LU/ha[2]	kg/ha N[3]	Jan[4, 5] / Feb	March	April	May	June	July	Aug	Sept[4, 5]	
<1.0	≤85			25			15			40
1.25	106		15	28	15		15			73
1.5	128		28	35	25		23			111
1.75	149		29		26		26		17	142
2.0	170		34	53	42		42		31	202
2.12	180	32	32	48	38		38		28	216
2.25	191	31	41	54	37		37		37	237
3.35	200	30	53	53	37	37		37	27	275
2.47	210	31	54	54	56	37		37	37	306
>2.47	≥210	32	49	55	38	38		38	28	279[6]

1. Rates shown above refer to recommended application of available fertilizer. Chemical fertilizer rates should be calculated by deducting the available N contained in organic fertilizer applications from the rates shown in the table above.
2. Livestock unit (LU) per ha refers to a mature dairy cow.
3. Total annual organic nitrogen (kg) excreted by grazing livestock averaged over the net grassland area (grazing and silage area). Stocking rate refers to grassland area only.
4. Rates shown above refer to grazed swards only, and are not suitable as a guideline value of the N requirement for the entire grassland area. The N requirement for the entire grassland area will depend on the proportions of the area that are grazed, or cut as silage or hay.
5. Chemical or organic fertilizers cannot be applied during periods when application is prohibited by NAP regulations.
6. At stocking rates above 210 kg/ha organic N, fertiliser N advice is constrained by the NAP regulations.
7. Total N use on the farm must comply with NAP regulations.

Table 1: Suggested Nitrogen Application for Dairy Farming Grazing

Objective

The purpose of this study was to assess the use of PC3, a novel biocatalyst, together with a new fertiliser and its ability to substitute traditional chemical Urea, while maintaining (or improve) crop yield and quality. The impact of on soil fertility and health will also be monitored.

PC3 is an Ecocert-certified organic biocatalyst produced by Bio-Organic Catalyst, Inc. (California, USA). PC3 increases dissolved oxygen and breaks down biofilm. This has the effect of promoting aerobic conditions in the soil, increasing the health of the soil microbiome, and increasing crop health and crop yields. PC3 is applied at very high dilutions, typically 1:250,000 (4ppm).

PC3 acts as a powerful adjuvant or delivery system, greatly increasing the effectiveness of organic and non-organic inputs. This effect is achieved in two ways. 1. PC3 is a strong dispersant. Adding nano-amounts of PC3 to inputs (fertilizers, pesticides, etc.) increases their effectiveness. 2. PC3 improves the plant's ability to absorb nutrients, so fewer inputs are needed.

PC3 also keeps irrigation systems and greenhouses free of scale and slime much more effectively than traditional toxic acids, bleaches and biocides, with no pollution.

The new fertiliser being tested has two (2) innovative components;

- An organic acid complex
- Attractive particle size with a portion being under 150nm.

The biodynamic fertiliser being tested demonstrates multiple advantages as compared with current traditional solutions: they do not separate into layers when exposed to heat and light, the prepared solution can be stored not for hours or days, but for years, remaining active at the same time. Though the most important is that it ensures the full wetting of plants surface, they are completely absorbed by plants and are not washed out by rain.

In addition to their physicochemical characteristics, it is important to note that the biodynamic fertiliser manufactured by UAB Innoparmis Agroscience (Republic of Lithuania) is non-toxic and has a low heavy-metal profile. It does not use traditional chelating agents, such as EDTA, EDDHHA, HEDTA, EDDHA, OTPA. The process uses a free-ions capturing technology that bases itself solely on organic acid coatings.

Manufacturing process does not use various additives, such as silicon dioxide, titanium dioxide, silver oxides, catalysts, dispersants, emulsifiers, adjuvants, nano- additives, preservatives. To ensure maximum absorption of minerals and not denature them, as all process steps are carried out at low temperatures.

Innoparmis Agroscience claims that their biodynamic fertiliser line is easy release, non-toxic for soil and plants and can be used in a tailor-made fashion based on crop, crop cycle and soil type. It is important to note that the product line is stable and maintains its nutrient availability in a wide pH range (from 3,5 to 8,5)

The biological effectiveness of biodynamic fertilisers, manufactured by UAB Innoparmis Agroscience, which had been submitted for investigation to “Natural Fertilisers Limited” (Ireland) was studied during this grazing grass investigations.

The purpose of investigation was to define the impact of reducing the amount of nitrogen, while using the Bio-Organic Catalyst Inc. biocatalyst combined with the Innoparmis AgroScience biodynamic fertilisers, on standard grazing grass in Ireland.

SITE, AGRICULTURAL AND CLIMATIC CONDITIONS, INVESTIGATION METHODS

Investigation Site

The experimental plot is located near Tinahely village, Co. Carlow, Ireland (lat. 52°48'N, long. 6°26'W, 132m asl) and was run in collaboration with a farmer who owns the land. Lab analysis were carried out by IAS laboratories **(**Unit 4 Bagenalstown Business Park, Moneybeg, Muine Bheag, Co. Carlow, R21 YX99).

Figure 3: Satellite image of the plot area (X marks paddock where study was conducted)

Figure 4 : Trial map displaying pot layout and replication

Trial design

The study was conducted from August 2022 to December 2022. The field (Figure 1) measuring 2 hectares was divided into 10 plots with nine plots measuring 12 x 28 m (336 m^2) with 3 m borders in place between plots and a final plot measuring 24 x 90 m (2160 m^2) was located adjacent to the plots. This large plot was treated as the trial control and 3 treatments were applied to the remaining plots (i.e. 3 replicates). The 4 treatments were as follows:

The products used for this trial are the following;

- From BASF
    1. UreaMax46 (46% N)

- From Innoparmis Agroscience
    1. BioDynamic Fertlizer Super Micro Plus
    2. BioDynamic Fertiliser Enriched Iron 10%
    3. BioDynamic Fertiliser Potassium

- From Bio Organic Catalyst
    1. BioDynamic: Phyto-C3 Organic

The products are described in the table below;

Nutrients	N (%)	P (%)	K (%)	Mg (%)	Ca (%)	S (%)	Fe (%)	Zn (%)	Cu (%)	Mn (%)	B (%)	Mo (%)
UREAMAX (46N)	46.00											
Biodynamic Fertilizer Magnesium 7%				7.00								
Biodynamic Fertilizer Enriched Iron 10%	2.50		2.50	0.70	2.50	6.00	10.00	2.00	0.25	1.50		
Biodynamic Fertilizer Potassium 35%	7.50		35.00									
Biodynamic Fertilizer Super Micro Plus	4.50	1.00	4.50	1.00	2.00	7.50	4.50	4.50	0.50	1.50	0.35	0.20
Phyto-C3 Organic	PHYTO C3 is a breakthrough organic biocatalytic water conditioner utilizing a green biochemistry for superior cleaning performance of of organic and inorganic fouling present in lines											

Table 2: Characteristics of Products used in the trial

The application program that was followed is;

Ryegrass

First grazing Cycle

Treatments	Area Covered	First Application (Kg/hectare)	Second Application (Kg/hectare)	Application instructions
Treatment 1	**2520 m2** [28x90]			
UREAMAX (46N) - 20 units/acre	53.6 Kg	53.6	0	sprinkle Ureamax (46N) over the surface of the grass
minerals are to be disolved in 100L of water and applied to the 3 parcels				
Treatment 2	**1008 m2** [3(12x28)]			
PHYTO-C3 Organic (ppm)	4 L	2	2	Disolve all components and apply throough spraying on a basis of 600L/ hectare
Biodynamic Fertilizer Super Micro Plus	2,3 Kg	1.48	0.8	
Biodynamic Fertilizer Enriched Iron 10%	4,6 Kg	2.28	2.28	
Biodynamic Fertilizer Potassium 35%	4,3 Kg	1.48	2.78	
minerals are to be disolved in 100L of water and applied to the 3 parcels				
Treatment 3	**1008 m2** [3(12x28)]			
PHYTO-C3 Organic (ppm)	2 L	2	0	Disolve all components and apply throough spraying on a basis of 600L/ hectare
Biodynamic Fertilizer Super Micro Plus	3,8 Kg	2.28	1.48	
Biodynamic Fertilizer Enriched Iron 10%	4,6 Kg	2.28	2.28	
Biodynamic Fertilizer Potassium 35%	2,3 Kg	0.8	1.48	
minerals are to be disolved in 100L of water and applied to the 3 parcels				
Treatment 4	**1008 m2** [3(12x28)]			
PHYTO-C3 Organic (ppm)	6 L	6	0	Disolve all components and apply throough spraying on a basis of 600L/ hectare
Biodynamic Fertilizer Super Micro Plus	2,8 Kg	0	2.78	
Biodynamic Fertilizer Enriched Iron 10%	2,8 Kg	0	2.78	
Biodynamic Fertilizer Potassium 35%	2,8 Kg	0	2.78	

Table 3: Fertiliser Application for Cycle 1 and Cycle 2

For the third cycle, decided to increase the level of the fertiliser supplied by Innoparmis Agroscience to evaluate the impact on increasing crude protein. The objective was purely exploratory.

Ryegrass — **Final grazing Cycle**

Treatments	Area Covered	First Application (Kg/hectare)	Second Application (Kg/hectare)	Application instructions
Treatment 1	2520 m2 [28x90]			
UREAMAX (46N) - 20 units/acre	53,6 Kg	53.6	0	sprinkle Ureamax (46N) over the surface of the grass
minerals are to be disolved in 100L of water and applied to the 3 parcels				
Treatment 2	2,7,9			
PHYTO-C3 Organic (ppm)	4 L	2	2	Disolve all components and apply throough spraying on a basis of 600L/ hectare
Biodynamic Fertilizer Super Micro Plus	12 Kg	3	3	
Biodynamic Fertilizer Enriched Iron 10%	5 Kg	5	6	
Biodynamic Fertilizer Potassium 35%	15,4 Kg	7	8	
minerals are to be disolved in 100L of water and applied to the 3 parcels				
Treatment 3	1008 m2 [3(12x28)]			
PHYTO-C3 Organic (ppm)	2 L	2	0	Disolve all components and apply throough spraying on a basis of 600L/ hectare
Biodynamic Fertilizer Super Micro Plus	12 Kg	3	2	
Biodynamic Fertilizer Enriched Iron 10%	5 Kg	5	5	
Biodynamic Fertilizer Potassium 35%	15 Kg	6	8	
minerals are to be disolved in 100L of water and applied to the 3 parcels				
Treatment 4	1008 m2 [3(12x28)]			
PHYTO-C3 Organic (ppm)	6 L	6	0	Disolve all components and apply throough spraying on a basis of 600L/ hectare
Biodynamic Fertilizer Super Micro Plus	15 Kg	0	5	
Biodynamic Fertilizer Enriched Iron 10%	0 Kg	0	8	
Biodynamic Fertilizer Potassium 35%	10 Kg	0	9	

Table 4: Fertiliser Application for Cycle 3

For all applications, we added a biological yeast-based surfactant, Phyto-C3 Organic that is manufactured by Bio-Organic Catalyst USA. PHYTO C3 is a breakthrough organic biocatalytic water conditioner utilizing a green biochemistry based on yeast for superior cleaning performance of organic and inorganic fouling present in lines. Our main purpose is to prevent the clogging of the nozzles, ensure that the spray lines are clean and help in the increasing the absorption of the minerals by the plant.

The treatments being assessed can be summarized as such;

	Trt 1	Trt 2	Trt 3	Trt 4
For Cycle 1 - 2				
% Nitrogen Reduction		**98.6%**	**99.2%**	**99.1%**
Reduction of Fertilizer Use		**79.3%**	**80.2%**	**84.4%**
For Cycle 3				
% Nitrogen Reduction		**95.1%**	**95.2%**	**95.2%**
Reduction of Fertilizer Use		**39.8%**	**40.7%**	**44.4%**

Table 5: Fertiliser Total Quantity and Nitrogen reduction

The control treatment was applied as granular fertiliser via broadcasting from a fertiliser spreader on days 4 – 8 of the grazing grass growth cycle.

Treatments 2, 3 and 4 were applied as a liquid by means of an agricultural sprayer in 2 applications, the first taking place on day 4 – 8 and the second taking place on days 12 -16 of the grazing grass growth cycle. Spraying was carried out early in the morning between 7:00 and 8:30, bringing the sprayer to plants as close as possible. The sprayer model used was a mounted Tolmed Klara, manufactured in Poland.

Figure 5: Sprayer Model used for study application

A fixed rotation length was employed on the plots whereby a herd of grazing dairy cows returned back to the plots to graze the plots. Prior to each grazing the following measurements were recorded:

- Herbage yield: Within each plot, herbage was harvested to a height of 4cm using a Gardenia motor harvester from 3 discrete areas measuring

0.25 m2 each. The mown herbage was placed in a sample bag and a subsample analysed in the laboratory to determine DM%. The average herbage yield per plot was determined in kg DM/ha.

- Herbage quality: another subsample was analysed in the lab for grass herbage quality parameters including DM digestibility, crude protein, phosphorus, potassium and organic matter.

- Morphology: full, intact perennial ryegrass tillers were obtained from ground level by cutting the roots of the plant while gently pulling the shoot away from the soil. Ten of these tillers were selected at random and measured for their extended tiller height (ETH), extended sheath height (ESH) and blade width. Free leaf lamina was calculated as ETH minus ESH.

- Soil fertility analysis: Soil cores (10cm) were taken from each plot at the start and end of the trial period. These samples were analysed by the laboratory and analysed for pH, phosphorus, potassium and micronutrients.

- Worm count: conducted using the GrassVESS methodology.

- Soil bacterial counts

Results:

Soil fertility:

Table 6 displays the soil test results from the start of the study. The results suggest that the soil is sub-optimal phosphorus (i.e.< index 3) but has high levels of potassium and optimum pH (>6.3). Despite this the soil would be reflective of typical soils in Ireland. High levels of the micronutrients magnesium, copper and zinc but low levels manganese were recorded.

Parameter	Method	Result	Unit	Very Low Index 1	Low Index 2	Normal Index 3	High Index 4
Phosphorus (P) Morgan's	SOP 2127	4.18	mg/l	3	6	10	30
Potassium (K) Morgan's	SOP 2127	187.6	mg/l	50	100	150	200
pH (Water)	SOP 2001	6.4	pH units				
pH (SMP)	SOP 2002	6.4	pH units				

Lime Requirements (Tonnes/ha): **3.75**

P Index (Grassland): **2** **P Index Other Crops (Beet, Barley, Wheat, Oats, Maize, Rape):** **2**

Nutrients

Analysis	Result	Unit	Guideline	Level	Response to Application
Morgans Magnesium	139.2	mg/l	51 - 100	High	None
Zinc*	3.98	mg/l	1.81 - 2.35	High	None
Copper*	3.47	mg/l	1.41 - 2.1	High	None
Manganese*	15.34	mg/l	17.1 - 30	Low	Likely

Based on S.I No 605 of 2017, European Communities (Good Agricultural Practice for Protection of Water) Regulations 2017, i.e. the Nitrates Directive.

Table 6: Soil physical and chemical indices of the experimental field

Weather Conditions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Cumulative / Average
Average rainfall (mm)	79	68	62	44	53	60	69	81	65	95	88	93	859
2022 rainfall (mm)	28	83	59	43	36	63	25	37	153	153	94	68	841
Difference (mm)	-51	15	-4	-1	-17	2	-44	-45	89	58	5	-25	-18
Average temperature (ºC)	5.2	5.4	6.6	8.8	11.4	14.2	16	15.5	13.6	10.7	7.3	5.6	10
2022 temperature (ºC)	5.4	7.2	7.4	8.4	12.6	14.2	17.2	16.9	13.5	12.1	8.9	3.8	10.6
Difference (ºC)	0.2	1.8	0.8	-0.4	1.2	0	1.2	1.4	-0.1	1.4	1.6	-1.8	0.6

Table 7: Meteorological data taken from Oakpar, Co. Carlow (nearest weather station to trial site)

At the start of the trial period (July and August) low levels of rainfall were experienced, with rainfall deficits of 44 and 45 mm experienced during the two months. This combined with higher than average temperatures created drought conditions which reduced plant growth during this period. Figure 2. shows the national decrease in perennial ryegrass growth during this period. From September, higher than average rainfall was experienced, with 89 and 58 mm more rainfall in September and October, respectively.

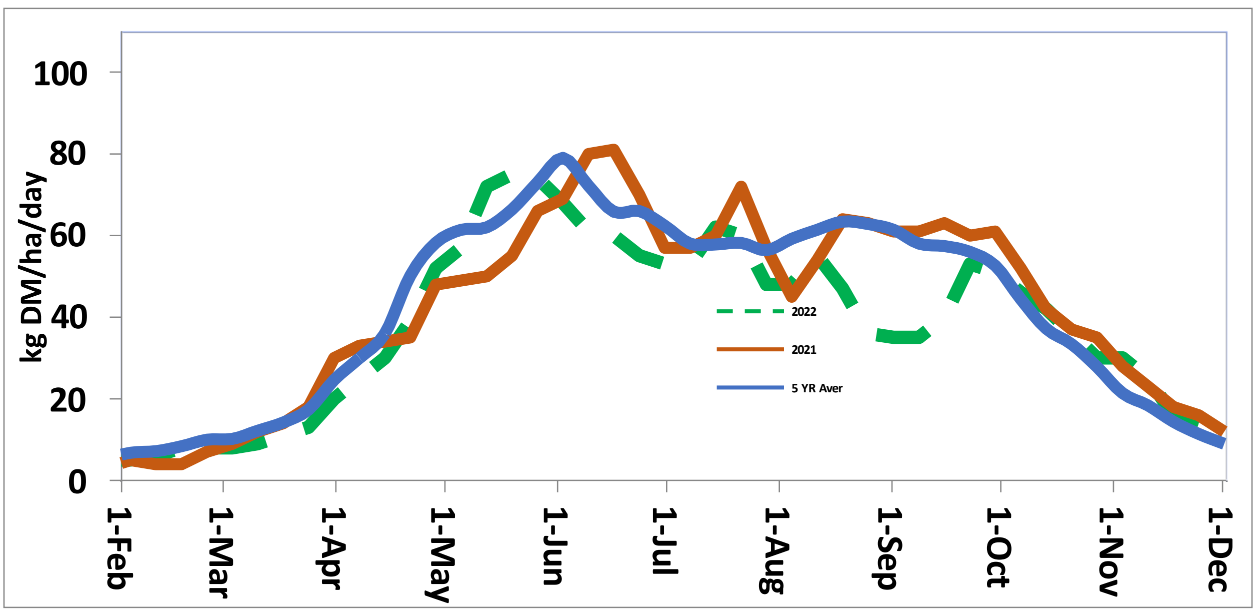


Figure 6: National herbage growth fluctuation per year

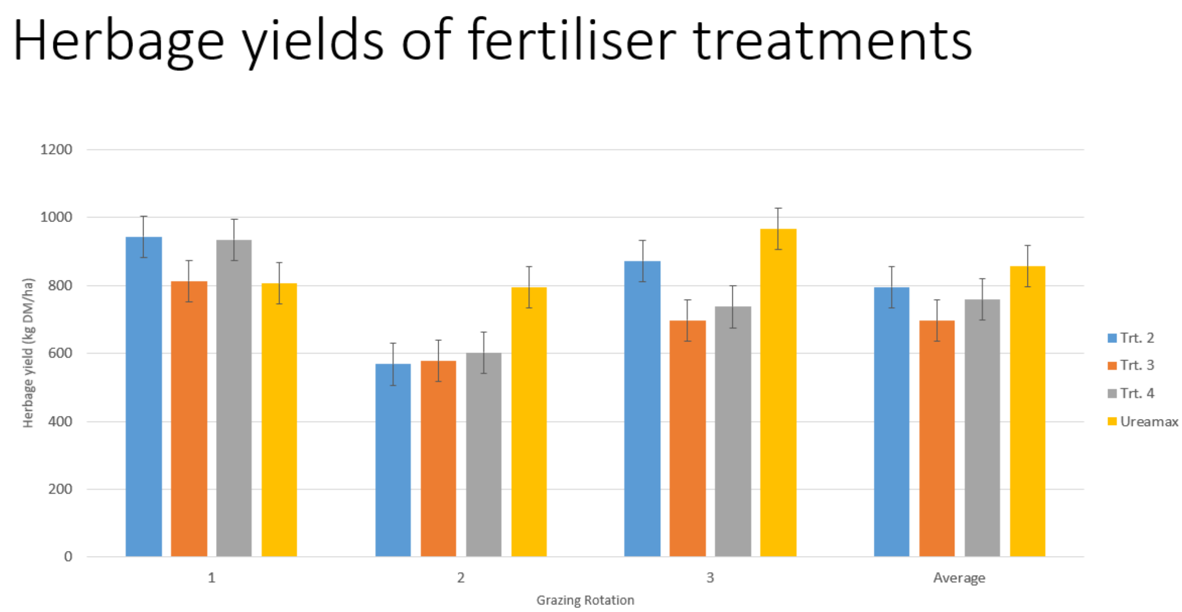


Figure 7: Grass growth yield

There was no statistical difference between treatments for average herbage yield. A treatment x grazing event interaction was recorded as the control treatment yielded higher in rotation 2 than the other treatments. Cumulative yield also did not differ significantly between treatments.

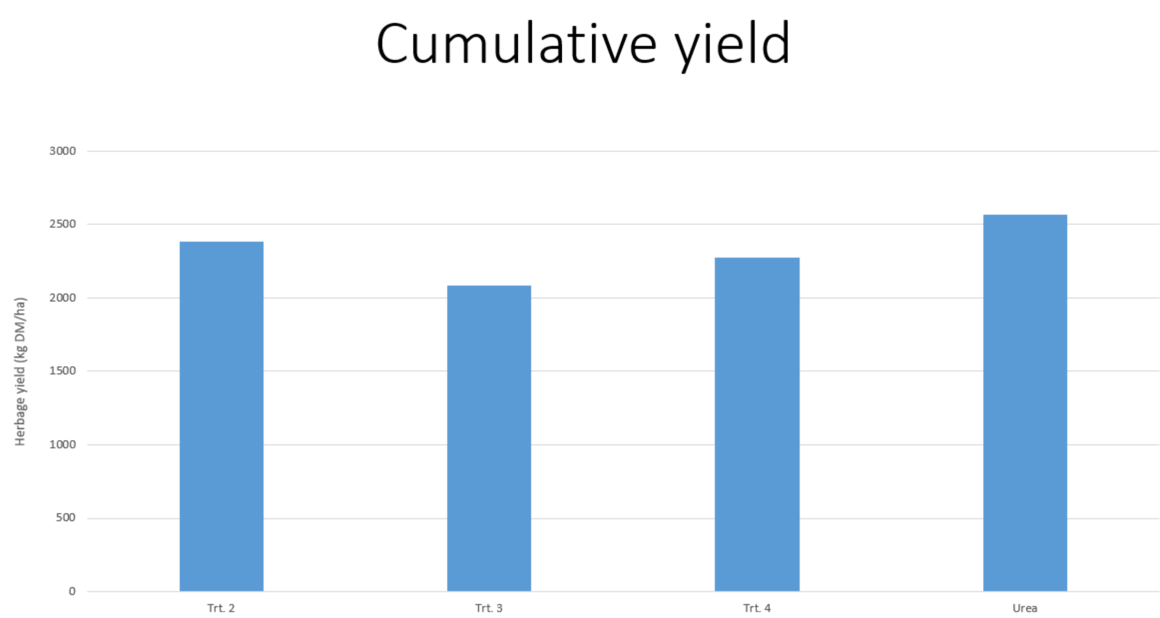


Figure 8: Cumulative Grass growth yield

Simple statistical analysis

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Treatment	3	29	2.02	0.1326
Grazing_rotation	2	29	9.31	0.0008

Least Squares Means						
Effect	**Treatment**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**
Treatment	Treatment 2	830.84	61.4079	29	13.53	<.0001
Treatment	Treatment 3	731.84	61.4079	29	11.92	<.0001
Treatment	Treatment 4	794.17	61.4079	29	12.93	<.0001
Treatment	UreaMax	892.39	61.4079	29	14.53	<.0001

Figure 9: Grass growth yield – statistical analysis

Herbage quality

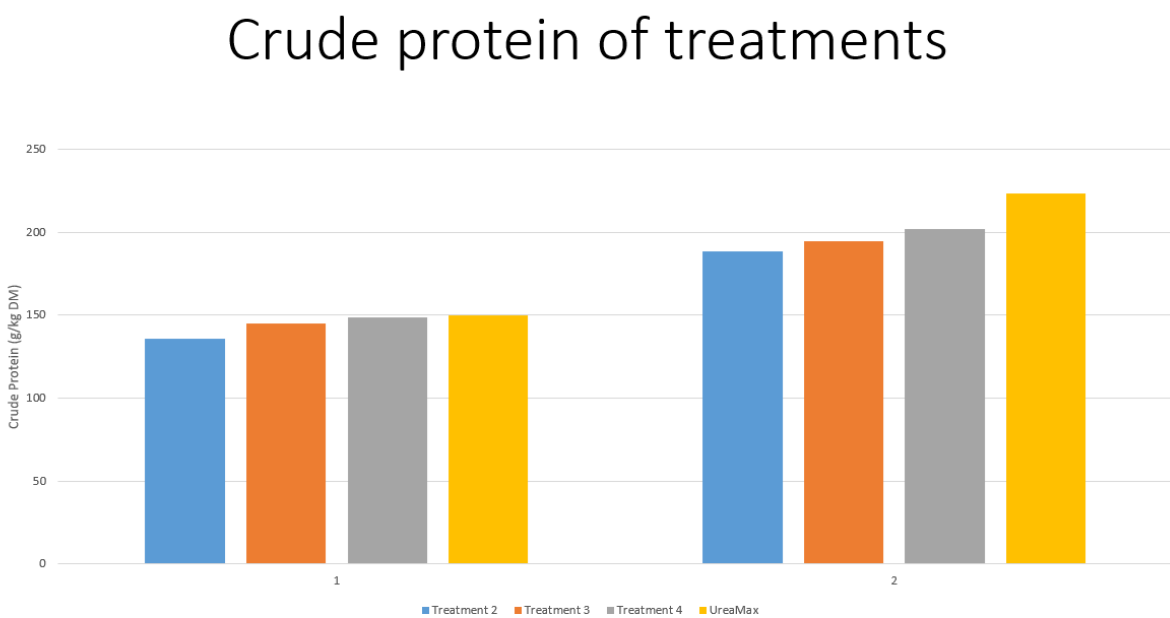


Figure 10: Crude Protein Levels

No significant difference in crude protein was recorded between treatments in either grazing event. There was however a large increase in crude protein in rotation 3. We can also see a difference between the UREAMAX control group and the treatment groups when looking at the crude protein content of the grazing grass. Treatment 4 seems to be the best performing in this case, though all three treatment programs seem to develop an adequate level of crude protein; ranging between -1 and -16% when compared to the control Group. A minor adjustment in nitrogen levels to the treatment programs can be performed and lead to similar and/or better results than the UREAMAX control.

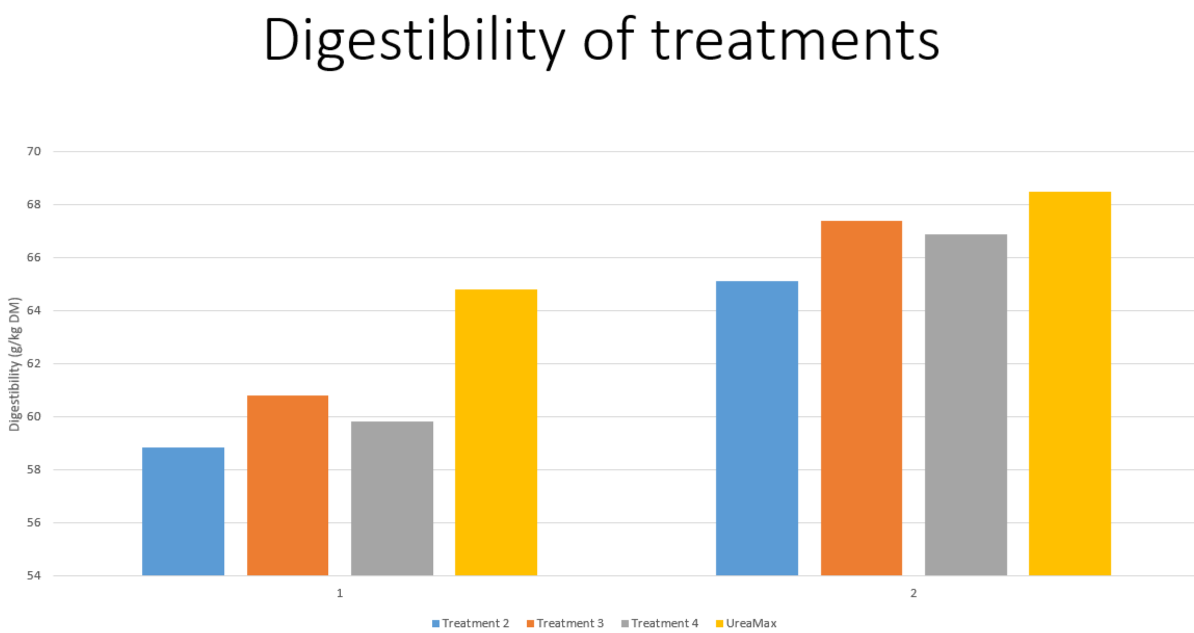


Figure 11: Digestibility of Grazing Grass

A significant difference in digestibility was recorded between treatments in rotation 1 with digestibility highest for the control treatment at 65%. All other treatments reported similar digestibilities at about 60%. An important characteristic of grazing grass is the digestibility factor of the grass. This provides an indication of the digestibility of the grass by the cow and its conversion efficiency to milk. From the results observed, we cannot state a trend or an obvious relationship between the treatment programs and their performance in respect to the UREAMAX control. Further investigations will be required to optimize this characteristic in grazing grass.

Micronutrients analysis

When looking at the mineral profiles of the grass, we notice that the treated plots demonstrate a more complete mineral profile where higher levels of minerals were observed across the board, with the exception of sodium. In the case of Potassium, we also observed that levels were highly fluctuating. This fluctuation is not easily explained and will need to be observed more closely in further studies.

Grazing Cycle 1						
	4 ppm		2 ppm		6 ppm	
	Trt 2	% Reduction	Trt 3	% Reduction	Trt 4	% Re
Cycle / Cycle performance		98.6%		99.2%		
Average of KJN	2.6	-11%	2.5	-13%	2.7	
Average of Phosphorus (mg/kg)	3314	30%	4044	58%	4295	
Average of Potassium	20672	-32%	15142	-50%	209	
Average of Zinc	105.33	112%	110.17	121%		
Average of Iron	603.67	197%	501.67	147%		
Average of Dry matter	26.03	22%	23.50	10%		
Average of Organic matter	91.53	1%	91.27	0%		
Average of D Value	58.83	-9%	60.80	-		
Average of Crude Protein	135.67	-10%	144.67			

Grazing Cycle 2			
	4 ppm		2 p
	Trt 2	% Reduction	
Cycle / Cycle performance		98.6%	
Average of KJN	2.5	-15%	
Average of Phosphorus (mg/kg)	4438.3	25%	
Average of Potassium	19639.3		
Average of Zinc	68.2		
Average of Iron	702.0		
Average of Calcium	598		
Average of Magnesium			
Average of Sodium			
Average of Sulfur			
Average of Copper			
Average of Manganese			
Average of Molybdenum			
Average of Cobalt			
Average of Selenium			
Average of Iodine			
Average of Alum			
Average of O			
Average			
Avera			
Av			

Table 8: Mineral levels and organic indicators – Grazing Cycle 1-2

Grazing Cycle 3						
	4 ppm		2 ppm		6 ppm	
	Trt 2	% Reduction	Trt 3	% Reduction	Trt 4	% Reduction
Cycle / Cycle performance		95.1%		95.2%		95.2%
Average of KJN	4.3	-16%	N/A	N/A	4.1	-20%
Average of Phosphorus (mg/kg)	5566.7	39%	5333.3	33%	5466.7	37%
Average of Potassium	28766.7	-20%	26200.0	-27%	30100.0	-17%
Average of Zinc	168.6	406%	157.9	374%	182.1	447%
Average of Iron	703.7	76%	1233.0	208%	912.3	128%
Average of Calcium						
Average of Magnesium						
Average of Sodium						
Average of Sulfur						
Average of Copper						
Average of Manganese						
Average of Molybdenum						
Average of Cobalt						
Average of Selenium						
Average of Iodine						
Average of Aluminium						
Average of Organic matter	90.03	1%	89.27	0%	82.20	-8%
Average of Dry matter	15.63	25%	14.23	14%	14.37	15%
Average of D Value	65.13	-5%	67.40	-2%	66.87	-2%
Average of Crude Protein	188.33	-16%	194.33	-13%	202.00	-9%

Table 9: Mineral levels and organic indicators – Grazing Cycle 3

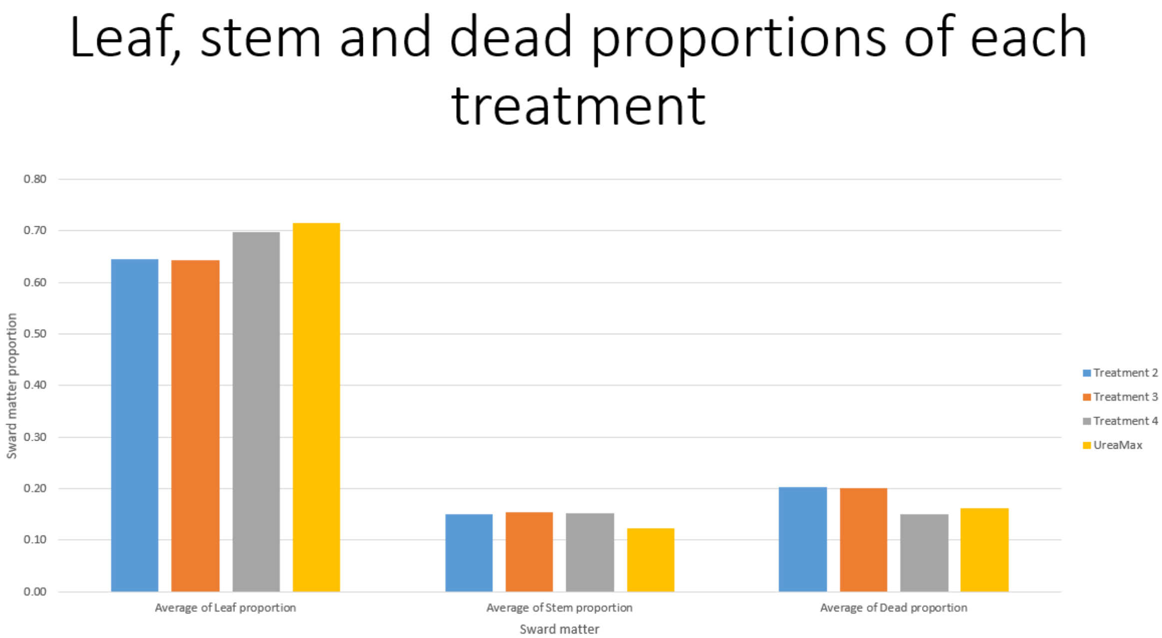


Figure 12: Leaf, stem and dead proportion

Treatment	Extended Tiller Height (cm)	Extended Sheath Height (cm)	Free Leaf Lamina (cm)	Blade width (mm)
Treatment 2	19.5	4.4	15.1	2.7
Treatment 3	19.6	4.5	15.1	2.6
Treatment 4	20.3	4.4	15.8	2.8
UreaMax	20.3	5.1	15.2	2.4

Figure 13: Grass physical characteristics

No differences were observed between the morphological traits of the grass swards. This is unsurprising as swards contained the same varieties of perennial ryegrass and were harvested at similar levels of DM yield, therefore differences would not be expected to occur. Going forward the value of morphological assessments of the treatments needs to be considered as similar since they have yielded little differences and additionally their influence on sward performance is limited. In future studies, these measurements will only be required if significant DM Yields are observed between the treatments.

	Worms (no. / m2)	Organic matter (%)	Moisture Content (%)	Active Bacteria (ug/g)	Total Bacteria (ug/g)	Active Fungi (ug/g)	Total Fungi (ug/g)
2	15.67	18.30	27.40	3.53	513	0.00	0.00
3	21.67	20.20	27.90	2.13	515	0.00	0.00
4	21.33	16.10	34.10	14.49	736	20.50	60.00
1 (Ctrl)	15.00	17.40	32.00	9.03	883	9.60	24.00

Treatments	Worms (no. / m2)	Organic matter (%)	Moisture Content (%)	Active Bacteria (ug/g)	Total Bacteria (ug/g)	Active Fungi (ug/g)	Total Fungi (ug/g)
1							
2	4.44%	5.17%	-14.38%	-60.91%	-41.90%		
3	44.44%	16.09%	-12.81%	-76.41%	-41.68%		
4	42.22%	-7.47%	6.56%	60.47%	-16.65%	113.54%	150.00%

Table 10: Soil characteristics – post trial

The soil analysis conducted after the three grazing rotations are displayed in table 10. Worm count differed between treatments ranging from 15 worms (Control and treatment 1) to 21 worms (treatment 2 and 3). The number of active bacteria were lower for treatment 2 and 3 (<3.5), moderate for the control (9) and highest for treatment 4 (14.5). A similar result was found for active fungi where no active or total fungi were reported for treatments 2 and 3. The control had relatively moderate levels of active/total fungi (9.6 and 21 respectively) and treatment 4 had the highest relative levels of active and total fungi (20.50 and 60, respectively).

When looking at the difference in treatments between the cycles, we notice that the values of minerals, organic matter and crude protein vary quite differently. The latter is indicative of possible mismanagement of the received samples and discrepancies in analytical methods use. Future testing will be needed to better comprehend the impact of the new fertiliser and assess the effect on the grazing grass & soil.

For a proper development of grazing grass, the correct balance of nitrogen, phosphorous, potassium and magnesium need to be maintained. In addition, it is important that some micro elements such as zinc, manganese, and sulfur can help in optimizing grazing grass in producing the right level of organic matter/density, as well as having a positive benefit on milk and cattle meat production.

Unfortunately, the laboratory handling the testing was unable to test the samples in a reasonable timing due to COVID-related absenteeism. The trial results cannot be deemed as accurate and it was decided to measure the soil for the same parameters prior to starting the new season. This will be called the "carryover effect". The assumption is that the beneficial impact of the treatment, if any, will be seen in the soil after time seeing that the microorganism and worms are live creatures and can proliferate.

From the observed results, future studies should measure;

1. crude protein
2. herbage yield
3. digestability
4. root development and
5. soil characteristics

in order to assess the performance of the fertiliser regimen.

Carry Over Effect

Prior to starting the second season, it was decided to measure the soil for critical parameters, as well as bacterial and fungi population

Treatments	Active Bacteria (ug/g)	Moisture Content (%)	Total Bacteria (ug/g)	Organic matter (%)	Total Fungi (ug/g)
2	2.29	34.7	696	13.6	30
3	6.21	34	657	14.2	75
4	3.72	35.6	732	15.3	45
1 (Ctrl)	0.45	29.8	344	13.6	8

Treatments	Active Bacteria (ug/g)	Moisture Content (%)	Total Bacteria (ug/g)	Organic matter (%)	Total Fungi (ug/g)
1					
2	509%	116%	202%	100%	375%
3	1380%	114%	191%	104%	938%
4	827%	119%	213%	113%	563%

Table 11: Carry-over effect mineral and organic indicators

Treatments	Phosphorous (mg/l)	Potassium (mg/l)	pH (water)	pH (SMP)	Magnesium (mg/l)	Zinc (mg/l)	Copper (mg/l)	Manganese (mg/l)
2	3.15	128.5	6.5	6.6	249.2	3.07	2.81	7.26
3	3.62	129.1	6.5	6.6	249.1	3.3	2.32	7.18
4	3.93	185.6	6.5	6.6	256.1	3.23	2.16	6.04
1 (Ctrl)	2.56	144.6	6.6	6.7	256.8	3.05	2.88	8.53

Treatments	Phosphorous (mg/l)	Potassium (mg/l)	pH (water)	pH (SMP)	Magnesium (mg/l)	Zinc (mg/l)	Copper (mg/l)	Manganese (mg/l)
1								
2	123%	89%			97%	101%	98%	85%
3	141%	89%			97%	108%	81%	84%
4	154%	128%			100%	106%	75%	71%

Table 12: Carry-over effect mineral and organic indicators

When looking at the soil characteristics prior to starting the 2023 grazing grass season, we noticed that the treated groups had similar pH, magnesium and zinc content profiles to the control.

We saw a noticeable difference in phosphorous, where the treated groups were significantly higher than the control group.

In terms of copper, manganese and potassium, we noticed that the treated groups had slightly less of these minerals when compared to the control group.

When measuring the bacteria and fungi population, we notice that the treated groups demonstrate a much higher population versus the control group. Active Bacteria, Total Bacteria and Total Fungi all demonstrate significant increase in their populations, ranging from 2 to almost 14 folds.

The impact of this increase on grazing grass yield and quality still needs to be determined, but the positive impact of the treated group on soil bacterial and yeast population can be clearly stated.

We also notice and increase in moisture content of the soil in the treated groups. The latter help improve crop germination in drier, warmer seasons.

As for the organic matter, we can state that both treated and control groups have a similar profile. This demonstrates that the use of synthetic nitrogen fertilizer have little effect on soil organic matter within our trial.

We also measured the worms population in order to determine if there is a noticeable difference between the different treatments. We notice that the worm population is widely varied from plot to plot, regardless of the treatment it has received.

Further work will be required to further assess the variability observed in the worm population. It might be more appropriate to measure the impact of the biodynamic fertilisers on worm populations through controlled laboratory in-vitro setups.

The other variable that we took in consideration was the assessment of the roots structures depending on the treatment received.

Figure 14: root structures; plot 1 through 10

The root structures were collected in order be used as a baseline of comparison for the end of the study. No specific differences can be observed between the treatments.

CONCLUSIONS

The study has demonstrated that the use of the biocatalyst together with biodynamic fertilisers has a positive impact on grazing grass development;

- Similar levels of dry matter production recorded between treatments
- Similar yield to the control group with no adverse effects on quality

Though the treatment groups almost eliminated completely the use of synthetic Nitrogen (95.1 to 99.2% reduction of Nitrogen) a positive impact has been observed with the use of the biodynamic fertilisers, we cannot fully substitute the use of synthetic Nitrogen. Further investigations will be necessary to assess how this new type of fertilisers can be used in conjunction with traditional synthetic fertilisers to contribute to the reduction of its use, in accordance with the EU Green Deal.

The herbage yields harvested were lower than that traditionally practiced, usually in the range of 1400 kgDM/ha, on Irish farms caused by the large moisture deficits experienced during the drought periods in august and September which affected sward growth.

Further trials will be required to assess the impact that the observed increase in bacteria and fungi population have on promoting the medium to long term growth of grazing grass yield and quality.

Future studies should be conducted where other characteristics such as moisture content, organic matter and worm populations are tracked and measured to assess how they develop in the soil during repeated use of the biodynamic fertilisers from Innoparmis Agroscience in combination with Phyto-C3 from Bio-Organic Catalyst.