agKnowledge
TNM™ "Total Nutrient Management"
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TRACE ELEMENTS

If I wanted to be a millionaire I would sell trace elements brews to farmers.

It is so easy – mention animal health, pump in a little doubt, crank up a bit of fear, and, hey presto, another sale. The absence of scruples would of course be essential!

You can protect yourself from such a salesmen with a little information.

There are four trace elements that are regularly required in pastoral agriculture in New Zealand. Molybdenum (Mo) and copper (Cu) are added to fertiliser mixes because they are essential for plant growth. In contrast, cobalt (Co) and selenium (Se) are not required for plant growth, but are added to the fertiliser to ensure that the grazing animal's nutrition is meet.

The critical levels for these trace elements, for optimal pasture and animal production, are given in Table 1.

Table 1: Critical levels for the key trace elements

Trace element	Critical levels in pasture (ppm)	
	Dairy	Sheep
Mo	0.10[1]	0.10[1]
Cu	5[2] (10)[3]	5[2] (10)[3]
Se	0.03[3]	0.03[3]
Co	0.04[3]	0.08[3]

Notes: 1) clover only sample not mixed herbage. Not required for animal production
2) critical level for plant growth
3) critical level for animal growth

The typical chemicals used to add these trace elements to fertilisers and their recommended application rates, and frequency, are given in Table 2.

Table 2: Form, application rates and frequency of application of key trace elements

Trace element	Chemical form	Rate of application	Frequency
Mo	Sodium molybdate	50 g/h	every 4-5 years
Cu	Copper sulphate	10 kg/ha	initially, then 5 kg/ha every 4-5 years
Se	Selcote ultra prills	0.5 g/h	annually
Co	Cobalt sulphate	240-350 g/ha	annually for 5-10 years, then 60-100 g/ha annually

Notes: 1) clover only sample not mixed herbage. Not required for animal production
2) critical level for plant growth
3) critical level for animal growth

Molybdenum (Mo) needs special mention. Mo deficiency was discovered in the 1950s and most sedimentary soils – and this includes most hill country in both North and South Islands – require Mo on an ongoing basis. If it is deficient, clover will be absent or growth very poor. Unfortunately, the importance of this trace element seems to have been forgotten, or farmers have been frightened away from using it, for fear of inducing Cu deficiency in animals. It is true that excessively high plant Mo levels (> 1 ppm) can inhibit the intake of Cu in the animal, but this should not prevent farmers from using this essential trace element.

Excessively high pasture Mo levels occur when Mo is used more frequently than required (see Table 2) and/or lime is applied in addition to the Mo. Increasing the pH rapidly increases Mo availability in the soil and hence plant uptake (see Box 1). Indeed this is one of the major benefits of liming marginally Mo deficient soils. But of course it is much more cost effective in hill country to apply the small inputs Mo rather than large inputs of lime.

The key to managing Mo inputs is regularly monitoring of both clover Mo and animal Cu levels. This should be part of any ongoing soil fertility-monitoring plan.

So what is the story with the other trace elements required for plant and animal production, such as manganese (Mn), zinc (Zn) iron (Fe) and boron (B)?

Most soils have plenty of reserves of Mn, Zn and Fe and hence there is no need to include them in the fertiliser mix. To do so simply increases fertiliser costs for no return. For this reason I become suspicious whenever I see a fertiliser mix - and I see many - which includes these trace elements. So should you! The only situation where these trace elements may become deficient is on coarse textured soils (sands) that are over limed (ie the soil pH is pushed up above 6.5).

Boron is more problematic. Some crops, especially the root crops; turnips, swedes and beets, have a higher requirement for B than pastures. The reason for this is that B is involved in the sugar and carbohydrate metabolism of the plant. Plant reproduction also demands B, and for this reason B is often required on clover and lucerne seed crops. Apart from these situations the need for B is questionable. I would need to see clover B levels consistently below the critical level of 13 ppm, before I would recommend this trace element.

There was a time when trace element requirements could be predicted by knowing the soil group. Sedimentary soils need Mo and Se, pumice soils need Co, and peat, which have no reserves, need all four. Today trace elements problems do not necessarily follow this pattern. The reason for this is that we have used up the initial soil reserves by exporting products from the farm for 40-50 years. For example, Co deficiencies are now being found on ash soils.

It is essential therefore that you have a good monitoring program. Regularly measure the trace element status of your pastures and animals. Approaching the problem in this way gives you peace of mind and keeps you safe from the salesman who wants to sell you an expensive trace element brew.

One final point though. Remember the major cause of trace element deficiencies in grazing animals is a lack of quality feed. Greater feed intake means more trace element intake, meaning that, better-feed animal are healthier animals.

FERTILISER ECONOMICS IN HILL COUNTRY

With the upturn in prices, especially in the sheep and beef , it is timely to re-examine the economics of fertiliser use in this sector. To explore this I am going to use the mythical 'average' sheep and beef farmer as the benchmark. The key factors describing Mr Average's farm are given in Table 1.

Table 1: Descriptors of the Mr Average's farm

Enterprise	Dry sheep
Area	549 ha
Soil	Steep sedimentary soil
Olsen P	8
Stocking rate	10 SU/ha
Gross margin	$50/SU
Super (on ground)	$240

His experiences since the mid 80s have made Mr Average a little fertiliser-shy but he is now bold enough to ask the big questions:

- What is the optimal soil nutrient status for my farm that will maximise my profitability?
- How much fertiliser is required to achieve the economically optimal soil fertility and is it a good investment?
- Will I be better off financially if I just maintain current soil nutrient levels?
- What happens if I apply no fertiliser

Using Overseer (see Box 2), the estimated amounts of fertiliser P, for each of three scenarios - labelled maintenance, zero and economic optimum – each year for the next 10 years has been estimated (Table 2). [For simplicity we will only concern ourselves with P at this stage because a) it drives the pasture production response curve and b) being the most expensive nutrient, it also drives the overall economics].

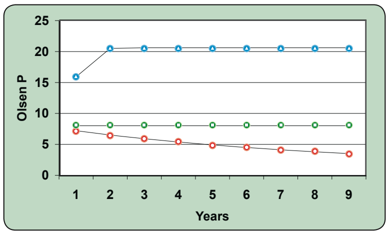
Table 2: P requirements for three scenarios on Mr Average's farm

Scenario	Calculated amount of P required (kg P/ha/yr)			
	Year			
	1	2	3	4 - 10
Zero	0	0	0	0
Maintenance	14	14	14	14
Economic optimum	120	73	24	24

The zero option is self-explanatory. The amount of fertiliser P to make good the nutrient losses from the farm, and hence maintain the current Olsen P level of 8, is about 14 kg P/ha/yr. To optimise profits over a 10 year period requires capital inputs of 120 and 73 kg P/ha in year 1 and 2, and then sufficient P to maintain the 'new', higher P status of Olsen P 20, thereafter.

We can 'see' the consequences of these scenarios by following the changes in Olsen P over time (Fig 1). By definition the maintenance input maintains the Olsen P. If fertiliser is withheld the Olsen P level falls from 8 to 3 over ten years. The economic optimum requires capital inputs in year's 1 and 2, and these push the Olsen P up to about 20. This then is the economic optimal P status for this farm. [Pasture and animal production follow these same trends as in Fig 1, and so, for the sake of simplicity, the relevant graphs are not shown].

Fig 1: Changes in Olsen P as a result of three scenarios: No fertiliser (circles), maintenance (squares) and economic optimal (triangles).



The obvious question is; which is the best investment in the long term?

There are a number of ways to look at this. We can calculate the profit ($/ha), (after deducting all the costs of purchasing and applying fertiliser), for each scenario, for each year, and sum these over the 10 year period, taking into account the declining value of money over time (this is the Net Present Value, NPV). This calculation assumes the costs and prices are constant over time. Alternatively we can calculate the return on the fertiliser investment – the internal rate of return (IRR). The results are shown in Table 3.

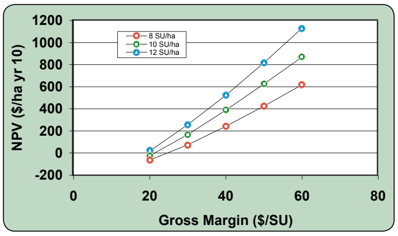
Table 3: The Net Present Value (NPV) and Internal Rate of Return (IRR) of three scenarios

Scenario	NPV (yr 10) ($/ha)	IRR (%)
Zero	0	0
Maintenance	24	5.9
Economic optimum	331	13.9

These figures show that for this farm, and relative to applying no fertiliser, applying a maintenance input will put an extra $24/ha ($13,000 on a whole farm basis) into the farmers back pocket. The return on the fertiliser investment is about 6.0%. Could you get a better return by putting you money 'in the bank', taking tax into account? In contrast, optimising the soil fertility results in a profit of $331/ha ($181,000 over the whole farm) with a return on investment of 14%. Fertiliser, even in this rather extreme farming situation, is a good investment.

Many hill country farmers will be doing better than 10 SU/ha at a gross margin of $50/SU. Figure 2 shows how NPV changes with either SR or GM/SU. At a GM of $50/SU the NPV from fertiliser increases from 200, 300, 400 $/ha, with unit increases in SR and increases from zero to $600/ha as the GM increases from 20 to 60 $/SU. [As an aside, it is easy to now understand why farmers did not apply fertiliser during the late 80s when GMs dipped below 20].

Fig 2: The effect of stocking rate (SU/ha) and gross margin ($/SU) on the net present value (NPV, $/ha) for an average sheep and beef farm.



Clearly both stocking rate and gross margin have a large impact on the NPV. Thus, the way to increase the return on the fertiliser dollar is to do things that either increase the carrying capacity (ie improve pasture utilisation, better subdivision etc) or increase the value of the product from the farm (ie increase lambing percentage, finer wool, changing the sheep / beef ratio etc).

The input costs, such as fertiliser price and the cost of transport and spreading, have relatively little impact on the long-term profitability of fertiliser use, compared with SR and GM. This is surprising given that most farmers worry about these costs rather than focussing their attention on the main drivers of profitability. As the saying goes, "Don't Sweat the small stuff."

One final point. By way of comparison, the IRR on fertiliser for a sheep and beef farm operating at 12 SU/ha at a GM of $70/SU is between 30-40 %, about the same as it is for an average dairy farm producing 700 kg MS/ha. The point I hope is clear - fertiliser is an excellent investment. But many of you already knew that, didn't you?

Box 2 : OVERSEER

Overseer is a piece of software – it is a tool. But it is a very unique tool because it is a world first. It represents the fact that applied soil science in NZ is the best in the world! It is so good that the EU is looking at it for their use.

At its heart, Overseer contains advanced 'models' that describe how P, K, S and lime behave in soils and affect pasture production. These models are dynamic, which means that Overseer can examine the economic outcome of different fertiliser strategies, over time, at an individual farm level. This has not been possible before.

It is an expert system - it is not designed for farmers but for Consultants to examine long-term fertiliser options for their clients. Ask your Consultant to analyse your farm, using OVERSEER to ensure you are getting maximum returns from you fertiliser dollar.

CALCIUM, LIME AND SOIL pH

A correspondent has raised the question; if the soil Ca level is high is there likely to be much response to lime, and, what is the effect of superphosphate on soil Ca? These are good questions because there seems to be some confusion about soil Ca, its importance, and how it is measured.

Calcium Status of NZ Pastoral Soil

The Table below contrasts the critical levels of Ca for soils, pastures and animals with the typical levels found in pastoral systems. This shows that our New Zealand soils have abundant supplies of Ca. This is a consequence of the Ca-rich parent materials from which they are formed and the fact that they are not very old. Not surprisingly Ca deficiency in New Zealand soils, pastures and animals is unheard of.

Table 1: Diagnostic Criteria for Calcium

Component	Measurement	Critical level	Typical level
Soil	exchangeable Ca (me/100 gm)	< 1.0	5-10
	Quick test Ca (QT)	< 1.5	8-16
Pasture	Clover (% Ca in DM)	< 0.20	0.70
	Ryegrass (% Ca in DM)	< 0.30	0.70
Animal	Pasture (% Ca in DM)	< 0.40	0.70

In addition, New Zealand farmers have historically used lime, superphosphate and RPR, all of which contain significant quantities of Ca. Higher analysis P fertilisers have lower Ca contents or do not contain any Ca.

Table 2: Calcium Content of Fertilisers

Fertiliser	Calcium Content (%)
Lime	30
Superphosphate	20
RPR	30
Triple superphosphate	14
DAP	0

The net effect of these two factors is that most NZ soils used for agriculture are awash with Ca. Is this likely to change?

The Calcium Balance

The inputs and outputs of Ca from a typical dairy farm and a high producing dairy farm are given in Table 2. In both situations the inputs exceed the outputs. This is mainly because of the inputs of Ca in lime and super. If DAP was used instead of super as the source of P, both farms would still be in positive balance, but if this was coupled with no lime inputs, both farms would be in deficit (-126 and - 141 kg Ca/ha for the average and high producing farm respectively). Thus providing a liming program is in place it does not really matter which P fertiliser is used as a source of P – there will always be a positive balance.

Table 3: Calcium Inputs and Outputs

	Source	Amounts of calcium (kg Ca/ha/yr)	
		Average dairy farm[1]	High producing dairy farm[1]
Inputs	Rain	5	5
	Superphosphate	89[2]	130[2]
	Lime	170[3]	170[3]
	Subtotal	**264**	**305**
Outputs	Milk	11	15
	Transfer	8	10
	Leaching	114	134
	Subtotal	**133**	**155**
	Balance	**+113**	**+146**

Notes: 1) Average = 800 kg MS/ha. High = 1200 kg MS/ha
2) Average = 450 kg super/ha/yr. High = 600 kg super/ha/yr
3) Lime = 2.5 tonnes/ha/5 yrs.

Soil Ca and Soil pH

The relationship between soil pH and soil Ca for a set of 97 topsoils from throughout NZ is shown in Figure 1.

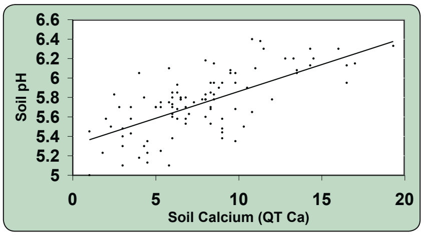
This relationship is weak – there is a general trend for soil pH to increase with soil Ca but it is not strong. For example, soils with a pH of 5.5 have soil Quick Test (QT) Ca levels ranging from about 1 to 10. Why is this?

The reason is that adding Ca per se does not change the soil pH. For example, adding materials that contain Ca, such as gypsum (calcium sulphate) or CAN (calcium ammonium nitrate) have no effect on soil pH. Field trials show that annual applications of super (which contains Ca as gypsum) over a long period of time have no effect on soil pH.

Soil pH can only be increased by adding a source of alkali, and the most common alkali, because it is the cheapest, is carbonate. It is commonly applied as either limestone (calcium carbonate) or dolomite (calcium, magnesium carbonate). Think of it this way: the active ingredient in lime is the carbonate not the Ca!

Thus, some of the Ca we add to our soils is accompanied with carbonate which increases the pH. But also large amounts of Ca are applied as super and the pH does not change. Thus, while there is a rough trend between soil pH and Ca it is not strong.

Fig 1: Relationship between Soil pH and Soil Calcium (QT Ca)



So which measurement should be used to determine lime requirements?

Lime increases pasture growth because it increases the soil pH, not because it increases soil Ca. In turn, the increase in pH can trigger many other changes in the soil that are beneficial to plant growth (see Box 1). For this reason pasture responses to lime are related to the soil pH and not soil Ca. Soil pH then, and not soil Ca, should be used to determine if lime is required.

Box 1 : EFFECTS OF LIMING

The most important effects of liming as far as NZ pastoral soils are concerned are:

1) Increases soil biological activity stimulating the mineralisation of organic matter releasing N. Particularly important over the pH range 5.5 to 6.0.

2) Increases the availability of soil Mo. A positive if on a Mo deficient sedimentary soil. A problem if pasture Mo concentration goes above 1 ppm, which can induce Cu deficiency in animals.

3) Decreases Al and Mn. toxicity. Only important on very acid soils with high concentration of toxic Al and Mn (ie some soils with pH less than 5.5).

4) Decreases the availability of soil Zn and Mn thereby inducing deficiency. Only a problem if the pH is high (> 6.5) on coarse textured soils

Some laboratories report Ca results in terms of % Ca base saturation (this is the proportion of the total exchange sites containing Ca). Some Consultants say that there is an ideal % Ca saturation and that this should be the guide for determining soil Ca requirements. I advise caution. This approach to soil testing and fertiliser advice is flawed and will result in excessive inputs of Ca as discussed in The Fertiliser Review No 4).

Too Much Calcium?

Calcium is benign – too much in the soil, plant, animal system is unlikely to have deleterious effects. The problem is that of the four cations in the soil (Ca, Mg, K and Na) Ca is the most strongly held in the soil (on the cation exchange sites referred to collectively as the cation exchange capacity). If over time too much Ca is added it tends to push the Mg off the exchange sites into the soil solution from where it can be leached. This is in fact one of the reasons why Mg deficiency is becoming more prevalent. After decades of farming soil Mg reserves are being depleted because Mg is being lost from the farm in products and by leaching.

There has been some alarmist comment in the press on this issue. Bryan McLeod claims (Dairyman May 2001) that a tonne of lime per hectare will displace 460 kg Mg/ha, one assumes, per year. This is ill-considered nonsense. About 20-30 kg Mg/ha/yr is all that is required, even when lime is used, to maintain existing soil Mg levels.

My Advice?

- Use soil pH as the sole guide to determine lime requirements – optimum pH is 5.8-6.0
- Most soils have plenty of soil Ca and are in a positive balance in terms of inputs and outputs.
- Soil Ca, expressed as the % Ca base saturation is meaningless and misleading – ignore it.
- If you are using super and lime then you can forget about Ca.

SOIL PHYSICAL QUALITY

The history of soil fertility research in the past 50 years has focussed on the chemical quality of soils – defining nutrient deficiencies, developing and calibrating soil tests, determining nutrient requirements. This is not to say that soil scientists did not appreciate the importance of the biological and physical properties of soils – it is simply a reflection of priorities. These are changing. The nutritional problems on most pastoral soils have now been solved, or at least, we have the information and technology to solve them. We are now into fine-tuning and other issues need to be addressed. Soil physical quality is an example.

Soil physical quality can be damaged when excessive pressure is applied to the surface of soils. Soils are particularly vulnerable when waterlogged. The pressure may simply be due to the number of heavy hooves per unit area but can also come from heavy machinery, especially if the activity is repetitive on the same area.

Work at AgResearch has shown that one pugging event depressed subsequent pasture production by 20-80%, depending on the soil group, and that this effect can last up to 4-8 months. In the heavier soils studied (clays and clay loams), the soil structure in the top 10 cm had not returned to 'normal' even after 14 months and during this period, water took ten times longer to drain away relative to the unpugged soils. Recovery on the coarser soils (loams and sandy loams) was complete within 14 months. There is also evidence from Taranaki (Dr G Sparling, Landcare) and Southland (John Drury, AgResearch) showing that the more intensive the farming the poorer the physical quality of the soils.

Luckily, soils are reasonably resilient and robust – to an extent they are self healing. The natural, seasonal wetting and drying cycle, means that the physical units which make up the soil (called pedons in science) are continually breaking down and reforming, thereby retaining their structure. So while there is no need for panic we do need to be aware of these effects and avoid unnecessary damage. The key is to look at your wet soil management in relation to your grazing requirements and ask – what can I do to graze wet soils while minimising the damage?

There are two ways to determine if damage has occurred. Digging some holes in affected and nonaffected areas is a start and it helps to know what to look for. Landcare have produced a self-help manual, including excellent photographs to guide you. Alternatively, AgResearch (Celentis Analytical Laboratory) has developed a commercial test that measures the air-filled porosity of soils – in effect it measures how much space there is in the soil for those vital components, air and water. An ideal soil has an air-filled porosity of at least 10% - meaning that 10% of the soil volume can be filled with air or water. According to the calibration work at AgResearch pasture production decreases by 10% for every 1% decrease in porosity below the this critical level.

Dr Roberts (AgResearch) has listed several ways to avoid or limit damaging soil physical quality:

1. When the soil is waterlogged, restrict the time the animals are out grazing by using a loafing pad or the farm race.
2. Installing a feeding pad
3. Use sacrifice paddocks - paddocks that are up for recultivation and regrassing.
4. Keep heavy machinery, and this included the heavy roller, off waterlogged paddocks.
5. Adequate draining – hump & hollow, field tiles etc – of consistently wet paddocks
6. Subsoiling or soil aeration of areas that are prone to waterlogging.

MAINTAINING FERTILISER QUALITY STANDARDS

Recall from The Fertiliser Review No 6, that I had complained on your behalf to the Advertising Standards Authority about a series of advertisements on TV regarding Maxicrop, that useless product which the High Court said cannot and does not work (have you brought my book –"Science Friction" – yet?). The sad news is that I had to withdraw my complaint because it was going to cost $3,700 to have the case heard. Fertiliser Information Services Ltd is not yet big enough to cope with this type of expenditure!

The taxpayer has already spent about $0.75m to have the case against this product heard (Have you purchased my book – "Science Friction" – yet!). Why should I, as a private citizen and taxpayer, have to front up with a further $3,700, to a quasi-government organization, to have the case heard again? Why can they not make a ruling on the basis of the High Court conclusion?

Recall also that on your behalf I raised an issue of misleading advertising with Fertmark, regarding the products of Script Fertiliser Ltd. I am informed that the matter has been resolved and the offending advertisement should not appear again. Good on you Fertmark.

A final point. If you do not know, Fertiliser Information Services Ltd is being sued by Summit-Quinphos for $700,000 for allegedly defaming Summit-Quinphos and Dr Quin in my book "Science Friction" (have you purchased a copy yet?). I'm still hoping to get the matter resolved before the lawyers get hold of too much money but it will require a steady hand! Was it Roosevelt who said, "The price of freedom (in this case freedom of speech) is eternal vigilance"? Then there are the legal costs!

PRICE WATCH: NITROGEN FERTILISER

Those of you who follow "Price Watch" will have noticed that the major differences in the price of nutrients occurs between product-types. There is generally little difference in the nutrient costs, at least for the major product types, between the two major companies (Ballance and Ravensdown). Furthermore the original reason for providing cost comparisons in The Fertiliser Review was to highlight the large cost savings that can be achieved by selecting the correct base products.

To reflect this emphasis Price Watch will present the costs of nutrients ($ per kg nutrient) as the average cost calculated from the latest price lists of the 2 major companies. Where the prices between the companies differs by more that $0.10/kg nutrient the range will be given. [Note Summit-Quinphos does not make its retail costs available publically and cannot therefore be included in these surveys].

Table 2: Calcium Content of Fertilisers

Product	Average cost[1] ($/kg)
Urea	0.87
DAP	1.24
Sulphate of Ammonia (granular)	1.45
N superphosphates[2] (Nitro super and ammoniated super)	1.20 - 1.53 (Ravensdown)
N-Mg superphosphate[3] (SuperMag and PastureMag)	0.88 - 1.07 (Ravensdown)
DAP mixes[4] (DAP S Super and DAP 13 S)	1.20

Notes:
1) based on the average retail price ex works from Balance (1/8/01) and Ravensdown (1/6/01), after deducting the value of the other nutrients.
2) mixes of sulphate of ammonia and super – may go lumpy on storage. Prompt spreading is advised.
3) these products contain Mg as well as N, P and S. They have better physical quality than the N supers

Comments

Since the last N Price Watch (Autumn 2000) all N fertiliser have increased in price in terms of $/kg N. Urea remains the cheapest form of N. Refer to the Price Watch (Fertiliser Review Autumn 2000) for other relevant comments.