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"The Independent Fertiliser Experts"

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TALKING ABOUT SOIL ORGANIC MATTER

Organic matter (OM) accumulates over time in fertilised, legume-based New Zealand pastoral soils and reaches a maximum – a steady state - after 20-50 years. The amounts of OM present at steady state depends on the climate and parent material, and is lowest on drier soils, increases with increasing soil moisture conditions, and is highest on soils containing the mineral allophane (i.e. the volcanic soils).

The main components of organic matter are carbon (C), nitrogen (N), phosphorus (P) and sulphur (S) which come respectively from photosynthesis and legume N fixation, while P and S, typically come from superphosphate fertiliser. Interestingly the ratio of these nutrients is typically 100:10:1:5:1.5 and reasonably constant.

Table 1 shows some typical concentrations (%) of C and N for NZ pastoral topsoils at steady-state, from which the total amounts of organic matter and organic N have been calculated.

Table 1: The concentration of carbon (C) and nitrogen (N) and the amounts of organic matter (OM) and organic N in the topsoils of some important soil groups.

Soil Group	% in 0-7.5 cm		tonnes/ha-18.5 cm	
	C	N	Organic matter	Organic N
Sedimentary (dry)	1-2	0.1-0.2	30-60	1.8-3.5
Sedimentary (wet)	3-5	0.3-0.5	90-150	5.3-8.8
Volcanic and Pumice	6-10	1.0-1.2	175-300	17.5-21.0
Organic	25-50	1-2	370-750	8.8-10.0

These results illustrate that most developed fertile New Zealand pastoral topsoils contain large amounts of OM. This is a consequence of the in situ cycling of organic matter that occurs in the pastoral system. To put this into an international context, temperate cropping soils in the Northern hemisphere typically have C levels of between 1-3%. Given the central importance of OM in defining many aspects of soil quality this is why New Zealand pastoral soils are regarded as having a high quality. This evidence stands in stark relief to those alarmists who would have you believe that chemical fertilisers and conventional farming is ruining our soils. Bollocks!

There are two important components of organic matter; humus ('dead' organic matter sometimes referred to as humic acid, humin or humates) and the 'living' organic matter – the microbial biomass. The former is defined as the dark-coloured amorphous material formed as the end-point of the decomposition of plant material in soils. It does not include fresh plant litter. Microbial biomass is the mass of living micro and macro organisms in the soil.

Table 2: Amounts of humus and microbial biomass in some New Zealand soil groups.

Soil Group	Organic matter (tonnes/ha)	Humus (tonnes/ha)	Microbial Biomass (live-weight tonnes/ha)
Sedimentary (dry)	30-60	25-50	3-7
Sedimentary (wet)	90-150	80-140	10-18
Allophanic and Pumice	175-300	160-270	20-35
Organic	370-750	310-670	20-35

These amounts of biomass are impressive (Table 2). These soils will typically carry between 5-20 SU/ha, which equates to an above-ground live weight of about 0.25 to 1.0 tonne per hectare. There is more live-weight below the soil!! Amazing.

The amounts of humate in developed soils are also very large – we are not dealing with grams or kilograms – we are dealing with tonnes! Given these numbers do you really believe the salesman who tells you that your soils are run-out and need a kick start of 0.5 kg humate/ha? Dreaming!

What feeds and sustains these high levels of Humus and Microbial Biomass is the residues being returned to the soil from the pasture. Consider a pastoral situation at steady-state. Assume a rate of pasture production of 10 tonnes DM/ha/yr and a pasture utilisation of 80%. That means about 2 tonnes of DM/ha being returned to the soil of which roughly 50% gets incorporated into the soil per year. Much of this is sugar in the form of carbohydrate. Do you really believe the salesman when he says add some molasses to the soil to get the bugs 'moving.' Dreaming again.

The sequence is: feed the pastures (i.e. correct all nutrient deficiencies), grow more pasture, more plant residues returned to the soil and hence greater soil biological activity. There is considerable scientific evidence to support this **(see Fertiliser Reviews No. 13, 20, 32)**

The important rule of thumb is: *feed the pasture and the bugs will look after themselves.* Compare this with the pseudo-science mantra coming from the Kinsey-Albrecht corner of the market **(see article, "Oh Dear Oh Dear" in this edition of the Fertiliser Review).**

ARE YOUR NUTRIENT TANKS FULL?

Implications for Fertiliser Management

Soil tests measure only a proportion of the nutrients present in a soil – they are proxies for the total amount of plant available nutrients in the soil.

This is analogous to measuring the oil in the sump of an engine. Rather than draining the sump to find out how much oil is left, we use a little graduated stick - the 'dip-stick' – which gives a proxy measurement for the total oil in the sump. Please note that just because they are proxies for the real thing does not diminish their value – they are just a quick convenient way of measuring things.

We are all familiar with, or should be, the common soil test values we get on soil test reports, but it can be fascinating to realize what these proxies actually represent. It gives a different perspective on managing soil fertility.

Soil Phosphorus (P)

The Olsen P test extracts only about 1% to 4% of the Total soil P, (depending on soil group). Table 3 shows the amount of Total P (to an arbitrary topsoil depth of 18.5 cm, representing a typical A horizon) in various soil groups, relative to the Olsen P level in the top 75 mm (the standard soil testing depth). Take a specific case: the optimal Olsen P level for a high producing dairy is about 35-40, such soils will contain about 2-4 tonnes Total P/ha in the topsoil. This is equivalent 22-44 tonnes/ha of super.

Table 3: Approximate amounts of total P in some New Zealand topsoils for given levels of Olsen P

Olsen P (0-75mm)	Approximate Total P (kg P/ha/0-18.5 cm)[1]			
	Volcanic	Pumice	Sedimentary (wet)	Sedimentary (dry)
10	1060	500	580	750
20	2650	1000	1150	1500
30	3180	1500	1730	2250
40	4240	2000	2300	3000
50	5230	2500	2880	3750
60	6360	3000	3450	4500

About half of this Total P is in an inorganic form (i.e. associated with minerals in the soil) and the balance is in an organic form **(see previous article in this edition)**. Most of this Total P is plant available over time (years) - it is being continuously turned over as part of the soil/pasture/animal P cycle. Importantly it is not locked up and gone forever, as some unscrupulous salesmen may claim.

Calculations show that the utilisation of P in this cycle is about 80-90%. Yes, there are some losses (about 10-20%) due to the removal of P in animal products (milk, meat, wool), as P runoff (P attached to soil particles) and transfer of P to non-productive areas of the farm (lanes, under trees and along hedgerows).

It is estimated that between 20-40% (depending on soil group) of this Total P is labile – meaning rapidly available (months) for plant uptake. Thus, at Olsen P 35-40 there is about 300-400 kg/ha of readily available P, equivalent to about 3-4 tonnes of super/ha.

Practical Implications

It is from this perspective that some aspects of the management of soil P fertility become clearer. For example, the Anion Storage Capacity (ASC) test (the former P Retention test) is a proxy for the size of the soil P tank. Soils with high P retention, such as the volcanic soils, have big P tanks and therefore require large inputs of capital P to get them 'cranked up'. Once the tank is full (i.e. the Olsen P is in the optimal range) maintenance inputs only are required to replace the losses of P from the soil – the 10-20% mentioned earlier. This is why capital fertiliser P inputs are much greater than maintenance P inputs on these soils.

So why is it necessary to fill the tank up to get maximum pasture production? The engine-sump-oil analogy is useful. A certain amount of oil is required in the sump to maintain the oil pressure essential to lubricate all the components of the engine. So it is with soil P. A certain amount of Total P and labile P is required, (depending on the soil group), to achieve the required P pressure (soil P concentration) around the plant roots. Capital inputs of P are required to initially fill the soil P tank to achieve the correct soil P pressure and then annual maintenance P inputs are required to make good any losses that occur over time so as to maintain the soil P pressure. Beware of the salesman who says –"there is plenty of P in the soil, add my magic brew and make it plant available" – he is asking you to let the P 'pressure' decline.

This perspective is also handy to tackle another question: does it matter when fertiliser P is applied? If P is deficient (i.e. the P tank is not full) then the time to apply capital P is now, straight away, immediately – the sooner the deficiency is eliminated the sooner the benefits in terms of an increase in pasture production will accrue. But once the P tank is full (lets say Olsen P 35-40) it will contain about 300 to 400 kg P/ha of immediately available labile P. This is about ten times more than the amount of maintenance P require to top up the P tank (say 30-40 kg P/ha). In other words because the pool of immediately available P is 10 times greater than the P losses, it does not matter when, during the year, that the maintenance P application is made. Also, this is the reason why, when the P tank is full, fertiliser P inputs can be withheld for some time (several years) before the soil becomes P deficient.

This situation is very different for the nutrient S, as we will now explore.

Soil Sulphur (S)

Unlike P, most (> 95%) of the S in soils is present in an organic form – it is part of the organic matter. This form of S does not leach and is not plant available. To be used by plants the organic S must be broken down by soil microbes (mineralized), to sulphate S. This sulphate form of S can leach and is also affected by fertiliser sulphate additions.

In the absence of leaching events and fertiliser sulphate S additions, there is an equilibrium between organic S and sulphate S. As the plant 'sucks' up sulphate S or sulphate S is leached, the bugs get to work and break down more organic S to restore the equilibrium. This is why we have two soil tests for soil S – sulphate S and extractable organic S (EOS).

The amounts of Total organic S and sulphate S (0-18.5 cm depth) associated with increasing levels of either test (0-75mm) are given in Table 4. All of the sulphate S is plant available, and it is estimated that about 1.7% of the Total organic S is mineralized in a given year. Thus, the amount of plant available S in NZ topsoils at typical soil sulphate S levels of between 5-10 (0-75mm) is about 30-40 kg S/ha/yr.

Table 4: Approximate amounts of the organic S and sulphate S in New Zealand topsoils for given soil test levels

Soil Test (either sulphate S or extractable organic S) **(0-75mm)**	**Total Organic S (kg/ha-18.5 cm)**	**Sulphate S (kg/ha-18.5)**	**Plant Available S (kg/ha-18.5 cm/yr)**
5	1000	9	26
10	1740	18	47
15	2470	27	68
20	3190	35	85

Practical Implications

Unlike P, the pool of available soil S in most NZ soils is small and about the same size as the amounts of S required to make good the losses of S and maintain optimal pasture growth (i.e. about 30-40 kg S/ha/yr). In other words there is no soil S buffer as there is with P. This is why fertiliser S must be applied annually and that, if fertiliser S inputs are withheld, most soils will quickly develop (within 12 months) S deficiency.

Another important implication relates to soil testing. The soil sulphate pool is small (< 5%) and can be extremely variable over time because of the leaching events and additions of sulphate S fertiliser. This makes the sulphate S soil test unreliable as a measure of the ability of the soil to provide S to the plant. Organic S is a much better guide to soil S reserves and should be routinely measured in any soil-testing program.

One final comment. It can be inferred from the table above that if the EOS level is above 10 there should be sufficient sulphate S becoming available from the organic pool annually to met the annual pasture S requirement. However, as discussed elsewhere in this edition **(see article "Talking about Organic Matter")**, there are some soils which, because of the drier climate, will never accumulate enough organic matter such that the EOS level is greater than 10. This means that annual fertiliser S inputs will always be required on such soils. It also explains why so many of the soils on the drier east coast of both Islands were and are so S deficient.

Soil Potassium (K)

Soil K is different again, because all of the K in soils is in an inorganic form and is all plant available. K is also mobile just like sulphate S. The amounts of plant available K present in the top-soil (0-18.5 cm) at various levels of Quick Test K (QTK 0-75 mm) are shown in Table 5.

Table 5: Amounts of available K in topsoils at various levels of MAF Quick Test K (QTK)

QTK	Total K (kg/ha-18.5 cm)
4	135
6	200
8	270
10	340
12	400
14	470
16	540
18	600

Practical Implications

The optimal QTK for all pastoral soils in NZ is about 7-10 and at these levels the amounts of K available in the topsoil are about 240 to 340 kg K/ha. Given the size of these numbers it is no wonder that large inputs of capital fertiliser K are required to increase soil QTK levels K (0-75 mm) (the rule of thumb is 70 kg K/ha to increase soil QTK by I unit).

Note also that the amount of K in the soil/pasture/animal cycle is about 10 times that for P and S. For example, pasture K concentrations are about 3-4% in DM whereas pasture P and S levels are about 0.3-0.4%. Thus, the losses of K via product removal, leaching, runoff and transfer to non-productive areas, are proportionally larger than for P and S. Typically they are 80-100 kg K/ha/yr for high producing dairy farms. This represents a large proportion, about 30-40%, of the total plant available K. Thus K is similar to S – the K buffer is not large and hence soil K levels can be quickly depleted (within years) if no fertiliser K is applied. For this reason annual inputs are essential.

Soil Nitrogen

There is no adequately calibrated soil test for available soil nitrogen under pasture. This is not through lack of trying on behalf of soil scientists. Many PhD students have been given this task and failed. The best we can do is use an approximation to estimate the amount of plant available N in the soil.

Like its close chemical cousin S, most of the N (>99%) in topsoils is present in an organic form and must be mineralised to become plant available. Providing the C/N ratio is around 10-12, which is mostly the case in developed pastoral soils, about 2% of the Total N is mineralised annually. Applying this the estimated amounts of available N coming from the accumulated organic N pool can be estimated as shown in Table 6. In the absence of fertiliser N, the source of this accumulated N is from N fixation by clovers and is why N fixing clovers are so important in our pastoral system.

Table 6: Approximate amounts of plant 'available N' in some New Zealand pastoral topsoils.

Soil Group	Amounts of Available N (kg N/ha/yr)
Sedimentary (dry)	35-70
Sedimentary (wet)	105-175
Volcanic and Pumice	350-420
Organic	175-200

Typical pasture production on these New Zealand soil groups ranges between about 5-15 tonne DM/ha annually. Assuming a pasture with 75% grasses this equates to 3.75 to 11.2 tonnes grass DM/ha. To grow these amounts of grasses would require an N input of between a 100 to 300 kg N/ha/yr. This free N would cost $140 to $420/ha if it were purchased as fertiliser N. We forget this little gem of knowledge at our peril.

FINE PARTICLE APPLICATION (FPA)

I was contacted recently by a farmer enquiring about Fine Particle Application (FPA) of fertilisers. Apparently a company is drumming up business telling farmers that they can cut their fertiliser costs if they apply their normal fertiliser as a fine particle slurry, sprayed onto pasture.

It is claimed that this FPA is much more efficient than conventional granular fertiliser applications. In other words, less fertiliser nutrients and hence lower costs for the same pasture production.

I first wrote about this back in 1999 **(see Fertiliser Review No. 3)**. I summarized the relevant data and concluded that the form in which nutrients are applied is irrelevant. As far as the plant is concerned, it does not matter whether nutrients are applied in a solid granular form, or as a slurry, or in a water soluble solution.

Thinking that I should update myself I contacted the company asking if they had any new research data that I should consider. They sent me three articles. Only one was from a refereed journal and it did indicate a beneficial effect of FPA urea relative to granulated urea. But the rate of N application was very high (100 kg N/ha) and it was conducted on small plots. The other two articles showed no practical effects. I reported back to the company saying that I was not convinced, bearing in the mind earlier research.

I was then told about a nation-wide series of trials conducted by the old Summit-Quinphos company. I have put feelers out hoping to get hold of this research. In the meantime my advice would be "the balloon has gone up - hold all tickets."

OH DEAR, OH DEAR, OH DEAR: LET THE BUYER BE AWARE, AGAIN!

I have recently been alerted to two new fertiliser companies making their presence felt in the market; AgriGanics Ltd, (Canterbury based), and Hortigro Ltd (Pukekohe based). They have several things in common.

They both use, what they now call the Kinsey-Albrecht Program (i.e. they use an American soil testing laboratory coupled with Albrecht's Base Cation Ratio Theory for developing fertiliser advice) AND they both sell fertiliser products and potions of dubious economic and agronomic value. They join another more established similar outfit called Abron, **(see Fertiliser Review Nos. 27 and 29)** in their offering to the market.

Why should you beware? There are a number of reasons.

First, the Kinsey-Albrecht approach is based on the philosophy, or should I say mantra: "Feed the soil and let the soil feed the plants." This is why they recommend products, which they claim feed and stimulate the soil biology. They are normally given fancy names like bio stimulants, probiotics, soil ameliorants.

Most of these products either do not work **(see Fertiliser Review No. 8)** or have not been scientifically tested. Their sales patter includes concepts and words like: holistic, sustainable, natural, soil health, soil biology and nutrient balance. This is seductive, after all every farmer wants these things - once the salesman gets you saying "yes" you are putty in his hands.

Does "feeding the soil to feed the plant" work? Short answer, No! That is not the way the real world works. As explained above **(see article "Talking about Organic Matter," Fertiliser Review this issue, and in Fertiliser**

Review No. 32) the science shows that the system works in exactly the opposite way! Remember the rule of thumb: Feed the plants and the bugs will look after themselves.

Making matters worse, the Kinsey-Albrecht system is flawed in other ways. Plants do not give a toss about the ratio of nutrients providing the minimum amount of each nutrient is present **(see Fertiliser Review 26)**. To use so-called "ideal ratios" as a basis for giving fertiliser advice results in applying nutrients that are not needed (based on the amounts present) and not applying nutrients that are most definitely needed.

Here is a recent example of advice from Hortigro, to a dairy farmer. They recommended a brew to be applied at about 250 kg/ha. It supplied 16 units of N, 5 of P, 30 of S, 16 of Mg and 14 of Ca. It also included the trace elements, boron, copper and cobalt. The cost to the farmer, $233/ha. Leaving aside the likelihood that this soil does not require Ca, Mg, B or Cu, the value of the nutrients, based on current fertiliser prices in this brew is about $85!

It is a double tragedy for the farmer – not only is he paying through the nose for nutrients he does not need, but it is predictable that the pasture production on the farm will decline over time because of declining levels of soil P and K, because the amount of P recommended was trivial and no K was recommended.

This is not just about bad science and dubious products. Companies like this have a very pervasive effect on farming generally, even if you do not get sucked into using their products, because they undermine farmer's confidence. Of course farmers want healthy productive soils but to be told, by implication or otherwise, that conventional science-based farming is ruining his soils is very unhealthy and damaging psychologically.

The solution lies with you, the farmer, the consumer. If you want to see an end to this nonsense you need to take action. The Fair Trading Act has been changed for your benefit **(see Fertiliser Review No. 34)**. It puts the onus on the proprietors to prove that their claims are supported by evidence at the time the claims are made. The Commerce Commission phone number is easily found.

MANAGING NUTRIENTS IN FARM DAIRY EFFLUENT (FDE)

A dairy cow produces about $25 worth of nutrients in the dairy shed. For the average dairy that represents about $10,000. If these nutrients are used efficiently then it saves an equivalent amount of fertiliser costs. Therein lies the rub – how? Confounding the problem is that the management of FDE is today far more complex with imported supplements, feed pads, sumps and storage ponds.

Using Overseer 6, Mr Bob Longhurst, now working for agKnowledge, has done some desk-top analyses. The figures presented below are for typical Waikato conditions and use data from the DairyNZ Economic Survey (2013-14) (Table 7). Further it is assumed that the imported feed is fed in paddocks and that there is no in-shed feeding or feed pad usage.

MANAGING NUTRIENTS IN FARM DAIRY EFFLUENT (FDE) continued…

Table 7: Owner operated production systems for 2013-14 season

Farm system	Low (1 & 2)	Medium (3	High (4 & 5)
Area (effective ha)	131	147	153
Peak cows milked	334	413	474
Stocking rate (cows/ha)	2.5	2.8	3.1
Production (kg MS/ha)	877	1,065	1,277
Imported feed (t DM used)	100	250	474

Nitrogen

Looking first at nitrogen (N). Table 8 shows the N generated per cow in the dairy shed for the three farm systems examined, and the amount of N getting to the sump and then into the storage pond. These results show that the average cow is depositing around 9 kg N per year at the dairy shed (equivalent to about 20 kg urea). Some small losses occur between the dairy shed and the sump (2-3%) but much larger N losses occur in the storage pond (~22%). This is due to ammonia volatilisation.

Table 8: Amount of N in effluent (kg N/cow/yr) after generation at the dairy shed (Losses as percentage in brackets)

Farm system	Low (1 & 2)	Medium (3)	High (4 & 5)
N generated at dairy shed	9.0	9.2	9.4
N in dairy sump	8.8 (2.2%)	8.9 (3%)	9.0 (3%)
N in storage pond	6.8 (23%)	7.0 (22%)	7.1 (22%)

The Regional Council rule requires that not more than 150 kg N/ha can be applied in FDE. For a 400 cow herd this would mean that the size of the effluent block would need to be 24 ha if the FDE was from the sump, but only 19 ha if it came from the pond after storage.

Potassium

Potassium (K) is the other major nutrient present in effluent. However, unlike N it is not subject to losses through the effluent treatment system, meaning that the ratio of the two nutrients changes (Table 9).

Table 9: Effect of different effluent treatments on N and K in FDE (units in kg/cow/year)

Effluent management	Nitrogen	Potassium	N:K ratio
Generated at dairy shed	9.2	8.5	1.08
Spray from sump (12-24 mm)	8.9	8.5	1.04
Pond – spray regularly (< 12 mm)	7.2	8.5	0.85
Pond – spray infrequently (low rate)	7.0	8.5	0.82

MANAGING NUTRIENTS IN FARM DAIRY EFFLUENT (FDE) continued…

The amount of N and K generated by the average 400 cow herd at the sump would be 3,560kg N and 3,400 kg K per year. To comply with the Regional Council maximum N loading of 150 kg N/ha/yr, would require 24 ha and that would mean that the K loading was 142 kg K/ha/yr. This is well above the maintenance K requirement on a high producing dairy farm (80-100 kg K/ha/yr) and thus the soil K level will increase up and up over time. This could have implications for animal health.

This problem becomes worse if the FDE was pumped infrequently from a storage pond. The change in the N:K ratio would mean that 179 kg K/ha will be applied when the N input reaches 150 kg N/ha.

To avoid this problem effluent blocks will need to be increased in size so that the total K loading is equal to the maintenance K requirement.

Liming Effect

FDE has a liming effect – it is not large but the consequence is that soil pH levels on Effluent blocks increase over time (years). This needs to be watched and managed because if the soil pH levels increase above 6.5 the trace element balance in the pasture can change with deleterious effects on animal health – pasture Mo levels rises and zinc (Zn) and manganese (Mn) decline. This is another reason the increase the size of the effluent block.

Other nutrients

Besides the N and K there are of course other nutrients, albeit at much lower concentrations present in FDE. Most of the excess phosphorus (P), calcium (Ca) and magnesium (Mg) ingested by a cow is excreted in the faeces and thus end up in the solid fraction of the FDE, which largely settles to the bottom of the ponds as sludge. In contrast sulphur (S) and sodium (Na) behave differently. If the pond is pumped regularly these nutrients are likely to be distributed in the ratio 2:1 in liquid:solid. However after long storage in the pond the ratio is likely to be 1: 2.

Table 10 presents the average amounts of all the important nutrient found in FDE at the shed. Unlike N and K the other nutrients are not greatly affected by the proportion of supplements in the diet (i.e. the farm system).

Table 10: Typical annual amounts (kg nutrient/cow per year) of nutrients in FDE generated at dairy shed

	N	P	K	S	Ca	Mg	Na
kg/cow/year	9.1	1.2	8.4	0.9	1.2	0.6	0.1
Relatively to N	1.0	0.13	0.92	0.10	0.13	0.06	0.01

Dr. Doug Edmeades