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REDUCTION OF NITROGEN AND PHOSPHATE FERTILISER INPUTS WHILE INCREASING PASTURE PRODUCTION

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Abstract:
Soil micro-organisms play a significant role in plant nutrient uptake and overall pasture and crop production. Micro-organisms aid in the conversion of atmospheric gases to plant available nutrients and facilitate locked up nutrients within the soil particle to be utilised by plants. However, the role of micro-organisms within the soil has been recently overlooked. Not only have pastures become heavily reliant on soluble synthetic fertilisers, but it seems New Zealand's farmers have too, spending approximately 1.5 billion dollars on fertiliser per year.

The two most applied fertiliser nutrient inputs are nitrogen and phosphorus. Phosphate fertiliser research in New Zealand has shown that where less soluble phosphate fertilisers are used, optimal pasture production can be achieved with lower soluble phosphate levels in the soil. Soluble phosphate and nitrogen fertiliser applications reduce mycorrhizal activity within the rhizosphere and consequently increase the plants reliance on high amounts of these soluble nutrients.

Recent developments in fertiliser strategies have shown a potential for humic compounds to aid in reducing synthetic fertiliser inputs, while maintaining pasture production. Humic acid encourages soil micro-organism activity and improves nutrient cycling and efficiency. Humic compounds also chelate soluble nutrients and increase plant root mass further improving water and nutrient uptake.

When planning to improve nutrient efficiency and plant uptake of nutrients it is important to consider the interaction of plant roots and plant symbionts such as mycorrhizal fungi and their associated bacteria. Consumers are becoming more aware of the impact that food production has on the environment. Nitrogen and phosphorus losses to water that result from use of soluble phosphorus and nitrogen fertilisers can have a detrimental impact on the environment and therefore the opportunity to use humic acid and other microbial stimulants along with slow release fertilisers should not be disregarded.

Introduction:
Fresh water quality has generally declined in New Zealand as agriculture has intensified and fertiliser use has increased. In 2014 the NZ government issued a National Policy Statement for Freshwater Management (NPS-FW) requiring Regional Councils to take responsibility for improving fresh water quality. This NPS-FW contains a National Objectives Framework (NOF) with numerical bottom-lines for nitrogen and phosphorus to ensure the ecosystem health in our rivers and lakes. Regional Councils are required to ensure that the waters under

their jurisdiction meet these national bottom lines and are required to develop rules to ensure these limits are met. (Clothier B 2016)

Fresh water bodies in New Zealand continue to fall in quality mainly due to an over-abundance of phosphorus or nitrogen or both and Regional Councils in all districts are adopting rules that use the software OVERSEER as an indicator of nutrient loss to water under different farming scenarios.

We can reduce nutrient loss from farmland to water by reducing the inputs of soluble phosphate (P) and nitrogen (N) fertilisers however most farmers cannot happily reduce soluble nutrient inputs if that leads to a reduction in overall production and nett income.

Therefore there is a need to find ways to be more efficient with the use of P and N fertilisers.

We are now spending 1.5 billion per annum on fertiliser in NZ with the major proportion of that spend going towards soluble P and N fertilisers.

Value is mainly perceived as getting maximum kg of nutrients on the ground for the $ spent however a better approach would be to place emphasis on farm productivity and the value of the farm outputs when valuing the fertiliser inputs. Fertiliser forms, fertiliser amendments and microbial products that help supply plant nutrient requirements and enhance efficiency of nutrient use are increasing in use globally but their use is largely unexplored in NZ. Just as in animal and human nutrition we are only beginning to understand the importance of soil microbes in the acquisition and delivery of essential vitamins and minerals.

An indicator that the soil and pasture plants are not using nutrients efficiently is a shallow root system. It is common on NZ farms to find pastures with shallow roots and lots of organic matter in the top 50 to 75 mm of the soil profile.

A change in fertiliser practices that involves the use of insoluble P fertiliser, reduced nitrogen inputs and regular applications of lime and humic acid results in increased biological activity. We find that pasture root systems start to exploit more of the soil profile and therefore have a much bigger soil volume from which to draw nutrients and water.

In the following sections we will look at the P and N cycles in soil and explore how with the use of humic compounds and other microbial stimulants, or through the use of microbial inoculums, we might improve the efficiency with which we use fertiliser nutrients.

Phosphorus:
The soluble P in soil at any time is maintained by a constant flux and some sort of equilibrium between P that is involved in the organic matter and microbial biomass and the P that is stuck to soil particles. Most of the transfer of forms of P in soil is mediated by soil microbiology.

P loss from the farm is mainly through soil loss and the loss of P that is stuck to soil particles. Therefore the lower soil levels of soluble and weekly bound P that we have, while maintaining optimal pasture production, the lower the P loss will be. New Zealand studies with different forms of P fertiliser have demonstrated that pasture production can be maintained at significantly lower soluble P status (measured by the Olsen P test) when we use insoluble P fertiliser (e.g. rock phosphate) compared to soluble P fertilisers such as single superphosphate (SSP) or triple super phosphate (TSP) (Perrot et al., 1993).

Investigation of the sizes of the various pools of P in NZ pasture soils highlight the following. (During 1984)

- Total P in NZ pasture soils is commonly between between 0.5 and 2.5 tonne per Ha
- Less than 20% of the plant uptake of P is likely to come through movement of displaced or exchanged P in soil solution (chemical interactions between sorped P and that in soil solution).
- More than 80% of P that pasture requires is likely to arise from the rapid organic cycle through the mineralisation of soil organic matter and microbiological biomass by micro-organisms in the soil. Therefore if we can improve the microbiological activity in pasture soils then we are likely to get better efficiency from our P resources.
- Annual fertiliser inputs of P required to maintain optimal pasture production are small compared to the total pool of P in the soil (often less than 1%)

Mycorrhizal fungi are involved in symbiotic relationships with the roots of pasture plants. The plants will supply energy to the fungi and bacteria in the rhizosphere and in return the fungi delivers back water and nutrients that the helper bacteria and the fungi have obtained from soil.

Improving the amount of mycorrhizal activity in the rhizosphere results in more efficient uptake of nutrients and water. Pasture plants develop smaller root systems with reduced mycorrhizal colonisation when the soluble P level in the soil is high and when frequent applications of soluble P fertilisers are applied (Nichols, S.N., Crush J.R. 2016; Jefferies et al 2003; Toro et al 1997; Li et al 2006).

Nitrogen:
Plants use more nitrogen in growth than any other plant nutrient and N is often the growth limiting factor for plants. Therefore since the early 20th century, when the Haber Bosch process for synthesising nitrogen compounds using N gas from the air was discovered, the use of nitrogen fertilisers have increased dramatically and have been a significant factor in the increase of crop and pasture production worldwide.

Research with nitrogenous fertilisers applied to NZ pastures has shown that increased N fertiliser applications lead to increased nitrate levels in pastures and soils which results in greater N leaching from soil and increased concentrations of nitrate in surface water and groundwater (Ledgard et al 1998).

In studying the nitrogen cycle in a grass and legume pasture soil it is evident that the transformations of the various forms of nitrogen that happen in soil are mediated by soil microbiology. Research shows that nitrogen fertiliser applications will reduce the legume content of pastures as the grass species out compete the legumes when luxury levels of N are present immediately after a fertiliser application (Theobold and Ball 1984).

N fertiliser applications also reduce the amount of N fixing done by rhizobia. Rhizobia strains remain the same but their ability or propensity to fix nitrogen diminishes with increasing N fertiliser applications (Dylan et al 2015).

On mixed pastures the response to N fertiliser applications reduces over time and we therefore apply increasing amounts of synthetic N to get the same response from pastures with the resultant increase in losses of N to air and water (Magesan and McFadden 2012).

Tools and products used to improve soil biological activity:
Currently N, P, K and S applications are based on soil tests which we use to calculate the nutrients required to meet the plant production plan. As nutrient delivery to plants is mediated by soil biological activity that we have little knowledge of it is increasingly evident that improvements in the efficiency with which soils and pastures use both P and N fertiliser inputs are available from this area of soil science.

Soil microbiologists generally agree that we have named and studied the functions of less than 10% of the organisms that live in healthy soil. Researchers and farmers are learning that if we consider not only the pool of available nutrients but also look at the likely nutrient cycling and delivery processes we may be more efficient with fertiliser inputs.

There are increasing numbers of products available to feed, stimulate and modify the soil microbial communities and the use of these products increases and is often fuelled by the need to reduce the impact of fertiliser practices on the environment.

Commonly used products that enhance microbial activity include humic compounds that are manufactured from highly oxidised leonardite deposits often found as overburden in coal mining.

Bio-stimulants or products that increase the activity of certain soil borne fungi and bacteria are also increasingly commonly used globally in crop and pasture production as are microbial inoculums that introduce beneficial soil microbes such as free living N fixing bacteria or P solubilising fungi and bacteria. The use of some of these products in New Zealand is reported below.

Fertiliser programmes that stimulate soil biology as well as supplying the nutrients required for optimal pasture production are being increasingly used by some New Zealand farmers.

Photos 1 and 2 below compare and contrast the deeper pasture root systems and soil structural improvements that are possible when soil biological activity is considered when applying fertiliser. Photo 1 is taken from an area that is receiving a soil biology friendly fertiliser programme which includes soluble humic acid, lime, elemental sulphur and rock phosphate. Photo 2 is on a nearby area with the same soil and climate, same farming system and a standard superphosphate fertiliser programme.

Photo 1
Biological Fertiliser

Photo 2
Soluble P and Soluble S fertiliser as SSP

Great Land:
Is a polymicrobial inoculum containing five commonly known plant growth promoting bacteria. The product was developed in Australia and has been under trial on pastures and crops in that country for five years. A field trial was established on a mixed dairy pasture in spring 2015 on a Waikato dairy farm. Three applications of Great Land were made during the first season of the trial in September and November 2015 and March 2016. In this trial, pasture production was measured using a plate meter pre and post each grazing on plots that were treated with Great Land and plots that had no Great Land application. All other management of the plots was the same for Great Land treated and untreated plots for the years before the trial was established and during the trial. This trial is continuing in the 2016/17 season.

The initial years dry matter production is presented below (fig1) and shows that Great Land applications resulted in approximately 8% greater pasture production than where no Great Land was applied.

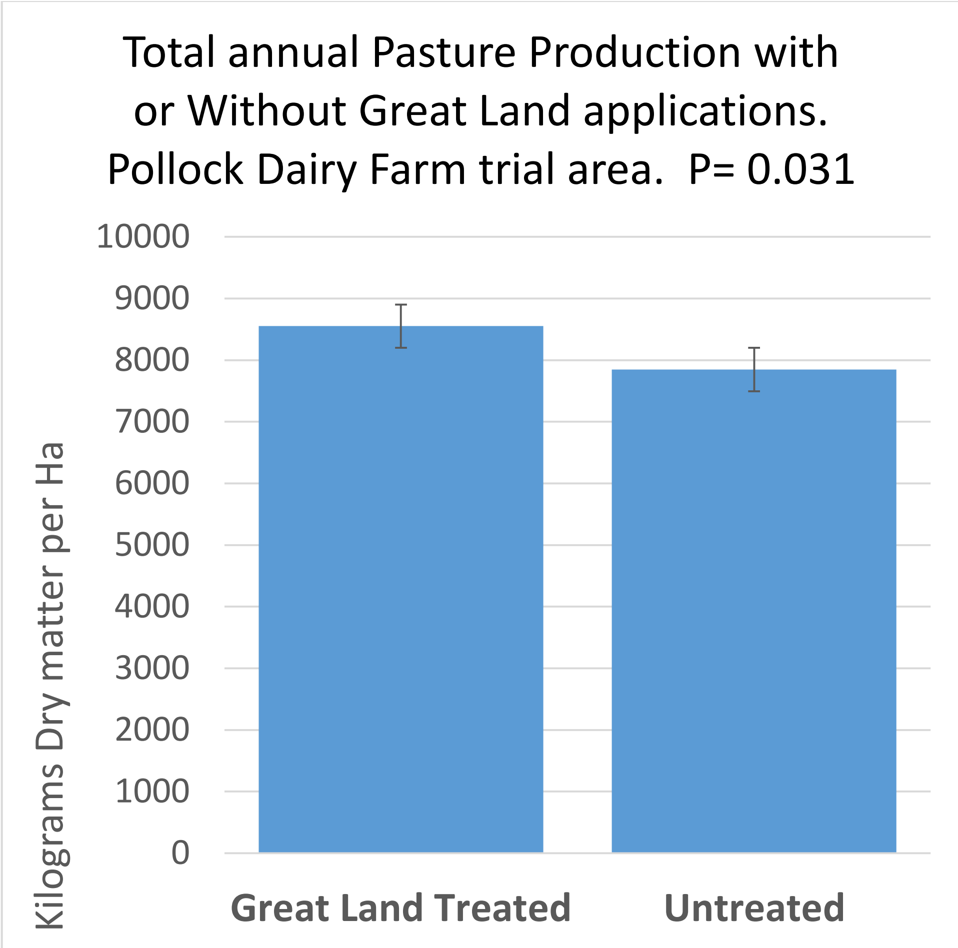

Figure 1

Foliar Fertilisers with bio stimulants:
Many trials and many different products have been used to demonstrate that foliar application of nutrients is more efficient than using solid fertilisers. In particular the use of nitrogen foliar applications on pastures in New Zealand has generally been shown to provide a greatly improved efficiency in terms of dry matter production per kg of fertiliser.

Figure 2 shows the results from a trial with Omnia Nutriology product Rapid N.

The product contains UAN which has biological stimulants added including kelp, trace elements, humic compounds and gibberllins. The results show that the Rapid N treated plots produced 10 times more dry matter per kilogram of N added when compared with granular urea applications. Some of the increased production from Rapid N could be attributed to the bio stimulants and plant growth hormones in Rapid N. The Ag Research scientists that conducted the trial deduced that if they accounted for the activity of the plant growth stimulants there was still a four fold increase in N use efficiency when granular urea is compared to Rapid N the UAN based foliar fertiliser.

Pasture Dry Matter produced per kg of N fertiliser from Omnia Rapid N compared to granular urea.

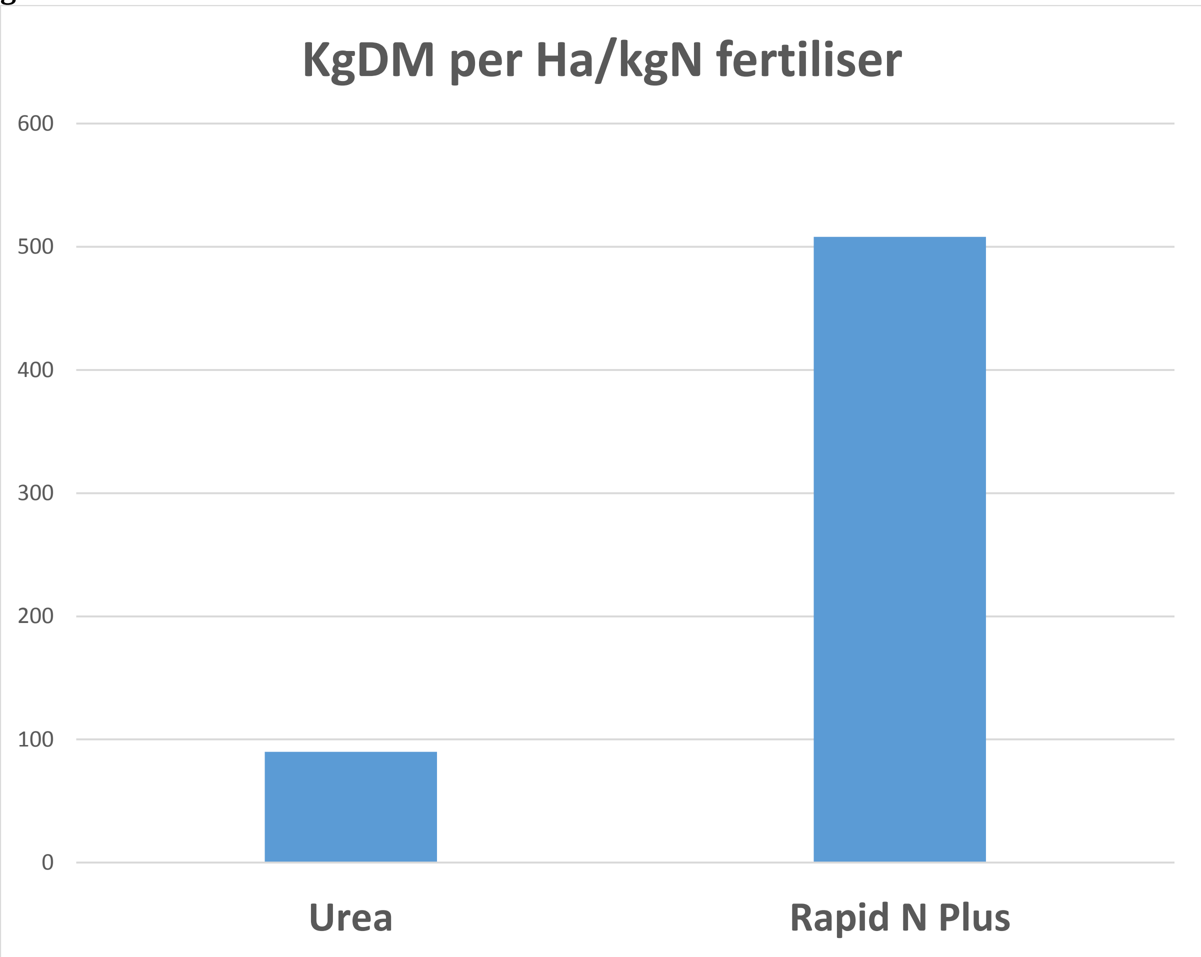

Figure 2

Nutrient efficiency on a whole farm scale:
We have made comparisons of nutrient inputs and modelled nutrient loss on farms that employ the standard fertiliser approach in New Zealand compared to farms that attempt to improve nutrient use efficiency by using humic compounds with all fertiliser applications and also use foliar fertiliser applications when they are most beneficial.

Table 1 compares farm production figures, fertiliser inputs and N and P loss as modelled by OVERSEER for a Canterbury dairy farm that, for more than 5 years, has employed a fertiliser programme that focuses on building a healthy soil and deep root systems. This farm is compared with the neighbouring farms of similar scale and production system that use a standard fertiliser approach based on annual applications of potassic superphosphate and regular applications of urea after each grazing.

Table 1

COMPARISON OF FERTILISER APPROACHES	Farm using Humic acid with all fertiliser. Insoluble P. Foliar N,P,K most of the year	Farms with standard fertiliser approach. Soluble P and all N as solids.
Pasture Harvest (Tonne DM/Ha/Year)	17.2	17.0
Kg N applied/Ha/year	115	250
Kg P applied/Ha/year	20	45
Kg MS/Ha	1600	1600
OVERSEER kg N Loss/Ha/year	32	50
OVERSEER kg P Loss/Ha/year	0.4	0.8

Conclusion:
It is evident that it is possible to grow as much or more pasture with much lower inputs of phosphate and nitrogen when the biological activity in the soil is considered at every fertiliser application. This results in a reduced environmental impact with N and P loss significantly lower than the neighbouring similar farms.

The soil water holding capacity on biological farms has also increases a measurable amount as soil health and structure is improved.

If we pay attention to soil biological functions and enhance them whenever we can we will be able to increase pasture production while lowering the impact our farming operations have on the environment. Research is required to demonstrate the use of greater soil biological activity and improved efficiency of fertiliser nutrients.

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